The Great Reversal: Information and Transportation Infrastructure in the Intermodal Vision

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The intermodal vision sees the value-added future of transport in terms of the ability to leverage the huge existing investment in modal transport infrastructure in the service of more efficient and effective logistics management in passenger, freight, and military domains. Intermodalism is not a substitute for modal transport and does not displace the long-standing focus on modal research, development, and infrastructure deployment. It is a complement to modal transport, providing vital leverage to obtain greater use from existing assets and provide useful transport services not previously available. Economic and security forces make greater intermodalism inevitable; the question facing transportation leaders is when and how intermodalism should be developed. Much of the needed research in the intermodal domain extends prior work in the modal domain, but it is especially important that research focus on the changes emerging and necessary in the broader technological and institutional areas of transport. In particular, research is required to apprehend and exploit the potential of sophisticated information infrastructure that is bringing about a "great reversal," in which the ancient dependence of communication and information on the transport infrastructure is being reversed, leading to a time in the near future when most transport will be dependent on the information infrastructure.

Meshing the Information Infrastructure

Contemporary transportation systems work remarkably well given the constraints under which they operate. As is shown in Figures 1 and 2, total transportation usage and per capita usage have been steadily increasing. The transport systems that have evolved are highly complex organizations of people, technologies, and knowledge. Yet in spite of these accomplishments, the demand for transportation capacity and services is outrunning the transport infrastructure as it is currently configured. This shortfall has prompted calls for greater attention to intermodal transport as a strategy for leveraging the modal infrastructure to the maximum degree possible.
The intermodal vision often arises from concerns about constraints in the existing modal-dominated transport world; certainly, much of the literature on the subject from engineering, planning, and policy focuses on this aspect of the issue. The rationale for the Intermodal Surface Transportation Efficiency Act (ISTEA) is essentially a brief for overcoming such constraints. However, as a derived demand in the economy, transportation usage reflects the circumstances of the underlying economic environment. "Logistics management" and "total cost" are continuing trends in manufacturing that drive the demand for intermodal services. Manufacturing and distribution managers are attempting to squeeze out internal inefficiencies and uncertainties through reengineering and process redesign. They are identifying the critical productive processes and attempting to redesign processes that are more reliable and efficient and add greater value to the core business. Transport is a critical uncertainty in the logistical chain of the production of most goods and services. Managers want to drive out the costs of uncertainty and inefficiency that plague transport and are pushing transportation service providers for improvements in speed, service, and cost. The effort to overcome transportation constraints is part of a still larger struggle to gain a greater return from expensive assets. From this viewpoint, at least in the freight transport sector, the challenge is not to conquer constraints but to add value.

This revolution in logistical thinking is not limited to freight but has driven changes in air and surface passenger transport. Deregulation, the growth of travel and tourism, and advances in aircraft and information technologies have brought about a huge growth in air travel and a fundamental restructuring of the airline industry. The route-and-price regulated
airlines of the mid-century have given way to a complex mix of hub-and-spoke air network operators, “segment” operators, and interline mergers, alliances, and partnerships using strategies such as code-sharing and route coordination. At ground level, frustration with congestion and delays has brought pressure for improvements in road and rail passenger capacity, especially in urban areas. Increasingly, the transit time of the work force is seen as a social cost rather than simply a burden for individual commuters to bear.

The arguments in favor of improved intermodal transport are convincing, but we believe many of the ideas for accomplishing such improvement lack scope and precision. Improvement in intermodal transport will require physical infrastructure improvements but, equally important, it will also require improvements in coordination and control to govern interaction between modes. In many ways, this will pose a greater challenge than improvement of the physical infrastructure; in fact, it is quite likely that investments in physical intermodal transport infrastructure will generate poor returns due to shortcomings in coordination and control. Each mode of transport is governed by its own institutional order and social conventions that have evolved over many years. The changes required to bring these into a new alignment for effective intermodal transport are likely to be difficult to achieve and slow in coming.

The resounding benefits from deregulation, coupled with a political climate that favors even more aggressive deregulation, prompt hope that letting markets “decide” will quickly solve the problem of achieving a new alignment; but this is unlikely. For one thing, markets are themselves socially constructed institutions and slow to change. A large part of the transport infrastructure has been treated as a public good for many years, and most of the rest has been subject to regulations intended to preserve important aspects of social welfare. Even if we wanted to move to “free” markets right away, the property rights embodied in the existing order would have to be reconstructed to allow the investors in the intermodal arena to collect rents that reward their investment. This kind of change usually occurs through complex legislative, judicial, and industry reforms that are at least somewhat experimental. They take time. The existing order has its beneficiaries who will not, without protest, support change that will hurt them financially. In many cases, these beneficiaries are well positioned to block changes in the existing order.

Building intermodal transport infrastructure requires policy makers, planners, and engineers to consider new ways of creating value. This will happen only through the construction of new physical systems at the nodes and a new institutional order that together allow both commerce and society at large to capture the value created by the enhanced intermodal network. The challenge is daunting because we do not yet know how to do many of the things that will be required for these tasks. Indeed, if the public and private pressures to improve intermodal transport and the potential returns to be gained in the process were not so great, it is likely that the challenges would prove insurmountable.

This paper draws a broader picture around the concept of intermodal transport than one usually finds in the literature dominated by policy, planning, and transportation engineering perspectives. It builds on existing policy-, planning-, and engineering-oriented views of the intermodal vision, and adds the perspectives of information management and institutional economics. The fundamental argument of this paper is that a coevolution of needs and capabilities has brought the United States, and many other countries, to the point where a serious investment in intermodal transport improvement is inevitable for competitive advantage (Figure 3), and that the investment in that improvement should begin soon. It argues further that the information management requirements are the key to understanding intermodal transport and that failure to meet these requirements effectively will cripple even the best-laid plans. Finally, it argues that a focused program of research into the high-level requirements for information infrastructure in support of intermodal transport is a necessary precursor and complement to any further development of intermodal transport infrastructure.

**Deconstructing the Intermodal Vision**

In the literature, the term “intermodal” is often used synonymously with “containerization.” However, we use a more precise definition that emphasizes elements of control and coordi-
nation over physical modality. The term "intermodal transport" is the coordinated passage of goods and people by way of two or more of the primary modes of transportation (sea, air, rail, road) from origin to destination, as defined by the passenger or the shipper and consignee, with a single travel directive (bill of lading or ticket) and a single price covering the entire trip.

This definition allows inclusion of a number of intermodal methods that are usually excluded from most discussions because they represent only a relatively small proportion of goods shipped—for example, air/road with less than 1 percent of domestic and exported freight by weight. We find air/road especially interesting because it is an intermodal activity that, in the case of the integrated cargo carriers (for example, Federal Express, Airborne Express, DHL, Burlington Express), has been a sector of exceptional innovation and economic significance. Our definition also shifts the discussion from the important but relatively narrow issues of constraint management to the question of the information required to coordinate the processes that allow the handling to take place at all. This takes nothing away from such technical achievements as containerization that have had a tremendous impact on the handling of freight, but these issues have been treated elsewhere at length, whereas the vital information issues have not.

**Domestic/International**

We also do not confine ourselves to a discussion of domestic transport only. The ramifications of an efficient intermodal transportation system extend far beyond national boundaries. The important and growing international components of long-distance intermodal transport are driven by changes in the nature of production, commerce, and trade that are altering the global economy. Domestic concerns are rightly a key focus of all segments of the world of U.S. transport, but the real world is quickly becoming interconnected by the closely coupled communications and transport infrastructures that we will discuss at length later in this paper. A restricted focus on domestic intermodal transport is not only shortsighted but fundamentally suboptimal for both economic and national security reasons.

**Public/Private**

Finally, our definition of intermodal transport deliberately ignores what is an important but distracting distinction between public and private transport activity. In fact, it is difficult to find any significant activity in any mode of transport that is completely public or private. But there are sectors where public or private issues dominate the agendas. For example, much of the urban passenger infrastructure of some cities such as New York is operated by public entities or regulated monopolies. Most of the national road network is public, paid for by tax...
monies. Airports and air-traffic control are basically public enterprises, as are seaports. However, many of the vehicles that use this public infrastructure or depend on the public enterprise are privately owned and operated, and most of the purposes behind travel and transport are private.

There is no clear reason to segregate or conflate the public/private dimensions of transport, but there are institutional reasons why we often find a particular preoccupation with one or the other. For example, a good deal of the literature on transport produced by federally funded research centers deals with issues of concern to federal policy makers—the federal highway system, air transport regulations, the state of the nation’s railroads, and so on. Predictably, the majority of this literature has a modal focus, in keeping with the mode-oriented institutional structure of federal and state involvement in transport. Similarly, industry-oriented literature tends to deal with the economic and technical aspects of competitive transport business, usually within modes, touching on public issues mainly with respect to public infrastructure and regulation. If this perfectly understandable differentiation in the literature reflects a gap in shared understanding of transport issues across public/private sectors and across modes, achieving the intermodal vision will require a movement of ecumenical proportions that faces serious challenges in bringing together different social communities. We do not underestimate that challenge, but we have deliberately chosen a definition of intermodal transport that dismisses the public/private distinction as completely as it assumes the bringing together of modes.

It is tempting when reflecting on these points to be critical of the policy makers, planners, and engineers in the transport world who have pursued narrow sectoral and modal agendas. This is probably the most serious mistake the true believer in the intermodal vision can make. The transport world has been dominated by communities with very sensible reasons for their sectoral and modal biases. These communities built and sustained the great achievements in transport that characterize the twentieth century. Along the way, they have accommodated and facilitated intermodal transport as need and occasion arose. Modal transport did the heavy work; intermodal transport was seen as a necessary exception. The contemporary intermodal vision in its most aggressive form attempts to reverse that traditional hierarchy, placing intermodal transport on top and relegating modal transport to the role of components in an intermodal network. This view is as misguided as a narrow modal view because it focuses attention on the wrong issues. The question is not modal versus intermodal, but rather the construction of a metavision of transport in which modal and intermodal are simply different views of the same problem.

We do not see transport as a matter of physical and organizational infrastructure, although these are necessary components of transport. Rather, we see transport as an essential human activity that is best considered in terms of social communities in action. A social community is a group of people who share common interests and concerns with respect to basic issues such as beliefs, productive enterprise, geographic proximity, and so on. Most individuals are members of more than one community—for example, a person can be a member of a geographic community such as a neighborhood, a professional community with members scattered across the country, and a religious community that might be global in scale.

Transport exists for travel and exchange of physical goods within and between these social communities. At the same time, transport is provided by yet other social communities, usually professional and commercial communities bound together by shared expertise, technology, and social conventions in addition to ownership and regulatory structures. A technical infrastructure enables transport but it is not the reason for transport and it does not provide value. Rather, social communities in the transport world use technology to make that value available to other social communities who extract that value.

Integration/Coordination

This distinction between transport-as-technology and transport-as-community-activity is important not only in order to understand why transport is socially important and complicated,
but also to draw the distinction between integration and coordination that is essential to our story. We will argue that intermodal transport requires a high degree of coordination, but that does not mean that intermodal transport requires integration. Integration is only one way to achieve coordination, as the integrated cargo carriers have demonstrated. There is a tendency among those schooled in rational management perspectives, especially systems rationalism, to believe that integration is an ideal to be pursued with vigor whenever coordination is needed. As we shall show, this is a pernicious mistake that shows up all too often in discussions of intermodal transport.

The communities who need transport do not think of the modality; they think of the objective of transport which is to move goods and people from origin to destination for reasons that make sense within and across communities. The modality distinction is an issue within the provider communities and, in an important but subtle way, within the communities of policy makers, regulators, funders, and others who bridge the "provider" communities and the larger "user" communities. To the extent that there has been unreasonable fixation on mode, the responsibility probably rests less with the actual provider communities who are just trying to get the job done than it does with those boundary-spanning communities that have built and sustained the institutional apparatus that forces modal distinctions through research, funding, legislative, and regulatory mechanisms. The intermodal vision is nothing more than a new form of conceptual hegemony if it merely reverses the hierarchy, putting intermodal over modal. Instead, the intermodal vision at its best seeks to eliminate the distinction between modes the way the user communities have long done.

**INEVITABILITY OF THE INTERMODAL VISION**

We proceed from the assumption that improvement of intermodal transport is inevitable for continued economic and social well-being. The hope for intermodal transport is based on a simple but significant assumption—that the existing transport assets in roads, rail, airports, and seaports constitute a robust set of links in the overall transport network but that the overall network is operating suboptimally because the "nodes" that allow coordinated use of multiple links are inadequate. The essence of the idea is that underutilized or inefficiently used capacity in the links of individual transport modes could be put to better use if intermodal passage were enabled. Intermodal transport therefore is a form of leveraging assets; it is expected to create value by improving on what is already in place.

The political discourse about transportation will, of necessity, shift in focus from the development of new links to more efficient use of existing links. This is in recognition of the fact that the basic modal infrastructure of the United States is now in place and will not expand significantly in the foreseeable future. The Interstate Highway System will not grow significantly in terms of new miles in the network, although improvements will be made in capacity. The rail network is, if anything, shrinking, although improvements will be made on certain roads (Figure 4). There will be few new airports or seaports constructed, although there will be improvements in the existing facilities. The result is increasing congestion in each of the modalities.

This slowdown in the construction of modal infrastructure links has several causes. One is the simple fact that the great infrastructure building campaigns of the last 5 decades have succeeded in their missions. The infrastructure desired has been largely completed. Another is the rise of concern about the social and environmental trade-offs inherent in building such infrastructure. Experience has taught that building major components of infrastructure displaces communities, disrupts the natural environment, and alters existing patterns of commerce. Organized opponents of such projects can mobilize considerable political power, and the costs of mitigating social and environmental problems have added greatly to the cost of the projects. New projects, especially if they are to be built with public money, face a major challenge of justifying the heavy costs in light of other social needs (Figure 5).

At all levels of government, there is intense scrutiny of public expenditures, especially if they require increased taxation or government administration. Most important to the long-run sta-
tus of the institutions governing transportation are the subtle changes in assumptions about social welfare and efficient subsidies. The long-accepted argument that infrastructure investments of public monies were generally in the national interest has been weakened, and in some parts of the country the only large-scale infrastructure projects under way involve private financing to be compensated by user fees in operation. There must be an extraordinarily strong rationale to justify a public subsidy for transport infrastructure, and that rationale is not provided by the old modal arguments for infrastructure except in severe cases of congestion.

The critics of large-scale public modal investment at the expense of intermodal investment can also point to the highly efficient intermodal transport provided by the private, integrated air cargo companies such as Federal Express or Airborne Express. These companies came out of nowhere in the late 1970s and within a decade had captured nearly half of the domestic

FIGURE 4  Rail mileage and freight growth [source: Datapedia of the United States: 1790–2000 (2)].

FIGURE 5  U.S. government transportation research, planning, and R&D outlays [source: U.S. Department of Transportation, 1994a (1)].
air cargo market. Although the air cargo community is not a significant player in terms of global freight tonnage moved (it moves less than 1 percent of cargo by weight), it moves more than 25 percent of the value of all cargo shipped (Figure 6). Also, through time-definite, small-parcel delivery, it has captured the attention of the population at large, displacing in fact and in opinion the public postal service monopoly on first-class mail. Put simply, the integrated cargo community has demonstrated that intermodal transport can be done well and profitably, with great benefits to user communities, and without overt government involvement. Modal transport now has a serious political counterexample to its long dominance. The user communities are now more inclined to accept the idea that alternatives to the traditional order might benefit them.

The reluctance to add to the public debt combined with the visibility of efficient intermodal transport in the integrated air cargo firms sets the mood for change in the modal order. However, they alone do not provide the impetus to move toward intermodalism. There must be arguments that value is gained in the move. Two arguments in particular are relevant here.

One, mentioned earlier, is the increasing globalization of the economy (Figure 7). The combination of international competition that has put severe pressure on production costs, together with growing knowledge and technical support that enable corporate downsizing and restructuring, has made "reengineering" a household word. The user communities of freight and passage services in the business world no longer accept the argument that the inefficiencies that they have wrung out of their own companies are impossible to achieve in the transport communities that serve them. They demand improved services without additional cost and leave it to the transport communities to figure out how to meet the demand.

The scope of the economic change under way is impressive. Fewer goods are being produced for local markets; goods are instead targeted for regional, national, and international distribution. Purchasing is moving away from bulk "economic order point" decisions with warehousing of inventory and toward continuous small orders that shift inventory onto producers or into the transportation system. The new business practices make it possible to take pieces of the existing transportation network and create alternative transport solutions in the logistical gaps of the existing rail, road, sea, and air regimes. Distributed production and distributed markets require appropriate transportation services to match their diversity in degrees of time-definiteness, pricing, and quality. The supply of existing transportation options does not meet the demands of firms competing in an environment that is made less dependent on physical location. The private segments of the freight and passage communities are undergoing radical change as they strive to compete in this new environment. Traditional impediments from institutional constraints and social convention are being challenged and overcome in the effort to survive, and new technologies and approaches are being enlisted. The question is no longer whether change will occur but rather what the newly evolving order will look like.
Finally, we turn to a vital but often overlooked incentive to focus on intermodal transport: national defense. The end of the Cold War has shaken the foundation of defense logistics just as it has many other aspects of defense strategy. Defense is fundamentally a matter of risk management; the benefits cannot be counted in what is won but rather by what is not lost in the event of conflict. Ideally, defense is the prevention of conflict by making the likely retaliatory costs borne by an aggressor too high to warrant the aggression in the first place—a highly sophisticated form of game playing with deadly stakes. The logistic model for defense during the Cold War was forward deployment of forces and materiel in the most likely theaters of action in the event of conflict between the two superpowers and their allies. As the Cold War began to wind down, it became clear that the national interests of the country in the future would be threatened by actions of smaller actors with the capacity to upset economic or social equilibrium vital to the United States. It is too expensive, if not impossible, to maintain forward deployment in all possible trouble spots, as the Iraqi invasion of Kuwait and the subsequent Gulf War amply illustrated. The evolving concept of defense based on rapid mobilization and deployment has begun to replace forward deployment.

Rapid mobilization and deployment pose very different requirements on defense than does forward deployment, particularly in the area of logistics. For one thing, it can never be clear in advance exactly where trouble will occur and deployment be required. Given that the bulk of military assets of the United States must be deployed from the United States to the theater of action, and that more than one threatening action could arise in widely separate parts of the world, it has been necessary to plan for a “two theater” contingency in which actions must be supported from both coasts of the United States simultaneously. Another challenge of rapid deployment is the huge volume of materiel that must be moved quickly if the military action is to succeed with tolerable losses to U.S. forces. Using advanced simulation technologies, it is relatively easy to plan for many different deployment contingencies, and defense logistics experts have developed sophisticated planning capacity in this area. But actual deployment depends on the immediately available presence of the necessary infrastructure to deploy the personnel and materiel in conformance with the plans. That is where the defense interest in civilian intermodal transport becomes a key political factor in the intermodal vision.

Defense has always depended on intermodal transport for expeditions outside the United States. Small, elite components of the U.S. armed forces, such as the U.S. Marines, pride themselves on being a comprehensive fighting force using fighter/bomber aircraft, helicopter gunships, armor, and infantry. These can also be looked at as the country’s integrated intermodal transport fighting forces, possessing the necessary land-, sea-, and airlift capacity to deploy immediately to anywhere they are needed. These units are important, but they are only a small part of the overall U.S. defense assets. The other components of the armed ser-
vices depend on coordination of various airlift and sealift commands to move the much larger volumes of personnel and materiel required to prosecute a serious campaign. And unlike the elite intermodal forces, the transport capacity required to move these larger units would be prohibitively expensive to maintain as military-only assets. It has long been the policy of the U.S. military to secure private transport in the form of aircraft, ships, railroad cars and trucks to help garrison forward deployment outposts and respond to crises. The need for rapid deployment to unpredictable destinations greatly increases the military's need for a comprehensive civilian intermodal transport infrastructure that can be mobilized and put to work in the case of a national emergency. Thus, it is in the interest of the national defense to build and maintain a highly efficient intermodal transport capacity that will serve the needs of normal user communities in peacetime and the special needs of the military community (and, by extension, the nation as a whole) during conflict.

Curtailed public infrastructure investment, the economic necessity of appropriate transport modalities, defense requirements, and the potential of intermodalism demonstrated by the success of physical innovations such as containers and the informational innovations of air integrators make it inevitable that attention will be given to the intermodal vision. Moreover, this concern is not limited to the United States. Transport is a global phenomenon with global consequences. Communities with traditional dependence on trade such as Singapore, Hong Kong, and the Netherlands have been investing heavily in intermodal transport infrastructure in anticipation of the time when national wealth will depend not only on the goods and services produced but also on the speed and efficiency with which they can be distributed. The issue, as noted earlier, is not whether but when. The advantages of intermodal approaches are becoming as persuasive as are the disadvantages of the older modal regime. The time to begin serious research and planning is now.

If our argument about the inevitability of intermodal transport improvements is correct, one might wonder why the vision of coordinated intermodal transport is not more widespread. No matter how powerfully motivated the intermodal vision might be, there are major constraints to be overcome before moving ahead with considerations of how to proceed.

The most obvious constraints lie in the nature of the business itself. Modal transport is difficult in its own right, especially as new technologies provide opportunities for competitively powerful changes in service levels and pricing. For example, trucking is a very basic and very old business; but a number of modern trucking firms have upset the industry equilibrium by using information technologies that allow shipment and truck tracking, which in turn make possible a level of time-definite delivery previously impossible in the industry. Multimodal transport is more difficult yet, even with the advent of critical technological reforms such as containerization. New complexities arise such as the establishment and enforcement of container size and weight standards across community boundaries (for example, rail, road, and ship). Intermodal is even more difficult because it takes on all the difficulties of modal and multimodal transport and adds further uncertainty and risk and problems of multiple agency involvement.

The solution, we submit, depends on a fundamental reconsideration of the problems of intermodal transport. It is not enough to change the tools of analysis; we must change our point of view and develop entirely new tools. For this purpose, we will take an historical view of the intermodal transport problem from two angles.

First, we examine the historical evolution that gives rise to the contemporary intermodal vision and the major institutional constraints. This will give us a sense of how and why the constraints we face are perfectly understandable and perhaps even predictable, although they will be difficult to overcome. If institutions are the carriers of history, as has been suggested, then we need to see how the carry-forward of prior institutional action shapes our options for the future. This gives us a sense of the space we can work within and, we hope, some idea of where our energies might be most profitably applied.

1 In time of a major overseas deployment, it is estimated that 95 percent of the troop airlift capability and 28 percent of the cargo airlift capability will come from civilian airlines. Most military cargo for international mobilization will be loaded by civilians at commercial ports (5).
Second, we examine the problem of intermodal transport from the standpoint of coordination through information processing and communication technology. We make the argument that contemporary intermodal transport solutions are vitally dependent on these new technologies and, in fact, that no serious progress will be made in achieving the intermodal vision without close attention to this set of opportunities.

The Historical Evolution of Intermodal Development

Regulation of transport is an ancient phenomenon, but it is not necessary to go back far into the historical record to see why prior regulations matter to our discussion of the intermodal vision. We can begin with the efforts of the U.S. government in 1887 to preempt the possibility of a railroad monopoly in transportation with the establishment of the Interstate Commerce Commission (ICC) to control entrance and exit to the trans-state rail transport industry, and to assess the fairness of rate structures used by that industry (6). In 1935 control of trucking and interstate bus industries was added to the responsibilities of ICC. The rationale behind ICC was to prevent the emergence of monopolistic dominance within or across transport modes and to protect the modes from predatory pricing and other cannibalizing actions that would threaten the stability of the industry. In the case of the fledgling domestic aviation industry, the Civil Aeronautics Board was established in 1938 to oversee the development of the important and highly competitive industry. The federal government set minimum safety standards and regulated fares and, through letting of lucrative air mail hauling contracts, selected the firms that later became powerful within the domestic airline and air cargo industries.

Although there were umbrella regulatory structures that crossed modes, as did ICC, there was considerable isolation of modes through the establishment of dedicated regulatory boards, reporting structures, and administrative hierarchies. Three broad forms of federal regulatory control shaped the evolving transportation industry: economic regulation controlling prices, market entry, and output; antitrust policy to control monopoly power; and social regulation to govern safety, access, and service quality (6). State transport regulations add another layer of complexity and increase the likelihood of conflicting regulation. Within modes, industry associations, unions, and other institutional forces added to the evolutionary stew.

Economic Evolution

Beyond the regulatory and other institutional forces shaping the evolving industry, there was the vital issue of capital generation necessary to lay the expensive physical infrastructure. Each major mode developed a largely unique capitalization system and supporting financial and accounting structures that further reinforced modal boundaries.

Seaports were generally capitalized by the local authorities that stood to benefit from the increased commerce the seaports would bring; airports subsequently adopted the same approach. Today, the vast majority of seaports and airports in the United States are owned by local governments, not by state governments or the federal government. In time, arguments favoring national investment to improve the functioning of local port infrastructure led to the establishment of federally administered trust funds to aid in building and improving port facilities.

The rail infrastructure was mostly capitalized by the private capital markets on the eastern seaboard, prior to the federally led effort to build a transcontinental railroad in the mid-1800s. The risks inherent in building such a huge project were deemed too great to attract sufficient private, at-risk capital, so the federal government added the incentive of large land grants along rights-of-way to stimulate investment. These grants were often huge; for example, the Southern Pacific Railroad, one of the original four partners in the transcontinental rail scheme, remains to this day one of California’s largest landowners because of land grants more than a century ago. The rail system has since become one of the most complicated modes of transport with respect to infrastructure support. The gradual decline and consolidation of railroad companies following the emergence of road and air transport com-
petition, and the subsequent rise of government subsidy in both passenger and freight rail through Conrail and Amtrak, raised many questions about the appropriate role of government in the transport sector. Generally, it was agreed that government subsidy should be phased out as soon as possible. The freight sector has been largely restored to its private capitalization status, in part through major changes in legislation regulating the rail freight industry that had been in place for many decades. The passenger sector is still heavily subsidized by government sources, both at the interstate level by the federal government and in urban and suburban areas by state and local governments.

The highway sector evolved quite differently than the other sectors, largely because of arguments that highways were inherently “public goods.” This argument maintained that most of the road and highway network could not easily be restricted in use to fee-paying users because placing toll collection points throughout the network would impede transit too greatly. Without a means to ensure that users would pay, the free-rider problem would make private investment too risky. Therefore, general levies plus excise taxes on products used mainly on the highways (for example, motor vehicle fuel, batteries, tires, etc.) were used to raise capital for building a road and highway infrastructure accessible to all without direct user fees. Highways, like railroads, are links in a network that crosses state lines; they are essential to interstate commerce. Road building in time became a key focus of the federal government, and federal excise taxes became a keystone in the highway trust fund structure that capitalizes highway building. Similar schemes are used at the state level for state highways and country roads, while it is increasingly common for municipalities to require land developers to pay the full capitalization costs of local roads in new developments. The effect of this evolution of regulations and capitalization structures has been to create tightly integrated and cloistered communities of social and economic interest within modes.

The modal social communities, bound by a common interest in asset use, emerged as powerful stabilizing forces for the status quo. Documentation and reporting methods, work practices, incentives, and community organizations all evolved to make modal transportation efficient for the majority of users. Once these social conventions were commonly accepted in the community, they became self-reinforcing and very stable. The corollary is that intermodal transport, while always part of the actual transport supersystem, has seldom been able to amass significant institutional power at the infrastructure-development level. Whenever a modal interest group hears the term “intermodal,” the immediate concern is that the modal trust fund will be raided and the modal regulatory structure will be pressed to change. Neither of these is attractive to the interests served by the modal-oriented institutional order. The perception by the participants of transportation as a zero-sum game is likely to be the most difficult problem to overcome in the pursuit of the intermodal vision.

Interplay of National Security

Another crucial component in this institutional evolution arises, as we noted earlier, from national security concerns. Defense is universally agreed to be the primary responsibility of the federal government, and defense logistics coordinators have always been faced with problems of coordination across modal as well as governmental boundaries. Moreover, substantial sectors of the U.S. transport infrastructure have been profoundly shaped by defense interests. In shipping, World Wars I and II brought major infrastructure improvements to ports as well as great buildup in the merchant marine. Maintenance of a minimal merchant marine capacity has remained a defense issue to this day, and efforts to improve sea shipping for rapid deployment purposes as in the Gulf War brought about the defense sector’s first serious efforts to use containerization and other intermodal technologies. The declining rail infrastructure of the country prompted defense concerns about maintenance of a minimal infrastructure for security needs and the strategic railways initiative. The air sector has been somewhat less affected by defense concerns because the armed forces have maintained their own dedicated air bases rather than depend on joint military/civilian fields. Also, the military has largely depended on its own specialized fleet of aircraft for cargo transport. But even in the air sector
defense has been a notable player, contracting with commercial carriers to move personnel en masse for major mobilizations such as the Gulf War.

It is difficult to find a closer relationship between defense interests and transport than in the interstate highway network. In 1922 an obscure Army Captain named Dwight Eisenhower led a convoy of Army vehicles on a cross-country expedition from the Atlantic to the Pacific to test the utility of the national highway system for military mobilization (7). His report was among several that criticized the highway system so severely that the federal government greatly expanded funding for highway construction and maintenance. More than three decades later, then-President Eisenhower signed into law the National Defense Interstate Highway Act to build a national network of limited access, high-speed, divided highways that would stand ready for military use in the event of an emergency and provide support for commerce and private use at all other times. The Interstate Highway System changed the country and its transport industries in profound ways. It is possible that the national highway network we have today would have been built without the impetus of national security concerns, but the great mobilizing power of defense issues at the federal level is unlikely to have been matched by any other institutional interest.

Evolution of Transport Communities

It is easy when focusing on large, visible institutional forces such as federal agencies and the military to overlook some more obscure but equally important players in the evolution. One of considerable significance is the group of research and development communities that have supplied most of the intellectual input to the conceptualization and planning of the transport infrastructure (see Figure 5 on p. 31). The two communities of greatest importance in the early decades of our story were engineering and management. Engineering has always been important because the artifacts necessary for building the infrastructure must be designed to meet tremendous physical demands cost effectively. Management has been important because the greatest driver of capitalization, excepting defense concerns, has been the needs of agricultural and industrial production, commerce, and trade. Moreover, the transport sectors are themselves enterprises that have to be managed efficiently. For nearly all of the nineteenth century and much of the twentieth century, these communities pushed the evolution of the transport infrastructure along the path of reliable technology for economic growth and, when the need was clear, for maintenance of national security.

As early as the 1930s, however, new communities began to arise in the fields of sociology, geography, atmospheric chemistry, and the life sciences that would greatly change the dominance of the efficiently engineered economic growth paradigm. By the 1970s, coalitions of urban geographers and sociologists, ecologists and environmental activists had begun an assault on the simplistic growth-oriented vision of infrastructure. Their tactic was to focus on the negative externalities that arise from large transport infrastructure projects and the subsequent use of that infrastructure. Air pollution, neighborhood disintegration, and increasing alienation and anomie of urban and rural populations were blamed on the huge highway projects of the Interstate system. The noise pollution from airports, greatly increased by jet aircraft, became the critical factor in airport expansion and siting. Rerouting and rehabilitation of rail lines to accommodate increased and/or faster traffic became an environmental concern to those living along the rights-of-way. Transport infrastructure development was no longer just a matter of good engineering and a sound business case.

In addition, transport infrastructure planners were surprised by the fact that the simplest approach to reducing channel congestion in the transport systems—adding capacity—was not working. For example, as each new lane was added to a clogged freeway, more traffic joined the system and congestion rose to previous levels. As early as the 1960s, economists pointed out that the only sensible way to control peak-load congestion was the application of a pricing system that would charge more for use during periods of high congestion, driving cost-sensitive users into less congested periods. But in a freely accessible system in which users did not pay directly, such schemes could not easily be implemented. And in any case, adding
new capacity (especially after the medians of the divided highway interstate network were filled with lanes) had become prohibitively expensive except in the most dire circumstances.

Faced with these new constraints, transportation engineers began to consider channel congestion problems more broadly. They began to implement controls on user behavior to make optimal use of the channels. A good example of this was the implementation of freeway on-ramp meters to slow "births" into the network, thereby keeping congestion below the threshold of flow degradation. This meter system was basically a modified hydraulic model of channel management, and it has worked very well. High occupancy vehicle (HOV) lanes were another innovation to make better use of the highway channel. In rail transport, double-decked passenger and freight container cars pushed the upper limits of capacity (namely bridge clearances). Larger aircraft made better use of constrained airport takeoff and landing slots and gates. Supercargo container ships and tankers made more efficient use of seaports and more economical crossings. And the possibility of load-leveling of demand across channels in different modes—such as shifting passenger traffic off highways onto rail—has made congestion management a major driver of the intermodal vision.

Roots of Deregulation

The big institutional story of the last 20 years has been a gradual reversal and redirection in the regulatory structure governing the various modes of transport. In the 1970s the United States became a net importing nation, interest rates soared, energy costs increased, and international terrorism created intermittent waves of panic in the passenger transport sectors. The United States went through the first of a series of recessionary shocks. Although transport volumes continued to rise, profitability in the transportation sectors declined. Firms were burdened by operating unprofitable lines and restricted by regulatory regimes from expanding services. A wave of liberalizing legislation got under way that relaxed market entry and exit, increased freedom to set rates, permitted horizontal and vertical mergers, extended services, and increased competition within and between modes. Although the specific impact of deregulation has played out differently in each mode, the general effect has been to increase interaction between modes and allow reorganization within modes. There has been innovation in the terms of contracts and services: delivery times, pricing, and quality. This liberalization of regulation enabled new approaches to meeting transport problems, among them intermodal transport.

Nevertheless, this 25-year period of incremental deregulation has not caused the institutional forces of yesteryear to disappear. Some regulatory bodies such as Civil Aeronautics Board have been disbanded, but the capitalization and administration of transportation is still highly modal and the reporting requirements throughout the passage of goods are still considered excessive. Social regulation has remained in place, and even in the current deregulatory environment there remain constraints on the development of new or enhanced infrastructure projects related to safety, noise, air pollution, economic disruption, and other concerns about externalities. These apply to both modal and intermodal projects. The switch of national defense to rapid deployment discussed earlier is both modal and intermodal. It is also worth noting that the strongly felt need among voters to shift much responsibility for government from the federal level to state and local governments gives a political boost to intermodal concerns, precisely because use intermodal infrastructure is invariably a matter of local facilitation of bridging modes. The federal government was essential in the construction of much of the huge installed base of modal transport infrastructure we now have, but the major decisions about intermodal projects will be local and not national in scope.

The Intermodal Vision in Historical Perspective

The challenge of intermodal transport goes up a notch when one takes the problem to the international level. Differences in language, in measurement systems, in rules and regulations all compound the already difficult problems just noted. International institutions that might,
at one time, have provided solutions have lost considerable leverage as transport has been deregulated. In fact, in some modal sectors, these international institutions (e.g., the International Air Transport Association) are seen by key actors within the transport sectors they regulate as a major source of impediments and problems in achieving intermodal solutions. Once again, the challenge is not merely to make the existing institutional order and social conventions work but, in many cases, to replace them with a new order and a new set of conventions that meet the growing need.

We repeat here a point made earlier: the intermodal vision is not ideally a reversal of the dominance of modal over intermodal but rather the recognition that transport as a whole depends on both modal and intermodal without such a hierarchy. History matters, and the institutional legacy we have inherited from the age of modal development brings strengths as well as impediments to the rise of the intermodal vision. Evolving institutional needs and priorities will likely be an advantage to the intermodal vision in the near future, along the lines presented earlier in the discussion of inevitability. It is naive to assume that the older institutional order will simply be swept aside and replaced by a new order. The elements of institution, social convention, technology, and changing commercial conditions will coevolve into a new order. In the remaining sections of this paper, we will consider an approach for research that will, we hope, facilitate that coevolutionary development process. We focus our attention on a story about the coevolving relationship between information and transport infrastructures—"The Great Reversal." This story signals a paradigm shift to a new perspective from which researchers, planners, and policy makers can productively approach the intermodal vision.

**THE GREAT REVERSAL**

For most of human history, communication beyond the carrying power of the human voice was subordinate to the transportation infrastructure of the time. Written correspondence or other physical tokens had to be carried by the transport infrastructure from sender to recipient. With a few exceptions that depended on line-of-sight transfer (for example, smoke signals, signal flags, semaphore), communication could go no faster than transport conveyances. Rapid conveyance was often developed specifically to speed the post, as in the case of the Pony Express—a novel experiment that lasted only 2 years but became an abiding legend.

The dependence of communication on transport lasted until the development of electronically transmitted communication in the form of the telegraph in the mid-nineteenth century. This development freed communication from its enslavement to transport, and subsequent developments in telephony and wireless broadcast of audio and visual signals brought about a revolution of enormous scope and scale. Communication separated itself from transport in many important respects, becoming a separate world of enterprise and, in some cases, engendering substitutes for transport, as in the case of telephone calls and, more recently, videoconferencing and electronic mail, as a means to replace face-to-face meetings.

A less clearly understood consequence of the advent of electronically based communication was the coevolution of communication and transport. The great importance of the railroads to the development of modern industry and commerce has been well documented (8), but the essential role of the telegraph in the success of the railroad is more obscure. In fact, the railroad and the telegraph were essential complements in a powerful communication/transport nexus (9). The physical infrastructure of the telegraph depended on the presence of a roadway along the telegraph right-of-way to facilitate construction and maintenance; the railroad provided this. The telegraph, in turn, made the railroad manageable as an efficient and safe rapid-transit system.

The railroads were actually responsible for two vital innovations in the information management sector. One was the publishing and distribution of written schedules of operation—departures, arrivals, and so on—that were unheard of before. Such uniform schedules were not for the convenience of passengers; they were vital for coordinating the movement of trains moving in opposite directions on single-rail lines. Unless a train operator could safely assume that opposing trains would meet at bypass sidings on a predictable schedule, safe and
efficient operation was impossible. But schedules were only useful when everything worked according to plan. The other need of the train system was the means to get exception information, such as news of breakdowns or the travel of specials, down the line more rapidly than the trains themselves could travel. The telegraph was not necessary to make the railroads run; it was necessary to make the railroads economically powerful contributors to the dawn of mass production and distribution that characterize the second industrial revolution.²

The information revolution with respect to transport goes beyond communications technology to include information processing technologies. Some of this development was in physical process control—the installation of computer processors in many aspects of vehicle operation, most notably in avionics, but increasingly in passenger automobiles and trucks. These developments have greatly improved the safety and efficiency of air and rail operations and have given rise to hopes for improved highway vehicle performance in the form of "intelligent" vehicles and highways.³ A less heralded development is the creation of technologies such as bar coding and scanners and "radio chips" that store and broadcast bursts of information.⁴

In the freight world, the objective has been to put more intelligence into the package, either in the form of scannable codes that trigger access to records in an information network scanning the packages or in the form of on-board information storage that provides key inputs to the control system regarding routing, contingencies, and so on. Ideally, this would make a package more like a passenger, providing the equivalent of the on-board intelligence systems that make passenger intermodal transport coordination comparatively easy. Ironically, some of the most interesting recent innovations in the passenger market have come through precoordinating transit routes and transfers so that the passenger has to worry about very little of the coordination in an intermodal trip. In a sense, the result has been an effort to "passenger-ize" cargo transport and to "cargo-ize" passenger transport (11). The benefits of one can accrue to the other.

In addition to these device-based information processing technologies, both passage and freight transport have benefited from computerization of transport documentation. Documentation in the form of tickets, bills of lading, letters of credit, customs declarations, and so on has always been vital to transport. As computerization spread in the 1950s and 1960s, this powerful technology was applied to transport documentation problems with great success leading to development of EDI standards to facilitate intrafirm and interfirm communi-

² It is also worth mentioning that the railroads contributed greatly to a second revolutionary innovation in communication, the deregulation of the U.S. national telephone infrastructure. One of the first serious attacks on the hegemony of the AT&T Bell System was a railroad implementation of a proprietary, intrafirm telephone system using company right-of-way. AT&T sued the railroad, arguing that the railroad was prohibited by the Communications Act of 1934 and its amendments from operating an interstate telephone system. The decision of this case in the railroad's favor was one of the first breaks in the telephone monopoly structure. Two decades later, another railroad challenged the long distance telephone monopoly again by developing a subsidiary, SPRINT, to provide long-distance service to commercial customers over lines run on railroad right-of-way, using the local monopoly telephone network to route the calls into and out of the SPRINT points of presence. This action, together with the microwave long-haul network of Microwave Communication, Inc., that "jumped over" AT&T's right-of-way constraints, precipitated the actions that led to the Modified Final Judgment of 1984 in the U.S. Department of Justice antitrust suit against the AT&T Bell System. This judgment spun long-distance telephony off into deregulated and competitive markets and began a process that will lead in this decade to the wholesale elimination of the local telephone service monopolies.

³ Note that this is basically a channel-capacity improvement strategy that probably will not have a big impact on intermodal transport.

⁴ One example of such a radio chip is ProfitMAX, a system based on a module that is attached to the shipment and transmits status information to the Texas-based monitoring station. Depending on the configuration, the module has positioning, shock, and video sensors and is being developed to include electronic data interchange (EDI)-messages (10).
Much of this development was concealed from those outside the “back offices” of transport firms, but important strides were made in the creation and reconciliation of shipment documentation that would later come to fruition in the form of the sophisticated shipment tracking systems so essential to time-definite delivery in the freight world. More obvious to the public was the rise of the computerized reservation systems that helped revolutionize the air travel industry. This technology has subsequently spread to rail travel and other reservation and ticketing venues.

Developments in the communications and information processing arenas took on greater significance with respect to transport when they became tightly coupled. This enabled the evolution of what might be called “transport governance systems” that could introduce efficiencies and drive costs out of the transport value chains. In essence, the goal of these systems is to make whole transport chains more “intelligent” so that they can operate effectively with greatly reduced labor inputs and at faster speeds.

None of these developments in the transport world would be possible without a rapidly evolving information infrastructure. Moreover, we argue that the future of both passenger and cargo transport is fundamentally dependent on information infrastructure as communication was once dependent on transport. It is not that transport is impossible without the information infrastructure—transport was taking place long before information infrastructure could have been a meaningful concept. Rather, we argue that transport will be impractical without a complementary information infrastructure. The great payoffs in transport over the next 2 decades, as we argued above, are in leveraging the existing modal infrastructure through intermodal infrastructure development and a concerted process of social learning so the user communities can exploit the advantages provided by this new infrastructure.

Through the use of information technology in the integrated air cargo sector, we have provided some examples of the promise envisioned. Let us take another example that is less well developed but has been the source of much speculation. In the effort to move passengers from almost exclusive dependence on one mode of travel—namely the automobile/road system—and onto alternative forms of transport, a great deal of attention has been paid to the physical infrastructure required to exploit the alternative channels (be they bus, rail, or intermodal mixes). Of course, the physical infrastructure is necessary before any substitution is possible, but it is not the only necessary component. There must also be an information infrastructure in place that manages the coordination within and between the various transport legs. This coordination happens on various levels. First, scarcity of goods presupposes the allocation of these resources between various individuals and involves information as well as decision processes. The earlier mentioned reservation systems fall within this category. Once allocation of the transport service has occurred, coordination on a more operational level has to take place. It is the transfer of documents as well as the coordinated use of the infrastructure. We often forget the tremendous investment in coordination facilitators that make the automobile/road system function effectively: provision of maps, signage, driver training (organized and ad hoc), on-air traffic advisories, and so on. There are now active efforts to put global positioning technology to work in automobiles to facilitate this coordination function.

The automobile/road system is comparatively simple to coordinate because the passenger is also the driver and can direct the vehicle expressly to his or her destination, as long as the road network goes there. This is, in fact, the great attraction of the system: it is personal rapid transit. The most serious difficulty facing substitutes based on nonpassenger-directed conveyances such as buses, trains, shuttles, and so on is the precoordination the passenger must do to organize the routing. The creation of an effective intermodal substitute to the automobile/road system will instantly fail if the only provision is an excellent physical infrastructure. The essential shortfall will be the inability of the passenger to make the right choices, in

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4 It is interesting to note that adoption of EDI itself has been slower than anticipated despite the continuing hype surrounding new messages and networked systems using EDI. In our estimation it is not underdeveloped technology that is holding EDI back but rather the institutional capacity of the user community to use the benefits of the technology.
advance, to enable the substitute to be as effective and reliable as the automobile/road alternative. The huge number of origins and destinations possible even in a modest urban or suburban area makes the publication and distribution of point-to-point routing suggestions impossible. And any effort to create a call-in system for routing suggestions will create the worst “help-desk” problem in history. In fact, the only reasonable solution to this problem is likely to be the deployment of an easily accessible, automated, and self-learning help-desk infrastructure that passengers can access for advice and update on the basis of their own expertise. Unless passengers have such assistance as part of the intermodal transport alternative, they will never adopt it in sufficient numbers to make it economically or politically viable.

The beauty of this broad vision for transport, both modal and intermodal, is that the intersecting technological regimes generate new opportunities in transport and create economically valuable “bandwagon” enterprises as well. Providing intermodal transport alternatives increases the size and profitability of the transport and creates demand for information and communications goods and services. The requirements of the supporting informational infrastructure in turn creates demand for specialized skills to support the application of the technologies. At the regional level, increasing the competitiveness of transportation systems creates competitive opportunities to increase regional dominance and to sell transportation services abroad. It is possible that the value-added arising from these bandwagon developments will exceed the value-added from improved operation of the transport systems.

However, to reap the benefits of improved transportation operations, we need an organizational strategy to mobilize and coordinate the resources. Two strategies in particular command attention. The first is vertical integration of a transport value-chain. The second is loosely or tightly coupled cooperative relationships between specialized actors. Both strategies are attempts to manage uncertainty: vertical integration reduces the uncertainty of goal incongruity and supply risk by internalizing potentially unreliable actors; cooperative relationships reduce the impact of changing markets by maintaining flexible resource and labor supplies. Both can be highly effective in their appropriate domains. Vertical integration is the more proven of the two and no stranger to transportation. However, we suggest that there are limits to vertical integration as the dominant strategy in the environment we have foreseen for intermodal transportation.

COORDINATION IN INTERMODAL TRANSPORT

Coordination through Vertical Integration

Vertical integration has been a highly successful strategy where conditions of market stability and standardization of products exist. It extends beyond ownership of the pieces of a value-chain to structuring of the connections between the links in the chain. It is characterized by central planning and authority and formalization of procedures that eliminate decision alternatives that use assets suboptimally within the organization. In our example of air transport this strategy is epitomized by the air integrators. Their strength lies in controlling door-to-door delivery of a well-defined product—in other words, time-definite delivery of packages within a small-weight limit.* By controlling the entire physical infrastructure from the trucks, planes, and air hubs, as well as the information and communications infrastructure—from the creation of standard bar coding of packages to the accounting systems—the integrators can monitor and control the entire production process. Ownership provides the security to invest in expensive proprietary systems, the benefits of owning performance information, and the authority to impose uniformity throughout the entire organization. This control translates to reduced uncertainty for the firms using the air integrators services and increases the transport users’ ability to plan (12).

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* Currently the small-weight limit is 150 pounds.
While acknowledging the effectiveness of vertical integration, we also recognize that its success relies on certain environmental conditions—namely, high-volume, standardized products in stable markets. The integrators have been successful because they operate in a highly standardized niche market that allows them to gain volume. As geographical and product heterogeneity increases, flexibility becomes more important, thus diminishing the advantages of vertical integration. In the case of intermodal transport, the very essence of this modality is the development of a supply of transport solutions for markets demanding flexible and appropriate transportation. We argue that because of the tight constraints associated with vertical integration, this strategy will not meet the challenges of intermodal transport.

For empirical evidence, we simply note that during the late 1980s the traditional air cargo community of forwarders and carriers was deeply fearful that the integrated carriers would take over the whole air cargo industry. After all, the integrators' growth had been astounding. But much of that growth was in the creation of new business (for example, routine next-day document delivery) and not in the substitution for traditional air cargo services. More important, after a decade of spectacular growth, the integrators seem to have reached the limit of their penetration into the traditional air cargo community. They proved, as others have in the past, that there are problems with as well as advantages from integration. The major disadvantage of integration is the need to specialize in the general—to provide a commodity-like service that appeals to customers with highly similar needs. Thus, the integrators excelled at small-parcel delivery of uncomplicated cargoes such as documents and dry goods. More specialized cargoes such as large and bulky items, live shipments, hazardous shipments, and high-value perishable items do not fall within the competency of the integrators. Much of their business derives from the exceptional or "just-in-case" demand for which users are willing to pay a premium price. In the long run, users will shift much of this business to more appropriate regular intermodal solutions.7

Coordination through Cooperative Organization

As an alternative to integration, there are communities of transportation actors each specializing in a segment of the transport chain. To effect intermodal transport they cooperate out of necessity, coordinating physical passage of goods and information flow between their separate organizations. The constraints under which intermodal transport is envisaged to operate coincide more closely with a cooperative organizational environment. Shifting global markets, distributed production, flexible production, and customized transport solutions all make vertical integration risky. Cooperative relationships will dominate where logistical decision making is decentralized and logistical solutions are customized.

Although it necessitates a flexible network of partners, cooperation comes at the cost of coordination. When intermodal capacity is not vertically integrated, but rather is organized among multiple parties (for example, forwarders and carriers, airlines and airport shuttle services), the coordination problems can be severe. An integrated carrier bears all the risks of each segment of the chain. It might wish to reduce risks in some segments and tolerate greater risks in others, but ultimately the objective is to minimize risk to the firm across all the segments. This is in the interest of the carrier but not necessarily in the interest of the shipper or the consignee or the passenger. In a nonintegrated situation, each party in the segments will seek to shift risk to the other segments and reduce its own. The resulting game can be exceedingly complicated and turbulent until an industrywide set of conventions governing such practices evolves and an equilibrium is achieved. Such equilibria can be found in multimodal

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7 The integrators themselves are offering more diverse delivery alternatives. Once overnight service was the only service available; now services such as 2- or 3-day delivery are common. To maintain the multiplicity of services, we expect the integrators themselves will move toward a more cooperative organization to better provide these services.
transport in both passage and freight, but they have not been established in intermodal passage and freight. It will take time and a good deal of experimentation (with winners and losers) before such equilibria can be established.

The next challenge facing intermodal transport is the achievement of coordination across modes without integration. Equivalent levels of learning and technology mastered by the integrated air cargo companies, and other integrators in other transport domains, will have to be accomplished without the inherent advantages that come from integrated ownership. This will be much more difficult because different actors in the game would prefer to have others bear the costs and risks necessary to make the system work, without threatening the interests of the late-adopters. Given the huge front-end investments required to make nonintegrated intermodal transport function, and the fact that these are shared infrastructure investments that cannot be turned readily into proprietary rents for specific investors, nonintegrated intermodal transport faces a serious "bootstrapping" problem. For example, consider the Alameda corridor project in Los Angeles to put an above/below grade rail link between the Ports of San Pedro and the rail yards of central Los Angeles. There is consensus among all parties—ports, municipalities, county, state, railroads, steamship companies—that this project is essential for future economic welfare in the region. But, more than 10 years after the initial feasibility study, despite continued calls for its development, the project is still $700 million short of the estimated $1.8 billion required for the construction of this essential intermodal facility.

This bootstrapping problem also applies to the information infrastructure. Although the network externalities of cooperation might be recognized in the transport community, information asymmetries and vested interests inhibit shared information solutions. Developing shared data bases of community schedules and services is essential for origin-to-destination control. However, disclosure of information between actors shifts dependencies, and not accepting this fact may make participants reluctant to join. A single standard may be desirable for simplicity, but in a cooperative environment information standards and systems must support heterogeneity and diversity among the actors.

Numerous attempts have been made in the air-cargo sector to develop cargo community systems (CCSs) to extract the benefits of a coordinated community system in international transport. However, none of these systems has lived up to expectations primarily because the shared information benefits the carriers but not the forwarders who are responsible for the majority of international business (13). One of the largest systems, Encompass, owned by AMR (American Airlines) and CSX has spent $100 million to date on the development of a system that has had repeated cutbacks in services and generates only an estimated $10 million in annual revenues.

Our quest must be for solutions to industry organization other than vertical integration. As noted several times earlier, this is a difficult quest because, as the integrators have demonstrated, a complicated set of organizational, technical, and institutional factors had to come together to enable the rise of this single solution. Although this swarm of innovations can be rightly attributed at the descriptive level to the genius of the leaders of Federal Express and the other integrators who proved the concept could be done, we guess that there were other, failed innovative efforts in the intermodal air cargo arena that would prove the search has been hit-or-miss, as all learning-by-doing efforts are. Indeed, the subsequent problems with implementation of the CCSs and other information infrastructure approaches to coordinating the nonintegrated intermodal air cargo sector suggest precisely this. If we wish to make more rapid and profitable progress toward the intermodal vision in the air cargo world, we must improve our ability to capture the learning benefits from both the disappointments such as the CCSs as well as the stunning successes such as the integrators.

A RESEARCH AGENDA FOR INTERMODAL TRANSPORT

The challenge for those who conduct research into information and transport infrastructures is significant, but it can be met. In addition to the traditional lines of research into improve-
ment of transport technologies and infrastructure, which should continue and in some cases increase, we see a clear need for research in the following areas:

- **Socio-Institutional Reform.** Research is needed to document and evaluate the ongoing learning-by-doing experimentation in the transport world, especially with regard to innovations in use of information technologies and new organizational forms. A great deal of information is available on a few exemplary cases, such as computerized reservation systems, the integrators in the air transport domain, and the time-definite delivery trucking firms. But few of these studies are sufficiently deep and critical to provide the necessary level of social learning. More serious is the lack of careful evaluation of instructive but less spectacular experiments that might reveal innovations that, in different circumstances, could produce great payoffs. There is much new information being created as part of the experimentation under way, but we are not capturing this precious asset as social knowledge. The modest investment required to do this would produce manifold returns.

- **Complementarities in information and transport infrastructure.** Focused research should be conducted into the interdependent relationship between information infrastructure and transport infrastructure in both modal and intermodal transport. There is a need for theoretical work on the economic relationships between information management and transport that gives rise to these infrastructural interdependencies. This research must go beyond engineering and policy perspectives tied to the status quo. It must build on contemporary theories in institutional economics (for example, agency theory, game theory, transaction cost theory), as well as organizational sociology (for example, social network theory and new institutional theory). There is also a need for robust qualitative research to describe, in detail, the work worlds associated with existing intermodal transport activity, with particular attention to the techniques, practices, and conventions used to allow participants from different communities in the transport world to interact effectively. Recent work in industrial anthropology is suggestive of the kind of research needed.

- **Coordination with and without integration.** Experimental research should be undertaken on the technical components of intermodal information infrastructure that appear to offer advantages, especially in non-integrated circumstances. This experimentation should focus on the underlying technology, especially emerging information processing technologies illustrated by client-server systems, distributed data bases, expert systems, neural networks, and machine learning. It should also focus on emerging communication and processing technologies as seen in value-added network services, the Internet and World Wide Web, and “applet” based models of networked computing. Equally important, this experimental work should introduce and control for conditions that will confront such systems in vivo. The ability of a technology to perform in a tightly controlled, unrealistic setting yields little information about what will happen when the technology is subjected to the problems of real-world production environments. There is a real need for “testbed” capacity, similar to that provided for development of the Internet and the high-speed data communication networks that have been a focus of DARPA-sponsored research in the computing and communications field.

The purpose of such a research agenda is to build the knowledge base generally but more particularly to build capacity for what we call “high-level requirements analysis” related to the coming intermodal revolution. If, as we argue, the future of intermodal and modal transport is inextricably linked to information infrastructure, the creation of those coupled infrastructures will pose great challenges for designers and system builders. Much progress has been made on low-level requirements analysis that formalizes task sequences and derives from them the specifications for systems that will facilitate the doing of those tasks. What we seek is the means to assess the higher-level requirements for the system as it will be deployed in a complex milieu of organizational behavior and culture, which in turn is influenced by larger institutional order. Even an elegant technical system that meets low-level specifications exactly will fail in deployment if it fails to meet the requirements of the broader organizational and institutional order in which it functions. The payoff from improved high-level re-
quirements analysis capability is primarily in the avoidance, or at least reduction, of costly system failures.

CONCLUSION

The main driver behind the intermodal vision is economic opportunity. The demand for transportation is growing, and investment in transportation is essential for ongoing national and international economic development. This growth creates investment opportunities that call to the transportation community. Intermodal transport improvements are inevitable and are already under way, as the integrators have shown. But the larger intermodal vision will not happen through vertical integration. It will happen through value-added improvements that facilitate harmonization and cooperation. The pieces of the modal infrastructure have been built, but they are crudely stuck together with inefficient and inflexible "fixes." To create interconnects we have to work on the nodes between the modalities.

In this process, we must turn to information technology as a key enabler. We now have leverage at the intersection of technology and knowledge that has never been available before. We have the capacity near at hand to create a world of complementary information and transport infrastructures that will bring changes to transport that go beyond differences in degree; they will bring differences in kind. The future of transport in this vision is very different from that envisioned by the traditional transport communities, even at their most enlightened. Intermodal and intramodal transport must be thought of as a more profound challenge than simply dealing with congestion management. The real problems in congestion management lie with the precongestion problems upstream. Information technology has already been put to work as an upstream servant of infrastructure building, in the form of computer-aided design, transport simulation, and so forth. It is being used to improve vehicle performance and to substitute for transport such as with videoconferencing. The next major frontier is the integrated communications and transport infrastructure that makes possible what never was before.

There are lessons for all the different communities in the transport world. For the governmental policy and regulatory world, there are the lessons of deregulation, reregulation, devolution of power from the federal to the local level, and a renewed and altered need for transport infrastructure for national defense. There is also the coincidence of greater capitalization difficulty from traditional government sources and new capitalization opportunities from private sources and public/private partnerships. For the private firms in the various transport modes there are the lessons of increased sensitivity to the user communities, with their focus on the objective of transport rather than the means. Their demand for easy to manage, time-definite delivery at reasonable prices will not go away; it will grow as they see evidence that it can be provided. The competitive pressures will grow, and only the innovative will survive.

REFERENCES