Prometheus, Vol. 27, No. 2, June 2009

Reverse Salients at the Meta-System Level: The Case of Containerization

HARMEET SAWHNEY & XIAOFEI WANG

ABSTRACT *The power of Hughes' concept of reverse salients is evident in its widespread adoption and use in areas as diverse as water distribution, metals production, and mobile music businesses. In all these studies the reverse salient concept has been mainly applied to internal problems in the development of a large-scale system. We focus not only on reverse salients within a system but also at the meta-system level, wherein different systems come together to create a system of systems. We draw on the experience with containerization, which is a particularly interesting case study because it developed in response to the reverse salients at the meta-system level—the bottlenecks at the interfaces between motor carriers, railroads, and water carriers, the three systems that together form the overall surface transportation system. We examine the processes both within each system and also at the meta-system level and expand our understanding of reverse salients as a system development phenomenon.*

Keywords: reverse salients, containerization, overlay networks, intermodal transportation system

Introduction

Among the many seminal contributions made by Thomas Hughes to the study of large-scale systems is the concept of 'reverse salient'. Hughes borrowed the term 'reverse salient' from military historians who use it to identify a segment of an advancing battle line which has not been able to keep pace with other sections of the front. Hughes feels that this 'metaphor is appropriate because an advancing military front exhibits many of the irregularities and unpredictable qualities of an evolving technological system'.[1] In the case of technological systems, the 'reverse salients' arise whenever there is uneven growth between the different components of a system. The resulting imbalance leads to dysfunctional system development. The growth of the entire system is hampered and there is a need for an innovative solution if the expansion is to proceed. Thus reverse salients induce technological innovations by attracting institutional attention and resources and also independent

Prometheus ISSN 0810-9028 print/ISSN 1470-1030 online © 2009 Taylor & Francis
http://www.informaworld.com/journals
DOI: 10.1080/08109020902895284

inventers and entrepreneurs seeking fame and fortune. Once a reverse salient is resolved, the system evolves further and a new reverse salient arises and the cycle repeats, especially during the growth stage of the system.

The power of this concept is evident in its widespread adoption and use. It has been used in various areas: development of roads,[2] water distribution and treatment system,[3] immunodiagnostic testing practice,[4] history of the IT field,[5] renewable energy technologies,[6] metals production,[7] government technology procurement,[8] mobile music businesses[9] and many others. In all these studies the reverse salient concept has been mainly applied to internal problems in the development of a large-scale system. Discussion on the relationship between systems is scarce.

Thomson[10] discusses linkages between systems and how innovations in one system migrate to other systems. The adoption of an innovation by the recipient system in turn creates a reverse salient within that system and induces further innovations and subsequent transfers between systems. However, while Thomson looks at flow of innovations between systems, reverse salient is seen as an intra-system phenomenon, pretty much like other studies discussed earlier. In other words, as in earlier studies, here reverse salients are seen as inducing innovations within systems. What is different about Thomson[11] is that he focuses on the transfer of these innovations from one system to others. Hughes himself talks about the relationship between a system experiencing a reverse salient and other systems but in a limited way.[12] For instance, he notes 'when a reverse salient cannot be corrected within the context of an existing system, the problem becomes a radical one, the solution of which may bring a new and competing system'.[13] Christiansen and Buen's[14] study on the development of environmentally friendly energy sources, such as photovoltaic and wave power in Norway, points to this possibility. While these technologies are currently being developed within the existing energy system dominated by fossil fuels, nuclear energy, and hydropower, there is a strong possibility that they will grow into radical innovations that the incumbents may be hesitant to pursue or even fully understand the possibilities. In such a situation where the problem 'cannot be corrected within the existing system',[15] the breakthrough innovations are likely to be driven by independent innovator-entrepreneurs.

We, on the other hand, focus not only on reverse salients within a system but also at the meta-system level, wherein different systems come together to create a system of systems. It is here we make a unique contribution. In effect we look at reverse salients and the systems they occur in at dual levels of abstraction.

We use the experience with containerization as a case study for our explorations. Containerization is a particularly interesting case study because it developed in response to reverse salients at the meta-system level—the bottlenecks at the interfaces between motor carriers, railroads, and water carriers, the three systems that together form the overall surface transportation system. Conceptually, containerization is a relatively simple idea wherein the sending party places its cargo in a large box that is then 'seamlessly' transferred between trucks, railroad cars, and ships as per the optimal routing plan. In reality the implementation of containerization was a very complex endeavor since it required coordination between three mature systems with entrenched physical plants and well-established practices. We examine the processes both within each system and also at the meta-system level.

We start by examining the reverse salients plaguing the motor carriers, railroads, and water carriers before containerization. We then examine the reverse salients at the meta-system level and the development of containerization as a solution. Thereafter we examine the differing motivations of motor carriers, railroads, and water carriers to participate in the development of containerization and the major problems that had to be resolved in the implementation process. Finally, we discuss the implications for the development of transportation systems in specific and also understanding of reverse salients as a system development phenomenon.

Crisis Faced by Individual Systems before Containerization

Motor Carriers

The motor carrier industry started as a feeder to the railroads. The problem with the railroad was that it could not be extended to every farm and factory. The shipments had to be brought to the railroad stations via some other means, mainly horse drawn vehicles in the pre-motor carrier days. The motor carrier helped plug this gap between the railroad system and its customers. The railroads encouraged this complementary relationship since it increased their catchment area. In fact the railroads ran special 'good road' trains that provided equipment and workers to communities to build roads. The railways never suspected that the motor carrier, which seemed destined to be a short haul technology, would become a competitor. Eventually, with the development of long-distance capabilities and an expanding highway system, the motor carrier started becoming a competitor in an increasing number of business segments.[16]

Advancements in motor carrier capabilities gave shippers flexibility which they capitalized on in ways that changed location of facilities and business practices. They had less of a need to locate near railroad stations and accordingly we saw dispersion in the location of businesses. Also, businesses started shipping goods more often and in smaller quantities. In addition to enabling flexible delivery, the motor carrier service reduced warehousing costs because smaller shipments did not have to be stored till they aggregated into an economical railroad shipment. They in effect became an extension of the manufacture's assembly line playing the role of 'warehouse on wheels'. While all these changes increased the business of motor carriers, the small shipment, which became the largest category, entailed high handling costs and hence was not profitable. For instance, in the East Central zone small shipments, which were more than half of the total traffic, had an operating loss ratio of 115%. The figures were pretty much the same for other parts of the country. Furthermore, with the increased value of shipments, the insurance cost of motor carriers increased dramatically.[17]

The interface between the motor carriers and water transportation system was excellent. According to Barta (1967), 'water truck coordination is so good that there is little room for improvement. Wherever water service requires the supplement of truck service, the connection is readily available'.[18] The two worked well together in developing new services as the market conditions changed. On the other hand, the motor-carrier and railroad relation was very complex because they were both complementary services and competitors. The piggyback service wherein a loaded truck is placed on a flatbed railroad car for long haul transportation was a successful and mutually beneficial arrangement. It eliminated the need for freight transfer from a motor carrier to a railroad car at the starting railroad head and the reverse on reaching the destination. However, for the great bulk of the traffic that required loading and unloading of shipments, the transfer facilities between trucks and railroads were primitive.[19] On the other hand, with the construction of the interstate highway system and improvements in automotive technology, the motor carriers were becoming increasingly cost competitive with railroads even for long haul bulk shipments.[20]

Railroads

The railroads had been the dominant transportation technology for many decades. However, as noted above, increasingly the motor carriers were undermining their dominance. The long established rate structure of the railroads made them especially vulnerable to motor carrier competition as the latter's technological capabilities improved over time. The railroad rate structure was based on value of goods shipped. The high value commodities were charged higher and made a disproportionate contribution towards the fixed costs of the railroads whereas low value commodities often barely covered the marginal costs of shipping them. As the motor carriers' capabilities increased, they moved more and more into the high value end of the railroad business leaving the low value commodities to the railroads. The railroads increasingly found themselves in a bind because while they were forced to reduce rates for high value commodities, their attempts to increase rates for low value commodities met strong resistance.[21] Over time they were increasingly moving low value bulk commodities over longer and longer distances.[22] The railroads steadily lost short haul and intermediate haul traffic to the motor carriers.

With respect to long haul of low value bulk commodities, the railroads have long competed with water transportation up and down the Atlantic and Pacific coasts and between the two coasts via the Panama Canal.[23] In the interior the nation's extensive network of internal waterways allowed barges to compete with railroads on many routes. They moved grain, fertilizers, coal, steel, ores, chemicals, petroleum products and other basic commodities.[24] In many places the motor carriers combined with the railroads to give them a run for their money.[25] While the motor carriers and the barges worked well together, the water–rail coordination was poor. It was marked by outdated arrangements, unfriendly business relations, and a lack of understanding of the potential for combined service. The railroads had long believed that rail–water carrier connections were to their decided disadvantage.[26]

In addition to motor carriers and water carriers, the railroad dominance was also undermined by competition from oil pipelines, electrical grids, and airplanes.[27]

Water Carriers

Prior to World War II, coastal and inter-coastal shipping constituted the bulk of American maritime industry. In 1942 the War Shipping Administration requisitioned almost the entire domestic fleet of the US. Thus all the domestic cargo previously carried by water went to railroads.[28] On the other hand, the war fueled the growth of American shipping. The US emerged from the war as the leading maritime power with 60% of the world's tonnage.[29] In the post-war years, the US started downsizing the shipping tonnage to levels appropriate for peacetime activities. The 1946 Merchant Marine Sales Act made surplus ships readily available to both American and Allied owners.[30] Between 1946 and 1950, the Maritime Commission authorized the transfer of roughly 1.5 million shipping tonnage to foreign flags. Furthermore, to avoid the higher cost of labor, taxation, and insurance in the US, and to obtain favorable rates for loans, many American ship-owners registered their vessels under flags of convenience. By 1950 the American fleet had dropped to 32.5% of world tonnage.[31] Over the next few decades US maritime industry declined because of high labor costs which made it uncompetitive in the face of rising foreign competition. The federal government sought to support the American maritime industry with the Cargo Preference Act of 1954, which stipulated that not less than 50% of government cargo should be assigned to American flag ships, and the continuation of the subsidies instituted under the Merchant Marine Act of 1936 for both ship construction and operational costs of carriers involved in foreign trade.[32] However, the US as a maritime power fell from 5th place in 1965 to 10th place in 1975 in terms of numbers of ships and total tonnage.[33]

The share of domestic shipping served by the American merchant marines dropped from almost 70% in 1939 to 30% in 1953. About 50 coastal and intercoastal shipping companies were in business in 1940, but only three remained in 1960. The inland shipping industry also declined. This decline does not seem to have been triggered by a falling demand. For instance, in the Great Lakes region the demand for transportation of bulk commodities rose with the growing population and expanding industries.[34] The construction of the St. Lawrence Seaway also played a positive role in the rapid growth in export–import tonnage through the port of Chicago from the late 1950s to the early 1960s. Nevertheless, operating conditions on the Great Lakes remained difficult. Six shipping companies on the lakes were liquidated from 1960 to 1963.[35]

The biggest threat to inland water transportation came from foreign rivals and domestic rail carriers. Representing the major independent inland ship lines, the Great Lakes shipping fleets complained about the danger of being driven out of business at the hands of Canadian and other foreign shipping companies that had cost advantage.[36] In particular, Canadian ship operators were spotlighted because they received a government subsidy and therefore could build large carriers and operate at a lower cost.[37] The shipping industry blamed the railroads for practicing selective price-cutting in 1957–60, wherein railroads would draw on revenues from highly priced freight and cut their prices on the routes on which they competed with water carriers, who actually had lower costs.[38]

Most industry leaders attributed the industry's decline to government policies and hence lobbied for government support.[39] In particular, they asked the government to set clear standards for settling rate disputes between water carriers and railroads, to increase government use of domestic water carriers and to provide subsidies. Consequently, in 1955 the Maritime Commission seriously considered subsidizing American shipping companies for ship construction costs, operational costs and tax allowances to make up for the substantially lower shipping costs enjoyed by the foreign shipping lines operating in the Great Lakes.[40] In 1963, a bill was proposed to amend the Merchant Marine Act of 1936, with the objective of providing relief for American companies whose operations were threatened by low-cost Canadian and other foreign flag ships.[41]

The shipping companies also joined forces with trucking companies to compete with their common rivals—railroads. In 1954 Dave Beck, President of the International Brotherhood of Teamsters, had four large trailer-transport ships built to ferry loaded trailers between Atlantic Coast ports in the North and South. He predicted that the ferry service would combine the economies of low-cost water transportation[42] with the flexibility of a door-to-door motor freight service.[43]

Things seem to have become better for waterways in the latter half of the 1960s. Braxton B. Carr, president of the American Waterways Operators, Inc. observed a sharp expansion in industrial waterside plant locations in the second quarter of 1966.[44] In 1965, water carriers annually moved 431 million tons of freight, representing 14.5% of the nation's domestic commerce. Inland boat and barge operations handled 9.5% of the nation's freight movements.[45] However, in 1965 port congestion was building up and ships were spending most of their time in ports.[46] This disadvantage dampened any incentive to increase ship size or speed.[47] Although water transportation remained by a large margin the cheapest way to carry goods, the cargo-handling expenses at the dock became so high that they swallowed up a large share of the savings associated with water transport.[48]

Crisis at the Meta-System Level

There were many reverse salients in the growth and development of railroad, shipping, and trucking systems. What is interesting about the crises that induced the development of containerization is that with ever tightening coupling between different modes of transportation, the reverse salients started occurring at the interfaces between them. They had to do with the transfer of goods from one mode of transportation to another. The root problem was that while the propulsion of ships, trains, and trucks improved over the years, the handling of cargo remained a very primitive affair. As Morris Forgash, who headed the Special Subcommittee on Containerization and Standardization of the National Defense Transportation Association, observed in 1966:

> Each of our modes of transportation developed and improved its carrying units according to its own physical characteristics and needs. This created gaps between carriers and between modes which could be filled only by manual labor, transferring cargo from one unit to another.[49]

While this problem affected all modes of transportation, it was particularly severe for shipping lines.

The ships were forced to remain in ports for days because of labor intensive loading and unloading, according to one estimate about six days in ports for every four days at sea. This idle time, where no revenues were generated, negated the technological prowess of high tech ships, with expensive power plants and navigational equipment, to move goods from one point of the world to another at great speeds. Furthermore, the rising docking costs made the 'bottleneck' ever more problematic.[50] Quite clearly, as the material flows increased with globalization, there was a pressing need to mitigate this 'last mile' problem. The solution was seen in containerization. The metaphors that were used to conceptualize containerization are notable. Forgash (1966) saw containerization as 'forming a transit pipeline by all modes of transport—rail, highway, water, and air, separately or in any combination'.[51]

On a conceptual level, this problem is notable because it was basically that of reverse salients occurring at the couplings *between* systems or, in other words, at the meta-system level. We will now see how the solution was gradually developed.

Motivations for a Solution

There was parallel development of containerization in shipping, railroad, and trucking systems. As we will see below, the motivations were different in each of the three systems.

Shipping

Oceans liners were the first carriers to get serious about containerization.[52] Their problem was that the ships in which they had considerable capital invested were getting tied up at ports because of slow and labor intensive unloading and loading processes. One estimate was that containerization would reduce the unloading and loading process in a typical port from 3–5 days to 8–12 hours.[53] According to another estimate, the cargo handling capacity of a container terminal would be five times that of a break-bulk facility.[54] The problem ocean liners faced was the huge investments required for building containerships, containers, and the terminal facilities. In order to make this investment payoff, it was clear to the ocean carriers that 'ships, container, transfer facilities and inland carriage must have to form a continuous integrated chain'.[55] To make this possible the ocean carriers even went inland to generate demand and facilitate cargo movement to support their systems.[56]

Railroads

As compared to the ocean carriers, the railroads, like the motor carriers, faced much less re-handling problems and hence had no pressing need for containerization. They could see the utility of containerizing for international shipments but this traffic was relatively small compared to their overall business. They were therefore reluctant to make the investments to align with the system the ocean carriers were pushing.[57] Furthermore, they found it uneconomical from their point of view to invest in heavier containers that ocean carriers needed for their operating conditions. While ocean carriers required containers that could be stacked six high, the railroads and motor carriers rarely stacked even two high. Similarly, the ISO specification that containers withstand structural forces generated by a 30-degree roll by the ship was irrelevant for surface carriers.[58] On the other hand, the railroads were feeling competitive pressures from the motor carriers. The railroads started focusing on trailer-on-flatcar (TOFC) and container-on-flatcar (COFC) to gain competitive advantage. Industry estimates indicated a difference to the tune of 30% between the wind resistance of a TOFC and COFC car. Furthermore, the lighter weight of COFC saved energy costs and was cheaper to manufacture.[59] According to a New York Central estimate, containers with detachable road wheels were far more efficient, approximately 10 times, than simply riding trailers piggybacked on railroad flatcars.[60] These pressures nudged railroads along the containerization route.

Motor Carriers

The motor carriers were even more reluctant than the railroads in aligning themselves with the type of containerization system that the ocean liners were pushing for. Their big problem was that the standard-sized containers for inter-modal transportation offered less flexibility than the trailers they were already using. Furthermore, the motor carriers could not integrate these containers into their own domestic operations and had control over them only for a short period of time on legs between the inland shipper and a railhead or port.[61]

Thus we see that while all three systems stood to benefit from containerization, there was considerable difference in the level of benefit. Correspondingly, their willingness to bear the cost of containerization varied. Since the ocean carriers had the most pressing need, they took the lead.

Development of a Solution

Ocean carriers were the driving force behind inter-modal containerization. They were largely responsible for the development of specialized container cars, creation of a system for leasing containers, and getting the railroads to operate double stack unit trains on a contractual basis.[62]

Interestingly, the standards for the container size were relatively easily determined compared to the protracted battles that mark most standardization efforts. The constraints placed by highway transportation left little leeway for negotiations. The eight feet width was most quickly established because of the highway-width limitations even though the railroads would have preferred a wider width. Railway regulation, on the other hand, determined its maximum length of 40 feet. The eventual standard was based on an eight-foot cross section and lengths of 10, 20, 30, and 40 feet. They were largely based on highway regulations on trailer lengths and height restrictions created by bridges, tunnels, etc.[63]

Initially the containers were used in ‘captive’ or ‘closed cycle’ systems; i.e. the container movement occurred only within a particular company’s lines. It was only when containers started moving over competing lines and other modes to ‘completely fulfill the promise of containerization as the common denominator between surface and marine transport on a world-wide basis’,[64] that the system integration problems really arose.

One of the major problems was the imbalance in the directionality of traffic flow because it generates ‘deadheading’ wherein empty containers have to be transported from one point to another in keeping with the traffic demand.[65] Ocean carriers to some degree were protected by rate structures that took into consideration the peculiarities of each traffic route and hence could absorb the costs of returning empty or partially filled containers to the home port. However, the problem was acute for railroads and motor carriers.[66] One railroad even suggested that the rate should reflect empty movement to the tune of 10%.[67] One of the possibilities considered was mergers between transportation companies to create large multi-mode corporations. But eventually the solution was found in creation of container pools, which were independently run and open to all carriers. Carriers could rent containers on a *per diem* rental basis and pay only for the time they were under their control. In addition to mitigating the deadheading problem and cutting down supervisory and inspection expenses, pooling generated further savings via bulk purchase of containers. It also generated resources for state-of-the-art container design and other developmental work.[68] Furthermore, market research, planning and forecasting, and traffic control techniques were used to optimize flow of containers over all the different modes of transportation.[69]

While containerization created a seamless flow at the physical level, the flows at the institution level remained to be worked out. For example, the advantages of a single liability for international inter-modal shipments were quite clear in lieu of the existing situation where each mode had its own system of liability, which complicated securing insurance coverage. But the inter-modal shipments posed a problem for insurance underwriters because they had inadequate data on loss causes, loss ratios, and other such parameters to determine insurance rates for the new mode of transportation.[70]

Carriers pushed for reduction in insurance rates for containers on the argument that they reduced claims to less than 1% of all shipments. The insurance companies countered that containers did not reduce damage and therefore did not justify rate reductions.[71] Underwriters felt that while containers may reduce low-value pilferage, they were likely to increase high-value theft.[72] The federal government criticized the underwriters for not adapting to the changing needs of shippers. It acknowledged that underwriters' conservative attitude was shaped by their well-established practices and called for systematic collection and analysis of data.[73] Gradually with tightened security and improved container handling techniques, containerization proved to effectively reduce theft.[74] Thereafter insurance rates eventually went down.

The insurers saw two reasons why inter-modal transportation would further complicate how liability was assigned to each link in the system. First, it was almost impossible to determine at which stage of transit damage occurred since containers are not opened and checked at each transit point. Second, different carriers have varying levels of liability which would complicate settlement of insurance claims.[75]

These problems would be relieved if a single carrier could issue a combined bill of lading. This combined bill of lading would allow fixing of a single limitation of liability figure, irrespective of where loss or damage occurred; and that would make it much easier for settlement of claims. Cargo owners, when seeking damages, would have to come to an agreement with one carrier, as opposed to each and every carrier involved in different legs of the shipment.[76]

More than 30 years have passed without the development of a multimodal liability regime.[77] In the absence of a multimodal liability regime, the liability regime for the first mode of transportation is often extended by contract to successive modes of transportation used for the shipment. Without such a contractual agreement, the different modal liability regimes continue to apply and the parties must contend with vexatious issues such as identification of the point at which loss or damage occurred.[78]

Many of these issues hinged on the question whether the container system should be governed by the existing regimes for railroads, shipping, and trucking industries, or should it be considered a separate system?

Separate agencies—Interstate Commerce Commission (ICC), Federal Maritime Commission (FMC) and Civil Aeronautics Board (CAB)—were set up under different acts to regulate different transportation modes. For instance, ICC regulates inland waterways, truck lines, pipelines, and railroads, but it still has separate legislative authority and separate regulatory responsibility for each.[79] International Cargo Handling Coordination Association argued that containers should be considered as transmodalist. In other words, the containers should not be identified with any one particular mode of transportation.[80] According to them,

> transmodalist should be defined as an operator whose business is to move containers between two points in the world, performing complete routing by barge, airplane, truck, rail or ship, handling all the documentation involved,

> eventually achieving a single bill of lading and taking over the responsibility for the complete operation between two ends.[81]

That is, transmodalist integrates existing modes of transportation into a seamless system for movement of containers. FMC, ICC, motor carriers and other parties supported the notion of a transmodalist. FMC put in place suitable procedures for transmodalists to operate and ICC pushed for legislation to enact the concept of transmodalist into law. Some motor carriers argued that in order to create transmodalism existing regulatory agencies should be merged into one super-agency with authority over all modes of transportation.[82]

Railroads, truckers, and freight forwarders opposed the idea of transmodalism. Railroads argued that shifting control to transmodalist would not alleviate the problem of moving containers economically between various modes. They thought that the solution lay in designing a container system that would optimize efficiency across trucking, rail, and waterways simultaneously and not be biased in favor of any one mode. In particular, railroads urged the shipping companies, which were actively designing efficient port-to-port container systems, to pay attention to the container system in inland transportation. Truckers felt that as long as the underlying carriers controlled the rates transmodalism would not work. They argued that a transmodalist, who was supposed to set a through rate that reflected the true cost incurred, might have to pay the underlying carriers the rates published in their tariffs. In other words, the transmodalist rate would be largely determined by the sum of the underlying carriers' rates. Thus there would be no net gain in terms of costs. Freight forwarders asserted that they already performed all the functions of the transmodalist.[83] They feared that the transmodalism legislation sought by ICC would destroy their franchises and attract new competitors into their business. They also felt that the addition of another entity to the mix would further fragment an already fragmented system.[84]

The concept of transmodalist did not strike roots and got dropped out of the political agendas of all the parties. However, the US Department of Transportation was eventually created in 1967 to bring all the transportation modes under the purview of a single federal agency. This department oversees Federal Aviation Administration, Federal Highway Administration, Federal Motor Carrier Safety Administration, Federal Railroad Administration, National Highway Traffic Safety Administration, Maritime Administration, and Surface Transportation Board.

We have spotlighted a few important issues to illustrate the integration problems. There were a whole lot of other issues ranging from rates, where railroads had to move from the traditional rate structure based on value of commodity to per-trailer mile,[85] to the regulatory system, which had to be reoriented from transportation-mode specific regulation to one that optimized the overall transportation system, to paperwork, which had to be streamlined and speeded via electronic systems. There was also the physical infrastructure that had to be realigned. For example, in Honolulu containers had to be opened up at dockside and the cargo re-handled for consignee delivery because there were no normal-height truck receiving and loading platforms in Hawaii. A freight forwarding company developed specially designed lift gate trucks that could accept 20-ft, 24-ft containers straight from the unloading ship.[86] After the inevitable fits and starts, containerization grew rapidly. Between 1960 and 1967 the inventory of containers grew by more than 35% per annum to reach 127,000 units.[87] In terms of port infrastructure, in

1967 there were 63 full and 107 partial container berths in America. Many more were under construction or in the planning stage.[88]

Conclusions

The actual coming together of different network systems to enable containerization was a complex process. Much of the complexity stemmed from the fact that while different network systems had to cooperate to facilitate containerization they also had to maintain their competitive positions. All the players knew that 'the use of standardized containers in a systematic way will have a varying effect on each of the modes in the cargo transportation process'.[89] This varying effect shaped the relationships, ranging from competition to cooperation, between the three modes. The railroad–motor relationship was marked by a complex mix of both competition and cooperation. The relationships between water–motor and railroad–water were relatively straightforward. The former was that of genial cooperation and the latter that of bitter competition. The determining variable was perhaps the degree of interdependence, especially with regard to overlap and 'last mile' connectivity. There was little overlap between water and motor and the relationship was largely a complementary one. No wonder the water–motor relationship was one of mutual assistance and general cooperation. The railroad–motor relationship involved interdependence—railroads needed the motors for last mile connectivity and motors needed railroads for long-distance haulage—and there was considerable overlap in the middle-distance transportation business. These pressures generated complex dynamics of competition and cooperation. The relationship between railroads and water was that of pure competition; there was much overlap and no mitigating influence of a complementary relationship as neither could provide last mile connectivity or in general extend the reach of the other.

This complex jostling between the three modes was compounded by the fact that the regulatory authority was dispersed across different agencies. Morris Forgash thus laid out the task:

> To reach our goal, we must find a way to bring about complete co-ordination of the physical transportation plant. Two obstacles stand across our path. One is physical, and the other is in the realm of policy—government and managerial. Effective and efficient coordination requires interchange of equipment without transfer of cargo. Interchange requires, first, the physical ability to freely transfer equipment from one carrier and one mode to another; second, a willingness, or a legal compulsion, to effectuate interchange; and finally, a working arrangement for compensating each carrier, out of total revenue, for its contribution to the joint endeavor. The physical problem is to devise the interchangeable equipment. The policy problem is to encourage or require the making of workable arrangements for interchange and for an equitable distribution of revenues. Inherent in both problems are such questions as who shall own the jointly-used equipment and how can it be kept moving with a minimum of empty hauls.[90]

In addition to creation of new physical plant and coordination of commercial processes, containerization also required major institutional adjustments. For example, the customs agencies had to move their activities away from 'ports of entry' to 'regional inspection stations' so as to facilitate rapid flow of materials in and out of ports. The customs inspectors now examined containers at the actual points of receipt and not at the port where they were discharged from the ship.[91] Correspondingly, a whole system of feeder shipping, railroad, and trucking services had to be developed to link the main ports with satellite ports and inland stations.[92] The transportation companies had to develop arrangements for sharing containers and creating container pools to match supply with demand during peak periods.[93] Perhaps most vexing of all they had to develop revenue sharing mechanisms since the 'seamless' movement of containers involved services of many different 'networks'. This entire 'cooperative' endeavor was marked by competitive maneuvering and legal and legislative battles.

What Lesson Can We Learn from this Experience?

Airlines were late to containerize and they learned from the earlier efforts of ocean carriers, railroads, and motor carriers. They started by concentrating not on specific equipment requirements but the total system concept.[94] This approach was in marked contrast to the trial and error process and ad hoc improvisations of the surface carriers.

Consider the early years of containerization, which were marked by the parallel development of 'captive' container systems by individual carriers. The companies built their respective containers and facilities without due consideration of the compatibility with other companies in the same transportation mode, let alone the needs of other modes of transportation. For instance, the Missouri Pacific Railway promoted its aluminum containers on wheels in 1951; the Alaska Steamship Company started to carry wood and steel containers from Seattle to Alaska in 1953; Pan-Atlantic used 35-foot long containers because that was the maximum length allowed on the highways leading to its home base in New Jersey; Grace Line included small slots at the bottom of their containers for forklifts whereas ocean carriers that used cranes to lift their containers chose not to.[95]

Unlike the early adopters, airlines started containerization with a coordinated intermodal system in mind. Airlines started to combine services with truckers as early as 1960 to move containerized cargos worldwide.[96] Trial of sea–air movement started in 1962, when two airlines combined services with steamship companies to move cargo from the Far East to the Rocky Mountains area.[97] A rail–air container project started in 1967 to move containers from the US to the UK.[98] Although airlines have had standardized container sizes since 1966,[99] airlines started to use containers complying with ISO standards after they were adopted in 1968. In the 1970s, major airlines acquired hundreds of 8×8×20 foot intermodal air containers and conducted experiments involving moving air shipments with 8×8×20 foot containers in cooperation with truck, sea, and rail.[100]

Coordination with rail and truck helped airlines to extend their geographic reach. Sea–air alliance helped airlines lower rates and ocean carriers save time, consequently attracting additional traffic for carriers of both modes. Moreover, wide-body jets came to be widely built due to the need to carry containers.[101] Thanks to its optimal fit with 8×8×20 foot container, the 747 became an especially popular airplane.

On a conceptual plane, the case of containerization prompts us to expand our thinking beyond reverse salients at the system level, the main focus of current research, to the meta-system level. While reverse salients at both the system and meta-system level are similar in that they represent irregularities in an advancing technological front, the processes leading to the solutions are very different. The occurrence of a reverse salient within a system attracts very focused attention, both from the institutions charged with their development and independent entrepreneurs seeking fame and fortune. On a meta-system level, it is a very different ball game. Here there is the need for coordination between systems, which are often in competition with each other. The former has been studied at great depth. The latter has not received attention. We hope we have taken a significant step towards filling this gap in our understanding of reverse salients as a system development phenomenon.

Notes and References

1. T. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930*, The Johns Hopkins University Press, Baltimore, 1983, p. 14.
2. S. Knutsen and K. Boge, 'From public to private? The organization of road construction in Norway', paper presented at the *6th Annual Conference of European Business History Association*, Helsinki, 22–24 August 2002.
3. B. Barraqué, 'Past and future sustainability of water policies in Europe', *Natural Resources Form*, 27, 2003, pp. 200–11.
4. R. Miettinen, 'The problem of the problem in inventive activity', *Electronic Essays Dedicated to Matti Sintonen*, 2001. Available at: http://www.valt.helsinki.fi/kfil/matti/miettinen.pdf, last accessed 16 January 2009.
5. A. L. Friedman, 'Rhythm and the evolution of information technology', *Technology Analysis&Strategic Management*, 11, 3, 1999, pp. 375–90.
6. A. C. Christiansen and J. Buen, 'Managing environmental innovation in the energy sector: the case of photovoltaic and wave power development in Norway', *International Journal of Innovation Management*, 6, 3, 2002, pp. 233–56.
7. E. H. M. Moors and P. J. Vergragt, 'Technology choices for sustainable industrial production: transitions in metal making', *International Journal of Innovation Management*, 6, 3, 2002, pp. 277–99.
8. M. Fridlund, 'Shaping the tools of competitive power: government technology procurement in the making of the HVDC technology', Research Report to the European Commission (DG XII) in the Targeted Socio-Economic Research (TSER) program under the Fourth Framework Program, *Tema–T Working Paper 192*, Linköping University, Linköping, 1998. Available at: http://mats.fridlund.googlepages.com/ISEreportHVDC.pdf, last accessed 16 January 2009.
9. A. Takeishi and K. J. Lee, 'Mobile music business in Japan and Korea: copyright management institutions as a reverse salient', *The Journal of Strategic Information Systems*, 14, 3, 2005, pp. 291–306.
10. R. Thomson, 'Crossover inventors and technological linkages: American shoemaking and the broader economy, 1848–1901', *Technology and Culture*, 32, 4, 1991, pp. 1018–46.
11. *Ibid*.
12. T. P. Hughes, 'The evolution of large technological systems', in W. E. Bijker, T. P. Hughes and T. Pinch (eds), *The Social Construction of Technological Systems*, MIT Press, Cambridge, MA, 1987, pp. 51–82.
13. *Ibid*, p. 75.
14. Christiansen and Buen, *op. cit.*
15. Hughes quoted in *Ibid*, p. 237.
16. H. Sawhney, 'Public telephone network: stages in infrastructure development', *Telecommunications Policy*, 16, 7, 1992, pp. 538–52.
17. W. D. Baker, 'Motor carrier management strategy', *Transportation Journal*, 8, 1, 1968, pp. 48–56.
18. W. J. Barta, 'Water–rail coordination', *Vital Speeches of the Day*, 34, 1, McMurry Inc., Phoenix, AZ, 1967, p. 5.

19. E. G. Plowman, ‘The intermodality and cybernetics key to profitable computerization in transportation’, *Trasportation Journal*, 8, 3, 1969, pp. 51–5.
20. P. M. Zeis, ‘Competitive rate making in the United States’, *Transportation Journal*, 8, 4, 1969, pp. 34–42.
21. *Ibid.*
22. S. R. Klein, ‘Rail industry structure’, *Standard&Poor’s Industry Surveys*, 2, 2, 1991, pp. R15–8.
23. Zeis, *op. cit.*
24. Barta, *op. cit.*
25. Zeis, *op. cit.*
26. Barta, *op. cit.*
27. Zeis, *op. cit.*
28. R. d. l. Pedraja, *The Rise and Decline of US Merchant Shipping in the Twentieth Century*, Twayne Publishers, New York, 1992.
29. A. Gibson and A. Donovan, *The Abandoned Ocean: A History of United States Maritime Policy*, University of South Carolina Press, Columbia, SC, 2000.
30. *Ibid.*
31. B. Labaree, W. Fowler, Jr, E. Sloan, J. Hattendorf, J. Safford and A. German, *America and the Sea: A Maritime History*, Mystic Seaport Museum, Inc., Mystic, CT, 1998.
32. Gibson and Donovan, *op. cit.*; Labaree *et al.*, *op. cit.* The construction subsidy covered, within specified limits, the difference between the construction cost in the US and in Europe on ships built for operation on essential routes, as determined by the Maritime Administration. In no case could the subsidy be greater than 50% of the total cost of the vessel. Correspondingly, the operating differential subsidy partially covered operating costs of shipping lines on the designated essential trade routes to enable them to compete with foreign shipping companies (G. C. Wright, ‘Merchant marine faces many serious problems’, *The New York Times*, 29 June 1952, p. E10).
33. P. L. Zweig, ‘Technology goes to sea’, *The New York Times*, 6 March 1977, p. 103.
34. L. Dombrowski, ‘Transportation’, *Chicago Tribune*, 5 July 1963a, p. C8.
35. ‘Port Chicago sets export, import peak’, *Chicago Daily Tribune*, 22 October 1959, p. D7; L. Dombrowski, ‘Peal traffic passes through Chicago port’, *Chicago Tribune*, 18 December 1963b, p. C7; and Dombrowski, 1963a, *op. cit.*
36. *Ibid.*
37. *Ibid.*
38. E. A. Morrows, ‘Water carriers held poor risk; lack of a US policy blamed’, *The New York Times*, 5 October 1960, p. 80. In 1957–60 the railroads launched a furious campaign of selective rate cutting in order to drive out the coastwise and inter-coastal shipping lines, as reflected in the following example. The Transportation Act of 1958 provided that carriers shall not be made to hold up rates to a particular level to protect traffic of any other mode of transportation. Under the new law, rail carriers proposed several rate cuts in 1958. After railroads proposed a rate cut by over 60% for transporting printing paper from a large new mill in the South of Chicago, six Midwestern barge lines protested against it before the ICC. The barge lines maintained that the new rates would be below the full cost of handling the traffic and losses would have to be made up by overcharging other railroad traffic (‘Barge lines fight cut in rail rates’, *The New York Times*, 28 October 1958, p. 69).
39. Morrows, *op. cit.* The Great Lakes Ship Owners Association blamed the government for lack of a clear policy governing the relationship between the independent common carriers and the private carriers, lack of a clear standard in settling rate disputes between water carriers and railroads, restrictive tax write-off regulations, failure to make certain that half of government cargo was shipped abroad on American ships, and failure of the government to face the challenge of the Canadian Construction Subsidy Program (Dombrowski, 1963a, *op. cit.*).
40. N. Poulos, ‘Hints lakes shippers to get subsidy’, *Chicago Daily Tribune*, 18 March 1955, p. C7.
41. Dombrowski, 1963a, *op. cit.*

42. In 1954 it cost two and one-half cents a ton-mile to ship goods by truck, whereas it cost only one and one-half cents by rail and half a cent by water (A. H. Raskin, 'Union head backs "sea–land" trucks', *The New York Times*, 17 February 1954, p. 38).
43. *Ibid.* He expected this transportation plan to attract new traffic for trucks in building material, petroleum products, low grade chemicals, paper, floor coverings, beverages, and iron and steel.
44. 'Transport notes: waterside sites', *New York Times*, 20 July 1966, p. 59. He observed that 88 of the 176 production industries had announced construction or expansion programs along or adjacent to navigable waters. He argued that the availability of a commercial barge service and the effect this service had on the general freight structure were factors that accounted for the location of plants along the nation's 25,380 miles of commercially navigable waterways.
45. 'Shipping events: waterway rates', *The New York Times*, 19 May 1965, p. 94.
46. M. G. Graham and D. O. Hughes, *Containerization in the Eighties*, Lloyd's of London Press Ltd, London, 1985.
47. E. T. Laing, 'Containers, pallets or LASH? The economics of general cargo shipping', *QER Special* No. 13, Economist Intelligence Unit, London, 1973.
48. Pedraja, *op. cit.*
49. M. Forgash, 'Containerization-a tool of transportation', in G. F. Mott (ed.), *Transport Century*, Louisiana State University, Baton Rouge, LA, 1966, pp. 195–6.
50. J. R. Whittaker, *Containerization*, 2nd edition, Hemisphere Publishing, Washington, DC, 1975.
51. Forgash, *op. cit.*, p. 195.
52. A. Tazzoli, 'Cheaper than break-bulk', *Container News*, August 1968, p. 16; J. C. Taylor and G. C. Jackson, 'Conflict, power, and evolution in the intermodal transportation industry's channel of distribution', *Transportation Journal*, 39, 3, 2000, pp. 5–18.
53. 'Intermodal shipments to dominate transportation', *Container News*, December 1967, p. 20.
54. Tazzoli, *op. cit.*
55. E. Rath, 'Ways to spark faster growth-areas that need in-depth research', *Container News*, April 1969, p. 22.
56. *Ibid*, pp. 22, 24 and 41.
57. F. Muller, Jr, 'Why containerization lags', *Transportation and Distribution Management*, February 1968, p. 31.
58. *Ibid.*
59. R. Ray, 'Piggyback cuts its teeth', *Distribution Age*, June 1965, pp. 27–34.
60. K. Marshall, 'The long revolution', *Transportation and Distribution Management*, November 1970, p. 22.
61. M. C. Kluge, 'Parallel systems are insufficient', *Container News*, June 1968b, pp. 30–6.
62. Taylor and Jackson, *op. cit.*
63. Whittaker, *op. cit.*
64. F. Muller, Jr, 'The status of container standardization: hardware yes, paperwork no', *Transportation and Distribution Management*, February 1966, p. 27.
65. Kluge, 1968b, *op. cit.*
66. 'New job for the container manager', *Container News*, December 1967, p. 6.
67. 'The container decades: progress and problems', *Transportation and Distribution Management*, November 1970, p. 36.
68. M. C. Kluge, 'Open worldwide pool to all transport modes', *Container News*, July 1968c, p. 16.
69. 'Congressional bill designed to halt subsidy discrimination: propose greater flexibility for containerships', *Container News*, November 1967, p. 22.
70. 'Insurers should view vanned cargo apart from breakbulk shipping: no need seen for accumulation of good experience to lower rate-full text of US maritime administration's study on container cargo underwriting', *Container News*, December 1970, pp. 16–20, 70–6.
71. 'Expert believes insurers are myopic', *Container News*, April 1969, p. 12.

72. The underwriters felt that the entire container could be lost when it was stored in poorly lit, unfenced, and inadequately guarded areas. Also, since the shippers were still unfamiliar with the new system, they were likely to have problems with how cargo was packed in containers and how containers themselves were stored and handled ('West Coast parley uncovers problems', *Container News*, November 1968, pp. 24–39). Interestingly, one of the first commodities to be shipped via containers was whiskey because it was highly subject to pilferage (V. Postrel, 'The container that changed the world', *The New York Times*, 23 March 2006, p. C3).
73. 'Government steps into cargo insurance controversy', *Container News*, November 1970, pp. 16–8.
74. For instance, 25 containers with a value of about $1 million were stolen from New York and New Jersey pier areas in 1970. Next year thefts were cut to five containers, with a total value of $250,000, due to tightened security (R. Phalon, 'Cargo container thefts in port reported cut to five in 1971', *New York Times*, 7 March 1972, p. 78).
75. Whittaker, *op. cit.* During sea carriage there is a general presumption that the carrier is liable for losses or damage to the goods that occur while they are in its custody. However, according to Article 4 in the Hague Rule, a carrier is not liable for loss or damage to the goods that result from navigation problems or the management of the ship or from fire or from perils of the sea, etc. (H. D. Tabak, *Cargo Containers: Their Stowage, Handling and Movement*, Cornell Maritime Press, Cambridge, MA, 1970). The US ratified the Hague Rules in 1937 and incorporated them into US statutory law with the Carriage of Goods at Sea Act. The Hague Rules and the Carriage of Goods at Sea Act set out the basis for ship-owners' liability for cargo, precluding contractual exemptions of liability on the part of ship-owners and provided ship-owners with 17 specified defenses against liability. In 1968 a diplomatic conference convened in Brussels and adopted a protocol to amend certain provisions of the Hague Rules. A definition for 'package' was finally accepted by the Scandinavian countries and then by other countries. If the bill of lading enumerates how many individual packages are inside the container, the package formula at $662 applies to each one (G. Horne, 'US ship industry debates a new liability plan', *The New York Times*, 9 March 1968, p. 58). Shipping industry warned that the new formula would probably not be acceptable unless an overall limit on possible indemnity was written into the protocol (G. Horne, 'Ship men to fight liability change', *The New York Times*, 24 May 1968, p. 93). This protocol, the Visby Amendments, entered into force in 1977. In 1978 a diplomatic conference convened in Hamburg, Germany, adopted the Hamburg Rules, which consisted of 34 separate and detailed articles that replaced the Hague Rules and the Visby Amendments. The US government signed both the Visby Amendments and the Hamburg Rules but has not taken steps to recommend either of the treaties to the US Senate for ratification (Transportation Research Board, *Intermodal Marine Container Transportation: Impediments and Opportunities*, Transportation Research Board/National Research Council Special Report 236, Washington, DC, 1992).
76. Whittaker, *op. cit.*
77. The Multimodal Convention is a proposed international treaty-based liability regime governing multimodal carriage from inland origin in one country to inland destination in the other country. The US is not a party to the 1980 Multimodal Liability of Convention. (US Department of Transportation, *Cargo Liability Study*, Washington, DC, August 1998. Available at: http://ntl.bts.gov/lib/22000/22900/22922/cargolivab.pdf, last accessed 16 January 2009). In 1980 the United Nations Convention on the Multimodal Transport of Goods allowed for the creation of a new entity, called a multimodal transport operator (MTO) which could offer to shippers a through bill of lading with a door-to-door system of liability (Transportation Research Board, *op. cit.*).
78. US Department of Transportation, *op. cit.*
79. G. Muller, *Intermodal Freight Transportation*, 2nd edition, The Eno Foundation for Transportation, Inc., Westport, CT, 1989.
80. M. C. Kluge, 'Integrate transport modes for success', *Container News*, May 1968a, p. 16.
81. 'Congressional bill designed to halt subsidy discrimination: propose greater flexibility for containerships', *op. cit.*

82. 'Playback on "fifth mode"', *Container News*, November 1967, p. 14.
83. G. Horne, 'A new approach in shipping urged', *The New York Times*, 31 July 1967, p. 53.
84. 'Playback on "fifth mode"', *op. cit.*
85. Ray, *op. cit.*
86. 'Special trucks for Hawaii', *Container News*, April 1969, p. 10.
87. 'Containerization study published by US Steel', *Traffic World*, 28 March 1970, p. 147.
88. 'Urges international service group to coordinate modes', *Container News*, November 1967, p. 24.
89. McKinsey and Company, *Containerization: The Key to Low-cost Transport*, Report to the British Transport Docks Board, London, June 1967, p. 9.
90. Forgash, *op. cit.*, p. 196.
91. McKinsey and Company, *op. cit.*; The Port of New York Authority, *Container Shipping: Full Ahead; a Forecast of How Containerization of Oceanborne Foreign Trade Will Develop by 1975, and its Effect on the New York–New Jersey Port*, The Port of New York Authority, New York, 1967.
92. Whittaker, *op. cit.*
93. The Port of New York Authority, *op. cit.*
94. 'Air freight forwarder demands incentives', *Container News*, December 1970, p. 30.
95. Marc Levinson, *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger*, Princeton University Press, Princeton, NJ, 2006.
96. 'Pan AM and trucker link cargo systems', *The New York Times,* 5 June 1960, p. S18.
97. J. Carter, 'Pacific carriers in sea–air test', *The New York Times,* 5 December 1962, p. 93. Under the trial arrangements, sea–air alliances were created to induce more cargo to move by air and ship instead of all by air. Some high-value, low-bulk commodities (electronic components, optical goods and certain textile) had previously moved entirely by air. A spokesman for Flying Tigers Line estimated that a 5,000-pound shipment of binoculars from Tokyo to New York entirely by sea would cost $860, including packing and handling, and take about 33 days. The shipment moving wholly by air would cost $5,200 and take about three days. If the cargo went by sea to San Francisco and then was trucked to NY, the cost would be around $1,060 and the time would be 18 days. The sea–air program could move the cargo for $860 and do it in 13 days.
98. 'Rail–air freight project test to begin Sunday', *Chicago Tribune*, 2 March 1967, p. G7.
99. K. Ross, 'Over air, land, and seas', *Chicago Tribune*, 18 June 1973, p. A2.
100. Muller, 1989, *op. cit.*
101. Ross, *op. cit.*