Intermodal Transportation and Containerization

Source: Rodrigue and Slack (2013)

The Nature of Intermodalism History as well as competition between modes has tended to produce a transport system that was **segmented and un-integrated**. Each mode, particularly the carriers that operated them, has sought to exploit its own advantages in terms of cost, service, reliability and safety. Carriers try to retain business and increase revenue by maximizing the line-haul under their control. All the modes saw the other modes as competitors, and were viewed with a level of suspicion and mistrust. The lack of integration between the modes was also accentuated by **public policy** that has frequently barred companies from owning firms in other modes (as in the United States before deregulation), or has placed a mode under direct state monopoly control (as in Europe). **Modalism** was also favored because of the difficulties of transferring goods from one mode to another, thereby incurring additional terminal costs and delays, mainly because the load unit needs to be changed, which is common for bulk transportation. Since the 1960s major efforts have been made to integrate separate transport systems through intermodalism, which took place in several stages, first with the setting of maritime networks which then better connected with inland networks. From a functional and operational perspective, two components are involved in intermodalism:

**Intermodal transportation.** The movements of passengers or freight from one mode of transport to another, commonly taking place at a terminal specifically designed for such a purpose. In North America, the term intermodal is also used to refer to containerized rail transportation. Therefore, intermodal transportation in the literal sense refers to an exchange of passengers or freight between two transportation modes, but the term has become more commonly used to strictly related to container transportation.

**Transmodal transportation.** The movements of passengers or freight within the same mode of transport. Although "pure" transmodal transportation rarely exists and an intermodal operation is often required (e.g. ship to dockside to ship), the purpose is to insure continuity within the same modal network.

What initially began as improving the productivity of shipping evolved into an integrated supply chain management system across modes and the development of intermodal transportation networks.

**Intermodal transportation network.** A logistically linked system using two or more transport modes with a single rate. Modes are having common handling characteristics, permitting freight
(or people) to be transferred between modes during a movement between an origin and a destination. For freight, it also implies that the cargo does not need to be handled, just the load unit such as a pallet or a container.

This involves the use of at least two different modes in a trip from an origin to a destination through an intermodal transport chain, which permit the integration of several transportation networks. Intermodality enhances the economic performance of a transport chain by using modes in the most productive manner. Thus, the line-haul economies of rail may be exploited for long distances, with the efficiencies of trucks providing flexible local pick up and deliveries. The key is that the entire trip is seen as a whole, rather than as a series of legs, each marked by an individual operation with separate sets of documentation and rates. This is organized around the followings concepts:

1. The **nature and quantity** of the transported cargo. Intermodal transportation is usually suitable for intermediate and finished goods in load units of less than 25 tons.

2. The **modes of transportation** being used. Intermodal transportation is organized as a sequence of modes, often known as an intermodal transport chain. The dominant modes supporting intermodalism are trucking, rail, barges and maritime. Air transportation usually only require intermodalism (truck ing) for its "first and last miles" and not used in combination with other modes. Additionally, load units used by air transportation are not readily convertible with other modes.

3. The **origins and destinations**. Distances play an important role as the longer the distance, the more likely an intermodal transport chain will be used. Distances above 500 km (longer than one day of trucking) usually require intermodal transportation.

4. Transportation **time and costs**. Intermodalism tries to use each mode according to their respective time and cost advantages so that total transport costs are minimized.

5. The **value of the cargo**. Suitable for intermediate cargo values. Low and high value shipments are usually less suitable for intermodal transportation. High value shipments will tend to use the most direct options (such as air cargo) while low value shipments are usually point to point and relying on one mode such as rail or maritime.

6. The **frequency of shipments**. Intermodalism functions well when cargo flows need to be continuous and in similar quantities.

2. Forms of Intermodalism The emergence of intermodalism has been brought about in part by technology and requires **management units** for freight such as containers, swap bodies, pallets...
or semi-trailers. In the past, pallets were a common management unit, but their relatively small size and lack of protective frame made their intermodal handling labor intensive and prone to damage or theft. Better techniques and management units for transferring freight from one mode to another have facilitated intermodal transfers. Early examples include piggyback (TOFC: Trailers On Flat Cars), where truck trailers are placed on rail cars, and LASH (lighter aboard ship), where river barges are placed directly on board sea-going ships. A unique form of intermodal unit has been developed in the rail industry, particularly in the US where there is sufficient volume. Roadrailer is essentially a road trailer that can also roll on rail tracks. It is unlike the TOFC (piggyback) system that requires the trailer be lifted on to rail flat car. Here the rail bogies may be part of the trailer unit, or be attached in the railway yard. The road unit becomes a rail car, and vice-versa. While handling technology has influenced the development of intermodalism, another important factor has been changes in public policy. Deregulation in the United States in the early 1980s liberated firms from government control. Companies were no longer prohibited from owning across modes, which developed a strong impetus towards intermodal cooperation. Shipping lines in particular began to offer integrated rail and road services to customers. The advantages of each mode could be exploited in a seamless system, which created multiplying effects. Customers could purchase the service to ship their products from door to door, without having to concern themselves of modal barriers. With one bill of lading clients can obtain one through rate, despite the transfer of goods from one mode to another. The most important feature of intermodalism is the provision of a service with one ticket (for passengers) or one bill of lading (for freight). This has necessitated a revolution in organization and information control. At the heart of modern intermodalism are data handling, processing and distribution systems that are essential to ensure the safe, reliable and cost effective control of freight and passenger movements being transported by several modes. Electronic Data Interchange (EDI) is an evolving technology that is helping companies and government agencies (customs documentation) cope with an increasingly complex global transport system. Intermodal transport is transforming a growing share of the medium and long-haul freight flows across the globe where large integrated transport carriers provide door to door services, such as the high degree of integration between maritime and rail transport in North America. In Europe rail intermodal services are becoming well-established between the major ports, such as Rotterdam, and southern Germany, and between Hamburg and Eastern Europe. Rail shuttles are also making their appearance in China, although their market share remains modest. While rail intermodal transport has been relatively slow to develop in Europe, there are extensive interconnections between barge services and ocean shipping, particularly on the Rhine. Barge shipping offers a low cost solution to inland distribution where navigable waterways penetrate to interior markets. This solution is being
tested in North America, although with limited success so far. The limits of intermodality are imposed by factors of space, time, form, pattern of the network, the number of nodes and linkages, and the type and characteristic of the vehicles and terminals. 3. Containerization

The container is what makes the world go round.

The driver of intermodal transportation has undoubtedly been the container, which permits easy handling between modal systems. While intermodalism could take place without the container, it would be very inefficient and costly. At start, a distinction is necessary between containerization and the container.

**Container.** A large standard size metal box into which cargo is packed for shipment aboard specially configured transport modes. It is designed to be moved with common handling equipment enabling high-speed intermodal transfers in economically large units between ships, railcars, truck chassis, and barges using a minimum of labor. The container, therefore, serves as the load unit rather than the cargo contained therein. The reference size is the 20 foot box of 20 feet long, 8’6” feet high and 8 feet wide, or 1 Twenty-foot Equivalent Unit (TEU). Since the great majority of containers are now forty foot long, the term Forty-foot Equivalent Unit (FEU) is also used, but less commonly. "Hi cube" containers are also common and they are one foot higher (9’6”) than the standard.

**Containerization.** Refers to the increasing and generalized use of the container as a support for freight transportation. It involves processes where the intermodal container is increasingly used because it either substitutes cargo from other conveyances, is adopted as a mode supporting freight distribution or is able to diffuse spatially as a growing number of transport systems are able to handle containers.

The development of intermodal transportation and containerization are mutually inclusive, self strengthening and rely of a set of driving forces linked with technology, infrastructures and management. One of the initial issue concerned the different sizes and dimensions of containers used by shipping lines, which were a source of much confusion in compiling container shipping statistics. A lift could involve different volumes since different box sizes were involved. As a result, the term TEU (Twenty foot Equivalent Unit) was first used by Richard F. Gibney in 1969, who worked for the Shipbuilding & Shipping Record, as a comparative measure. Since then, the TEU remains the standard measure for containerized traffic. The usage of containers shows the complementarity between freight transportation modes by offering a higher fluidity to movements and a standardization of loads. The container has substantially contributed to the adoption and diffusion of intermodal transportation which has led to profound mutations in the
transport sector. Through reduction of handling time, labor costs, and packing costs, container transportation allows considerable improvement in the efficiency of transportation. Thus, the relevance of containers is not what they are - simple boxes - but what they enables; intermodalism. Globalization could not have taken its current form without containerization. Intermodalism originated in maritime transportation, with the development of the container in the late 1960's and has since spread to integrate other modes. It is not surprising that the maritime sector should have been the first mode to pursue containerization. It was the mode most constrained by the time taken to load and unload the vessels. A conventional break bulk cargo ship could spend as much time in a port as it did at sea. Containerization permits the mechanized handling of cargoes of diverse types and dimensions that are placed into boxes of standard sizes. In this way goods that might have taken days to be loaded or unloaded from a ship can now be handled in a matter of minutes. Containers are either made of steel (the most common for maritime containers) or aluminum (particularly for domestic) and their structure confers flexibility and hardiness. Another factor behind the diffusion of the container is that an agreement about its base dimensions and latching system was reached through the International Standards Organization (ISO) within 10 years of its introduction. From this standard, a wide variety of container sizes and specifications have been put in use. The most prevalent container size is however the 40 foot box, which in its 2,400 cubic feet which carry on average 22 tons of cargo. However, transporting cargo in a 20 foot container is usually 80% of the cost of transporting cargo in a 40 foot container because irrespective of the size a 20 foot container requires the same amount of intermodal movements even if it takes about half the space during transport and at terminals. There are five main types of containers:

- **Standard container.** Container designed to carry a wide variety general cargo. They are often labeled as dry containers because they carry dry goods either in break bulk (most common) or bulk (less common) form. Cargo is loaded and unloaded through a double door which marks the "back side" of the container.

- **Tank container.** Container designed to carry liquids (chemicals or foodstuff). It is composed of a tank surrounded by a structure making it the same size than a standard 20 foot containers, including its four latching points.

- **Open top container.** A container with an open roof and designed to carry cargo that is too large to be loaded through standard container doors, such as machinery. The container is loaded from the top with a tarpaulin used to cover its contents.

- **Flat container.** Container having an open roof and sides designed to carry heavy and oversized cargo. The cargo transported is left exposed to outdoor conditions.
- **Refrigerated container.** Also known as a reefer. Container designed to carry temperature controlled cargo, often around or below freezing point. It is insulated and equipped with refrigeration plant maintaining the temperature constant.

A significant share of international containers are either owned by shipping lines that tend to use them as a tool to help fill up their ships or by leasing companies using containerized assets for revenue generation. In the United States, a large amount of domestic containers of 53 foot are also used. Doublestacking of containers on railways (COFC: Containers On Flat Cars) has doubled the capacity of trains to haul freight with minimal cost increases, thereby improving the competitive position of the railways with regards to trucking for long-haul shipments. While it is true that the maritime container has become the work horse of international trade, other types of containers are found in certain modes, most notably in the airline industry. High labor costs and the slowness of loading planes, that require a very rapid turnaround, made the industry very receptive to the concept of a loading unit of standard dimensions designed to fit the specific shape of the bellyhold. The maritime container was too heavy and did not fit the rounded configuration of a plane’s fuselage, and thus a box specific to the needs of the airlines was required. The major breakthrough came with the introduction of wide-bodied aircraft in the late 1970s. Lightweight aluminum boxes, called unit load devices, could be filled with passenger’s baggage or parcels and freight, and loaded into the holds of the planes using tracking that requires little human assistance. Containerization represents a revolution in the freight transport industry, facilitating both economies of scale and improvements in handling speed and throughput, with containerized traffic has surged since the 1990s. This underlines the adoption of the container as a privileged mean to ship products on international and national markets, particularly for non-bulk commodities where the container accounts for about 90% of all movements. Containerization leans on growth factors mainly related to globalization, substitution from break bulk and more recently the setting of intermediate transhipment hubs. Although containerization initially superimposed itself over existing transportation systems, as it became a dominant mean of freight transportation it created its own unique system of exclusive modes and terminals. Globalization and containerization as closely interrelated. According to UNCTAD, between 1970 and 1990 trade facilitation measures accounted for 45% of the growth in global trade while membership to global trade organization such as GATT/WTO accounted for another 285%. The container accounted for an additional 790%, exceeding all the other trade growth factors put together. The diffusion and adaptation of transport modes to containerization is an on-going process which will eventually reach a level of saturation. Containers have thus become the most important component for rail and maritime intermodal transportation. The challenge remains about the choice of modes in an
intermodal transport chain as well as minimizing the costs and delays related to moving containers between modes. 4. Advantages and Challenges of Containerization Among the numerous advantages related to the success of containers in international and hinterland transport, it is possible to note the following:

- **Standard transport product.** A container can be manipulated anywhere in the world as its dimensions are an ISO standard. Indeed, transfer infrastructures allow all elements (vehicles) of a transport chain to handle it with relative ease. Standardization is a prevalent benefit of containerization as it conveys a ubiquity to access the distribution system and reduces the risks of capital investment in modes and terminals. The rapid diffusion of containerization was facilitated by the fact that its initiator, Malcolm McLean, purposely did not patent his invention. Consequently all segments of the industry, competitors alike, had access to the standard. It necessitated the construction of specialized ships and of lifting equipment, but in several instances existing transport modes can be converted to container transportation.

- **Flexibility of usage.** It can transport a wide variety of goods ranging from raw materials (coal, wheat), manufactured goods, and cars to frozen products. There are specialized containers for transporting liquids (oil and chemical products) and perishable food items in refrigerated containers (called "reefers" which now account for 50% of all refrigerated cargo being transported). About 1.6 million TEUs of reefers were being used by 2009. In many developing countries, discarded containers are often used as storage, housing, office and retail structures.

- **Management.** The container, as an indivisible unit, carries a unique identification number and a size type code enabling transport management not in terms of loads, but in terms of unit. This identification number is also used to insure that it is carried by an authorized agent of the cargo owner and is verified at terminal gates. Computerized management enables to reduce waiting times considerably and to know the location of containers (or batches of containers) at any time. It enables to assign containers according to the priority, the destination and the available transport capacities. Transport companies book slots in maritime or railway convoys that they use to distribute containers under their responsibility. As such, the container has become a production, transport and distribution unit.

- **Economies of scale.** Relatively to bulk, container transportation reduces transport costs considerably, about 20 times less. While before containerization maritime transport costs could account between 5 and 10% of the retail price, this share has been
reduced to about 1.5%, depending on the goods being transported. The main factors behind costs reductions reside in the speed and flexibility incurred by containerization. Similar to other transportation modes, container shipping is benefiting from economies of scale with the usage of larger containerships (The 6,000 TEUs landmark was surpassed in 1996 with the Regina Maersk and in 2006 the Emma Maersk surpassed the 14,000 TEU landmark). A 5,000 TEU containership has operating costs per container 50% lower than a 2,500 TEU vessel. Moving from 4,000 TEU to 12,000 TEU reduces operating costs per container by a factor of 20%, which is very significant considering the additional volume involved. System-wide the outcome has been costs reductions of about 35% by the use of containerization.

- **Speed.** Transshipment operations are minimal and rapid, which increase the utilization level of the modal assets and port productivity. A modern container ship has a monthly capacity of 3 to 6 times more than a conventional cargo ship. This is notably attributable to gains in transhipment time as a crane can handle roughly 30 movements (loading or unloading) per hour. Port turnaround times have thus been reduced from an average of 3 weeks in the 1960s to less than 24 hours, since it is uncommon for a ship to be fully loaded or unloaded along regular container shipping routes. It takes on average between 10 and 20 hours to unload 1,000 TEUs compared to between 70 and 100 hours for a similar quantity of bulk freight. With larger containerships, more cranes can be allocated to transhipment; 3 to 4 cranes can service a 5,000 TEU containership, while ships of 10,000 TEUs can be serviced by 5 to 6 cranes. This implies that larger ship sizes do not have much differences in loading or unloading time. A regular freighter can spend between half and two-third of its useful life in ports. With less time in ports, containerships can spend more time at sea. Since a ship generates revenue while at sea, containerships are more profitable. Further, containerships are on average 35% faster than regular freighter ships (19 knots versus 14 knots). Put all together, it is estimated that containerization has reduced travel time for freight by a factor of 80%.

- **Warehousing.** The container limits damage risks for the goods it carries because it is resistant to shocks and weather conditions. The packaging of goods it contains is therefore simpler, less expensive and can occupy less volume. This reduces insurance costs since cargo is less prone to be damaged during transport. Besides, containers fit together permitting stacking on ships, trains (doublestacking) and on the ground. It is possible to superimpose three loaded and six empty containers on the ground. The container is consequently its own warehouse.
**Security.** The contents of the container are anonymous to outsiders as it can only be opened at the origin, at customs and at the destination. Thefts, especially those of valuable commodities, are therefore considerably reduced, which results in lower insurance premiums. Theft was a serious issue at ports before containerization as longshoremen had ready access to cargo.

In spite of numerous advantages in the usage of containers, some challenges are also evident:

- **Site constraints.** Containerization implies a large consumption of terminal space. A containership of 5,000 TEU requires a minimum of 12 hectares of unloading space, while unloading entirely its containers would require the equivalent of about 7 double-stack trains of 400 containers each. Conventional port areas are often not adequate for the location of container transshipment infrastructures, particularly because of draft issues as well as required space for terminal operations. Many container vessels require a draft of at least 14 meters (45 feet). A similar challenge applies to container rail terminals, many being relocated at the periphery of metropolitan areas. Consequently, major container handling facilities have modified the local geography of container by forcing relocation to new sites at the periphery.

- **Infrastructure costs.** Container handling infrastructures, such as gantry cranes, yard equipment, road and rail access, represent important investments for port authorities and load centers. For instance, the costs of a modern container crane (portainer) are in the range of 4 to 10 million $US depending on the size. Several developing countries cannot afford these infrastructures with local capital and so have difficulties to participate effectively in international trade as efficient load centers unless concession agreements are reached with terminal operators.

- **Stacking.** The arrangement of containers, both at terminals and on modes (containerships and double-stack trains) is a complex problem. At the time of loading, it becomes imperative to make sure that containers that must be taken out first are not below the pile. Further, containerships must be loaded in a way to avoid any restacking along its numerous port calls where containers are loaded and unloaded.

- **Thefts and losses.** While many theft issues have been addressed because of the freight anonymity a container confers, it remains an issue for movements outside terminals where the contents of the container can be assessed based upon its final destination. It is estimated that about 10,000 containers per year (27 per day) are lost at sea when they fall overboard containerships. Rough weather is the major cause, but improper
container stacking also plays a role (distribution of heavy containers). Yet, the loss rate remains very low since 5 to 6 million containers are being transported at any given time.

- **Empty travel.** Maritime shippers need containers to maintain their operations along the port networks they service. The same number of containers brought into a market must thus eventually be relocated, regardless if they are full or empty. On average containers will spend about 56% of their 10 to 15 years lifespan idle or being repositioned empty, which is not generating any income but convey a cost that must be assumed in one way or the other. Either full or empty, a container takes the same amount of space on the ship or in a storage yard and takes the same amount of time to be transshipped. Due to a divergence between production and consumption, it is uncommon to see an equilibrium in the distribution of containers. About 2.5 million TEUs of empty containers are stored in yards and depots around the world, underlining the issue of the movement and accumulation of empty containers. They represent about 20% of the global container port throughput and of the volume carried by maritime shipping lines. Most container trade is imbalanced, and thus containers "accumulate" in some places and must be shipped back to locations where there have deficits (mostly locations having a strong export function). This is particularly the case for American container shipping. As a result, shipping lines waste substantial amounts of time and money in repositioning empty containers.

- **Illicit trade.** By its confidential character, the container is a common instrument used in the illicit trade of drug and weapons, as well as for illegal immigrants. Concerns have also been raised about containers being used for terrorism. These fears have given rise to an increasing number of regulations aimed at counteracting illegal use of containers. In 2003, following US inspection requirements the International Maritime Organization (IMO) introduced regulations regarding the security of port sites and the vetting of workers in the shipping industry. The US, itself established a 24 hour rule, requiring all shipments destined for the US to receive clearance from US authorities 24 hours prior to the departure of the vessel. In 2008, the US Congress has passed a regulation requiring all US-bound containers to be electronically scanned at the foreign port of loading, prior to departure. Needless to say, these measures incur additional costs and delays that many in the industry oppose.

Yet, the advantages of containerization have far outweighed its drawbacks, transforming the global freight transport system and along with it the global economy. 5. Intermodal Transport Costs There is a relationship between transport costs, distance and modal choice that has for
long been observed. It enables to understand why road transport is usually used for short distances (from 500 to 750 km), railway transport for average distances and maritime transport for long distances (about 750 km). Variations of modal choice according to the geographical setting are observed but these figures tend to show a growth of the range of trucking. However, intermodalism offers the opportunity to combine modes and find a less costly alternative than an unimodal solution. It is also linked with a higher average value of the cargo being carried since intermodal transportation is linked with more complex and sophisticated commodity chains. As a result, the efficiency of contemporary transport systems rests as much on their capacity to route freight than on their capacity to transship it, but each of these functions have a cost that must be reduced. The intermodal transportation cost implies the consideration of several types of transportation costs for the routing of freight from its origin to its destination, which involves a variety of shipment, transshipment and warehousing activities. It considers a logistic according to which are organized transport chains where production and consumption systems are linked to transport systems. Numerous technical improvements, such as river / sea shipping and better rail/road integration, have been established to reduce interchange costs, but containerization remains the most significant achievement so far. The concept of economies of scale applies particularly well to container shipping. However, container shipping is also affected by diseconomies involving maritime and inland transport systems as well as transshipment. While maritime container shipping companies have been pressing for larger ships, transshipment and inland distribution systems have tried to cope with increased quantities of containers. Thus, in spite of a significant reduction in maritime transport costs, land transport costs remain significant. Between half and two-third of total transport costs for a TEU is accounted by land transport. Public policy is also playing a role through concerns over the dominant position of road transport in modal competition and the resultant concerns over congestion, safety and environmental degradation. In Europe, policies have been introduced to induce a shift of freight and passengers from the roads to modes that are environmentally more efficient. Intermodal transport is seen as a solution that could work in certain situations. In Switzerland, for example, laws stipulate that all freight crossing through the country must be placed on the railways in order to try to reduce air pollution in alpine valleys. The European Union is trying to promote intermodal alternatives by subsidizing rail, and shipping infrastructure and increasing road user costs. Since intermodal transportation is mostly the outcome of private initiatives seeking to capture market opportunities it remains to be seen to what extent public strategies can be reconciled with a global intermodal transport system which is flexible and footloose. While economies of scale enabled to reduce the unit costs of maritime, inland intermodal transportation costs account to about 50% of the total costs if terminal costs are included. With the deregulation and privatization trends that began in
the 1980’s, containerization, which was already well established in the maritime sector, could spread inland. The shipping lines were among the first to exploit the intermodal opportunities that deregulation permitted. They could offer door-to-door rates to customers by integrating rail services and local truck pick up and delivery in a seamless network. To achieve this they leased trains, managed rail terminals, and in some cases purchased trucking firms. In this way they could serve customers across the country by offering door-to-door service from suppliers located around the world. The move inland also led to some significant developments, most notably the double-stacking of containers on rail cars. This produced important competitive advantages for intermodal rail transport and favored the development of inland terminals. It also required various forms of transloading between maritime and domestic container units.