Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Project

Department Fahrzeugtechnik und Flugzeugbau

Contributions of Air Cargo to Today's and Future Intermodal Freight Transport

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Abstract

This project contains a literature research about the theme cargo chains for different transport modes and the contribution of air cargo transport in those general cargo chains. Through comprehension and description of the today's cargo chains, the compatibility between the different transport modes will be checked in order to investigate and suggest possible evolutions towards the future cargo chains.

First of all, the aspects of a general cargo chain for all transport modes were described. The project focuses on how an ideal cargo chain should work and the sequence of the different stages from input till output. By describing separately air, road, rail and sea transport modes, congregation between air and the intermodal transport modes have been researched. After this general description the air cargo chain has been taken under the magnifying glass. The research is especially deepened into advantages and drawbacks of the combination between the air transport mode and intermodal transport modes in the general cargo chain, as the functionality of standardisation in the whole process.

Subsequently a survey has been made of different transport devices used in all transport modes with a more detailed look to the one's used in air freight transport in order to result in a classification of three types of transport devices. Side activities, such as loading and unloading and other cargo handling activities in air cargo transport were briefly mentioned along this project.

Finally after describing factors influencing air cargo transport, the actual cargo chain is able to be optimized in order to have a more efficient cargo transport in the future and finally a reduction of costs, and a gain in time can be achieved. Some developments and evolutions, such as centralisation, multimodality, etc. are substantiated by several actual examples.

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DEPARTMENT OF AUTOMOTIVE AND AERONAUTICAL ENGINEERING

Contributions of Air Cargo to Today's and Future Intermodal Freight Transport

Task for a *Project 2*

Background

Air cargo differs in many ways from other modes of cargo transport, i. e. by truck, rail or ship. This results largely from the fact that freighter aircraft very often are converted passenger aircraft and that much cargo is transported in the confined lower deck compartments of passenger aircraft. This leads to a great amount of handling (e. g. re-packing of air cargo containers) needed when integrating air cargo into an intermodal cargo chain causing high handling costs and financial penalties. This project is part of the aircraft design research project "Green Freighter" (http://GF.ProfScholz.de).

Task

The project task is to support the development of new freighter aircraft configurations by describing the various types of today's cargo transport and pointing out needs and possibilities of improvement.

The task includes

- a description of the air cargo chain including means of transport and interface points,
- a survey of container types used in air and other types of cargo transport,
- a comparison between different modes of cargo transport regarding costs, time, environmental issues, standardization, handling and interfaces,
- a conclusion highlighting possible developments of a specially designed freighter aircraft with respect to the design of the fuselage and the cargo compartment.

The report has to be written according to German DIN standards on report writing!

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List of Abbreviations

A	Airbus
ACLP	Airport City Logistic Park
ALPA	Air Line Pilot’s Association
APIE	Air Power International Express
B	Boeing
C	Celsius
CIFAL	Centre International de Formation des Acteurs Locaux
e.g.	exempli gratia
ER	Extended Range
etc.	etcetera
F	Freighter
FAB	Fördertechnik und Anlagenbau
FAK	Freight All Kind
FedEx	Federal Express
FEU	Forty-feet Equivalent Unit
ft	foot (')
FTZ	Free Trade Zone
GDV	Gesamtverband der Deutschen Versicherungswirtschaft
GFRP	Glass Fibre Reinforced Plastic
GPS	Global Positioning System
HAGF	Highways Agency Guide to Freight
ITRI	Industrial Technology Research Institute
IATA	International Air Transport Association
ICAO	International Civil aviation Organization
in	inch (")
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
IT	Information Technology
JIT	Just In Time
kg	kilogram
L	Lockheed
LD	Load Device
LR	Long Range
LTL	Less Than Truckload
m	meter
MD	McDonnell-Douglas
min.	minute
MIT	Massachussets Institute of Technology
NTSB	National Transportation Safety Board

RFID	Radio Frequency Identification
RO-RO	Roll On – Roll off
SARS	Severe Acute Respiratory Syndrome
SCM	Supply Chain Management
TC	Technical Committee
TEU	Twenty-feet Equivalent Unit
ULD	Unit Load Device
US	United States
USA	United States of America
vs.	versus
WWW	World Wide Web

Definitions

Air Cargo

"Air cargo is the merchandise or goods, called freight, partially transported by air. In terms of packaging requirements, air cargo is similar to Less-Than-Truckload shipments, and typically moving faster than five hundred miles per day. Air shipments may be booked directly with the carriers or through brokers or online marketplace services." (**Wikipedia 2007**)

Cargo Chain

A cargo chain is the concatenation of steps (e.g. packing of the freight, (un)loading of the freight, transfer, transport, etc.) in order to transport cargoes from a starting point, generally the producing factory, to an ending point, generally the store.

Cargo Handling

"Cargo handling is the process of packing, loading, unloading and distributing merchandise or cargo from a transport device. " (**based on The Freedictionary.com 2003**)

Containerisation

"Containerisation is a system of intermodal freight transport cargo transport using standard ISO containers that can be loaded and sealed intact onto container ships, railroad cars, planes, and trucks." (**Wikipedia 2007**)

Intermodal Transport

"Intermodal transport involves the use of at least two different modes in a trip from origin to destination through an intermodal transport chain. " (**Rodrigue *et al.* 2007**)

Logistics

"Logistics is the art and science of managing and controlling the flow of goods, energy, information and other resources like products, services, and people, from the source of production to the marketplace. It is difficult to accomplish any marketing or manufacturing without logistical support. It involves the integration of information, transportation, inventory, warehousing, material handling, and packaging." (**Wikipedia 2007**)

Supply Chain Management

"Supply chain management (SCM) is the process of planning, implementing, and controlling the operations of the supply chain with the purpose to satisfy customer requirements as efficiently as possible. SCM spans all movement and storage of raw materials, work-in-process inventory, and finished goods from point-of-origin to point-of-consumption." (**Wikipedia 2007**)

1 Introduction

1.1 Motivation

This project is a part of the "Green Freighter" project. The “Green Freighter” project is a research project over a period of 3 years, that started in 2006. The concept is to work out a research about cargo aircraft configurations in order to design a cargo aircraft in the future. The main accents lay on environmentally friendly and economic aircraft operations. Therefore, a general preliminarily study concerning air cargo transport is necessary.

In order to have a good idea about the design of the cargo configuration of the „Green Freighter“, the various methods used in today’s cargo transport have to be investigated. As a consequence, all aspects of the actual cargo chain have to be taken under the magnifying glass.

1.2 Aim of the Project

As mentioned in the motivation, the study of the actual cargo chain is unavoidable. The aim of this project is to give a good overview about what a cargo chain is, which elements are participating or influencing the cargo handling and which possible improvements can be made in order to have a more efficient cargo transport.

The project should imply explications about the actual cargo chain in its totality and a thorough research about the different container types used in today’s air cargo transport. In order to compare with the other cargo transport modes, the compatibility concerning cargo handling should be investigated as well as aspects influencing the cargo chain.

Finally some suggestions shall be worked out to improve the cargo handling in time or reduce the handling costs.

1.4 Literature Review

This project is a literature review about air cargo chains and air cargo handling operations. The literature sources are mainly a hodgepodge of internet sites and internet articles. The most important sources are mentioned below.

For general knowledge about containers, containerisation, logistics, etc. **Wikipedia** sufficed in order to collect general information. **Wikipedia** is a site made by and made for people. It constitutes an excellent base to seek for further thorough information.

Inamar Cargo Insurance is insurance company against loss of cargo. Originally they only insured maritime transported cargo. Meanwhile they expanded and insure currently also air cargo. Their site provide guidance and manuals concerning ULD classification, cargo handling, cargo hazards, etc.

Freighteronline.com is an excellent base for investigation about load devices used in air cargo transport. It also offers aircraft configurations and additional data (e.g. payload graph, locations of cargo compartments, etc.) for a wide range of currently flying freighters.

1.5 Structure of the Project

The main part of this project consists of descriptions and overviews about the air cargo chains with its side aspects. The project consists of following chapters:

Chapter 2 describes generally the cargo chain and the concerned aspects.

Chapter 3 is a survey about the different container types in air cargo transport and other transport modes. The compatibility between those modes is taken into consideration.

Chapter 4 explains the influence of the main factors such as environment, costs, time, standardisation, etc.

Chapter 5 suggests possible developments and optimization towards the future concerning air cargo transport.

2 The Cargo Chain

This chapter includes a brief but general overview about the actual cargo chain with its side aspects. By starting to describe the general cargo chain for all transport modes, followed by a look at the impact of the cargo types to the choice of transport mode, the use of an air cargo chain should be clarified. Finally, the part where the air cargo chain is involved will be taken under a closer look. Issues experienced in today's cargo handling will be emphasized in order to suggest some optimization.

2.1 The General Cargo Chain

The cargo chain is the concatenation of steps in order to transport cargoes from a starting point, generally the producing factory, to an ending point, generally the store. As the transportation between different points being the most important factor, the cargo market consists mainly of **trucking, rail, seaborne and air cargo**. All these different means of transport have an interaction with each other when cargo needs to be transferred. It is obvious that all types of transport can be present in a cargo chain but the most common basic cargo chains generally consist of the combinations shown in Figure 2.1.

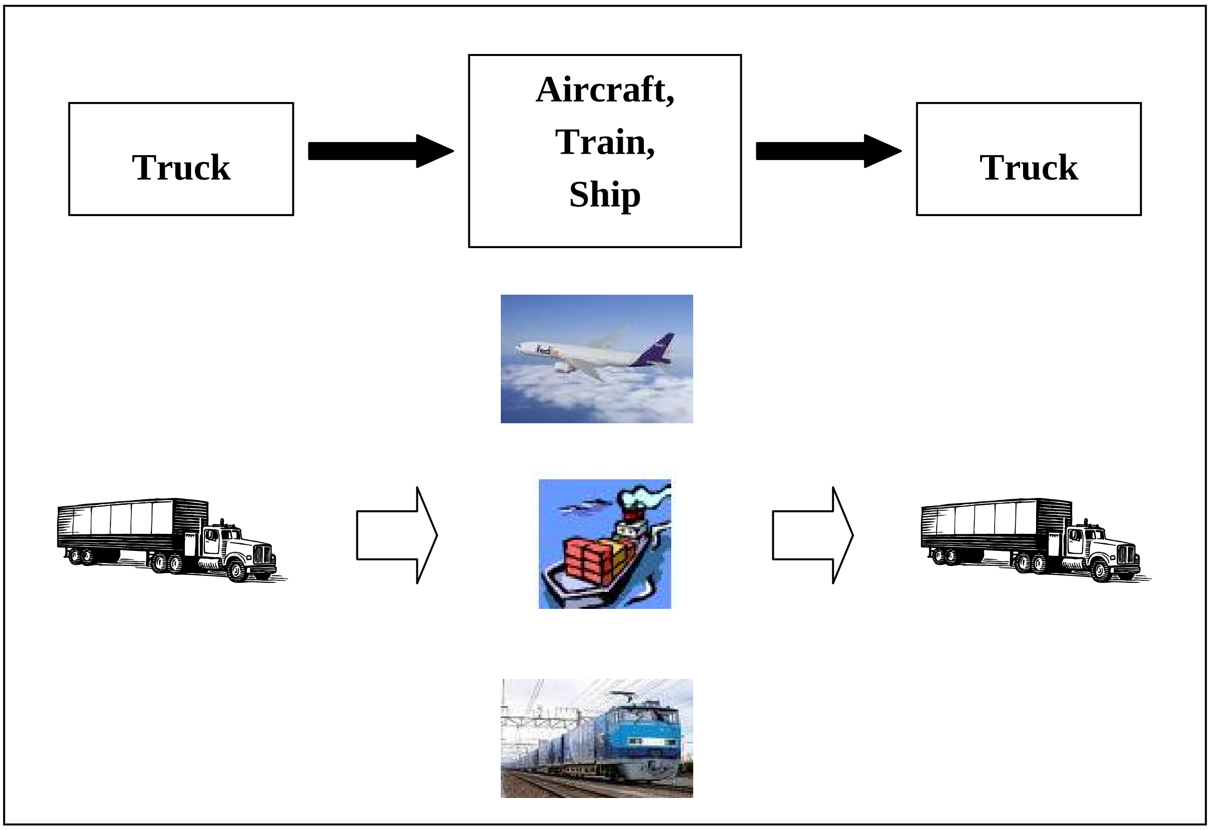


Figure 2.1 Basic cargo chains: transportation

Dependant on the situation, economical advantages, available facilities, environmental aspects, etc. other variations occur (e.g. truck – air – truck – train).

Each mean of transport has some **specific characteristics** why it is used or not used for. Some of those are mentioned below.

- **Truck:**
  Trucks are generally used for short to intermediate distances over land. They can carry all types of cargo. Trucks have the advantages of easily reaching beginning points or destinations, due to the world wide road infrastructure. A second huge advantage is that it is an intermodal mean of transport, which leads to compatibility with rail and sea cargo transport. With the increasing number of road traffic, trucks are sensible to traffic jams which can result in a loss of time (and money).

- **Train:**
  Freight trains are generally used for intermediate to long distances over land. Sometimes “undersea” transport is also performed by rail if there is an available passage, e.g. The Chunnel (**Wikipedia 2007a**). They can carry all types of cargo. Trains have the huge advantage of having a straight connection, and are not subject to traffic jams. Loss of time can be significantly reduced. A drawback is that the destinations of trains are mostly an intermediary destination and not the final destination (e.g. store). This makes combination with other transport modes necessary.

- **Ship:**
  Container ships are generally used for very long distance cargo over sea. They have the largest freight capacity of all transport modes and are able to carry a large amount of containers. All cargo types are able to be transported. As the delivery time being a drawback, the transportation of time critical freight/units will be avoided.

- **Aircraft:**
  Freight aircraft make also large cargo capacity transport possible over very long distances. The advantage of cargo aircraft is that transportation occurs in the air. So both, over sea and over land transportation, are replaceable by air transport. The delivery time of air cargo is significantly lower than for ships, which makes it attractive to transport time critical freight. An important drawback is that not all cargo types are transportable, as the cargo should be palletized or containerized. So mostly solid goods are transported by air.

Due to the increasing popularity of production in low-cost countries and the expansion of assembled export products, air transport and sea transport are potential competitors, as they both function for long distance transport.

A first important factor in order to achieve an optimal and efficient working cargo chain is the relation between the type of transported freight and the mean of transport. A second factor is that many times different mean of transport need to interact with each other. This is called **intermodality**. The next paragraphs treat those interactions between cargo type and transport mode and mutual transport modes.

2.1.1 Cargo Transport Modes

Transport modes are the means by which freight is carried. They fall into one of three basic types, depending on over which physical environment they travel. Those three types are land (road, rail and also pipelines), water (maritime shipping), and air (air cargo transport). Each mode is characterized by a set of technical, operational and commercial characteristics.

Figure 2.2 illustrates that because of their operational characteristics, several freight transportation modes have different capacities and levels of efficiency. While the truck is certainly the mode which has the least capacity, it has a level of flexibility (speed and door-to-door services) unmatched by rail, fluvial and aeronautical transportation.

Vehicle	Capacity	Truck Equivalency
Barge	1500 Tons 52,500 Bushels 453,600 Gallons	57.7 (865.4 for 15 barges in tow)
Hopper car	100 Tons 3,500 Bushels 30,240 Gallons	3.8
100 car train unit	10,000 Tons 350,000 Bushels 3,024,000 Gallons	384.6
Semi-trailer truck	26 Tons; 910 Bushels 7,865 Gallons 9,000 for a tanker truck	1
Post-panamax containership	5,000 TEU	2,116
VLCC	300,000 tons 2 million barrels of oil	9,330
747-400F	124 tons	5

Figure 2.2 Performance comparison for several freight modes (**Rodrigue *et al.* 2007**)

On the following pages, the different mean of transportation are subdivided by sort and clarified (**based on Rodrigue *et al.* 2007**).

- **Road transportation**:

  Road infrastructures are large consumers of space with the lowest level of physical constraints among transportation modes. However, environmental constrains are significant in road construction. Road transportation has an average operational flexibility as vehicles can serve several purposes but are rarely able to move outside roads. Road transport systems have high maintenance costs, both for the vehicles and infrastructures. They are mainly linked to light industries where rapid movements of freight in small batches are the norm.

  Vehicles enrolled in road transportation vary from delivery vans to trucks with ISO-containers. Figure 2.3 illustrates and example of a lorry carrying an ISO-container.

Figure 2.3 Lorry with Maersk container (**Philadelphia Port Authority 2007**)

- **Rail transportation:**

  Railways are composed of a traced path on which are bound vehicles. They have an average level of physical constrains linked to the types of locomotives and affected by the gradient. Heavy industries are traditionally linked with rail transport systems, although containerization has improved the flexibility of rail transportation by linking it with road and maritime modes. Rail is by far the land transportation mode offering the highest capacity with 23000 tons coal train being the heaviest load ever carried.

  Many improvements concerning rail transportation have been achieved. One of them is the double stacking of containers in order to double cargo capacity in. This example is shown in Figure 2.4 on the next page.

Figure 2.4 Double stacked containers (**Haggerty 2004**)

- **Maritime transportation**:

  Because of the physical properties of water conferring buoyancy and limited friction, maritime transportation is the most effective mode to move large quantities of cargo. Main maritime routes are composed of oceans, coasts, seas, lakes, rivers and channels. However, maritime circulation takes place on specific parts of the maritime space, particularly over the North Atlantic and the North Pacific. The construction of channels, locks and dredging are attempts to facilitate maritime circulation by reducing discontinuity. Comprehensive inland waterway systems include Western Europe, the Volga / Don system, St. Lawrence / Great Lakes system, the Mississippi and its tributaries, the Amazon, the Panama / Paraguay and the interior of China. Maritime transportation has high terminal costs, since port infrastructures are among the most expensive to build, maintain and improve. High inventory costs also characterize maritime transportation. More than any other mode, maritime transportation is linked to heavy industries, such as steel and petrochemical facilities adjacent to port sites.

  Figure 2.5 illustrates the “Emma” from ***Maersk***, as being one of the biggest cargo ships transporting containers.

Figure 2.5 ***Maersk*** Line Containership (**Maasvlakte 2006**)

- **Air transportation**:

Air routes are practically unlimited, but they are denser over the North Atlantic, inside North America and Europe and over the North Pacific. Air transport constraints are multidimensional and include the site (a commercial plane needs about 3300 meters of track for landing and take off), the climate, fog and aerial currents. Air activities are linked to the tertiary and quaternary sectors, notably finance and tourism that require movements of people. More recently, air transportation has been accommodating growing quantities of high value freight and is playing a growing role in global logistics.

Among the cargo aircraft there are two main categories regarding operations, namely military and civil cargo transport. The ***Antonov*** An-225, illustrated in Figure 2.6, is the world's largest freighter aircraft and is used for military purposes. The ***Boeing*** B-747, illustrated in Figure 2.7, is currently the largest civil freighter flying in our skies.

Figure 2.6 ***Antonov*** An-225 (**Maasvlakte 2006**)

Figure 2.7 ***Boeing*** B-747 (**Jade Cargo 2007**)

2.1.2 Cargo Types

Cargo is a term used to denote goods or produce being transported generally for commercial gain, usually on a ship, plane, train, van or truck. Nowadays containers are used in all intermodal long-haul cargo transport. Types of freight are subdivided in following categories (**Haggerty 2004**):

- small package delivery,
- less-than truckload (LTL) freight,
- airline belly freight,
- palletized freight,
- containerized freight,
- and bulk cargo.

These different types are subject to the transportation mode. An overview of the cargo types for different transport modes is quoted on the next page (**Wikipedia 2007e**).

1. **Marine Cargo Types**

   Transport over sea is the most popular transport mode, leading to development of the transport of a wide range of cargo types:

   - **containerized cargo,** including the transport of small components (e.g. toys, shoes, etc.) to larger components (e.g. auto and machinery parts, etc.),
   - **automobiles,**
   - **project cargo,** including oversized or overweight freight to fit in a container (e.g. factory components, manufacturing equipment, etc.),
   - **break bulk cargo** is material stacked on wooden pallets but is declining with the growth of containerization,
   - **bulk cargo** defined as commodities, not really suitable for pallets or containers. The cargo compartment is integral to the mean of transport. In this category, a distinction is made between liquid bulk (e.g. oil, gas, etc.) and dry or solid bulk (e.g. powders, granular particles, coal, etc.).

2. **Air Cargo**

   Air cargo is commonly known as freight and first consisted of the carriage of mail in 1911. But with the introduction of larger cargo airplanes, the range of freight type extended. Air cargo is generally packaged into boxes, which are **palletized** or **containerized** in specific air cargo load devices.

3. **Train Cargo**

   Trains are capable of transporting large numbers of containers which are coming from the shipping ports. Trains are used as they can pull a large amount and generally have a direct route to the destination. Train cargo consists of containers suitable for a large range of freight, including:

   - **liquid bulk cargo** (in specific tank-type containers),
   - **solid (dry) bulk cargo** (e.g. steel, wood, coal, etc.),
   - **general cargo** (in basic intermodal containers not requiring environmental control).

4. **Van/Lorry Cargo**

   This mean of transport is suitable for **all kind of freight**, as generally being the link between the three former explained transport modes.

2.1.3 Intermodal Transport

Intermodal transport involves more than one mode of transport. For example, passenger stations which provide transfers between buses and trains are described as intermodal (see: intermodal passenger transport). This article describes intermodal as applied to the transportation of freight in a container or vehicle, using multiple modes of transportation (rail, ocean vessel, and truck), without any handling of the freight itself when changing modes. The advantage of utilizing this method is that it reduces cargo handling, and so improves security, reduces damages and loss, and allows freight to be transported faster (**Wikipedia 2007b**).

Conventionally, the competition between the modes has tended to produce a transport system that is segmented and un-integrated. Each mode has sought to exploit its own advantages in terms of **cost, service, reliability and safety**. But standardisation of transport devices and the development and integration through intermodalism lead to a greater profit for all separate transport modes.

Today, intermodal transport is transforming a growing share of the medium and long-haul freight flows across the globe. Large integrated transport carriers provide door to door services. The limits of intermodality are imposed by factors of space, time, form, pattern of the distribution network, the number of nodes and linkages, and the type and characteristic of the vehicles and terminals. Intermodality can be conceived as the transition from one mode of transportation to another, and is organized around the followings five concepts mentioned on the next page (**Rodrigue *et al.* 2007**).

1. The nature and quantity of the transported commodities
2. The modes of transportation being used
3. The origins and destinations
4. Transportation time and costs
5. The value of the commodities and the frequency of shipment

Intermodal transport include transportation by rail, road and sea. So when intermodality is mentioned, air transport is not always taken into account. The issue is now that with transfer of one of those modes to an aircraft **rehandling** is necessary with a loss of time as result. The reason is that air cargo containers differ from the actual ISO-containers used in intermodal transport. Small adaptations and evolutions are already made (e.g. AGA - 20 ft Box container (M-6) , which is similar to the ISO-container), but a lot of improvement still needs to be performed (**based on Freightersonline 2007a**).

Figure 2.8 illustrates an ISO-container used for intermodal transportation.

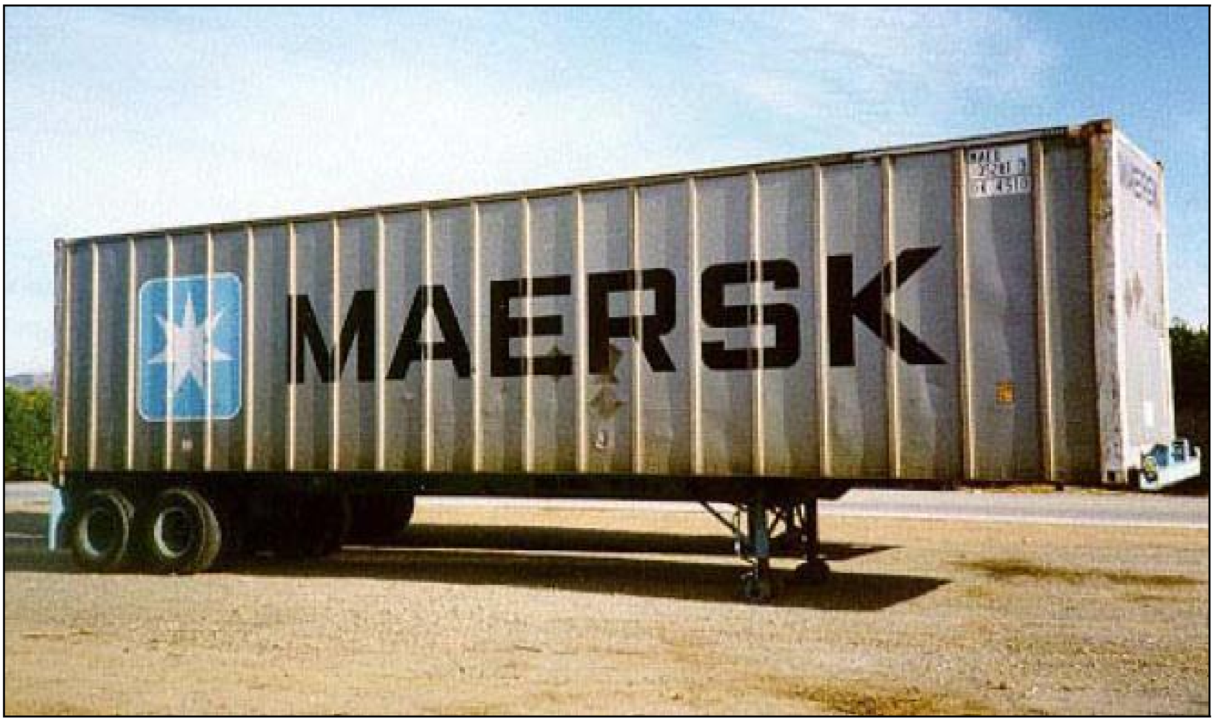


Figure 2.8 Shipping Line intermodal ISO container (**Haggerty 2004**)

2.2 Air Cargo Chains

The air cargo chain is the part of the chain where the freight is coming into the departure airport till the freight has left the destination airport. As consequence, the air cargo chain is roughly consisting of following steps (**based on Siemens 2006**).

1. Import in the logistic centre
   The freight can eventually be rehandled into ULDs or stored, if necessary.
2. Distribution to the concerned aircraft
   By means of intra-airport transport devices (e.g. dollies)
3. Loading of the aircraft:
   By use of specific infrastructure (e.g. loading bridges)
4. Transportation of the freight
5. Unloading of the aircraft
   This part is similar to the loading part, but in inversed way
6. Redistribution in the logistic centre:
   This part is similar to the distribution part, but in inversed way
7. Export of the freight

These steps are treated more in detail in the sections “Air Logistics” and “Cargo Handling” and “Cargo Loading”. The Figure 2.9 is a schematic representation of the air cargo chain.

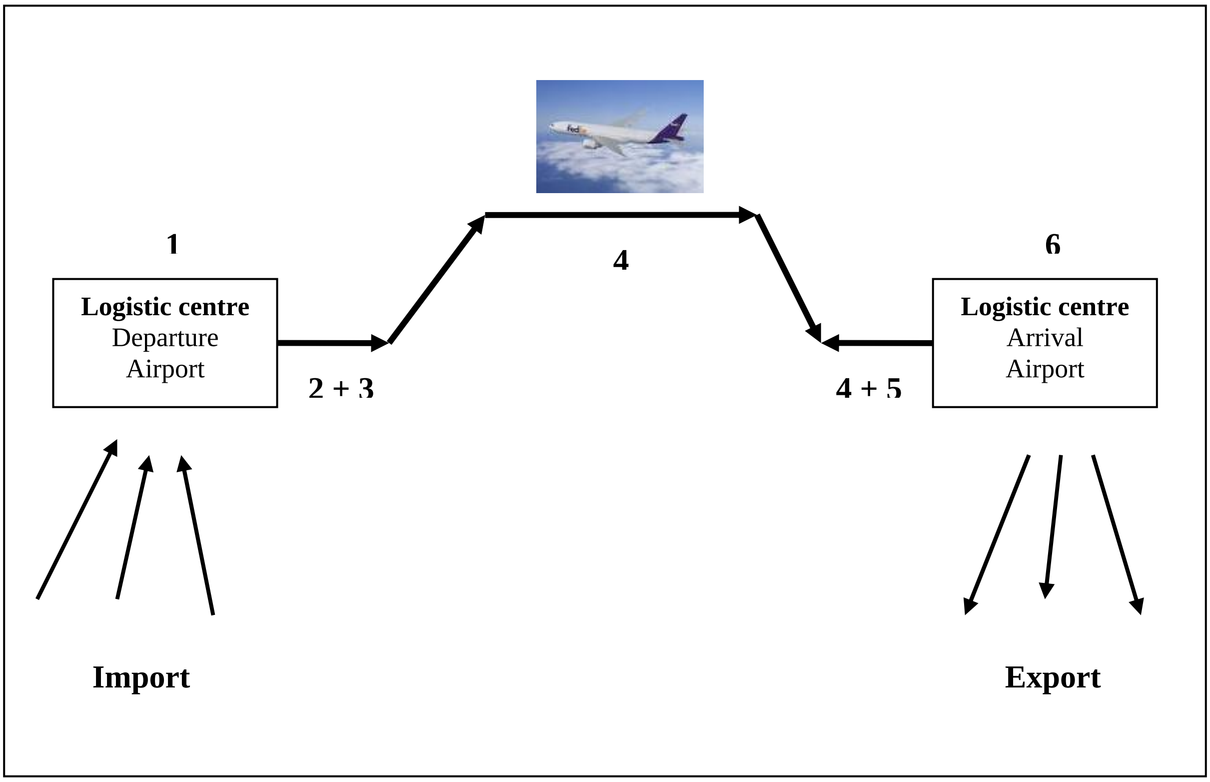


Figure 2.9 Schematic visualisation of the air cargo chain

The use of air cargo in a general cargo chain can be encouraged for multiple reasons. The most important (mostly from an economical point of view) are enumerated below (**based on Siemens 2006**).

- transport of time critical freight (e.g. urgent packages, data, parts, etc.),
- air cargo market is aided to reduce inventories and cycle time,
- shorter time to the market is reachable,
- high value to weight products dominates the new economy,
- global supply chains are the new competitive units,
- and speed and agility are as important as price and quality to compete in many high-value sectors.

In order to meet transport criteria set up by the cargo companies, there are different freighters available. Freighters are generally manufactured new (e.g. B747-400 ERF) or are made of former passenger aircraft (MD-10). The different types of cargo aircraft are generally classified as mentioned below:

- **freighters,**
  Fully used for cargo transport (e.g. B-747 F, MD-11F, new A-380)
- **combi aircraft,**
  Transportation of passengers and cargo (e.g. ***Alitalia*** has MD-11 Combi carriers for more than 200 passengers and a main deck cargo after)
- **and convertible freighters.**
  The conversion from passenger aircraft to freighter should occur in max. 24 hours, and the conversion from freighter to passenger aircraft should occur in max. 48 hours (e.g. MD-11CF of ***MartinAir-Holland***)

The biggest air cargo carriers are ***Polar Air Cargo***, ***Atlas Air***, ***DHL***, ***Lufthansa Cargo*** and ***Fedex*** (**Haggerty 2004**).

The section air cargo is subdivided into a general word about logistics in the air cargo chains, followed by the general handling procedures in air cargo chains with the side aspects such as hazards and standardisation. In the end a brief overview of the actual air cargo market and the possible prospects is given.

2.2.1 Air Logistics

According to the **International Training Center for Government Authorities and Civil Society Leaders** Some major evolutions in the past decades, concerning air cargo transport, have been occurring (**Kasarda 2006**).

- Firms are clustering near major airports:
  Air cargo provides connectivity, speed and agility to new-economy global supply chains and the connectivity to corporate customers nationally and worldwide.

- Development of multimodal air logistics platforms at major airports:
  Together with integrated surface transportation networks offering firms superior speed, agility, and highly efficient **Supply Chain Management (SCM)**.

- Speed and agility:
  Major airports become magnets for time-critical manufacturing, distribution and SCM.

A logic consequence of those evolutions is that an increasing centralisation around airport is occurring. Speed and agility are created by integration of **supply chains, information systems and transportation systems**. Therefore, new logistical systems demand new air cargo infrastructures:

- Integration of transportation (air, road, rail with connections to ports)

- Soft infrastructure support (e.g. free trade zones, 24/7, express customs clearance, open skies for air cargo, logistics education and training programs)

- Advanced information and communication systems (e.g. wireless fidelity, broadband, fibre optic, etc.)

- Manufacturing, “flex-tech” and distribution facilities located adjacent to or accessible to multimodal airport site

Where logistic centre used to be only equipped with facilities for road transport, the present-day multimodal logistic centre looks like a “beehive” giving competitive advantages. Although multiple factors (e.g. location, available infrastructure, laws and regulations,…) lead to constraints in evolution of logistic centres, many development have already been achieved (e.g. Hong Kong Airport with its Marine Cargo Terminal).

Figure 2.10 represents schematically the present-day and future logistic centre.

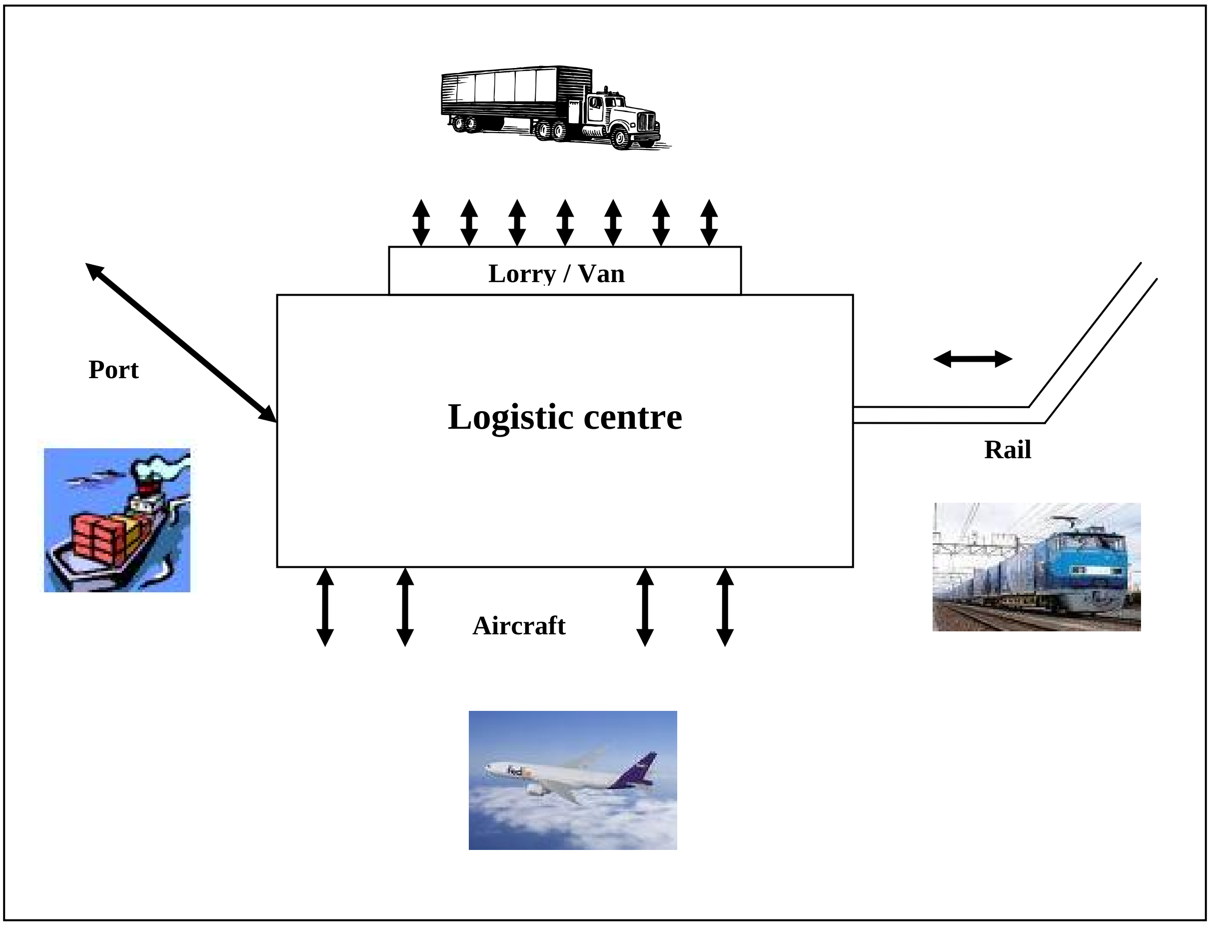


Figure 2.10 Schematic visualisation of a fully integrated multimodal logistic centre

2.2.2 Cargo Handling

Cargo handling is the **process** of packing, loading, unloading and distributing merchandise or cargo from a transport device. Concretely, it means as from the cargo enters the logistic centre till it the airplane takes off and as from the plane has landed till the cargo is leaving the logistic centre. It is also the part of the air cargo chain where by improvement, significant time reduction can be achieved. Figure 2.11 is a real-life example of a cargo chain (**Siemens 2006).**

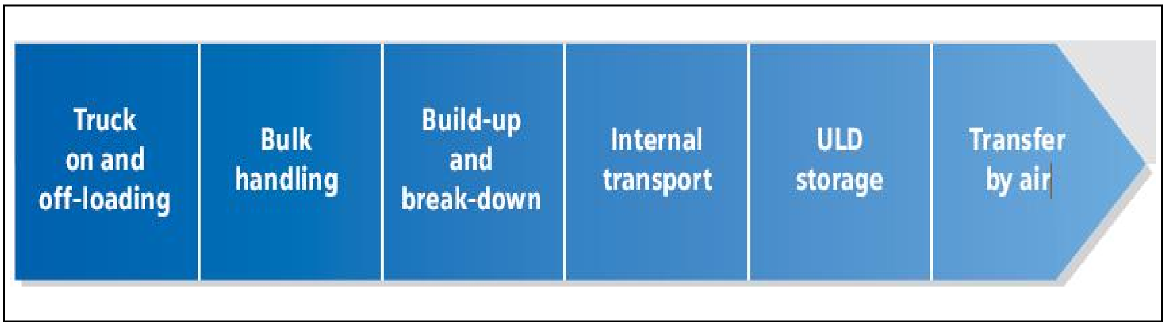


Figure 2.11 ***Siemens*** cargo chain (**Siemens 2006**)

Cargo handling systems includes:

- loading ramps,
- build-up/break-down areas,
- cargo safety check,
- ULD transport,
- storage systems,
- high-bay warehouses,
- and information technology and communication systems.

Efficient **ramp handling** is essential for cost-effective cargo handling. It demands efficient and safe facilities. A wide product range of truck dock systems, from stationary dock lifts to complex movable machines with on-board weighing equipment and ULD contour checking devices, is available. Figure 2.12 illustrates the loading ramps (**Siemens 2006**).

Figure 2.12 Loading ramp facilities (**Siemens 2006**)

Build-up and break-down areas are the centres of productivity in every cargo terminal. Freight is picked and consolidated by destination, time zone, flight number and other criteria at the workstations in the build-up and break-down area. A large range of facilities is available, such as elevating transfer vehicles, transfer vehicles, turntables and drive-on conveyors. Most of them are supported with a high level of automation.

As **safety** being a main pillar in aviation, **cargo check** is an activity of major importance in cargo handling systems. Safety checks include **identification** of the freight, **weighing** of the loaded ULD, checking the **content** of the ULD. Concerning the content, it is very important to seek after hazardous elements. Different tests needs to be applied, such as X-ray check, simulation of flight conditions by low-pressure chambers, etc. It is necessary to take into account that additional security checks can have a considerable impact on the workflow in a terminal.

For **ULD transport**, mechanical handling equipment should include all the components needed for a safe and secure material flow, such as transport roller-decks, right-angle roller-decks and turntables for ULDs.

Efficient freight **storage** in a cargo terminal, for pallets and containers, is extremely important.
Storage equipment consist of stacker cranes and the storage system, up to four levels high are loaded by elevating transfer vehicles. The storage system accommodates half-size units to 10/15-feet or 20-feet ULDs to full or empty ULDs to pallets. Figure 2.13 illustrates a storage system in a cargo terminal.

Figure 2.13 Freight storage by elevating transfer vehicles (**Siemens 2006**)

A larger storage facility is a **high-bay warehouse** that is up to eleven levels high (about 36 m). Rail-guided elevating transfer vehicles are used in such cases to keep within the tolerances needed for storage and retrieval. Storage space sizes are ten, fifteen and twenty feet. Concerning the throughput, up to 120 m/min for traversing and up to 60 m/min for lifting and lowering is achievable. Figure 2.14 illustrates a example of a high-bay warehouse.

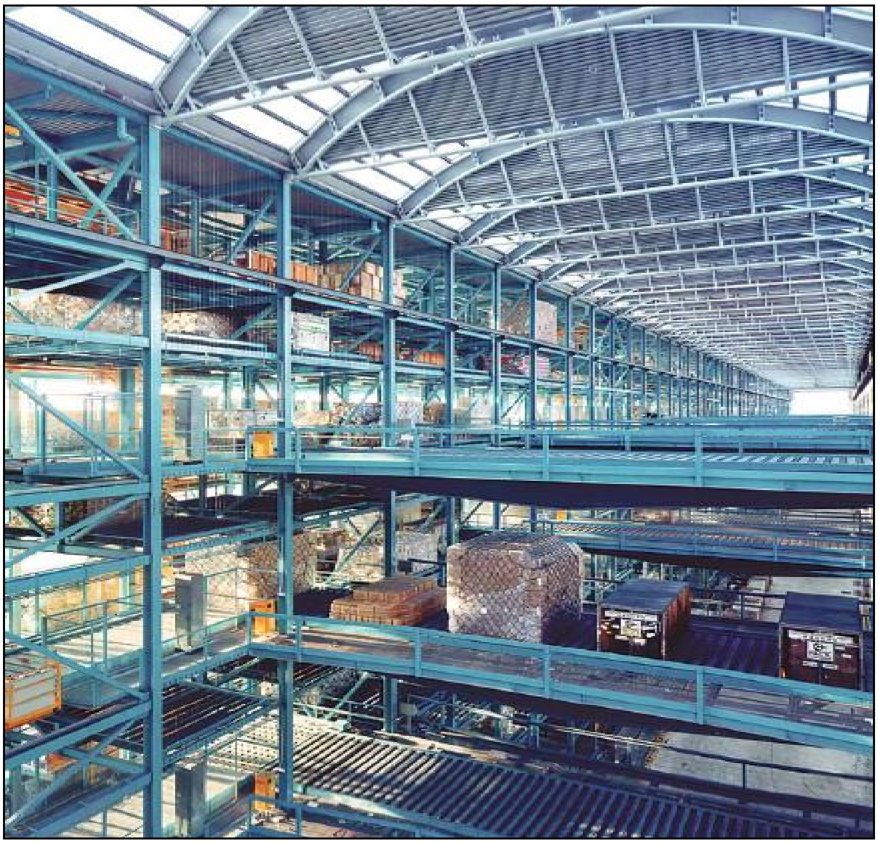


Figure 2.14 High-bay warehouse (**Siemens 2006**)

As **Information Technology (IT)** became an important part in the general society, it became an indispensable item in cargo handling to have an inventory and a better visualisation on the process. Siemens Cargo Handling Systems provides two IT solution:

- Management system:
  Cargo Compact controls the entire material flow, makes all relevant data available to the warehouse management and allows visualisation. Integrated functionalities optimize the workflow throughout the system. Defined interfaces ensure uninterrupted communication with lower-level machine controls and higher-level host systems.

- Cargo Warehouse Management:
  The warehouse management system is specially developed for freight processing and is suitable for all types of material handling systems. Functionalities are going easily through an inventory, supporting the management of all processes and providing smooth communication.

These different aspects in the cargo handling system lead to different advantages, such as a better balance between efficiency and higher profitability, minimizing engineering expenditures, commissioning times and service costs. After all life-cycle costs are reduced at a higher productivity (**Siemens 2006**).

2.2.3 Cargo (Un)loading

Cargo (un)loading is indirectly also a part of cargo handling. Dependant on aircraft type, freight type and airport facilities, the way of (un)loading can change. For airplanes two main types are known, namely side cargo door loading and nose cargo door loading. Figure 2.15 and 2.16 illustrates respectively side door and nose door loading (**Haggerty 2004**).

Figure 2.15 B757: Side door loading (**Haggerty 2004**)

Figure 2.16 B747: Nose door loading (**Haggerty 2004**)

In order to have a proper loading of the aircraft, different facilities, equipment and items are available. Some are mentioned below:

- tie-down attachments,
- power-drive units,
- reinforced structure,
- large side access door
- cargo restraint systems,
- etc.

To have “intra-airport” cargo movements, different transport devices are also available. The most common known are dollies and transporters. **Dollies** can be serially attached in the shape of a train. They fit for containers and pallets (**GDV 2006**).

Transporters or cargo movers are multifunctional. They perform lifting, dropping and conversion processes. As consequence, they replace device like truck docks, converters, slave palette movers or forklift trucks. Whether dealing with bulk freight or pre-packaged ULDs, in combination with slave pallets, the ***FAB – Cargo Mover*** can control all logistical air cargo handling functions.

Figure 2.17 illustrates the transfer of freight from a dolly to a transporter. Figure 2.18 illustrates a new-generation cargo mover, namely the ***FAB – Cargo Mover*** (**FAB 2007**).

Figure 2.17 Transfer of a pallet from a dolly to a transporter (**GDV 2006**)

Figure 2.18 The multifunctional FAB – cargo Mover (**FAB 2007**)

2.2.4 Cargo Hazards

As in all systems cargo is exposed to potential hazards. Some hazards are present during the handling and storage of the freight (in-terminal), other hazards during flight. Recognition of the hazards are therefore an important factor in order to prevent potential treats. The prudent selection of transportation services will assist the shipper in realising successful loss-free delivery of the goods.

As mentioned before air cargo environment hazards are subdivided in two categories, namely **in-flight hazards** and **in-terminal hazards (based on Inamar 2007)**.

1. **In-flight hazards:**

- **Acceleration and deceleration** pressures are exerted on cargo during takeoff and landing. Compression forces are exerted during rough landings.

- **Turbulence**, causing rough or "bumpy" flight conditions, subject cargo to rapid alternating vertical movements, imposing heavier pressure one moment, and almost weightless conditions the next.

- As **altitude** increases, atmospheric pressure decreases, subjecting liquid cargo to leakage hazards and pressurized cargo to increased internal pressure.

- Aircraft cargo compartment **temperatures** normally range between -1°C and 21°C. However, cargo aboard an aircraft parked in freezing or very hot weather will be subjected to unusual cold or heat conditions.

- The main **cargo compartments** of air freighters are normally well equipped for adequate stowage. Passenger aircraft belly compartments, however, are often loaded with limited cargo restraint equipment permitting the possibility of movement during flight and inviting damage from adjacent cargo.

2. **In-terminal hazards:**

- Many larger terminals are equipped with conveyor systems and **mechanical cargo handling** gear, permitting rapid and safe movement within the terminal. In smaller terminal facilities, **manual handling** involves the stacking of cargo on pallets and in containers. Overcrowded conditions contribute to handling damage as cargo may be stacked above recommended heights or repositioned frequently.

- The **storage** compartment in a terminal should be equipped with adequate material. Modern terminals provide segregated security areas for high value cargo, and some have cold storage (reefer) facilities for perishables.

- Cargo is exposed to the weather while en route to **loading ramps**. If cargo transfer carts, pallets and containers are not adequately covered, water damage may result. High-value cargo is particularly susceptible to theft when not in the aircraft or in the terminal.

- **Security**-conscious carriers should provide maximum physical measures to protect cargo from theft or pilferage. Examples include restricting working areas to employees, applying modern locking and alarm devices and enforcing strict cargo documentation procedures.

- The handling of **dangerous cargo** should be performed by trained personnel. The specifications concerning dangerous cargo handling are described in the ***ICAO Technical Instructions For The Safe Transport of Dangerous Goods by Air*** or ***IATA Dangerous Goods Regulations***.

- Terminals with a lack of equipment or overcrowded conditions, requiring outdoor storage, are subject to increased **theft** risks and **deterioration** of the cargo.

In case of handling or storage operations of the cargo, following specific aspects should be considered by the shipper (**Inamar 2007**).

- rapid acceleration and deceleration during lifting and lowering,
- improper forklift operations,
- pushing and dragging cargo when inadequate material handling equipment or inexperienced labour is used,
- weight of superimposed packages,
- failure to keep stacks plumb,
- long-term storage resulting in crushing of shipping packages,
- and inadequate packing and improper marking of cargo.

In order to prevent potential accidents, **marks and symbols** are used to warn the shippers of the cargo contents.

2.2.5 Standardisation of Cargo Handling Operations

Safety is on of the most important aspects to consider in cargo handling operations and systems. Safety can be increased due to good formation of shippers and crew members along with the use of safe equipment. In order to that procedures are fluently applied, **standardisation** is indispensable, and therefore a cornerstone of safety.

Consistent action and reaction, based on use of standard procedures, can be effectively applied to improve the safety and the efficiency of cargo handling. Below are some reasons why standardisation is necessary to be applied (**Young 2007**).

- The actions of many organizations must be carefully coordinated.
- Combinations of shippers, packages, containers, and aircraft are virtually limitless, and can change constantly, even within one airline.
- Variety of processes, methods, individuals and organizations, in combination with lack of consistency, increases level of risk.

Potential for cargo to be handled, loaded and documented incorrectly is greater for an all-cargo aircraft airline operation than for a passenger airline operation. This is due to a greater exposure to **various types** and **sizes** of **cargo**, increased **weights** involved and **different containers** available.

One crucial factor is the correct computation of the aircraft **weight** and **balanc**e. The **"weight"** portion is straightforward. It is important to know what each piece of cargo weighs in order to avoid exceeding a specified limit. Significance of the "**balance"** or centre of gravity portion is more subtle. If cargo is placed in the wrong location, the total weight will not change, but the airplane operation may still have dramatic impacts. Figure 2.19 illustrates an improper loading concerning "balance" with considerable consequences.

Figure 2.19 Improper loading (**Young 2007**)

In 2004, the situation was that standardisation in cargo handling was still missing. A high need of standardised items and procedures are necessary as different documentation provide opportunities for errors to occur. **Non-standardised** forms are used to identify size, weight and nature of containers. Data on these documents are entered manually and can result in **transposition** of numbers, **misidentification** of containers and lodging of the **wrong weight information**.

After multiple incidents and accidents, pilot association (e.g. ***Air Line Pilot's Association International***) ring the tocsin to have a greater standardisation, raising some important matters concerning weight scales and detection and prevention of damage due to mishandling of the cargo.

- **Weight scales:**
  Some domestic and international carriers use the IATA tolerance (± 1%) while others use a different tolerance.

- **Damage:**
  Damage to cargo, ULDs, packages may not immediately be observable (e.g. a leaking container inside a larger container).

Some recommendations to avoid the problems areas are:

- Development of **standardised forms** to contain specific, safety-critical information in load documentation, load manifests, and other forms used in the loading or cross loading of an aircraft. The design and use of such forms should minimise the potential of incorrectly reporting weight and pertinent location information.

- Development of a **uniform weigh scale tolerance** and frequency of calibration for scales used in air cargo operations. The pilot association recommends the use of the IATA tolerance (±1%) and a frequency of calibration of the weigh scale sufficient to maintain the tolerance.

- Development of **standard procedures** and guidance material to allow personnel performing or supervising safety-critical tasks to verify that all task steps are completed in the proper sequence.

- Ensure **training programs** for cargo supervisors, loaders and ramp personnel include familiarisation with the safety implications of aircraft being loaded incorrectly.

2.2.6 Air Cargo Market

To end the chapter concerning air cargo chains, it is important to see the current state of the air cargo market. Most actual economic models show large correlation between air cargo growth and economic growth. Multiple factors have led to the current crisis:

- economic slowdown in USA and Europe,
- September 11th,
- increased security costs,
- reduction of information technology and "high-tech" equipment sales,
- SARS virus,
- geopolitical conflicts.

The actual state of the market is that sea transport takes 99% of the cargo market and leaves only 1% for air transportation by weight (opposite for passenger transport). Capturing the top 1% to 2% of sea transport, causes a large growth in the air freight market.

Following facts (gathered from multiple sources) which helps to situate where the air cargo transport is situated in the global cargo market, concerning the present and the future.

- 40% of the value of world trade goes by air (vs. under 2% by weight),
- world air cargo traffic is expected to triple by 2020 (international express 3 times faster),
- world air cargo traffic will grow at 6.4% per year,
- Fastest growing air freight markets are those connecting Asia-Pacific to Europe and North America,
- recent trends in the air cargo industry are falling yields, integrator expansion, and consolidations of freight forwarders.

Air cargo transport is a **high-value** transportation sector which is slightly recovering from a crisis but looking upwards and expecting great prospects. It comes towards an expansion and development. Therefore analyst from Airbus predict that the world freighter fleet will double by 2020, without including the passenger aircraft system.

Figure 2.20 on the next page illustrates the air cargo fleet forecast. This does not include the passenger aircraft system, which in the year 2000 carried 48% of the global airfreight traffic, and is projected to carry 43% of that traffic in 2020 (**based on Morales 2004**).

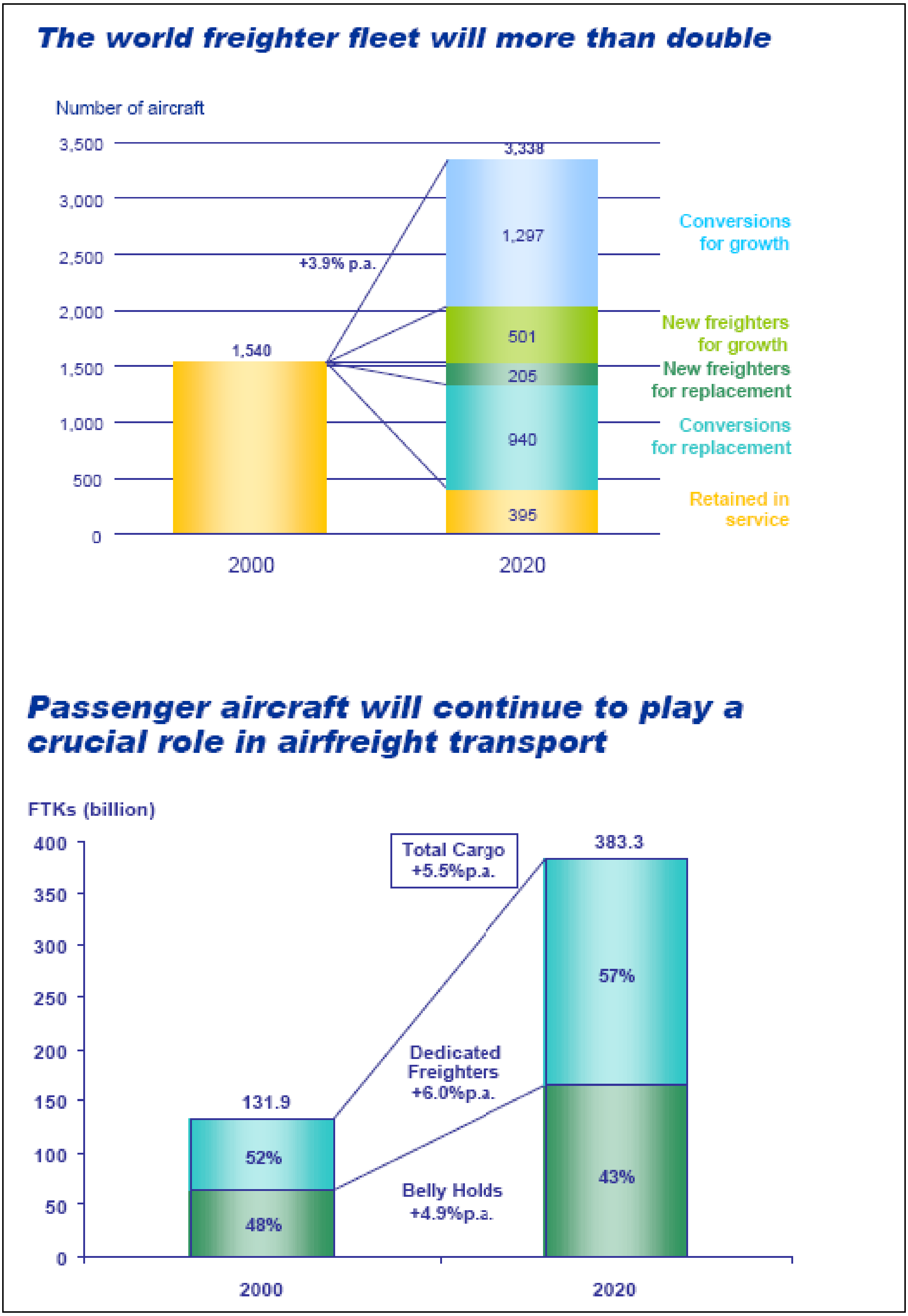


Figure 2.20 Air cargo fleet forecast (**Morales 2004**)

Airbus analysts also predict that most new production freighters will be large aircraft. To be able to support such a large increase in traffic, Airbus predicts that future freighters will need to be utilized much more often and that they will grow in size, increase capacity per aircraft, and thus achieve lower unit operating costs. The catch, as Prof Clarke pointed out, is that larger aircraft are nice only if you can fill them up all the way.

However, even though a majority of new production freighters will be large aircraft, the intermediate or regional size of aircraft will still comprise the majority of the actual market. In this table, you can see the breakdown of cargo planes into four different segments (**Morales 2004**):

- the feeders,
- the regional freighters,
- the long range freighters,
- and the really large freighters.

Figure 2.21 illustrates those different cargo aircraft types according to their payload capacity.

	Payload	Aircraft types	Open market neutral payload
Feeders	< 30 tonnes	BAC One-Elevens, BAe 146s, DC-9s, 737s, 727s	22 tonnes
Regional freighters	30 - 60 tonnes	707s, DC-8s, 757s, 767-200s, A300s, A310s, DC-10-10s	45 tonnes
Long range freighters	30 - 80 tonnes	DC-10-30/40s, L-1011s, 767-300s, 747combis, MD-11combis	60 tonnes
Large freighters	> 80 tonnes	MD-11s, 747s, A380s	120/110 tonnes (new/converted)

Figure 2.21 Freighter aircraft size (**Morales 2004**)

3 Container Survey

In order to know what the different possibilities are in air cargo chains it is important to have a good overview about the different transport devices used in all cargo transport. The compatibility between different transport modes will be tested afterwards so that optimisation of air cargo handling and transport can be attained.

Before starting the survey, it useful the have a deeper look into the definition of the term container. According to ***Wikipedia***, it is a standardised metal box used to transport loose goods. Due to the use of a standardisation, containers can be transported over water, road and rail without the goods being load or unloaded. Air containers, suitable for air cargo transport, are generally smaller and therefore repacking and handling is necessary.

This chapter gives a brief overview about the most common used containers in air cargo and other freight transport.

3.1 Unit Load Device

In the air transport industry, a **Unit Load Device (ULD)** is the correct terminology used for containers and loading units that are used for carriage of cargo by air on wide-body aircraft and specific narrow-body aircraft. They allow large quantities of cargo to be bundled into large units. Since this leads to fewer units to load, it saves ground crews time and effort, and helps prevent delayed flights. Each ULD is manifested separately so that its contents can be tracked. The cargo can consist of luggage, freight and mail.

ULDs come in two forms: pallets and nettings as well as and rigid containers. ULD pallets are rugged sheets of aluminium with rims designed to lock onto cargo net lugs. ULD containers, also known as cans and pods, are fully enclosed containers made of aluminium or combination of aluminium (frame) and plastic (walls) and, depending on the nature of the goods inside, may or may not have refrigeration units built-in (**Wikipedia 2007d**).

In order to classify ULDs, the air cargo transport industry distinguishes three basic categories:

- **air cargo pallets,**
- **lower deck containers,**
- **box-type containers.**

An additional category are the **contoured boxes**, known as the igloo configuration. But these are generally classified under the box-type containers. The only source which considers contoured boxes as a separate category is ***Inamar Cargo Insurance***.

A fourth type, namely **air/land containers**, has also been developed with the introduction of the of the 747-class freighter has permitted adding an air dimension to the intermodal container. Lightweight 20- and 40-foot containers permit land and air transportation without rehandling or reloading (**based on Inamar 2007**).

The first category is explained more thoroughly in the following section. The last two categories are explained as subchapters of **air cargo containers**. The **air/land containers** will be expounded in the section „Containers in other transport modes“.

3.1.1 Air Cargo Pallets

Air cargo pallets are designed for the use with conveyor systems in terminals and in aircraft. The low-profile flat pallet is equipped with fittings for securing the pallet firmly to the main deck of an all-cargo aircraft. Cargo is normally secured to the pallet by use of cargo nets, tightened over cargo by the application of tensioned straps. Pallets are often covered with contoured semi-structural covers called "igloos", "hulahuts", or "cocoons” to provide protection and keep cargo within safe dimensions for loading in aircraft. Igloos may be attached to the pallet by cargo nets that are placed over the exterior, or the igloo may be permanently attached to the pallet (**APIE 2004**).

The reason why air pallets can be used are various:

- **lower weight than containers,**
  Considering a comparable cargo capacity in weight and volume, the average weight of regular air pallets are significantly lower than the regular air containers.

- **loading of non-rectangular shapes freight,**
  A general non-rectangular form obtained by the stacking of boxes can be more efficiently placed on a pallet than stocked into a container.

- **integral part of the packing.**
  With a pallet as an integral part of the packing for internal transport within the factory, it is advantageous to use it in external transport to. Repacking the goods in form of a container becomes than superfluous.

Table 3.1 on the next page represents the most common used pallets in air cargo transport. The dimensions are drawn up by the **IATA** but can vary slightly to between different aircraft types and airline companies. The models below are suitable for almost every modern freight aircraft. These include the A300, A310, A340, B747F, B767 and B777. Only the M-6 type is specially designed for the B747F.

Table 3.1 Air Cargo Pallets (**Tradeway 2007 – Freightersonline 2007a**)

Classification	Description	Dimensions L x W x H [1] (volume)	Max. Gross Weight (kg)	Tare weight (kg)
LD-7 [2]	P1P – Flat Pallet with net	318 x 224 x 163 (10.2 m³)	4626 (lower deck) 6000 (main deck)	110
LD-7 [2]	P6P – 10ft Pallet with net	318 x 244 x 163 (11.15 m³)	5300 (lower deck) 6800 (main deck)	120
M-6	PGA – 20ft Pallet with net	608 x 244 x 244 (35.3 m³)	11300	540

[1] L = length (longest edge of the pallet) in centimetre,
W = width in centimetre, H = height in centimetre
[2] LD-7 pallet is available in two different floor dimensions

Other available pallettypes (**Freightersonline 2007a**) are following one's:

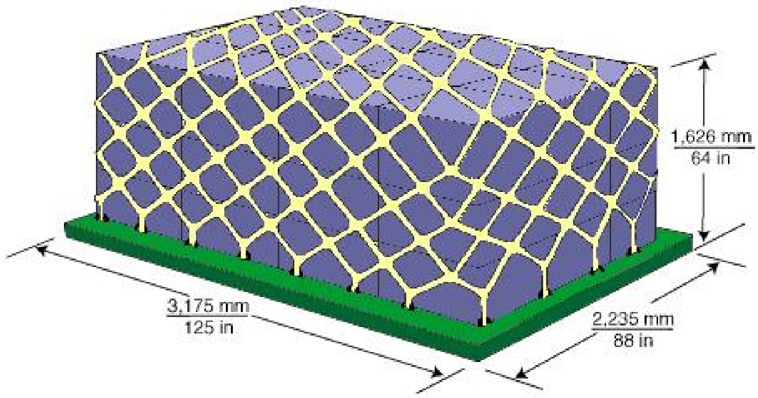
- PAD - P1P Pallet with folding wings and net (classification: LD-7),
  P1P base with folding wings for overhang, and reinforcement of corners and edges. Other prefixes are PAX or P1X.

- PNA - Half Pallet with net B767 (classification: HP),
  Half pallet squared off for B767 lower decks. Other prefixes are PQP, FQF or PPC.

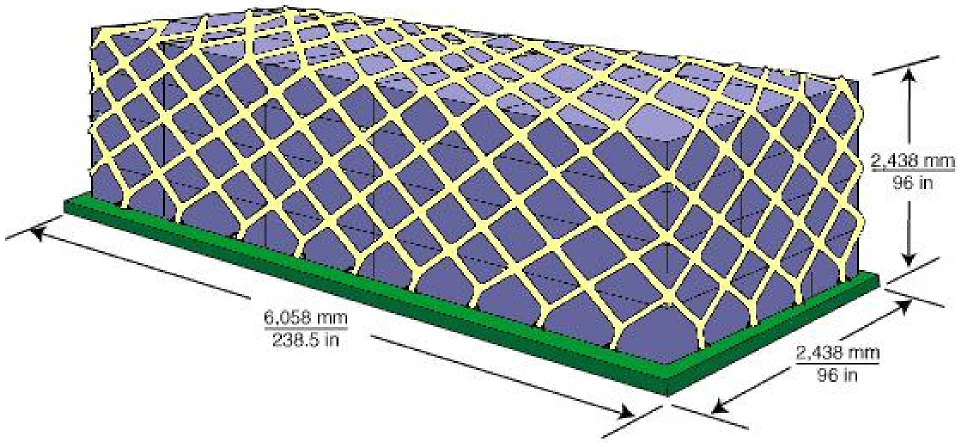
- PRA - 16ft Flat Pallet with net (classification: MDP),
  Main deck pallet with net. Other prefixes are PMA, P4A, P4M or PZA.

- XAW - P1P Pallet with fixed angle wings and net (classification: LD-7),
  P1P base with fixed wings for overhang and reinforcement of corners and edges.

The P6P-pallet, sometimes named PMC-pallets, are the most common used in air cargo transport (**ITRI 2007**). Unconventional pallettypes are quoted in the section „Unconventional and environmental controlled containers". Figure 3.1 and 3.2, on the next page, represents the pallets listed above in Table 3.1. Figure 3.2 is an example of a reinforced pallet.



P1P – Pallet / P6P – Pallet (width = 244 cm)



PGA – Pallet

Figure 3.1 Air cargo pallets (**Tradeway 2007**)

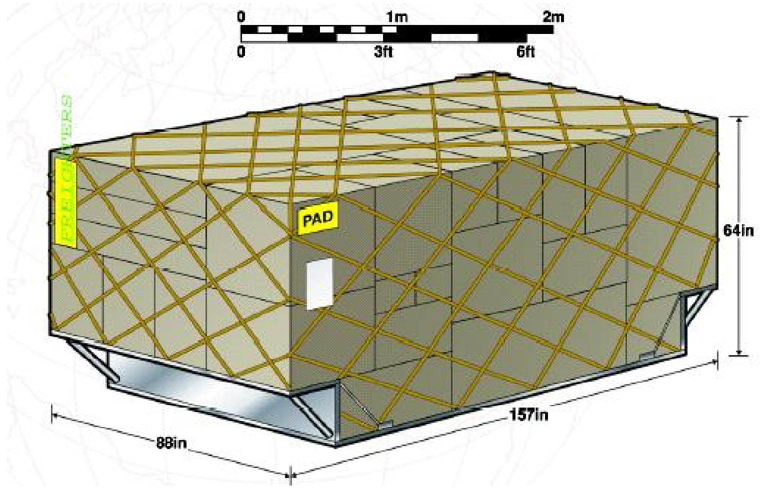


Figure 3.2 P1P - Pallet with folding wings (**Freightersonline 2007a**)

3.1.2 Air Cargo Containers

According to ***Inamar 2007***, cargo airliners strongly recommend the use of air cargo containers for cargo transport. The main reason is to speed up the loading and unloading of the aircraft. Sometimes cargo airliners (e.g. FedEx) even offer special kinds of tariffs, the so called FAK (freight all kinds) rates, to encourage this transportation mode. The other advantages of air cargo containers are multiple (based on **Inamar 2007**):

- **full protection of the cargo,**
  Freight which needs fragile handling can be stored in containers. Due to the enclosure, the freight is protected against weather, foreign object damages, damage during handling activities and theft.

- **reduction of the number of individual pieces,**
  The handling in terminals is one of the biggest factors influencing the cargo handling time. By storing freight into containers, a significant gain in time (and money!) can be achieved.

- **the most efficient use of the cubic capacity of the aircraft,**
  Containers are so designed to have a conformity of geometry with the fuselage-shape of the aircraft. Although, the filling of the container itself can pose an issue concerning a loss of space. This is illustrated in Figure 3.3, where the boxes at the left side of the container are stacked randomly.

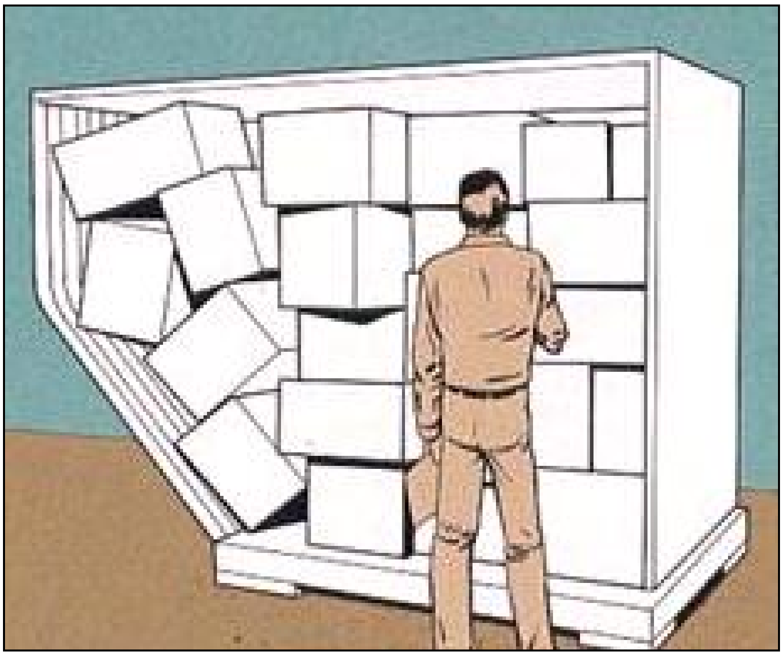


Figure 3.3 Stacking problem of containers (**Inamar 2007**)

- **wide range of freight type,**
  The type of freight isn't restricted to boxes or packed good as with air cargo pallets. Freight can also be stored under the form of bulk cargo or liquid cargo.

- **transportation in special environmental conditions,**
  When the freight requires transportation under special conditions e.g. pressurised, temperature-controlled, etc. a wide range of containers is available in order to meet the requirements concerning acclimatisation.

- **the use of mechanical handling facilities.**
  Due to the conformity and standardisation of the containers, the (un)loading of an aircraft can be in a certain way more "automated", which results in a gain of time.

With the use of containers, structuring of shipping is necessary in order to transport freight as efficient as possible. It is therefore very important to take into account the **weight limitations** of the containers in order to avoid overloading. So a selection of the appropriate type of container is of crucial importance!

As seen before, the classification of ULDs groups three basic categories. The first category are the air pallets, followed by the lower deck containers and the box-type containers. The two last mentioned categories are air cargo containers. A clear subdivision of air cargo containers is made based on the shape of the devices and not on the placement of those in the aircraft body. That's why upper deck containers are categorized as box-type containers as they both are placed in the main deck compartment of an aircraft. The main deck compartment is often also the upper deck compartment as most freighters only have two cargo compartments. A separate upper deck compartment is infrequent.

3.1.2.1 Lower Deck Containers

The first category among the air cargo containers are the **lower deck containers**. With the raise of the mixed cargo/passenger aircraft, lower deck containers have been developed and introduced for the use in the lower deck cargo compartments of those high-capacity aircraft. They are fully structured and completely enclosed. Cargo is loaded into the container, which may be equipped with shelves for accommodation of small or irregularly shaped cargo. The container doors of metal, fabric or a combination of both are closed and sealed. Containers are locked directly into aircraft restraint systems without need for nets or tie-downs. Lower deck containers are clearly recognizable to the contours at the lower side of the vertical edges (**APIE 2004**).

Table 3.2 represents the most common used lower deck containers in air cargo transport. The dimensions are drawn up by the **IATA.** LD-3s and LD-11s are compatible for the different freight aircraft in the ***Boeing***-family and all ***Airbus*** wide-bodies. The LD-2s and LD-8s have been developed for the narrow-bodies. Containers are also interchangeable due to ubiquity. This means that the same (or a multiple of) floor dimensions are available.

Table 3.2 Lower Deck Containers (**Tradeway 2007 – Freightersonline 2007a**)

Classification	Description	Dimensions D x W x H [1] BW [2] (volume)	Max. Gross Weight (kg)	Tare weight (kg)
LD2	DPE – Contoured Container	153 x 158 x 163 120 (3.4 m³)	1225	60
LD3	AKE – Contoured Container	153 x 210 x 163 156 (4.53 m³)	1588	80
LD6	ALF – Contoured Container	153 x 406 x 163 318 (6.94 m³)	3175	180
LD8	DFQ – Contoured Container	153 x 318 x 163 244 (6.94 m³)	2450	120

[1] D = depth (according to the longitudinal axis of the aircraft) in centimetre, W = width in centimetre, H = height in centimetre

[2] BW = base width

Other lower deck container types (**Freightersonline 2007a**) are enumerated below:

- AAF - Contoured Container on P1P base (classification: LD-26),
  Full width lower deck container contoured at both lower edges with a canvas door and built-in net door straps.

- AAU - Contoured Container on P1P base (classification: LD-29),
  Full width lower deck container contoured at both lower edges with a canvas or a built-in door.

- AKC - Contoured Container (classification: LD-1),
  Half width lower deck container contoured at one lower edge with a canvas or solid door. Other prefixes are AVC, AVD, AVK, AVJ. The “forkable” version has the prefix AVY.

- AKH - Contoured Container (classification: LD-3-45),
  Full width lower deck container contoured at both lower edges with a canvas door. Another prefix is DKH.

- AMU - Contoured Container on P6P base (classification: LD-39),
  Full width lower deck container contoured at both lower edges with a canvas door and built-in straps.

According to the **Industrial Technology Research Institute (ITRI)**, the LD3-container, is the most commonly used container in air freight transport. Environmental controlled and unconventional container types are quoted in the section „Unconventional Load Devices“.

Figure 3.4 on the next page displays the containers listed in the Table 3.2.

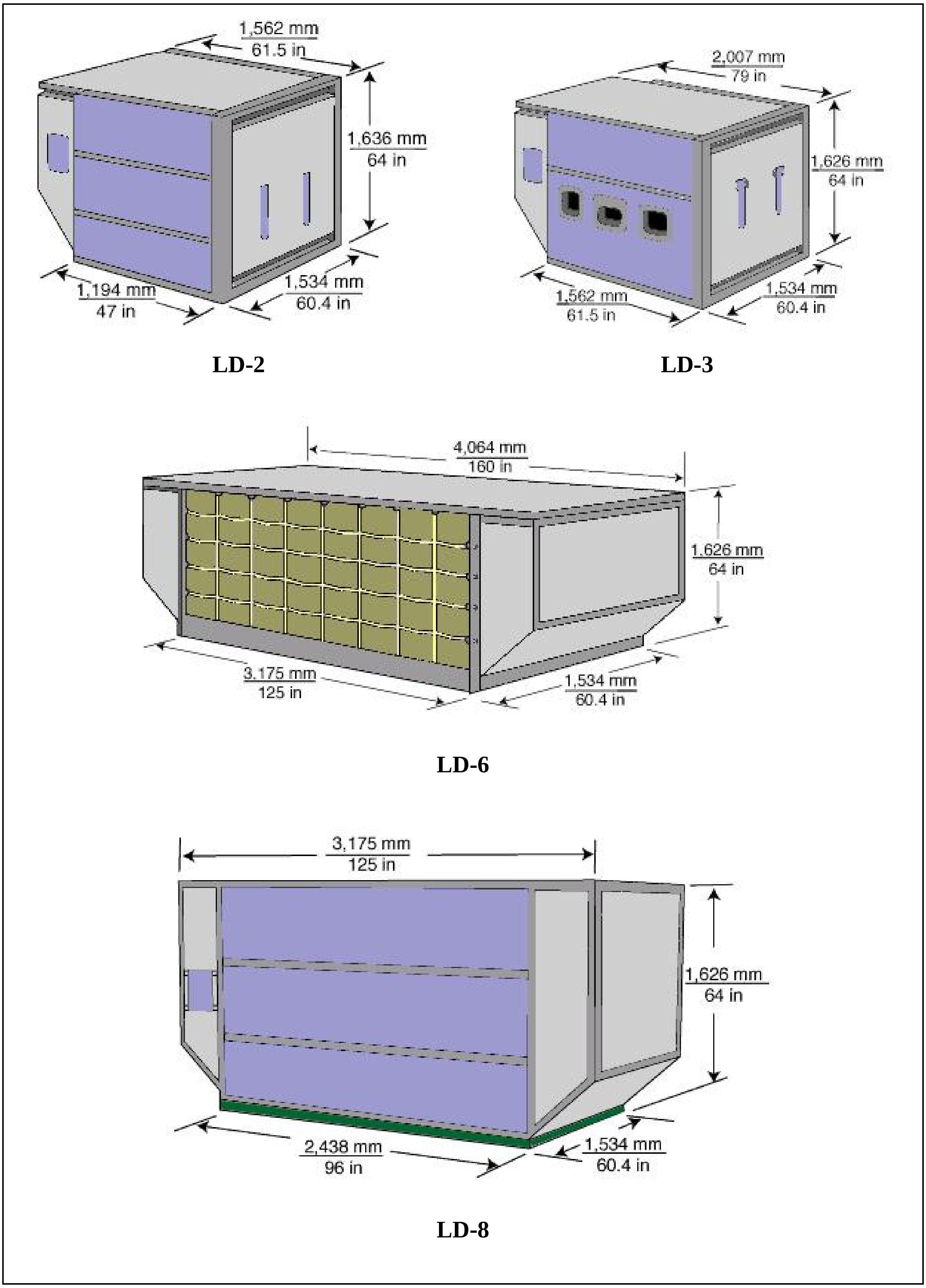


Figure 3.4 Lower Deck Containers (**Tradeway 2007**)

3.1.2.2 Box-type Containers

The second category among the air cargo containers used to consolidate shipments are the **box-type containers**. They have been developed in standard sizes to facilitate establishment of uniform shipping rates. These containers are constructed of wood, fibreglass, plywood, fibreboard, metal or combinations of these materials. Square-sided box-type containers are normally loaded on pallet-igloo combinations by the carrier for storage aboard the aircraft. Box-type containers are mainly used to load the main deck of a cargo aircraft.

The subclass “**contoured air cargo containers**” are contoured, semi-structural covers called type "A" used to provide protection for cargo and keep cargo within safe dimensions for loading in aircraft. These containers may have one side (front) open, with cargo secured by nets or have metal or fibreglass removable doors, which are capable of being sealed. Contoured "Boxes" - (igloo configuration) are handled and loaded aboard aircraft in the same manner as pallet-igloo combinations. Lower deck containers are obviously contoured, but to so called “**upper deck containers**” are contoured at the upper side of the vertical edges (**Inamar 2007**).

Table 3.3 represents the most common used box-type and upper deck containers. The dimensions are drawn up by the **IATA** but minor variations in dimensions can occur due to the differences in construction techniques and materials. The models below are suitable for almost every modern freight aircraft with a main deck loading capacity.

Table 3.3 Box-type and Upper Deck Containers (**Tradeway 2007 – Freightersonline 2007a**)

Classification	Description	Dimensions D x W x H [1] (volume)	Max. Gross Weight (kg)	Tare weight (kg)
M-1	AMA – Rectangular Container on P6P-base	244 x 318 x 244 (17.5 m³)	6804	350
M-6	AGA – 20ft Box Container	608 x 244 x 244 (35.3 m³)	11340	1000
LD-7 (contoured)	AKA – Upper Deck Container	224 x 318 x 163 (9.91 m³)	6033	200
LD-11	ALP – Rectangular Container	153 x 318 x 163 (7.2 m³)	3176	185

[1] D = depth (according to the longitudinal axis of the aircraft) in centimetre, W = width in centimetre, H = height in centimetre

Other main and upper deck container types (**Freightersonline 2007a**) are enumerated below:

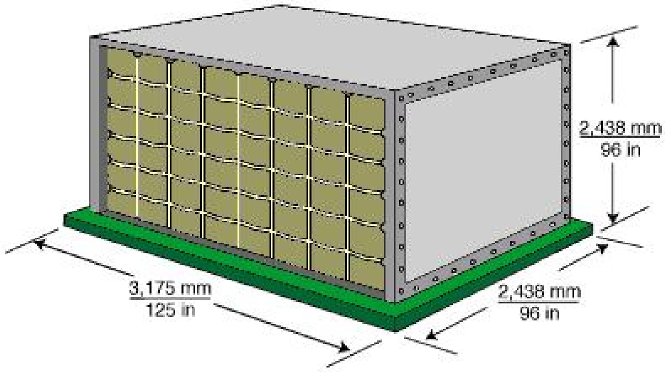
- AAP – Enclosed Pallet on P1P base (classification: LD-9),
  General purpose enclosed container fitted to P1P base with canvas doors and built-in net door straps. Some AAP-types are available with solid doors. Other prefixes are AA2, XAG, XAV.

- AMD - Contoured Container on P6P base (classification: M1H),
  Main deck upper container (variant on the AMA-container) contoured at one upper edge with a canvas door and built-in net door straps. Other prefixes are AQA, AQ7.

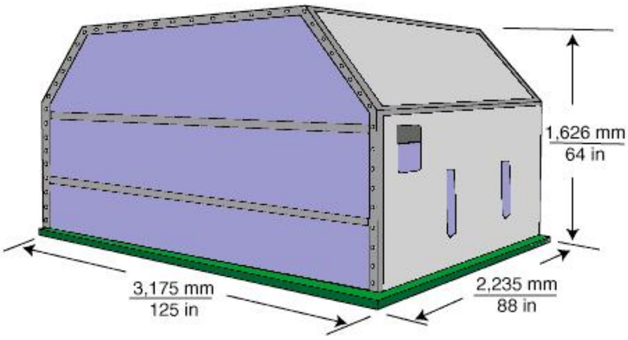
- AYY - Contoured Container on half pallet base (classification: Demi),
  Half width main deck container with top contour.

Environmental controlled and unconventional containertypes are quoted in the section „Unconventional Load Devices“.

Figure 3.5 and 3.6 on the next page displays the containers listed in the Table 3.3.

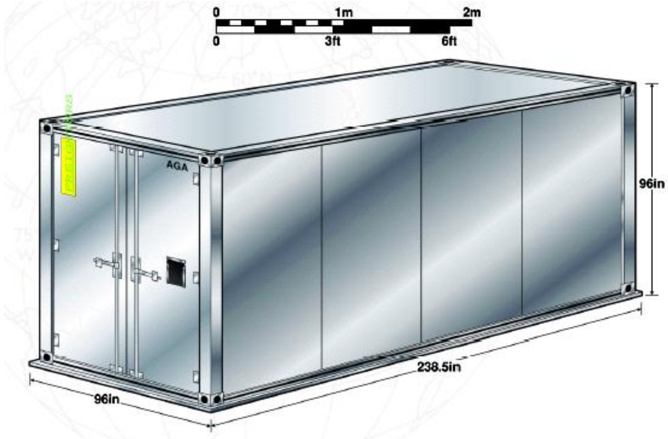


M-1

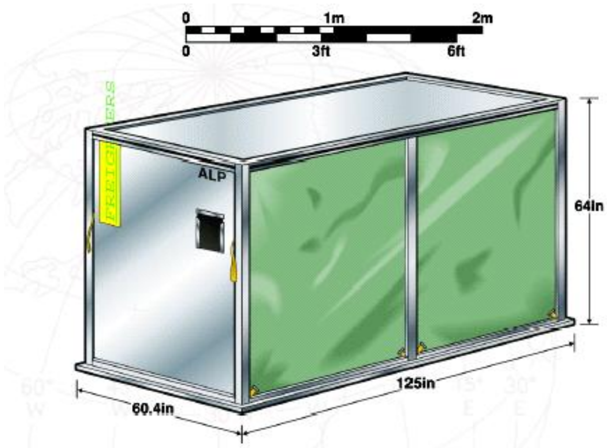


LD-7

Figure 3.5 M-1 Box-type and LD-7 Upper Deck Container (**Tradeway 2007**)



M-6



LD-11

Figure 3.6 M-6 and LD-11 Box-type Container (**Freightersonline 2007a**)

3.2 ULD capacity

Aircraft loadings can be made up of all containers, all pallets, or a mix of ULD types, depending on convenience. Below is a table indicating the maximum capacity of an aircraft for all-container and all-pallet configurations. In some aircraft the two types must be mixed as some compartments take only certain ULDs.

The **container capacity** of an aircraft can be described by measurements in positions. One position is the equivalent of the place occupied by a half-width container (LD1s, LD2s, and LD3s). Typically, each row in a cargo compartment is made of two positions. As an LD6 or an LD11 can be replaced by two LD3s and an LD8 can be replaced by two LD2s, a full-width container (LD6s, LD8s, and LD11s) is equivalent to two positions.

The **pallet capacity** of an aircraft is measured by the amount of PMC-type LD7s (with floor dimensions 96" x 125"), which can be placed. These PMC-pallets (P6P – 10ft Pallet) use approximately three LD3 positions (occupation of two positions of one row and the half of the second following row) or four LD2 positions. PMC-pallets can only be loaded in cargo compartments with large doors designed to accept those types. Therefore, small door compartments will only suit for the use of containers (**Wikipedia 2007d**).

The factors influencing the maximum pallet and container capacity are (**Freightersonline 2007b)**:

- **cargo deck layout** of the cargo compartment,
- shape of the **cross section** of the aircraft,
- **volume arrangement** of the lower cargo compartments,
- and **maximum payload** (weight restriction).

Table 3.4 on the next page illustrates the maximum cargo capacity for different aircraft types. These capacities do not take weight restrictions into account. Therefore, the actual capacity could be reduced due to weight limitations, as being the most restrictive factor.

Figure 3.7 illustrates the cargo capacity and the places of the cargo compartments for several aircraft.

Table 3.4 ULD-capacity for different aircraft types (**based on Wikipedia 2007d**)

Aircraft	**Max. Cont. Cap.**	**Max Pallet Cap.**	**Remarks**
A300-600	22 LD3s	4 pallets + 10 LD3s	
A300B2/B4	20 LD3s	4 pallets + 8 LD3s + 21 pallets (main deck)	
A310	14 LD3s	3 pallets	
A330-200	26 LD3s	8 pallets + 2 LD3s	
A330-300	32 LD3s	11 pallets	
A340-200	18 LD3s	6 pallets	
A340-300	32 LD3s	11 pallets	
A340-500	30 LD3s	10 pallets	
A340-600	42 LD3s	14 pallets	
A380-800	38 LD3s	13 pallets	
A380-800F	59–71 LD3s	58 pallets	Freighter aircraft capacity includes all decks
B727-100F	none	9 pallets*	*88" x 125" pallets only; narrow-body aircraft
B727-200F	none	12 pallets*	
B727-200C (combi)	none	11 pallets*	
B747-400F/ERF	32 LD1s (lower deck) + 30 pallets (main deck)		Freighter aircraft capacity includes all decks
B747-400ER	28 LD1s	4 pallets + 14 LD1s	
B747-400/300/200/100	30 LD1s	5 pallets + 14 LD1s	
B767-200	22 LD2s	none	
B767-300	30 LD2s	none	
B767-300ER	30 LD2s	4 pallets + 14 LD2s	
B767-300F	30 LD2s (lower deck) + 24 pallets* (main deck)		*accepts 88" x 125" pallets only
B767-400ER	38 LD2s	5 pallets + 18 LD2s	
B777F	30 LD3s + 27 pallets	37 pallets	Freighter aircraft capacity includes all decks
B777-300/300ER	44 LD3s	8 pallets + 20 LD3s	
B777-200/200LR/ER	32 LD3s	6 pallets + 14 LD3s	
B787-8/-3	28 LD3s	9 pallets	
B787-9	36 LD3s	11 pallets	
L-1011-500	19 LD3s	4 pallets*	*if equipped with fwd cargo 104" door
L-1011	16 LD3s	none	all series except 500
MD-11	28–32 LD3s	5 Aft(88") + 6 Fwd pallets	

AircraftCapacities and Dimensions

		Cubic Capacity	Maximum freight capacity	Access door dimensions
Airbus A-300C	Main deck Forward Aft	7,169 cu.ft.- 203 cu.m. 1,896 cu.ft. - 53.7 cu.m. 1,264 cu.ft. - 35.81 cu.m.	111,763 lbs - 50,695 kgs (total freight capacity)	101" x 141" – 257cm x 358cm 95.9" x 67.5" – 24.3cm x 171cm 71.3" x 67.4"-181cm x 171cm
Boeing 767-300	Main deck Forward Aft	3,600 cu.ft. – 101.9cu.m.	69,850 lbs - 31,684 kgs	AFT 700" x 69"- 178cmx175cm
Boeing 757	Forward Aft	700 cu.ft. - 19 cu.m. 1,090 cu.ft. - 30 cu.m.	25,700 lbs- 11,657 kgs (total freight capacity)	FWD 55" x 44"-140cm x 112cm AFT 55" x 44"-140cm x 112cm
Boeing 747C	Main deck Forward Aft Bulk compartment	9,145 cu.ft. – 259 cu.m. 2,225 cu.ft. – 63 cu.m. 742 cu.ft. – 21 cu.m. 1,271 cu.ft. – 63 cu.m. 800 cu.ft. – 22.6 cu.m.	92,000 lbs- 41,500 kgs 55,500 lbs- 25,175 kgs 20,400 lbs- 9,250 kgs 22,600 lbs- 10,280 kgs 14,800 lbs- 6,750 kgs	134" x 120"- 340cm x 305cm 104" x 66"- 264cm x 168cm 104" x 66"- 264cm x 168cm 44" x 47" – 112cm x 119cm
Boeing 747F	Main deck Forward Aft Bulk compartment	21,270 cu.ft. – 602 cu.m. 2,528 cu.ft. – 72 cu.m. 2,212 cu.ft. – 63 cu.m. 800 cu.ft. – 22.6 cu.m.	260,000 lbs– 117,936 kgs (total freight capacity)	134" x 123"- 340cm x 312cm 104" x 68"- 264cm x 173cm 104" x 68"- 264cm x 173cm 44" x 47" – 112cm x 119cm
Boeing 737	Main deck Forward Aft	2,730 cu.ft. – 77.3 cu.m. 875 cu.ft. – 24.9 cu.m.	39,000 lbs- 17,687 kgs (total freight capacity)	134" x 84.5"- 340cm x 214cm
Boeing 707F	Main deck Forward Aft	8,000 cu.ft – 227.2 cu.m. 875 cu.ft. – 24.9 cu.m. 910 cu.ft. – 25.8 cu.m.	90,000 lbs- 40,8244 kgs 14,300 lbs- 6,486 kgs 13,900 lbs- 6,305 kgs	134" x 86.6"- 340cm x 224cm 48" x 50"- 122cm x 127cm 48" x 48"- 122cm x 122cm 35" x 30"- 39cm x 76cm (smaller rear door)
Boeing 727-100C	Main deck Forward Aft	3,300 cu.ft. – 93 cu.m. 420 cu.ft. – 119cu.m. 470 cu.ft. – 133 cu.m.	37,960 lbs- 17,236 kgs (total freight capacity)	86" x 134"- 224cm x 340cm 48" x 35"- 122cm x 89cm 48" x 35"- 122cm x 89cm
DC 10-30CF	Main deck Forward hold Aft Bulk Compartment	12,236 cu.ft. – 346 cu.m. 2,155 cu.ft. – 61 cu.m. 1,413 cu.ft. – 40 cu.m. 459 cu.ft. – 13 cu.m.	84,865 lbs- 38,495 kgs 56,000 lbs- 25,401 kgs 35,000 lbs- 15,875 kgs 7,480 lbs- 3,400 kgs	102" x 140 "- 259cm x 356cm 104" x 66 "- 264cm x 168cm 70" x 66 "- 178cm x 168cm 30" x 36 "- 76cm x 91cm
DC 8F Jet Freighter	Main deck Forward hold Aft hold	5,092 cu.ft.– 144.2 cu.m. 688 cu.ft. – 19.5 cu.m. 724 cu.ft. – 20.5 cu.m.	83,790 lbs- 38,000 kgs 10,320 lbs- 4,690 kgs 10,470 lbs- 4,760 kgs	140" x 85 "- 356cm x 216cm 36" x 44 "- 91cm x 112cm 36" x 44 "- 91cm x 112cm
DC 8 Combi Freighter	Forward cabin Forward hold Aft hold	1,600 cu.ft. – 45.2 cu.m. 688 cu.ft. – 19.5 cu.m. 724 cu.ft. – 20.5 cu.m.	8,000 lbs- 3,600 kgs 10,320 lbs- 4,690 kgs 10,470 lbs- 4,760 kgs	140" x 85 "- 356cm x 216cm 36" x 44 "- 91cm x 112cm 85" x 140"- 216cm x 356cm
Super DC 8-63F	Cabin Forward hold Aft hold	10,331 cu.ft. – 293 cu.m. 2,500 cu.ft. – 71 cu.m.	119,000 lbs- 54,000 kgs (total freight capacity)	85" x 140"- 216cm x 356cm 63" x 54"- 160cm x 137cm
DC 9-33RC Freighter	Main deck Aft	2,680 cu.ft. – 76 cu.m. 420 cu.ft. – 11.9 cu.m. 318cu.ft. – 9 cu.m.	33,297 lbs- 15,135 kgs 6,952 lbs- 3,160 kgs 5,000 lbs- 2,265 kgs	113" x 81"- 341cm x 203cm 53" x 50"- 135cm x 127cm 36" x 50"- 91cm x 127cm
DC 9-15	Forward hold Aft hold	373 cu.ft. – 10.5 cu.m. 227 cu.ft. – 6.4 cu.m.	5,595 lbs- kgs 3,403 lbs- kgs	53" x 50"- 135cm x 127cm 36" x 50"- 91cm x 127cm
L1011-500F	Main deck Lower deck	12,066 cu.ft. – 342 cu.m. 3,415 cu.ft. – 98 cu.m.	146,500 lbs-66,518 kgs (total freight capacity)	134" x 100"- 340cm x 254cm
MD-88	Main deck Aft	1253 cu.ft. – 35.5 cu.m.	18,795 lbs- 8,525 kgs	FWD 48" x 34"- 122cm x 86cm AFT 48" x 35"- 122cm x 89cm

Figure 3.7 Cargo capacity of different aircraft (**Inamar 2007**)

Following example, of the A300-600F, illustrates the four different factors mentioned before concerning the ULD capacity of the freighter aircraft (**Freightersonline 2007b)**.

- **Cargo deck layout** of the cargo compartment:

  The arrangement of the ULDs on the main deck should be as optimal as possible concerning the use of the available area. And also needs the disposition of the ULDs around the centre of gravity point to be equilibrated during loading and flight in order to meet the **balance requirements** of the aircraft. This aspect is of crucial importance so that incidents and accidents wouldn't occur! Figure 3.8 illustrates two possible configurations of the main deck layout for an ***Airbus*** A300-600F. This type can contain a maximum of twenty one LD3s or a mix of four pallets and ten LD3s.

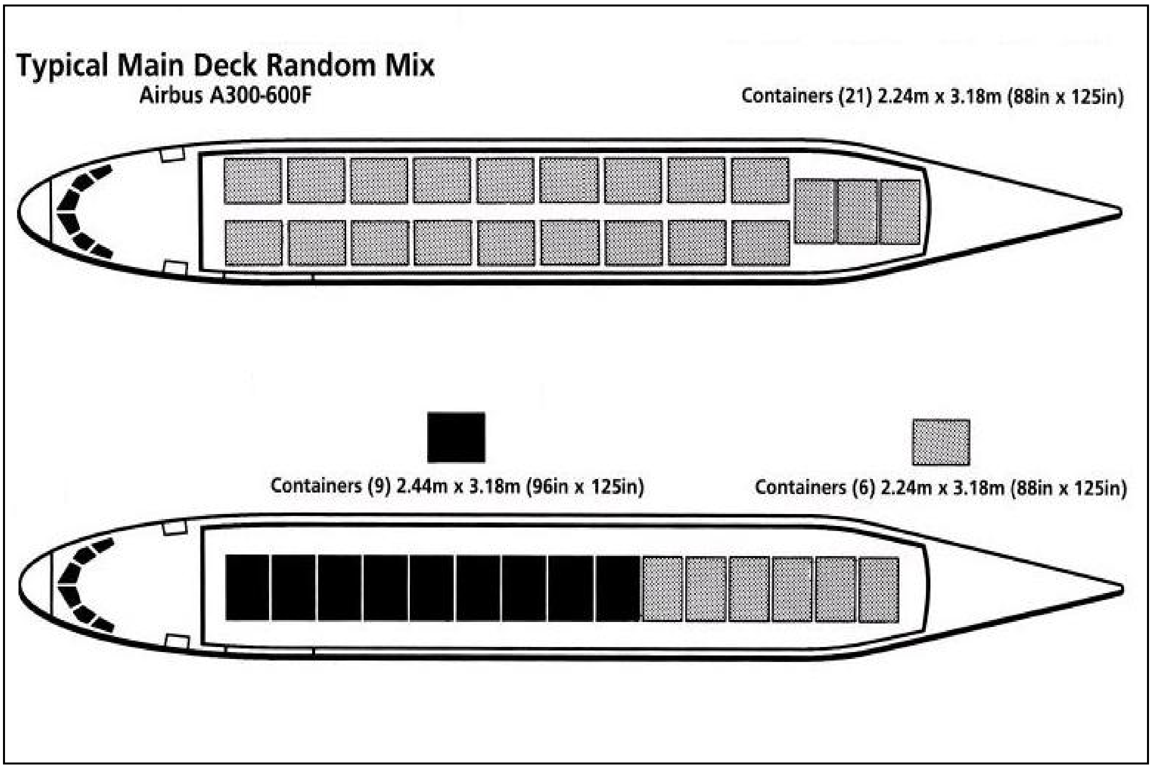


Figure 3.8 Airbus A300-600F: Main deck configuration (**Freightersonline 2007b**)

- Shape of the **cross section** of the aircraft:

  The requirements concerning the height and the geometry of the containers are directly related to the cross section or "bodyshape" of the aircraft. A constraint to bear in mind for the selection of a suitable container are the door dimensions. Figure 3.9 illustrates the cross section of an ***Airbus*** A300-600F, as well as the door dimensions and maximum height.

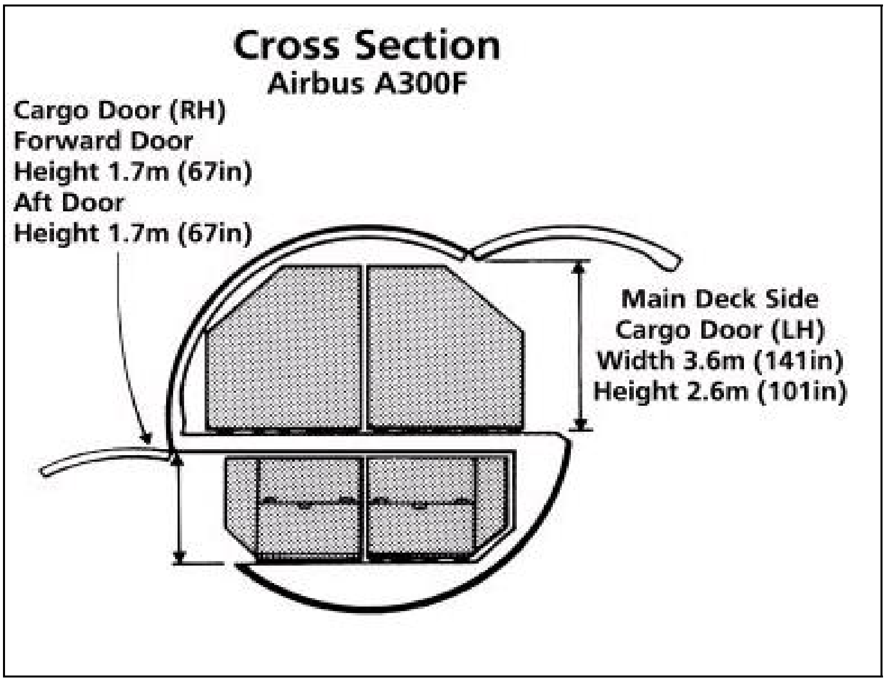


Figure 3.9 Airbus A300-600F: Cross section aircraftbody (**Freightersonline 2007b**)

- **Volume arrangement** of the lower cargo compartments:

  A good selection of the useful container types is necessary in order to use optimally the available space in the lower cargo compartment. Equilibration is once again of crucial importance! Figure 3.10 illustrates the volume arrangement of the lower cargo deck for an ***Airbus*** A300-600F, containing a maximum of twenty to twenty two LD3s.

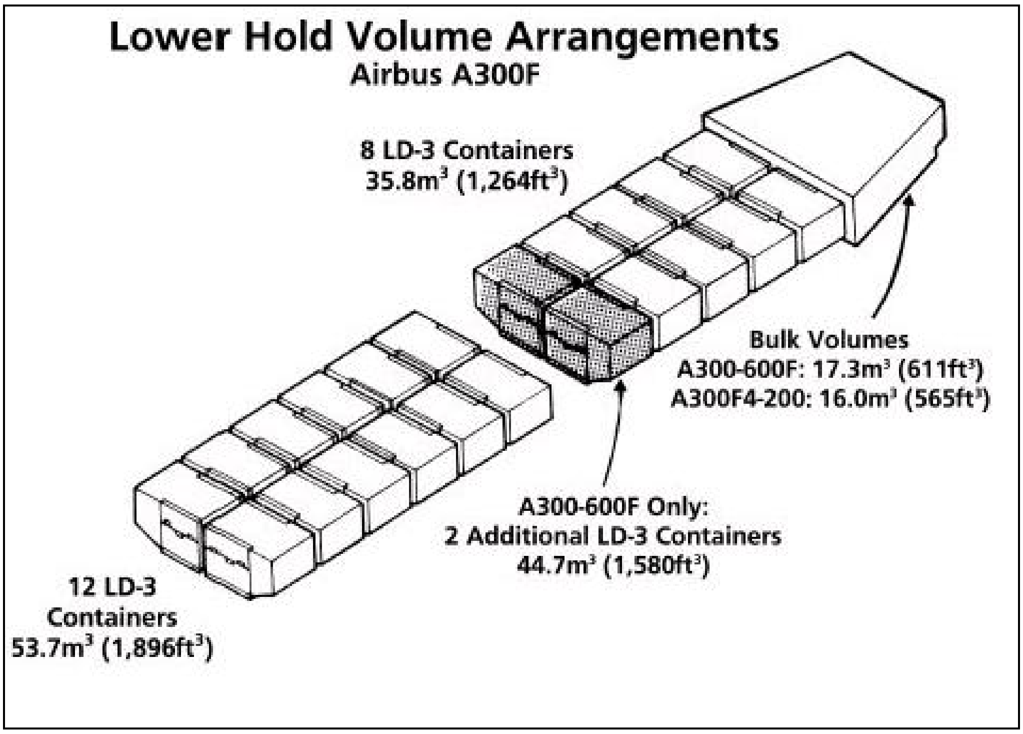


Figure 3.10 Airbus A300-600F: Lower cargo compartment (**Freightersonline 2007b**)

- **Maximum payload**:

  The most restrictive parameter for cargo transport is the **weight limitation.** The cargo aircraft can not be in any case overloaded as well as the ULDs separately. Any exceedance of weight can result in a catastrophe! The constraints for the ULDs are specified by ULDs manufacturers. For the aircraft, a graphic putting the range of the aircraft in function of the payload is furnished by the aircraft manufacturer. It is obvious that the payload will decrease with an increasing range, due to the requirement of additional fuel. Figure 3.11 illustrates the payload graph for an ***Airbus*** A300-600F.

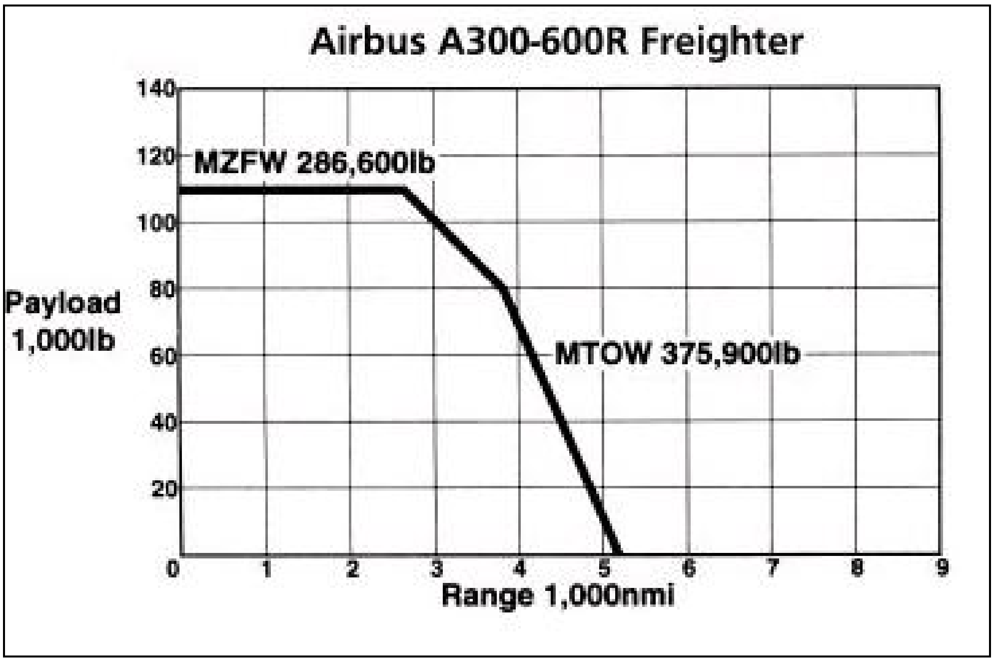


Figure 3.11 Airbus A300-600F: Payload range diagram (**Freightersonline 2007b**)

The data for several cargo aircraft concerning the ULD capacity with the above mentioned factors, are available on **Freightersonline.com 2007b**. This list, enumerated below, mainly consists of older-generation cargo airplanes:

- Airbus A300 (5 variants)
- Airbus A310 (2 variants)
- Antonov - An-12
- Antonov - An-124
- Antonov - An-22
- Antonov - An-225
- Britisch Aerospace Bae 146 (3 variants)
- Boeing B707 (2variants)
- Boeing B727 (4 variants)
- Boeing B737 (9 variants)
- Boeing B747 (6 variants)
- Boeing B757 (4 variants)
- Boeing B767 (2 variants)
- Douglas DC-8 (7 variants)
- Douglas DC-9 (8 variants)
- Douglas DC-10 (5 variants)
- Ilyushin IL-76 (2 variants)
- Lockheed L-100 (4 variants)
- Lockheed L-1011 (2 variants)
- Lockheed L-188
- Boeing MD-11 (2 variants)
- Shorts – Belfast
- Tupolev Tu-204

For the new-generation aircraft of the two world's leading aircraft manufacturing companies, ***Airbus*** and ***Boeing***, I refer to their homepages and specifically to underneath mentioned links:

- ***Airbus:*** http://www.airbus.com/en/aircraftfamilies/
- ***Boeing:*** http://www.boeing.com/commercial/products.html

3.3 Unconventional Load Devices

These pallets and containers have the purpose to serve for a specific application. This can vary from environmentally controlled devices to specially designed devices for the transport of “exotic” freight. The most common used types are enumerated below (based on **Inamar 2007**):

- **ventilated containers,**
  Equipped with ventilating ports on ends or sides, and used for heat generating cargo or cargo requiring protection from condensation (sweat) damage. Versions with powered air-circulating fans are available. Vents are normally fitted with baffles to prevent entry of sea or rain water.

- **insulated containers,**
  For cargo that should not be exposed to rapid or sudden temperature changes. Available in ventilated or non-ventilated versions. Some carriers provide containers with heating systems for special applications.

- **refrigerated containers,**
  Insulated and equipped with a built-in refrigeration system, powered by direct electrical connection or by diesel or gasoline generator. It is used primarily for foods or other commodities requiring a temperature con-trolled environment.

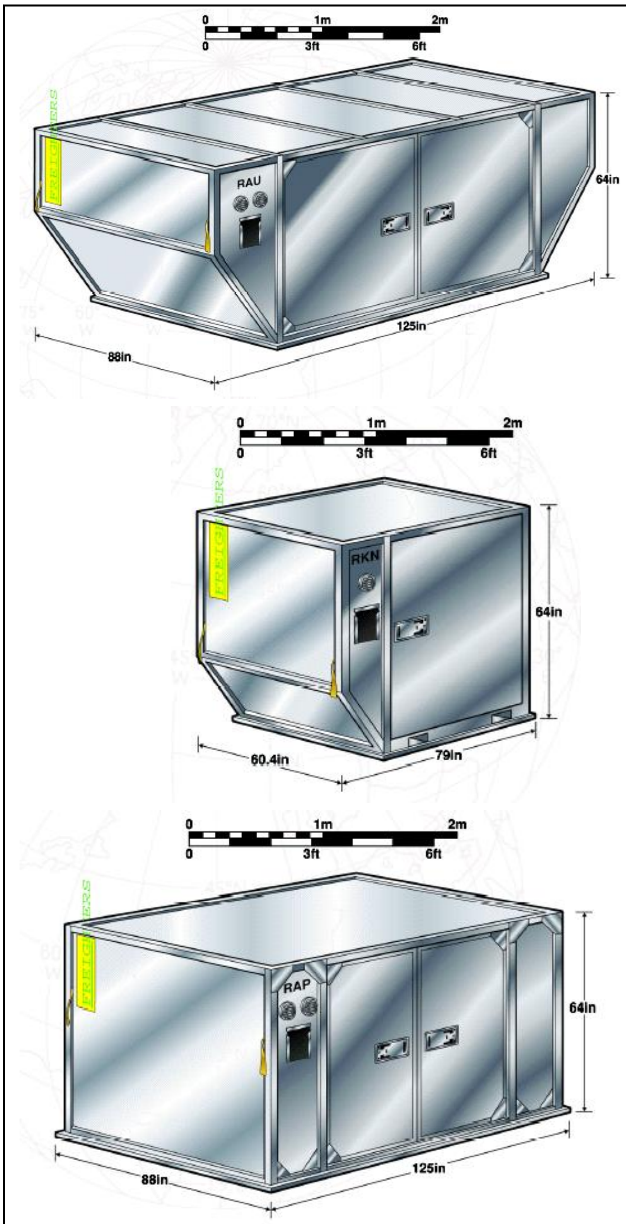
- **controlled atmosphere containers,**
  These systems carry a cylinder of liquid nitrogen and carbon dioxide. Through computer-based controls, the atmosphere within the container can be maintained at preset levels to meet requirements of commodity carried. Used mainly in the transport of produce to extend the post-harvest and storage life.

- **auto pallets,**
  Used for carriage of vehicles and available in enclosed or open versions. The PRA - 16ft Flat Pallet with twin Car Racks as VRA (classification: M-6),
  A variant on the PRA Pallet with a special moulding for car rack attachments. The support racks are available in pairs. Other prefixes are PMA, P4A, P4M or PZA.

- **livestock containers.**
  Configured for the nature of livestock carried; containers are available for transporting poultry, cattle and other livestock. Also, transport boxes can be loaded onto flats.

Some examples (**Freightersonline 2007a**) are enumerated below:

- **Cooled (refrigerated) and insulated containers** (Figure 3.12)**:**
  1. RAU - Contoured Cool Container on P1P base (classification: LD-29),
     Full width lower deck container contoured at both lower edges. It is the refrigerated version of AAU with a solid door.
  2. RKN - Contoured Cool Container (classification: LD-3 Reefer),
     Half width lower deck insulated container contoured at one lower edge with a solid door. All versions are "forkable". Another prefix is RVN.
  3. RAP - Cool Container on P1P base (classification: LD-9 Reefer),
     Insulated main deck container with a solid door.



RAU

RKN

RAP

Figure 3.12 Cooled insulated containers (**Freightersonline 2007a**)

- **Auto pallet:**

  PRA - 16ft Flat Pallet with twin Car Racks as VRA, classification: M-6 (Figure 3.13)

  A variant on the PRA Pallet with a special moulding for car rack attachments. The support racks are available in pairs. Other prefixes are PMA, P4A, P4M or PZA.

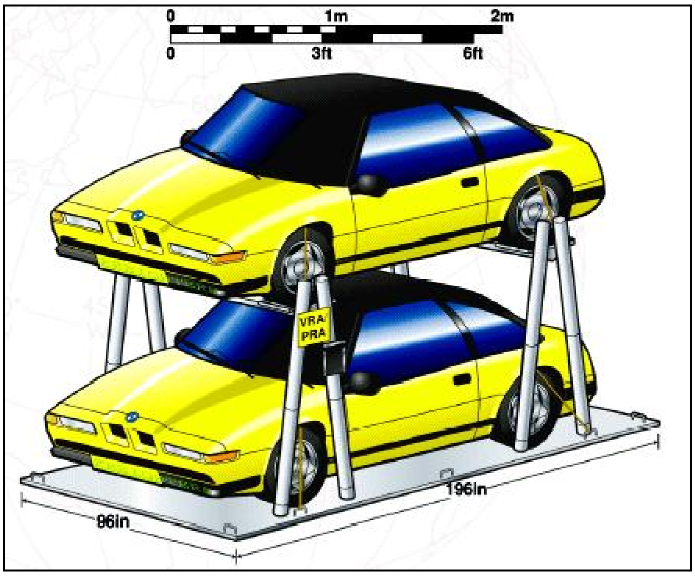


Figure 3.13 PRA - 16ft Flat Pallet with twin Car Racks (**Freightersonline 2007a**)

- **Livestock containers** (Figure 3.14)**:**
  1. KMA - Sheep/Goat Pens on P1P base with net (classification: Type A),
     Double and triple deck sheep/goat pens for transportation of livestock.
  2. HMA - Horse Box on P6P pallet base (classification: LD-9),
     P6P base with an IATA specified horse box stalls attached. Available with a canvas top or a solid roof. Some further modified versions available with position for escort.

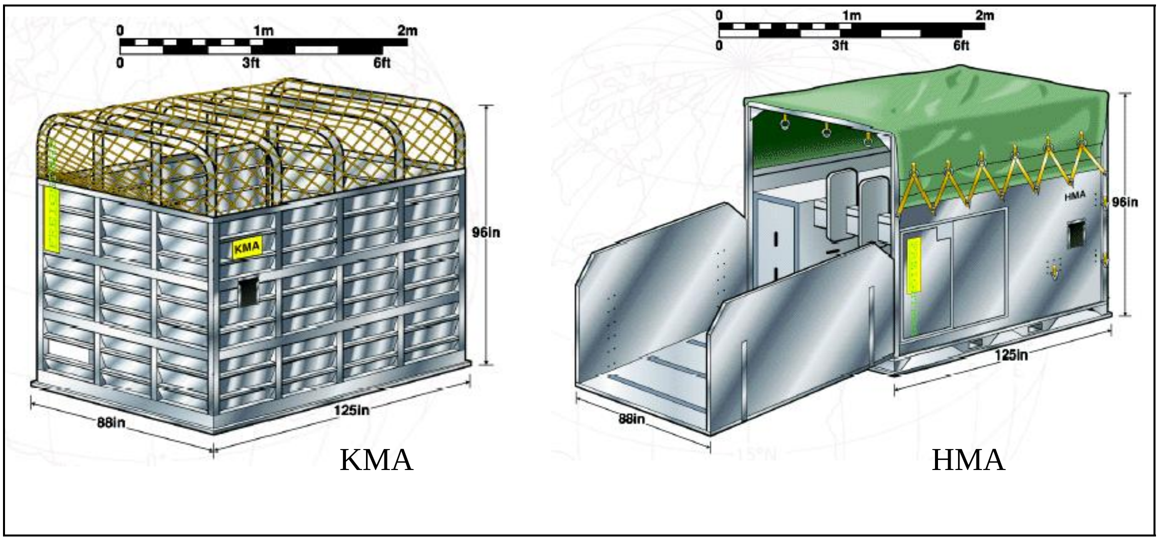


Figure 3.14 Livestock containers (**Freightersonline 2007a**)

3.4 Standardisation of Load Devices

Standardising organisations draw the specification for equipment and components used in the transport of freight. These can be national or regional bodies, international organisations, conventions or trade associations.

The international standards for air cargo and ground equipment are coordinated by the Technical Committee TC20/SC9 of the **International Organisation for Standardisation (ISO)**. The **International Air Transport Association (IATA)**, being a trade association of the ISO specific to the aeronautical sector, is responsible for the technical specifications of ULDs (**Done 2003)**.

Air carriers belonging to **IATA interline** (an association of sixty carriers) have an internal tracking and control system for ULDs for the benefit of the participating members. Under the IATA ULD Control Agreement, established in Geneva (1971), a central control and accounting system is put in place to return ULDs to their owners within a reasonable time. The system compensates the owner of ULD for the temporary absence of the unit from their system through payment of a daily demurrage and is also used to compensate for lost or damaged units (**Done 2003)**.

3.5 ISO Container

Standard intermodal container are generally made of **corrugated steel**. Small variants have walls made of **aluminium** (reinforced by stiffening profiles) or plywood with **GFRP (GDV 2007)**. For the intermodal container, five common standard lengths are available:

- 20 ft (6.1 m),
- 40 ft (12.2 m),
- 45 ft (13.7 m),
- 48 ft (14.6 m),
- and 53 ft (16.2 m).

In Europe the most common used containers are the 20-ft and 40-ft containers, while in the United States 48-ft and 53-ft containers are more popular.

The **container capacity** is relatively measured in **Twenty-feet Equivalent Units (TEU)**. A TEU is a measure of containerized cargo capacity equal to one standard 20 ft (length) × 8 ft (width) × 8 ft 6 in (height) container. Converted into metric units it is 6.10 m (length) × 2.44 m (width) × 2.59 m (height). The volume is approximately 38.5 m^3. These sell at about 2000 US Dollar in China, the biggest container manufacturer. The most used containers today are the 40-foot containers, which is equivalent to two TEU or one **Forty-feet Equivalent Unit (FEU)**. The 45-foot containers are also designated as two TEU. Concerning the height of the containers, it can vary from 4 ft 3 in (e.g. half-height containers) to 9 ft 6 in (e.g. high cube containers), but the typical height is 8 ft 6 in. When converting containers to TEUs, the height is not taken into consideration. TEUs are ideal to measure the capacity of a ship, for example.

The use of US measurements to describe container size (TEU, FEU), despite the fact that the rest of the world uses the metric system, reflects the fact that US shipping companies played a major part in the development of containers. The overwhelming need to have a standard size for containers, in order that they fit on all ships, cranes, and trucks, and the length of time that the current container sizes have been in use, makes changing to an even metric size impractical.

The maximum gross mass for a 20-ft dry cargo container is 24000 kg, and for a 40-ft, inclusive the high cube container, it is 30480 kg. Taken the tare mass into account, the maximum **payload** mass is reduced to approximately 21600 kg for 20-ft, and 26500 kg for 40-ft containers (**Wikipedia 2007f**).

3.6 Containers in other Transport Modes

This section represents a short overview of the most common used intermodal containers used for transportation by sea, rail and road. For further specifications concerning description, Figures, dimensions, weight and use, I refer to the link of ***Gesamtverband der Deutschen Versicherungswirtschaft (GDV) 2007.***

1. **Standard containers** (Figure 3.15)**:**
   The basic intermodal container, known as general purpose containers, is equipped with end doors suitable for the transport of all types of general cargo (dry cargo), which do not require environmental control while being en route. Variants with side doors are available when the use of end doors is not practical, as when the container must remain on a railcar while the cargo is being loaded or unloaded. The standard container is also in technical jargon called a 20-ft container and has a max. height of 8'6".

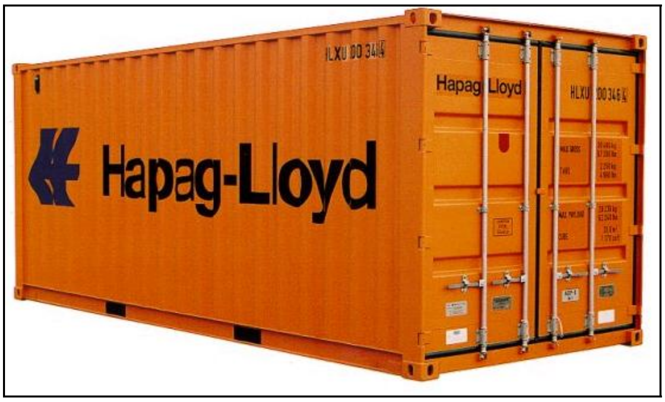


Figure 3.15 Standard 20' x 8' x 8'6" container (**GDV 2007**)

2. **High-cube containers:**
   High-cube containers are similar in structure to standard containers, but taller (max. height = 9'6"). They are mostly twice as long (40 ft) as the standard container. High-cube containers are used for all types general cargo (dry cargo). However, they are particularly suitable for transporting light, voluminous cargoes and overheight cargoes up to 2.70 m tall.

3. **Hard-top containers:**
   The walls of hard-top containers are generally made of corrugated steel. It has two typical distinguishing structural features, being a removable roof or accommodation allowing the roof to be lifted by a forklift truck. This simplifies the process of packing and unpacking. Hard-top containers are available in 20' and 40' dimensions and are used for all types general cargo (dry cargo), and especially for heavy or tall cargo and loading from above or through the doors by crane or crab.

4. **Open-top containers:**

   In order to simplify the process of loading and unloading, open-top containers have the structural feature of a roof consisting of removable bows and a removable tarpaulin. They suitable for the carriage of heavy, bulky or awkward items where loading or discharge through the upper side is required. Open-top containers are available in 20' and 40' dimensions.

5. **Flatracks** (Figure 3.16)**:**

   Flatracks consist of a floor structure with a high loading capacity, and with the possibility to stack several flatracks on top of eachother. They are mainly used to transport mill products, large heavy, bulky items, machinery and vehicles. Flatracks are available in 20' and 40' sizes.

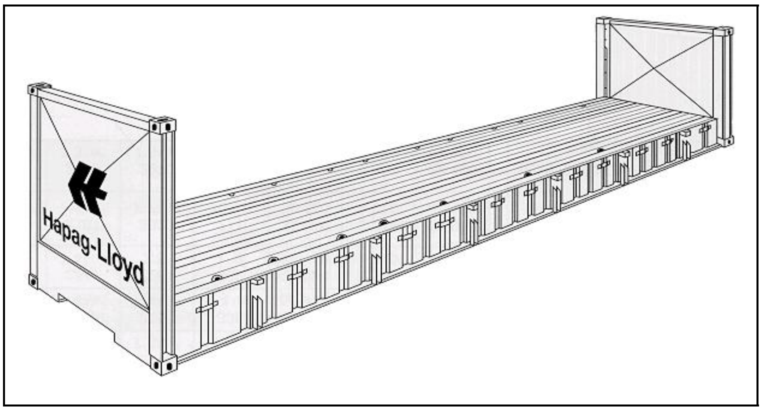


Figure 3.16 40' flatrack with two fixed and very stable walls (**GDV 2007**)

6. **Platforms** (Figure 3.17)**:**

   Platforms consist esclusively of a floor structure with an extremely high loading capacity. They are often flatracks with removable walls used for the transport of oversized and very heavy cargoes. Platforms are available in 20' and 40' sizes.

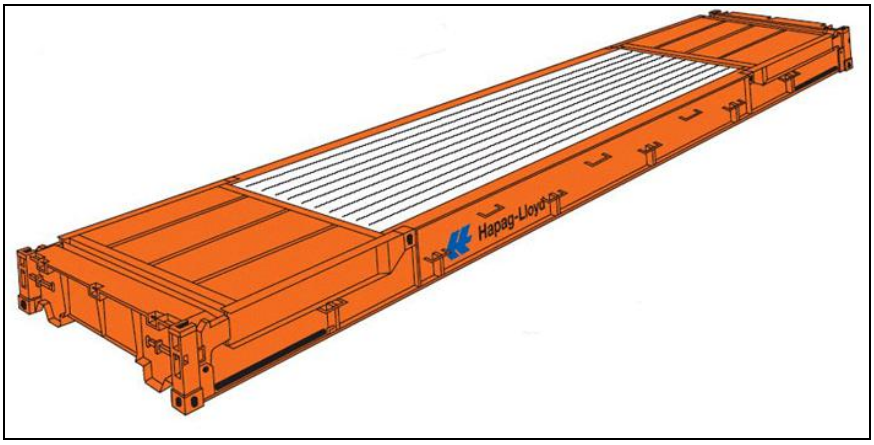


Figure 3.17 40' platform converted from a flatrack with removable end walls (**GDV 2007**)

7. **Ventilated containers:**

   Ventilated containers are also known as passive (naturally) ventilated or coffee containers. Ventilation is provided by ventilation openings in the top and bottom side rails. The openings do not let in spray, to prevent depreciation of the cargo by rain or spray, for example. A second type is the actively ventilated container, which simultaneously acts as insulated or refrigerated containers. Ventilated containers are used when cargo needs to be ventilated in transit (e.g. green coffee beans).

8. **Insulated and refrigerated containers** (Figure 3.18)**:**

   Two types of refrigerated and insulated containers are mainly available as 20' and 40' containers. The first type is with an **integral refrigeration unit** for controlling the temperature inside the container. The refrigeration unit is arranged in such a way that the external dimensions of the container meet the ISO standards and thus fit into the container ship cell guides, for example. The second type is the **porthole container** with the lack of a refrigeration unit. Such containers allow to have a larger internal volume and payload than integral units. On board, the inside of the container is supplied with cold air via the ship's central cooling plant. Off the ship, the temperature is controlled by a terminal refrigeration system or "clip-on units".

   The atmosphere control is usually established by flushing the container with nitrogen and CO_2. Refrigerated containers are used for goods which need to be transported at a constant temperature above or below freezing point. High-cube integral units are used in particular for voluminous and light goods (e.g. fruit, flowers). In both types, the doors constitute a weak point with as result the importance of the sealing and proper closing of suchlike containers.

Porthole container
with clip-on-it unit

20-ft container with
an integral unit

Figure 3.18 Refrigeration and insulated containers (**GDV 2007**)

9. Bulk containers (Figure 3.19)**:**

Bulk (or bulk cargo) containers are equipped with three loading hatches in the roof. Such containers may also be used for general cargo. On the door side, there are two discharge hatches, which are sometimes equipped with short discharge tubes for guiding the bulk cargo. Bulk containers are used in particular for transporting bulk cargo, such as grain, feedstuffs, spices. However, they may also be used for transporting general cargo.

Figure 3.19 20-ft bulk container with three loading hatches in the roof (**GDV 2007**)

10. Tank containers (Figure 3.20)**:**

Tank containers are used for liquid cargoes, such as foodstuffs (e.g. fruit juices, sweet oils, etc.) and for chemicals and especially hazardous materials (e.g. fuels, toxic substances, corrosion protection agents, etc.). They have a minimum filling grade of 80% to avoid dangerous surging of the liquids in transit and a maximum filling grade of 95% to allow sufficient “ullage space” for thermal expansion. They are generally designed for an operating pressure of up to 3 bar (above atmospheric) and temperature-controlled types are equipped with heating or insulation.

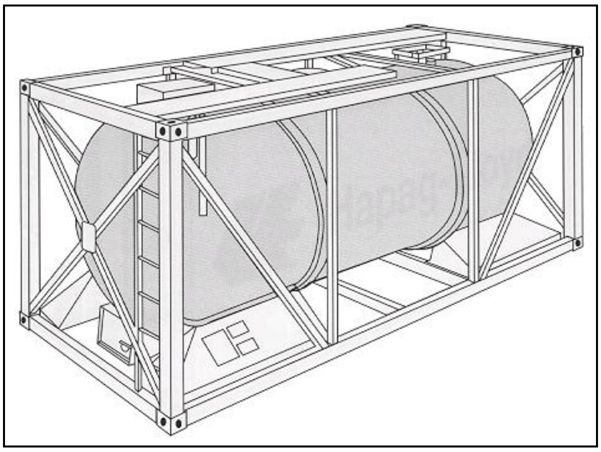


Figure 3.20 20-ft tank container (**GDV 2007**)

4 Cargo Chain Aspects

This chapter includes a brief description of parameters and criteria influencing the cargo chain. These main parameters are cost, time, environmental issues and standardisation. As the aspect standardisation already has been treated in the previous chapters, I will focus on the first three parameters in this chapter. The main source for this chapter is **Rodrigue *et al.* 2007**, unless explicitly mentioned.

4.1 Cost Aspects

4.1.1 Tendency of large freight transport

According to **Rodrigue *et al.* 2007**, container transportation reduces transport costs (relatively to bulk transportation) considerably, about twenty times less than bulk transport. 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% nowadays. 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. A 5000 TEU containership has operating costs per container 50% lower than a 2500 TEU vessel. Moving from 4000 TEU to 12000 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 30% by the use of containerization. The tendency of using larger container ships are illustrated by following two milestones, namely:

- The landmark of 6000 TEUs was surpassed with the Regina Maersk in 1996.
- The landmark of 14000 TEUs (the current largest container capacity) was surpassed by the Emma Maersk in 2006.

This tendency is obviously also valid for the other transportation modes where **transportation of larger freight amounts** lead to more efficient cargo chains in general. But the main advantage of maritime transportation is obviously its **economies of scale**, making it the cheapest per unit of all transport modes, which fits well for heavy industrial activities, e.g. mining. On the other hand, maritime transportation has one of the **highest entry costs** of the transport sector. The theorem of transporting larger freight amounts is also applicable for air freight transport, as that transport mode poses more restriction due to the container shape in relation to the body shape of freighters.

4.1.2 Intermodal Transportation Costs

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, trans-shipment 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 (e.g. river/sea shipping, better rail/road integration, etc.) have been established to reduce interchange costs, but **containerization** remains the most significant achievement so far.

Figure 4.1 on the next page illustrates the intermodal transportation cost function. Intermodal transport cost, C(T) between an origin and a destination and using an intermediary point of trans-shipment, is the summation of:

- composition costs C (cp),
- connection costs C (cn),
- interchange costs C (I),
- and decomposition costs C (dc).

Connection and interchange costs are related to national or international distribution costs while composition and decomposition costs are related to local or regional distribution costs. Significant costs reduction can be achieved with technical improvements for trans-shipment. However, with the increasing of traffic jams, particularly in urban areas, composition and decomposition costs may increase.

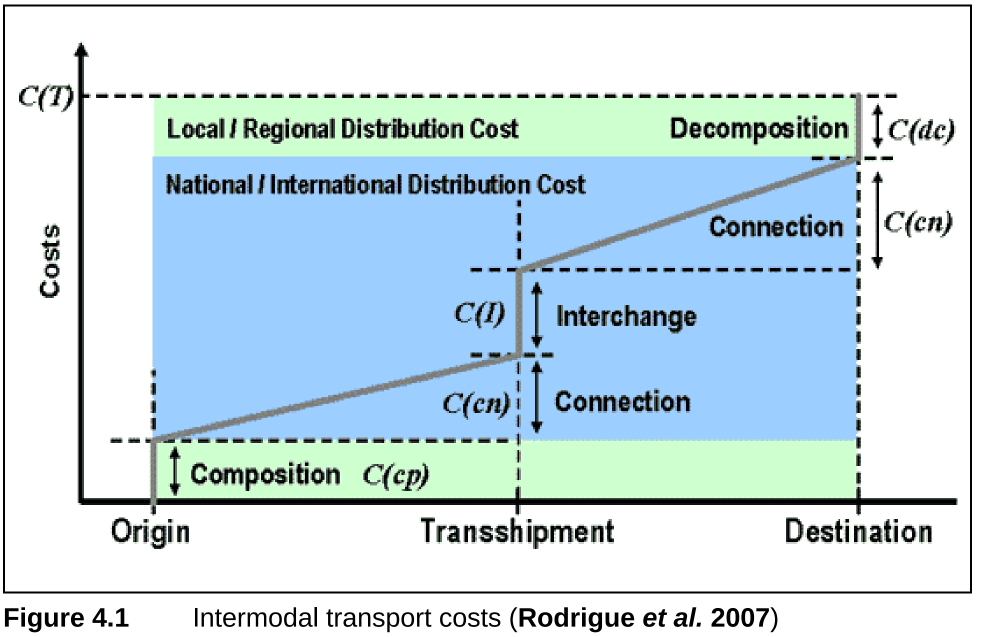


Figure 4.1 Intermodal transport costs (**Rodrigue *et al.* 2007**)

There is also 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).

Figure 4.2 illustrates this **relation** between **costs and modal choice** in function of the distance. Different transportation modes have different cost functions. Road, rail and maritime transport have respectively a C1, C2 and C3 cost functions. While road has a lower cost function for short distances, its cost function climbs faster than rail and maritime cost functions. At a distance D1, it becomes more profitable to use railway transport than road transport while from a distance D2, maritime transport becomes more advantageous. Point D1 is generally located between 500 and 750 km of the point of departure while D2 is near 1500 km.

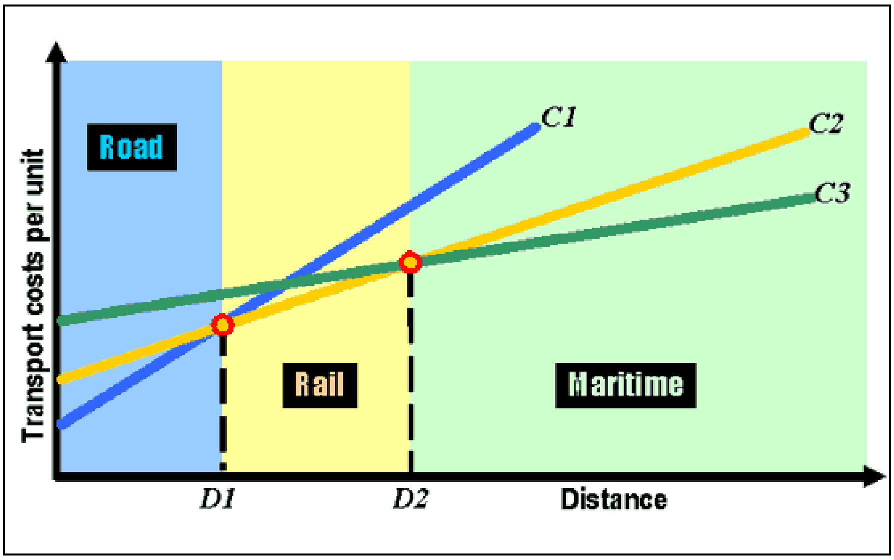


Figure 4.2 Relationship between distance, transport cost and mode (**Rodrigue *et al.* 2007**)

4.1.3 Air Transportation Costs

It is obvious that improving efficiency in the sideactivities (e.g. transshipment, warehousing, etc.) of air transport will lead to time reduction and entail cost reduction. However, the main factors influencing air transportation costs are **fuel price** and **fuel availability**. 2006, fuel accounted for about 30% of the operating costs of US airlines, up sharply from a few years earlier. For air transportation, finding a substitute for oil-based fuels is much more difficult than in ground transportation because the economic viability of flight depends on the use of a concentrated form of explosive energy. There is no easy substitute for fossil fuels in this regard. Still, the **fuel efficiency** of air transport has substantially improved in recent decades,

as high as 70% between 1960 and 2000, and possible future reductions are expected to take place at a rate of 1 to 2% per year.
Figure 4.3 illustrates the fuel efficiciency expressed in fuel burned per seat. Several factors contributed to the improvements in energy efficiency of aircraft in recent decades. The most significant (**Lee *et al.* 2001**) are:

- improvements in engine fuel per unit of thrust (about 70%),
- aerodynamic improvements (about 25%),
- other factors such as economies of scale of larger aircraft (about 5%).

It was advocated that structural efficiency improvements, such as weight reduction, made no contribution to improved energy efficiency.

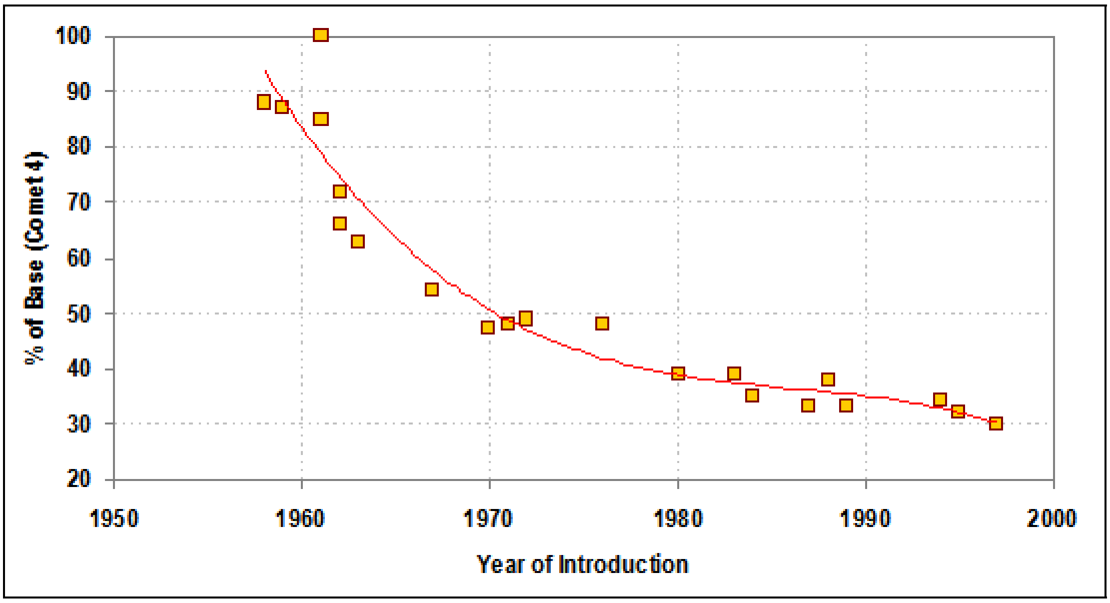


Figure 4.3 Trend in fuel efficiency related to the past decades (**Rodrigue *et al.* 2007**)

Regarding the **Green Freighter project**, one of the major aims that want to be achieved is environmentally friendly fuels which aren't so dependant on the oil industry. Due to the limitation of fossil fuels towards the future, considered as being a basic threats to the future of the airline industry, the quest for alternatives has become unavoidable. Possible suggested alternatives for kerosene are (**Penner *et al.* 1999**):

- ethanol,
- methanol,
- liquid methane,
- and liquid hydrogen.

4.2 Time Aspects

As the cliché says ***"Time is money, and money is time"***, it is clear that both aspects are unavoidably related to each other and that if one is changing, it will almost automatically lead to a change for the other one as consequence.

In the cargo chain, trans-shipment operations are minimal and rapid. A modern container ship has a monthly capacity of three to six times more than a conventional cargo ship. This is notably attributable to gains in trans-shipment time as a crane can handle roughly thirty movements (loading or unloading) per hour. **Port turnaround times** have thus been reduced from 3 weeks to about **24 hours**. 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 trans-shipment. E.g. five to six cranes can service a 5000 TEU containership implying that larger ship size 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, thus be more profitable to operators. Further, containerships are on average 35% (19 knots versus 14 knots) faster than regular freighter ships.

Concerning the other **intermodal transport**, it is often possible to combine rail transportation with road transportation, simply by carrying trailers. This is called **"piggy back"** and it is increasingly used to efficiently combine the inland potentials of rail and road transportation. The most flexible is obviously the **RO-RO (Roll On – Roll Off)** method where the tractor and the trailer are directly loaded on a rail platform. The driver usually rolls in with an outbound carriage and rolls out with an inbound carriage. Due to intermodality, this RO-RO system is also applicable with containerships, in addition to the crane (un)loading of the cargo. Overall, rail transportation is more efficient than road transportation, although its main drawback is flexibility as traffic must follow fixed routes and trans-shipment must be done at terminals.

If looking at **air cargo transport**, the time aspect is one of the most important facts towards the future which will be needed to improve in order to combine with intermodal transport. The actual situation is that an additional **repacking time** is necessary in order to transfer the freight from regular intermodal container to ULD, due to discrepancy in geometry. Some improvements have already been made, like e.g. introducing the M-6 Box Container (20-feet) for aircraft consisting of a main deck. A possible solution is that the containers would consist of **smaller internal removable units**, so that random loading would be avoided.

Figure 4.4, on the next page, represents an overview of the transport modes comparing elements, such as value, volume, servicing and distance.

Mode	Value	Volume	Service	Distance
Truck	Moderate to high	Loads of less than 50,000 lbs.	On-time performance above 90%.	Driver can go 500 miles per day. 2/3 of tonnage carried over less than 100 miles.
Rail	Moderate to low	Multiple car loads. No weight restrictions.	4 to 7 days delivery time. 60 to 85% on-time performance.	Average haul length between 600 and 800 miles.
Intermodal	Moderate to high	No weight restrictions.	3 days for cross country. On-time performance between truck and rail.	Average haul between 700 and 1,500 miles.
Air	High	Small. Most loads less than 100 lbs.	Normally overnight or second day.	More than 1,300 miles.
Inland Water	Moderate to low	Bulk shipments.	Varies according to segment. Competitive with rail.	Between 250 and 1,600 miles.
Coastal Water	Moderate to low	Containers, general freight and bulk shipments.	Function of distance. Between 2 to 5 days.	Between 500 and 2,000 miles.
International Water	High to low	Mainly containers and bulk shipments.	7 to 10 days trans-Atlantic and trans-Pacific routes.	More than 2,600 miles.
Pipeline	Low	Bulk shipment of liquids and gazes.	According to demand. 0 to 20 mph.	825 miles average distance for crude oil.

Figure 4.4 Modal profile of freight transportation for the US (**Rodrigue *et al.* 2007**)

Figure 4.4 provides an overview of operational considerations of freight transportation modes, notably in the American context. Most of the data also applies to other settings, such as Western Europe.

4.3 Environmental aspects

The relationships between transport and the environment are **multidimensional.** Some aspects are unknown and some new findings may lead to drastic changes in environmental policies as it did in regards of e.g. acid in the 1970s. The 1990s were characterized by a realization of global environmental issues, in essence by the growing concerns between anthropogenic effect and **climate change**. Transportation became an important dimension of the **concept of sustainability**, which is expected to become the prime focus of transport activities in the coming decades. These impending developments require a deep understanding of the reciprocal influence between the physical environment and transport infrastructures. The main factors considered in the physical environment are geographical location, topography, geological structure, climate, hydrology, soil, natural vegetation and animal life.

Furthermore, transportation is imbedded in **environmental cycles**, notably over the carbon cycle. The relationships between transport and the environment are also complicated by two observations:

1. A **contribution** of transport activities to **environmental problems**.
2. The contribution is at different geographical scales to environmental problems:
   - **Locally**: noise and CO emissions.
   - **Continental - national - regional** problems: smog and acid rain.
   - **Globally**: climate change.

Concerning the costs for the environmental issue, three types can be distinguished:

- **Economic costs**, which are related to the costs incurred to maintain an urban area according to the characteristics of its land uses.
- **Social costs**, which are included by the community disruption imposed by the land use density, pattern and interaction. Environmental externalities (e.g. noise, smog, odours,…) contribute to disrupt the quality of life. Transportation infrastructure, notably railways and highways are a physical barrier that divides a community and disrupt pedestrian or vehicular linkages.
- **Environmental costs**, which are related to the quantity of land taken at the expense of the natural environment, with consideration that land use contributes to environmental degradation as a source of waste (e.g. air - water pollution, hazardous materials, etc.).

Figure 4.5, on the next page illustrates a possible measurement system in order to quantify the impact of transportation to the environment.

Type	Field	Possible Measures
Economic Costs	Urban pattern and density	Average commuting distance
		Density of population
		Decrease in agricultural production
	Energy	Gasoline use per capita
		Energy per passenger km
	Infrastructure	Road density
		Public utilities provision costs
Social Costs	Community disruption	Environmental externalities
		Accessibility to facilities
Environmental Costs	Damage to the ecosystem	Land taken to the natural environment

Figure 4.5 Land use externalities (**Rodrigue *et al.* 2007**)

For further and more detailed information concerning the topic transportation and environment, I would like to refer to **Rodrigue *et al.* 2007** and **Lee *et al.* 2001**.

5 Evolution and Optimisation

This chapter deals with general examples in the evolution and optimisation of the (air) cargo chain. The examples which will be discussed in this chapter are general **air logistics**, **centralisation** and **hub** development and finally **multimodality**.

5.1 Air Logistics Evolution

The logistic support has become a crucial part in the cargo chain. It makes sure that the **flow of goods, energy and information** is controlled (**Wikipedia 2007h**). Principles like e.g. JIT are strongly based on logistics. According to **Kasarda 2006**, the specific part where the air cargo chain is acting, the **air logistic platform** is considered as being a strategy for competitive advantage. Some main advantages of the platform are enumerated below (**Kasarda 2006**):

- international gateway airports are able to **attract industry** and boost exports,
- **global markets** and **time-based competition** are targeted,
- full **integration** of **air, sea, road and rail** transportation modes are featured,
- utilisation of state-of-the-art **information systems**,
- recognition that **air cargo** is the **fastest growing mode** for international trade,
- **new policies**, including free trade zones, 24/7 services, express customs clearance, open skies for air cargo, one-stop servicing for foreign investors, logistics education and training programs, etc.
- achievement of unprecedented **integration of SCM** and high-tech manufacturing in combination with air cargo
- airport regions are emerging into an **international air commerce network**, giving the region's businesses quick and efficient access to suppliers and customers around the world,
- **commercial and industrial development** in the immediate airport area are expandable,
- implementation of **hubs** in the airports for multimodal industrial air commerce, leading to **JIT manufacturing and distribution**.

As main consequence, the today's airports are often considered as business magnets. Through development of multimodal air logistics platforms, firms will be able to improve **speed**, **agility** and highly **efficient SCM**. This is mainspring for firms and industries to locate themselves in the proximity of a highly logistically equipped airport.

5.2 Centralisation

As consequence of the expansion of air logistics among the airports, centralisation of industries, suppliers, etc. have occurred. A nice example which illustrates the increasing centralisation is the **Airport City Logistic Park (ACLP)**, e.g. in Beijing. The ACLP includes following elements (**Tiaca 2007**):

- integrated **planning** with customer interaction,
- streamlined **cargo flows** and procedures due to e.g. the application of latest **technology**,
- enhanced **efficiency** with handling time for express cargo reduced from 3 hours till 30 minutes and 24/7 service, speeding up the logistics flow.
- use of **IT systems**,
- etc.

The strategy is based on the integration of **hubs** into the airport. According to **Rodrigue *et al.* 2007**, the recent decades have seen the emergence of transport hubs, a strongly centripetal form, as a privileged network structure for many types of transport services, notably for air transportation. **Hub-and-spoke**, as a network structure, allow a greater flexibility within the transport system, through a concentration of flows. However, potential disadvantages may also occur such as additional trans-shipment as less **point-to-point** services are offered, which for some connections may involve delays and potential congestion as the hub becomes the major point of trans-shipment. The hub principle is illustrated on Figure 5.1.

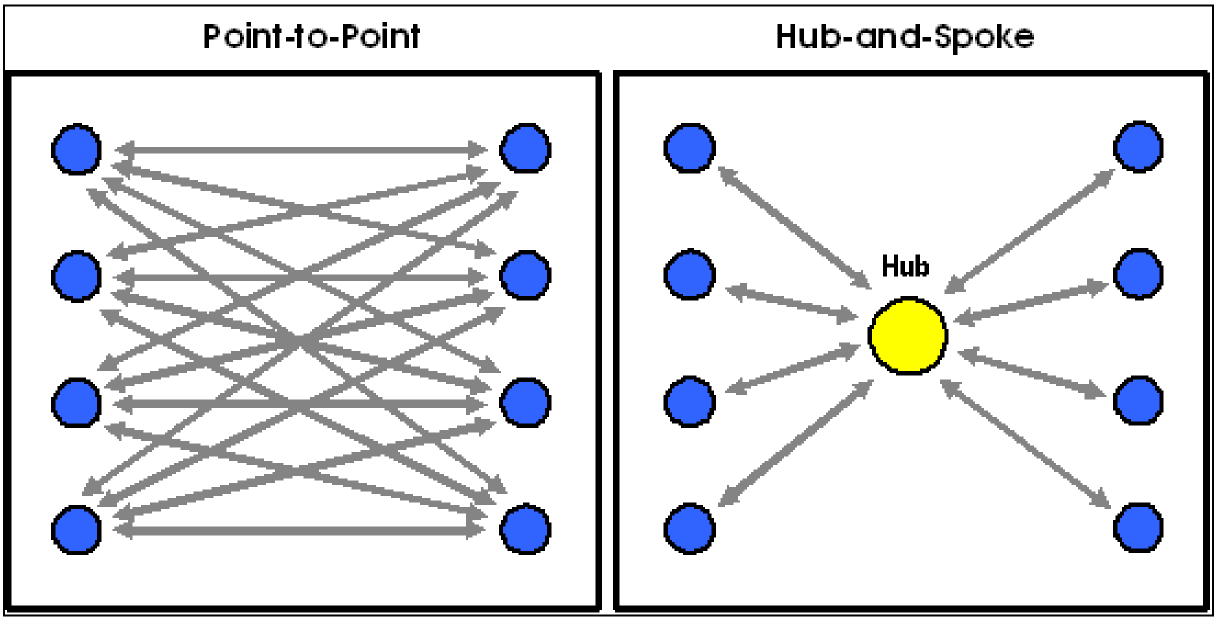


Figure 5.1 Hub principle (**Rodrigue *et al.* 2007**)

Applied e.g. on the **IT environment** of the ACLP of Beijing International Airport, the structure is less interconnected, leading to a greater efficiency. Figure 5.2 illustrates the difference between the current air cargo IT environments and the hub principle used in the IT environment of the ACLP.

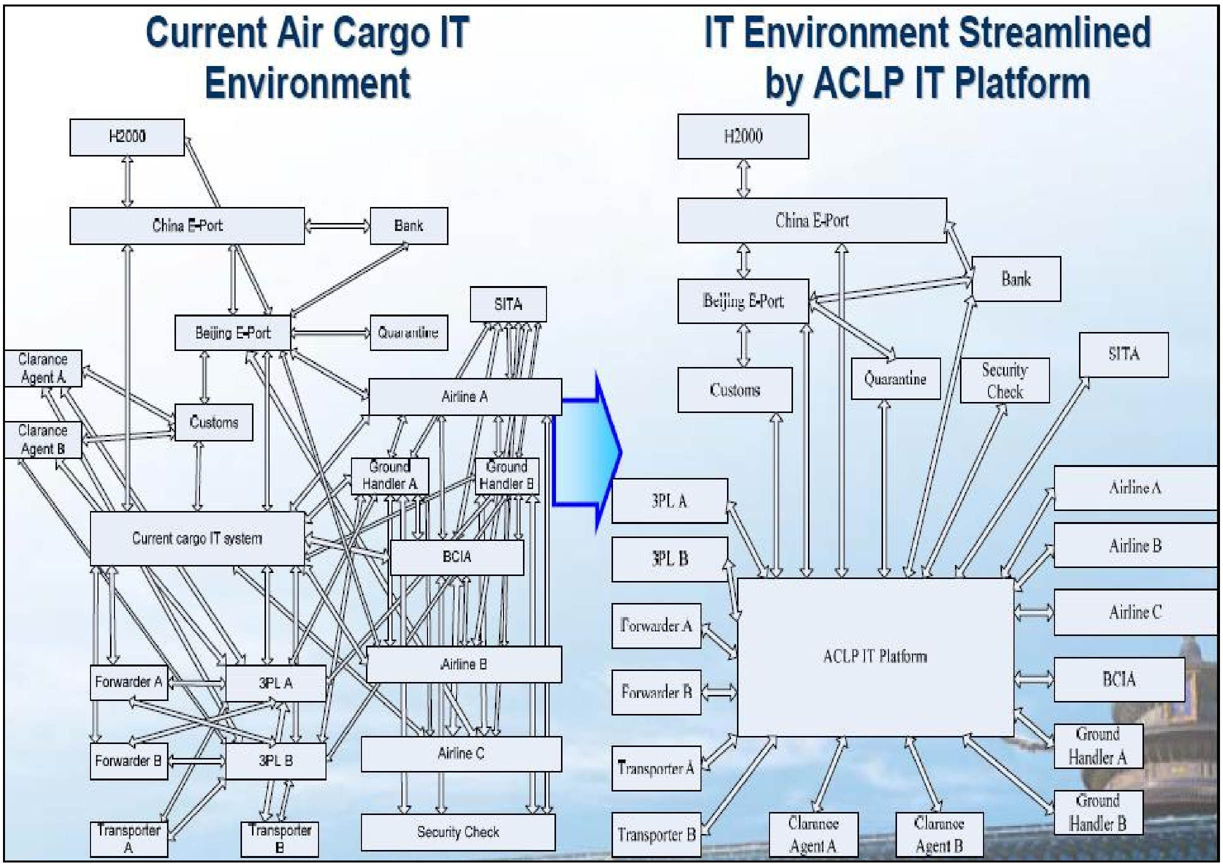


Figure 5.2 Point-to-point principle vs. hub principle (**Tiaca 2007**)

Another example of centralising processes is the **FAR Glory Park Taiwan** (**Tung 2007**) with a Free Trade Zone (FTZ). This world's unique consolidated park consists of five major functions:

1. **Air Cargo Terminal:**
   Import/export handling, handling of time critical cargos, trans-shipment, etc.
2. **Forwarder Building**:
   Providing sorting space and office for forwarders to pre-process cargo at the sources.
3. **Value-added Processing Park:**
   Value-added and simple processing, foreign labours, duty-free, tax exempt, etc.
4. **International Logistic Centre:**
   Providing international logistic value-added service and courier service.
5. **Business Operation Centre:**
   Business centres ,banks, exhibitions, international conference, etc.

Therefore a high need of effective **information flow** in the ***Park*** is necessary, some facts are enumerated below:

- goods processed in the ***Far Glory Air Cargo Park*** can be imported/exported directly,
- customs clearance is waved aside (only declaration via computer is needed),
- the aggregate time needed for the procedures in science-based Industrial Parks range from twelve to twenty hours,
- 98 to 100% of customers can receive the goods in two days,
- and electronic data transmission and cargo tracking system is made by RFID system (based on GPS tracking).

Figure 5.4 illustrates the different parts present in the ***Park***.

Figure 5.3 FAR Glory Air Cargo Park (**Tung 2007**)

5.3 Multimodality

Another possible improvement is to **integrate all transport modes** around the airport, with respect to geographical possibilities and environmental restrictions and legislation. As example, the **Hong Kong airport terminal** has set up a plan to be fully equipped for the integration of all transport modes. Due to the optimal geographical location of the airport, bordering the water, and accommodating rail and road transport, some sort of "super-hub" is about to be developed. The aim of the realisation is 2020. Figure 5.3 illustrates the excellent geographical location of the airport, and the opportunities to integrate all the transport modes (**based on Hong Kong Airport 2001**).

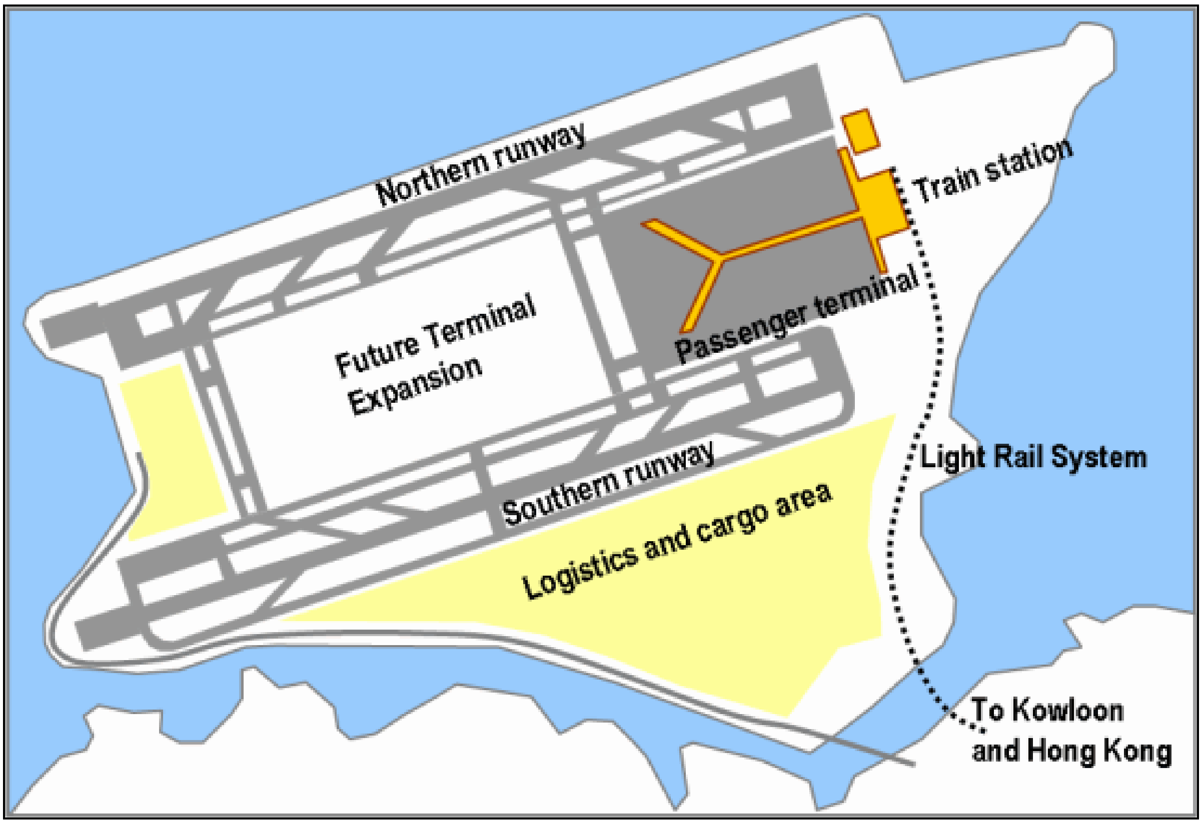


Figure 5.4 Hong Kong airport (**Rodrigue *et al.* 2007**)

6 Summary

By means of this project, general cargo chains (and more specifically air cargo chains) have been investigated in order to accentuate the discrepancy between air cargo transport and intermodal transport. This is necessary so that future improvements can increase the compatibility between air cargo transport and intermodal transport. Firstly, the cargo chain and its side aspects, such as air cargo handling procedures, standardisation of operations and load devices, etc. are hereby briefly described so that an overview about the topic is given.

Subsequently a survey about used load devices in (air) cargo transport notifies that LD3-containers and PMC-pallets are most frequently in air cargo transport, while 20-ft containers are generally used in intermodal transport. An improvement concerning size and geometry is a future aim in order to improve the efficiency of freight transport. Coherently, the research about intermodal load devices with the appropriate cargo types has been achieved.

The three main factors influencing the cargo chain and transportation are costs, time and environment. For the cost aspect, a tendency to use larger freight transport modes has been proven more efficient as result of containerisation. The use of containers led to more speed and flexibility. Another cost-reducing factor, and especially for air cargo transport, was the improvement of fuel efficiency which is a necessity towards the future, where fossil fuels will disappear. Concerning time reduction, again containerisation led to the greatest breakthrough. Compared to bulk freight, container shipping can go five to seven times faster. As third aspect, it is clear that transportation has a huge impact on the environment. A growing necessity to sustain the environment is causing that the environmental aspect can’t be overlooked anymore.

Finally this project proposes some suggestions and explications about cargo chain evolutions in order to optimise them. The importance of logistic support, leading to centralisation and hub-development is emphasized. Also the evolution towards fully equipped multimodal centres (e.g. Hong Kong Airport) is being dealt with.

The project should now provide a general overview about the term “air cargo” in order to use it in the preliminary phase of the Green Freighter project. It is important to know what possibilities are available today and what tendencies are occurring, to have a view in what can be expected from the theme air cargo. It is clear that air cargo transport can still be (and it needs to) expanded. There is still enough space to ameliorate aspects in order to achieve improvements. Continuous evolution is necessary so that air cargo transport can keep competing with the other transport modes. By offering new possibilities and facilities such as concepts like the Green Freighter, new paths are offered for transport sector.

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