V. INLAND PORTS PLANNING AND CARGOS HANDLING OPERATION*

1. Inland Ports Planning

1.1 General

The term inland waterway port or an inland waterway terminal conveys the idea of an end point. Indeed, traditionally, ports were perceived as end points of the transport system whereby water transport of cargoes was either originated or terminated. However, from a broader point of view, the one encompassing the so-called "chain of transport", ports or terminals are neither starting nor ending points; they are simply the intermediate points where cargoes are transferred between the links in the transport chain. The emphasis on the transfer function in this introductory section is made since:

(a) Ports' main function is to move the cargo and to avoid accumulating and damaging it;
(b) In order to efficiently fulfill their transfer function, ports or terminals have to possess convenient access (rail and road) to the connecting modes of transport.

The broader definition of a port seems especially appropriate for our discussion on inland waterway transportation (IWT). IWT is part of the domestic transportation system which also includes rail and road transpiration. IWT, unlike rail and road transportation, can only connect points which are located on the waterway network. Consequently, in most cases other complementary land transportation modes are required for the entire origin-to-destination transport. In other words, since in most cases the IWT cargo does not originate or terminate at the port site itself, the main function of the inland port is to transfer the cargo between IWT vessels, trains, and trucks.

The inland ports are important for the economic development of a country. The inland port, the rail, the road and the seaport are equally important. Usually, the greater part of domestic trade transpositions and borne by inland ports, but when the channel is wide and deep enough , some part of foreign trade transportations can also be borne by inland ports, and the oceangoing vessels can be through and berthing a year around. In this case, the function of inland port is the same as that of the seaport. The transfer of water to water or barge to oceangoing vessel is not needed. The inland port can transport the cargo directly.

Usually, the inland port is located on the bank of rivers, lakes and canals.

Almost every country has rivers or lakes but not many countries have canals. China has the longest canal, which is 1747 km long, and many ports are located on the twin banks.

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In Asia and Pacific region there are many rivers and many ports are extensively distributed over the twin banks.

1.2 Port Terminology

It seems that there is some confusion in applying the terms port and terminal. Therefore, prior to delving into technical discussion, there is a need for the classification of the terminology to be used. A port is composed of several terminals, or the terminals are components of a port. Sometimes, especially in the large inland ports, under the same port name there could be several locations, each with several terminals. For example, the Port of Nanjing has several locations. The major one located in Xinshengwei district, is composed of 3 public terminals, one general cargo terminal, one container terminal and one bulk cargo terminal. In reality, however, the term port, being the more general term, is used more often than terminal. Consequently, in the following chapters, the term port will be used as the general term, while terminal will be used only in the context of specific operation within a port.

Intra And Inter-Modal Transfer

The main function of ports, as was already indicated argued above, is cargo transfer. In principle, the transfer operation performed in ports can be classified as follows.

Intra-modal transfer, connecting two (or more) hauling services within the same mode of transport.

Inter-modal transfer, connecting two (or more) services from different transport modes.

For example, if some shipping company transports some cargoes from this service to that service only by vessel, we can say it is intra-modal transfer, if this transport action is performed by vessel first ,then by train car, and finally by truck, we can say it is inter-modal transfer.

Water-to-water transfer

The most common example of intra-modal transfer is that related to the change in the dimension of the waterway channel or to the change in routing. A typical case of an IWT intra-modal transfer due to change in the dimension of the channel takes place in ports located on the boundary of the deep navigation channel. This type of ports allow deep-draft vessels to be discharged into shallow-draft vessels, and shallow-draft vessels to be discharged into deep-draft vessels.

Usually, this transfer is operated at anchor if the dock is very busy, but sometimes, this transfer can be operated at berth when the electrical power supply is needed or the dock is vacant.

In addition, a typical routing-related intra-modal transfer takes place in ports located on a confluence of rivers or intersection of canals. These ports serve, naturally, as interchange points between the services on the various rivers (or canals). Another case is the ports which serve as regional load centers, accumulating or distributing main-route vessels (usually barges) among regional ports, as the Yangzhou Port, which is located at the confluence of the canal and

Changjiang, near Nanjing in Jiangsu Province. Here thousand tonnage vessels from Changjiang transfer to the hundred tonnage barge which goes in to the canal.

Land-to-water or water-to-land transfer

The transfer system in this type of ports, however, is not necessarily a direct vessel-to-vessel system but can also utilize an indirect path, through an on-site storage. Land-water transfer is the main function in inland ports; in each inland port, the most cargoes transfer by land-water or water-land. The port is the centre of a circle, the lowest price mileage is the radius, and in this region the cargo will be transported to the port. The reason is simple that is the lowest price. On the land side, there may be a storage yard, warehouse, dock etc., on the water side, there may be vessel, barge or sometimes oceangoing ship if the channel permits.

Multi-modal transfer

Though the intra-mode activity is an important function of ports, most of the inland ports are in essence inter-mode ports. This is because the IWT system is not a universal inland transport system providing a full point-to-point coverage. The IWT is limited, by definition, to serving points located on the waterway system. Consequently, in most cases complementary land transport is needed which dictates an inter-mode exchange. The inter-mode transfer is one of the most important characteristics of inland ports. In many modern inland ports a multi-mode selection is available, i.e. these ports offer vessel-to-vessel, vessel-to-train, and vessel-to-truck transfer services.

1.3 Classification of Inland Ports

The classification of ports discussed in the previous section was focused on defining the characteristics of single ports. Ports, however, are part of a broader transport network and as such can also be dealt with as a system which can sometimes bear a resemblance to hierarchical organizations with major (or hub) ports connected to smaller (or feeder) ports. The so-called port system and is organized according to the dimensions of their channel and structures (locks) which dictate, in turn, the size of vessel they serve. On the other hand, the throughput of a port is a target of the classification. In China, the throughput is an important target which can be used to appraise an inland port.

Channel dimensions

The classification of the channel dimension is decided by the vessel classification, and what size vessel the port can be dock is decided by the port classification. In China, the Changjiang is 6300 km long, over which are distributed 25 ports, and these ports can be divided into four "levels".

Lower Changjiang deep-draft ports:

These ports are located on the lower Changjiang , from Nanjing to the estuary where the, water depth is 10.5 M all year around , serving oceangoing vessels up to 25000 DWT, or barge fleet up to 30000 DWT. As you may know, Shanghai is a seaport, all vessels can dock there, and can also dock Nanjing and lower reach ports.

Lower Changjiang shallow-draft ports:

These ports are located on the lower reaches, from Wuhan to Nanjing, 700 km long ; the channel depth is 4--4.5 m, mainly serving barge fleet or oceangoing vessels up to 5000--7000 DWT.

Middle Changjiang shallow-draft ports:

These ports are located on the middle reaches, from Yichang to Wuhan, 630 km long; the channel depth is 2.9 m, mainly serving barge fleet or river vessels up to 3000 DWT.

Upper Changjiang shallow-draft ports:

These ports are located on the upper reaches, from Chongqing to Yichang 660 km long, the channel depth is 2.9 m, mainly serving barges or river vessels up to 1500 DWT.

Volumes of throughput

Throughput is an important target of the inland port, and the gross income of the port is decided by throughput. For all the enterprises, the finance is composed of two parts, one is fixed cost, another is variable cost; if the throughput is increased , the gross income will be increased, the variable cost will be decreased, and the economic benefit of the port will be good. So in China, the volumes of throughput is appraised as the capacity of the port.

1.4 Types of Cargos

All commodities and cargo forms are participants in the chain of transports , and ports are classified according to the types of cargo they handle. As already mentioned, cargoes can be classified according to their economic uses, or according to the way they are handled. The two classifications sometimes overlap. For example, corn can be shipped in bulk as well as in bags; bagged cargo , however, consists of corn as well as many other bagged commodities. So corn can be bulk cargo , but if bagged it is general cargo.

General cargoes

Usually, all commodities in bags or in boxes (paper box or timber box) or unitized , or single unit (usually big or heavy), are general cargoes, so commodities of this kind are many:

All daily necessities unitized
Corn, grain, wheat, rice in bags
Cotton , wool, jute, flax package
Structural steel
Woods and timbers
All cargoes in container
Cement, fertilizer in bags

liquid in drums

Bulk cargoes

In inland ports of developing countries, most of the breakbulk cargoes is handled "loose"; usually bulk cargo means the breakbulk cargoes. In China, bulk cargoes is moved by belt conveyor. The bulk cargoes are classified as follows:

Coal (powder, granular, lump)
Ore (Powder, granular, lump)
Corn, grain, wheat, rice (granular)
Fertilizer, animal foods (granular)
Sand, cobblestone (granular)
Cement (powder)

Liquid cargoes

Liquid cargoes can be classified as follows:

crude oil
fuel oil
petrochemical liquid
oil cooking
water

But most liquid cargo is crude oil and petrochemical products. All of these liquid cargoes are handled or transported in inland ports by pipeline.

1.5 Types of Terminals

In line with the above cargo definition, the terminals can be classified made into general cargo terminals and bulk cargo terminals. The general cargo terminals can be into neobulk terminals and container terminals, and the bulk terminal group will be divided into dry bulk cargo terminals and liquid cargo terminals.

The terminals of inland port are different from the terminals of sea port, and the main difference is the change of water depth and flow around the year. For example, in Changjiang, the difference in water stages between flood (August) and dry (February) seasons in the ports is comparatively large, it is the largest on the upper reaches and gradually diminishes toward the ports in the lower reaches. The maximum annual difference is 32.21 m in Chongqing, 15.81 m in Wuhan, 7.7 m in Nanjing, and about 3 m in Shanghai (tide range).

Owing to the change of the water stages the terminals of inland ports are mostly of the pontoon (floating pier), access bridge, ramp, etc., but the 90's from lower Wuhan port to Shanghai many new wharves have been put into operation and they are vertical type wharves with reinforced concrete structures.

Passenger terminals

Inland port passenger terminals can be found mostly in developing countries, since in these countries water transport of passengers by river buses quite popular. In developed countries, however, the main use of IWT for passenger transport is limited to river crossing and the terminal only provides a simple bridging device to facilitate moving on/off-board pedestrians and cars (ferry).

In developing countries, passenger terminals are quite large, and they can provide moorage for several vessels at the same time including accommodation for several hundred passengers and their belongings. For example, in Nanjing port, five 1500-passenger vessels may arrived at the passenger terminals at the same time, but we can only provide three berths, so other two vessels must waiting for berthing. However, this case does not often happen, last year the throughput of passengers was two million and five hundred thousand.

In China, passenger terminal in inland ports can roughly be classified into two types, one is the pontoon and access bridge, another is the pontoon and cable trolley on the ramp (in Chongqing).

The pontoon floats on water and follows the water change, up or down, passengers can go through the pontoon and access bridge boarding or unboarding. On the middle and lower reaches of Changjiang almost at the passenger terminals are of this types, but on the upper reaches, Chongqing passenger terminals are of pontoon and cable trolley type, vessels berth at the pontoon and passengers go into the cable trolley on the ramp moving up or down.

General Cargo Terminals

Most terminals are general cargo terminals in inland ports, so these terminals can be called Multi-Purpose terminals, usually capable of handling all forms of general cargoes as well as limited quantities of bulk cargo (by crab). In China's inland ports, there are two basic types of general cargo terminals; one type consists of pontoon, access bridge, storage yard or warehouse, the lift cranes fixed on the pontoon, and in the yard or warehouse there is the tyre crane or forklift; cargoes are put on the platform wagons which move between the pontoon and yard or warehouse. This type is simple and its investment low and the pontoon can go up or down following the water stages. Another is the reinforced concrete structure wharves, the lift cranes on the track move along the quayside, when the vessel berth at the quay, the crane can moving and operate along the track. In this case, the efficiency of cargo handling is higher than that of the fixed crane.

Cargoes can be loaded or unloaded from the vessel, and then transported by means of platform wagons. This case only takes place in terminals. If the cargoes go directly to the shipper, they can be transported by trucks.

Bulk cargo terminals

For single species cargo of a large quantity, such as coal, sand, and ore, the handling and transportation in a bulk cargo terminal is of two types, one is done at the loading terminal, the bulk cargo is outbound from land to water, another is at unloading terminal, the bulk cargo is inbound from water to land. However at any type of terminals the transportation on land is done by means of belt conveyer on the wharf by shiploader or shipunloader, and in the storage yard by stacker or reclaimer.

In inland ports, the shiploaders are of various types:

Fixed shiploader--the shiploader is fixed on the concrete piled structure, it can not move along the quayside, but can be rotated with in an angle and the boom can be extended or shortened to load the cargo into the hatch of the ship.

Another type of shiploader is fixed on the pontoon, it is a floating berth.

Movable shiploader--the shiploader move on the rail along the quayside, it is easy to move from one hatch to another, and the rail is fixed on the quay. Its capacity is large, and the annual throughput can be more than five million tons. Usually, these quays are constructed with reinforced concrete .·

Liquid cargo terminals

As mentioned earlier, crude oil, fuel oil, petrochemical liquid as well as its products are liquid cargoes. These cargoes can flow, so they are special bulk cargoes.

The characteristic of the liquid cargo terminal is pipeline transportation. Liquid flows through the pipeline, and pumps are the driving sources. In the liquid cargo terminal, you can not see the large and tall machines, you only see pipelines and pumps. In China's inland ports, these liquid cargo terminals use the pontoon and movable bridge, large tanks are located on the yard and the feeding arm is located on the pontoon. In Nanjing port, number six terminal is a crude oil terminal. It has six berths, the maximum oil tanker can be 35 thousand tons , it can accommodate, the crude oil feeding arm capacity is 1500 tons per hour, and the capacity of annual throughput can be more than twenty million tons.

The liquid cargo terminal of almost all inland ports use pontoon for the tanker to berth , not the vertical type reinforced concrete structures, because the water level change is large; in Nanjing port the annual change is about 7 meters .

For industrial terminals , the cargo transfer is only a secondary function, which the main one is manufacturing or distribution. Naturally, industrial terminals in the inland waterway system process or store cargoes which are typically shipped , such as raw materials in solid or liquid bulk form. Common industrial terminals include oil refineries, plastics plants, feed plants, construction materials plants, etc.

Industrial terminals can either have their own vessel loading facilities, or can use the facilities of a public terminal. In case they have independent loading facilities, they are usually simply an extension of the production or storage line and do not serve others. For example, in Nanjing Port, number five terminal is an industrial terminal, whose owner is Nanjing Petroleum Refinery. A new berth was constructed last year, it can accommodate 50 thousand-ton tankers, serving crude oil import and oil product export, and the annual throughput is about 10 million tons.

Up to this point, ports and terminals are classified according to five main characteristics: their basic transfer function (inter/intra-model), their cargo, their position in the overall port system, their ownership and use (public/private), and their cargo activities.

1.6 Terminal Demand Analysis

The previous section has already established the fact that ports are transfer points in a multi--modal transport system. The demand for inland port services is derived, thus, from the demand for inland waterway transportation (IWT). Since, as already stated in the previous chapter, IWT is not a selfsustained system but is heavily dependent on complementary modes of transport, the demand for IWT is part of the general demand for domestic transportation. The demand for transportation is derived from the demand for raw materials and finished goods which are transported to satisfy production or consumption needs.

Consequently, the analysis of demand for port services, if properly conducted, requires the analysis of the entire so-called demand chain. This kind of analysis is broad in nature and requires the understanding of regional, national, and sometimes international production, consumption and distribution patterns, and, especially, their relationship with the transport system.

Macro forecasting methods

The "macro" methodology for forecasting the demand for port services is based on the analysis of the previously--mentioned demand chain. The macro forecasting methodology identifies the role of ports in the global economy and examines the impact of different scenarios on the demand for port services. The common forecasting procedure is to analyze time series and develop a statistical relationship between the port throughput (commodity tonnage), and national and regional economic indicators (e.g., demography, employment, income, sectorial output, export/import, etc.)

The analytical process includes the selection of relevant predictors, and defining of a set of equations expressing either absolute or relative (elastic) values of the predicted variable as a function of the predictors. Once this relationship has been established, a range of scenarios in terms of basic assumptions is developed, and a respective range of forecasts is calculated. The macro-type forecasting is meaningful only on a regional or national basis, and since it is econometric in nature it is mainly effective for projecting commodity flows.

Micro forecasting methods

The "micro" methodology is geared toward forecasting the demand for a specific port. This methodology is based on an analysis of actual and potential users of the port. Micro forecasting applies "market survey" techniques, mainly mailed questionnaires complemented by telephone interviews, and for major users, face-to-face interviews. The data gathered include general information on type of business, volumes shipped/received per commodity, connecting modes of transport and ports in use. The face-to-face interviews with major port users are usually more comprehensive than the mailed questionnaires whereby port users are asked to:

(a) evaluate their present use of the port by listing (ranking) the important cost/quality factors in comparison to alternative ports;
(b) provide a forecast of their future use of the port. The interviews with potential users are similar in nature, although the focus is, of course, on the reasons of not presently using the port.

The preparation of micro forecasting, is time effort-consuming since it involves sending and compiling hundreds of questionnaires. The response rate to mailed questionnaires is usually low, typically in the 20-30% range. The success rate of is face-to-face interviews is much higher, but this interviews require coordination and are expensive if traveling to out-of-town head offices is required.

Combined Methods

Macro and micro forecasting methodologies are complementary. Macro-forecasting sets forth the overall, regional framework for the demand analysis, and is especially important for long-term planning purposes. Micro-forecasting is essential for assessing the immediate demand for a port and/or a specific port project. Desirably, macro forecasting efforts can be undertaken once every several years (e.g. five years) and updated periodically (e.g. once a year). Micro forecasting efforts, however, should be taken on a more route basis, as an integral part of any feasibility assessment for port projects. It is also recommended that in order to avoid based response, the face-to-face interviews should be conducted by an independent consultant.

National transport planning and market survey

A national or regional traffic report is a basis for port forecasting, and many inland ports cannot undertake independent and comprehensive macro forecasting efforts on their own. However, in many countries, the preparation of a macro-type forecast is greatly facilitated since the port forecast can be built on readily-available traffic flow forecast, sometimes called national (or regional) transport plans. Typically, a national transport plan lists, among others, commodity volumes (tonnage per year) moving between major origin and destination regions, divided to international and domestic movements, and divided by routes and transportation modes (modal split). In certain cases, the traffic is broken down to the level of specific river reaches, especially when the river has locks that might become bottle necks and if the traffic grows beyond the planned levels. Also, in case of locked rivers with locks, the lock statistics constitute a reliable source of data on regional traffic flow in the relevant section of the river.

National transport plans cannot be directly ascribed to port forecast since they are expressed in terms of commodities. Also, these plans only include inter-regional or international flows and ignore inter-regional flows which could be substantial.

Therefore, in order to adjust the transport plan to port needs, there is first the need to convert the commodities into by cargo forms and regroup them or , if possible, regroup them according to the types of terminals to be used.

For example, if the ports main facilities of a port is used for bagged grain, the overall grain tonnage in the national plan which is aggregated according to the type of grain (corn, wheat, etc.)

should be divided into bagged and bulk grain (since each is handled in a different type of terminal). Commonly, this division is based on a rough estimate of the relative share of various cargo forms (e.g. rice is 100% bagged while corn is only 50% bagged). A parallel analysis will be performed to identify the bagged cargo of all other commodities which are compatible with bagged grain in terms of terminal handling. This could include, for example, bagged milk powder, rice, sugar, chemicals, etc. Finally, the entire bagged cargo should be totaled and the demand for bag-handling terminals in a region calculated.

The national or regional planning of transportation is important for ports or terminals, but the market survey is very important too. The general definition of the marketing process is simple: watching buyers and sellers. For a port the marketing is done for the sellers, therefore the focus of marketing is on identifying potential buyers and introducing to them the products and services provided by the port. Consequently, an essential step in any marketing assessment involves a comprehensive examination of both the required products, and the potential clients (or uses) of these products.

Ports, in essence, provide or "sell" cargo transfer services. In the previous sections discussing forecasting and demand analysis, we used the term "cargo" without really delving into the real issues: Who controls the cargo? Who directs the cargo to the ports? Who are the port's clients, or who makes the decision to use the port?

There are two parties which are usually involved in the cargo route decision:

(a) Cargo owners, shippers and receivers, and their representatives (freight forwarders);
(b) Carriers, mainly ship or barge lines, and, to some extent, truckers and railroads.

In order to solicit cargo, therefore, the port representatives should contact the members of the two groups mentioned above.

1.7 Port Site Selection

New and existing site

According to the need of transportation of inland ports, the need to site an inland port arises in two common situations:

(a) the development of a new waterway (or a section of it);
(b) the growth in traffic which cannot be satisfied at the existing port facilities.

The subject of site selection for new inland ports as a result of development of a waterway system, however, is somewhat a mute subject. In most of the developed and some of the developing countries, the inland waterway system has been around for quite a long time, and development of new waterway is quite a rare undertaking. In other words, most of the ports in inland waterway system are already in place. In fact, the origin of many of the cities located along the IWT system was determined by the ports which had been historically developed from natural landing points.

Moreover, in some cases, the IWT port is part of a much larger industrial complex (park). So, even if a new site is developed, the port-related selection considerations are secondary in importance to the overall considerations related to locating industrial users.

Expansion or consolidation of existing ports or terminals which triggers facilities relocation is a more frequent case of sitting ports or terminals. Except for the need for an additional category, a common case of facilities for relocation stems from the change in cargo handling technologies. Modern terminals which host modern, high-capacity equipment usually require larger sites, resulting in the consolidation of several adjacent sites.

Categorization of siting consideration

The economic and commercial considerations are the fundamental considerations which guide the port site selection, and the decision-making process is quite straight forward: minimizing the economic (social) cost of port services to be provided at the proposed site. In a market driven society, however, the foregoing consideration is substituted by commercial consideration: maximizing the profitability of the new port. Profitability has also to do with minimizing the cost but also with the market position of the proposed site along with transportation connectivity. Another consideration, though of a different type, is political, usually related to regional development and income distribution policies.

Water-related considerations

The access to the navigation channel, there is a great difference between locating an inland port on a regulated waterway (man-made canals or canalized river) and locating it on an unregulated or partially regulated waterway (natural river). A basic requirement for any active port is to have a permanent access to the main navigation channel. Maintaining this access is much more difficult on rivers, because the great amount of mud and sand carried by current would deposit on the bottom of the river bed, where the navigation channel itself is unstable, than it is on a regulated waterway. In order to address the more general case, this section is mainly related to locating ports on rivers.

Most of the water-related problems stem from seasonal fluctuation in water flow due to seasonal precipitation and/or snow melting patterns. Rapid changes in water flow cause shifts in the location of the main channel, and large variation in water level, and may result in bank erosion and siltation in the port access channel . Naturally, port planners try to locate a port on a river stretch which is less exposed to these problems.

Desirable port sites can be found:

(a) On a deeper reach of the river where channel shifting, sedimentation and current action can be expected to be less severe;
(b) On a concave, high bank of the river where the channel is close to the shore , because this practice needs smaller docking structures.

Water environment is complicated and the above observations serve only as very general guidelines. Usually there is a need to conduct a detailed analysis of river hydrology, morphology and sediment movements so that the water attributes of each site can be accurately evaluated and quantified. The analysis should also consider the effects of the proposed port structures on the velocity of water flow and movement of bed materials so that future surprises can be avoided.

Land-related considerations

Land related considerations, unlike the water-related considerations which are unique, by definition, to inland waterway terminals, are more general in nature and also apply to the sitting of other transportation-intensive industrial facilities.

Common considerations include:

(a) Availability of waterfront land;
(b) Soil conditions and elevation;
(c) Utilities connection;
(d) Environmental impacts;
(e) Price of waterfront land.

The waterfront land is the prime consideration in the above mentioned list. This is a critical factor, especially in urbanized areas, where the demand for waterfront land, which stems from both water related and non-water-related uses, such as general commercial (waterfront hotels, restaurants, office buildings) or residential uses, exceeds supply. Even in less urbanized areas the availability of large vacant tracts of river front area that could potentially be developed is quite limited.

A "basic" general cargo terminal requires some 150-200 meters of water frontage and about 10 hectares of backland. A large, modern and multi-purpose port which consists of several cargo terminals and an accompanying industrial complex requires 500-1000 meters of water frontage and 50 plus hectares of backland .

Consequently, as a pre-requisite to locating river front facilities , there is a need to prepare a conceptual terminal layout including at the minimum, definition of the water frontage (linear meter), storage area , and other major space-intensive considerations. Also , it is important at this stage to include reserves for future expansion.

Soil condition, is an important consideration for sitting new port facilities since it can substantially affect construction costs. Port activities, by their nature , generate high dynamic and static loads due to the need to accommodate movements of heavy lifting machines, railcars and due to high stacking of heavy cargoes(steel, iron, containers). Soft soil or mud does not prelude sites: hard soil is needed. Land elevation is a companion consideration to soil condition. Low-lying land is exposed to periodical flooding and requires protection. Another related factor is the distance between the high-elevation waterline and the navigation channel, which dictates the size of the shore structures and cargo handling machinery, and can vary considerably from site to site.

On site utilities hook-up, including fresh water, sewer, electricity and telephone, plays an important role in site selection mainly for terminals.

The environmental considerations have been recently gaining much in importance. The environmental considerations revolve around two major aspects which are almost unavoidable in construction of new port facilities:

(a) Elimination of wetland;
(b) Compatibility of land use.

Construction of a river port or a terminal, especially at a low-lying location, is bound to result in both reduction in wetland and damage to the natural and biological resources of the nearly by and even outlying environment.

All the above-mentioned considerations can be eventually expressed in terms of "cost"; the cost of waterfront land, however, has a direct cost implication especially due to the scarcity of such land, and, especially due to the competition for it by non-maritime users. Land price reflects, in a free market society , the "best possible usage" of the tract of land under consideration. The usage of land is determined by local government.

Transportation Considerations

In transportation considerations of siting ports or terminals, the road and rail access in the transportation network plays a major role. Ports are a part of a multi-modal transportation network where they function as intra/inter model links, and the selected site for a port should provide for efficient connection between the water and land modes of transportation.

Efficient connection to a surface transport system or road and rail is indeed as important as connection to water transport. Most sites have road connections, or if missing, an access road to the nearby regional road can be easily constructed, but a rail connection, on the other hand , if missing, is difficult to be constructed.

Other cost considerations

The considerations grouped in this section are general in nature and do not necessarily typify inland ports. Important considerations include:

(a) Availability of trained and cost-effective labor;
(b) Availability of reliable and low cost utilities;
(c) Availability of financial incentives.

The consideration of availability and cost of local labor, is important, this is, however, not an important consideration for a general cargo terminals, which do not employ many people on site. Likewise, most of the cargo handling jobs do not require more than basic skills which can be obtained almost anywhere.

The availability of low taxes and other financial incentives is a critical factor in locating both cargo and industrial ports, since both require large capital investment. Ports are considered as important infrastructure and a catalyzer for economic growth. Therefore, local governments are inclined to provide ports with either indirect support through low taxes, or even with direct subsidy through favorable lease terms on public lands, construction of special-purpose utilities and road connection, provision of training courses for labor, or simply by offering subsidized credit.

Site selection process

Collecting and analyzing detailed data on the various attributes to support the informed decision-making process of port site is tedious and time consuming effort. This can also be quite costly if there is a need to review a large number of sites, and/or the readily-available information is limited so that there is a need for independent investigation including boring laboratory testing(for environmentally problematic locations).

Consequently, the site selection process should be both comprehensive and economical .A logical approach is to divide the process into several sequential stages, whereby the number of sites and the amount of information required per site are in inverse relationships. For example, start the selection process with a large number of sites, but collect only the basic data for each site, i.e., for preliminary selection. The preliminary selection is directed toward the elimination of the sites that do not meet threshold or minimum requirements. The remaining sites are subject to additional and more detailed investigation, which in turn can support the next round of elimination. The underlying idea is to progress in two parallel directions: to reduce the number of sites under consideration on one hand, while , on the other hand, to increase the amount of information required per site. The selection process includes, thus , several "rounds" of elimination until the final alternatives, usually 2-5 sites, are identified.

2. Cargo Handling Operation

2.1.General

As we know in inland posts, the cargo handling and transfer is done at terminals, which consist of :

(a) Terminal facilities;
(b) Terminal equipment;
(c) Labor and staffs.

Port operation , in a broad sense, includes a wide array of activities which take place at the site of the inland waterway terminals. The most basic activities include cargo handling activities, whereas other activities include storage and distribution, equipment maintenance, cargo processing, and other industrial activities.

Consequently , port operation is defined as a cargo handling(or moving) activity, performed by a designed company (gang or team), consisting of labor and machines.

Port operation can be described by posing three basic questions:

What is the cargo to be handled?

Who performs this activity?
Where and how is this activity performed?

Accordingly, answers can be grouped into three categories:

(a) Type and form of cargo, size (dimension, weight) of cargo unit, number of units moved in one cycle, origin/terminal points , rate (productivity), total volume;
(b) Number and professions of labor members, type and number of cargo handling machines, stevedoring tools;
(c) Layout of facilities, type and size of vessels, trucks and railcars, time (day/night) , weather conditions (temperature/rain).

As mentioned above, a convenient way of describing the overall port process is to describe it as a "pipeline" consisting of a series of operations which take place in several work stations. The port process is , in essence, an intermodal transport, moving the cargo between the vessel and the truck or train. The basic work stations which participate in the marine terminal process include the vessel, dock, storage yard, and gate. Consequently, most of the common port operations involve moving cargo between these station either along the gate-to- vessel line , in the outbound direction, or the vessel -to-gate line, in the inbound direction.

A convenient way of dividing this pipeline and the related operations is based on the main work stations where the activities take place. Accordingly, the basic options include:

(a) vessel transfer-moving cargo between the vessel, dock and yard;
(b) storage-holding cargo in transit;
(c) gate transfer-moving cargo between the yard and the land transport vehicle (truck or railcar), usually through the terminal gate.

For example , the port process of truck to ship transfer consists of all three operations in the outbound direction, the cargo is first unloaded from the truck, put into storage, then stored for a period of time waiting for the ship to arrive and finally loaded on to the vessel.

2.2 Terminal facilities

Inland waterway ports, depending upon the types of transport modes connected and type of cargo handled there, provide a wide range of services. Accordingly, these ports consists of a wide range of facilities to provide these services. For the purpose of simplification, this section will focus only on the most common inland port facilities, on those which are directly involved in the transfer of cargo between the vessel, rail, and truck. There facilities can be grouped into three main categories:

(a) docks and mooring structures;
(b) storage sheds and yard;
(c) gate and land transport accesses.

These terminal facilities are , in fact work stations in the major port's operations , or better called a process line. For example, in the vessel loading process the cargo is brought in through the gate to the yard, stored there and , later on , sent to the vessel side and loaded on board. The reverse sequence happens in the unloading operation. Even in the case of direct delivery, where cargo moves directly and the terminal consists of a dock, the two other terminal components are indirectly involved. This is because there is a need to store the rail/truck on-terminal and to control or regulate the entrance to it.

Docks and mooring structures

The main functions of docks and mooring structures. Inland waterways, by definition, are sheltered bodies of water. Thus , unlike open water , in most cases, there is no need for protection against waves and for the related structures (breakwaters). The dock is the most fundamental facility at the marine terminal. The dock has two basic functions:

(a) moorage (berthing) of vessels;
(b) support of cargo handling equipment.

In addition, the dock has several secondary functions , including:

(a) transfer of people and supply between the ship and the shore;
(b) utilities , such as hook-up, fresh water, electricity, telephone;
(c) support for vessel-shifting equipment (winch).

The function of the moorage structure is to secure the vessels (ships or barges) in place and to restrain her water-related movements. The most common and simple mooring structure in inland waterways includes a combination of breasting and tie-in dolphins. The tie-in can also be provided by anchors buried either on the bank, called deadman, or in the river and tied to a buoy. Since inland vessels are usually of small size, the mooring structure can be made simply of a cluster of wooden or concrete piles, with or without capping. The mooring structures are equipped with mooring posts (capstans) to which a series of lines are fastened (head, stern, spring and breast lines). The mooring structures as well as the vessels are protected from damage by a series of fenders made of energy-absorbing materials.

Every terminal requires additional support structures called docks. The dock can solely serve as a carrying platform of the cargo handling equipment or serve as a general-purpose platform where both equipment and cargo can be held. Since cargo handling equipment can vary widely according to the cargo form and throughput rates, the dock structures which provide the support can range from a simple river cell to a pile-based marginal apron.

In China, the most common dock structures can be divided into three groups:

(a) Closed type, or gravity-based structures;
(b) Open type, or pile-based structures;
(c) Inclined type, or sloped-trackway structures.

Closed type structures which are based on block walls are by far the most common structures in the river environment where the wave action, as well as the bottom depth, are limited. Also , closed structures are generally less expensive to construct than open structures, but the water depth can not be more than 5 meters. So the use is limited, only on the small river and for berthing barges less than 5 hundred tons.

Open type structures are based on the open piled structure. Usually , the most piles are made of reinforced concrete, the dock space provided by a T dock is still limited and restricts crane and truck/rail movements. Consequently, at large inland terminals , both the length and the width of the dock are extended, and the entire area between the dock and the bank is filled and paved (desirably capped with concrete) to provide a continuous working area.

At most terminals on the Changjiang, the apron area of the marginal dock is about 100-150 meters long and 10-15 meters wide. These docks , however, sometimes extend over several hundred meters supporting several adjacent terminals. The extension is necessary to provide efficient rail crane-to-vessel transfer along the dock. In Nanjing port, the Xinshengwei terminal is of this kind , where more than 25 thousand tons oceangoing vessels can berth.

The inclined type structures is manly characterized by its adaptation to the great range of water stage. On the upper reaches of the Changjiang, the range of water stage is over 16 meters at Yichang city, 32 meters at Chongqing city. In the inland ports from Yichang to Chongqing, most docks are of the inclined type structures, even the passenger docks. A cable car on the slope trackway travels to transport the passengers or cargoes.

Floating docks

The floating dock is not exactly a marine structure, but , since it is a common substitute for a fixed dock, it deserves a brief description. A floating dock arrangement usually includes two components:

(a) a captive pontoon serving as a dock;
(b) a gangway connecting the pontoon to the river bank.

The elevation of the pontoon which carries the cargo-moving machine can be freely to adjusted following the change in river level. To avoid transverse movements it is anchored to the river bed by a combination of spuds and mooring lines fastened to deadman on shore. The dock is usually made up of a deck pontoon with ballast(for stability) with the upper surface strengthened and paved. The dock is connected to the river bank with a short gangway or a bridge supported on the pontoon at the end and the other end on a roadway on the river bank. If the distance to the nearby river bank precludes a direct dock to bank bridge , an additional floating section is added to the dock to create a floating passage.

Floating docks are not different from fixed land-based docks in terms of functionality, and can handle both bulk and general cargoes. Like land-based terminals, the storage and other terminal facilities are located on shore and the dock is mainly used as a berthing structure and support the cargo-moving machines.

The main advantage of floating docks is their capability to be adjusted to different river stages and seasonal fluctuations. This adjustability is very important especially for rivers with wide fluctuations. The floating arrangement intends to keep both the operating vessel and the dock at

the same level. This even level results in shorter crane cycles,(shorter lifting pass), increased productivity as well as damage prevention due to the better control of the cargo in motion. This important advantage over the fixed dock is evident, especially at the river stage when the difference in level between the dock and the barge can reach thirty or more meters, making the movement of cargo and stevedoring crew between the vessel and the shore quite difficult.
More important is perhaps the low cost of the floating arrangement compared with comparable fixed docks. Floating docks cost somewhere between 1/3 and ½ of a comparable fixed docks. Also , floating docks can be relocated or even sold if the operation proved unsuccessful , a critical feature for start-up terminals. Floating docks are , however, limited in overall size and size of loading of handling equipment that can be supported on them. They cannot provide rail connection and they are more maintenance intensive.

Terminal Yard

The main functions of the terminal yard facilities include:

(a) Storage of cargo before or after loading or unloading;
(b) Storage of railcars and trucks;
(c) Provision of a series of cargo services such as protection against weather, damage, pilferage and hazards; inspection, sorting, consolidation and custom clearing , fire protection; long-term warehousing;
(d) Provision of general services such as equipment maintenance, administration offices, amenities for labor, etc..

The port cargoes stored in the terminal yard differ greatly in their sensitivity to moisture , changes in temperature and sun radiation. The decision to store cargoes outdoors is, of course, also a function of the climate conditions in the port area and the length of time the cargo is expected to stay in port. In the inland waterway system, the decision on the type of storage is quite obvious. Any cargo that is being carried in open barges can be stored in an open yard. Accordingly coal, ore, send, gravel, scrap and to some extend iron, steel and lumber can be stored outdoors while the rest require weather protection. In some cases , indoor cargo can be stored outdoor by using waterproof covers(tarpaulin).

Sometimes, the size and type (loading and pavement) of open storage or yard are a function of both types and volumes of cargoes to be stored, and a function of the cargo handling machines operating there. In the very basic case, whereby the yard is served by front-loaders or crawlers, the storage pad is simply a leveled and drained gravel-laden surface with road access for trucks. Asphalt or concrete pavement is required if steel and lumber are to be stored since their handling is performed by forklifts riding on relatively-small rubber tires. This is also the case if packaged goods such as barrels and craters are stored outdoors. The size of the storage pad is a function of the volume to be stored and the properties of the materiel to be stored(specific weight, repository anger), which affects their storage density. Determination of the volume to be stored is an operation-related decision.

Warehouses

The ports' warehouses or transit sheds are not different from common industrial storage sheds.

The basic warehouse is simply a shell structure, sometimes only a roof(no side walls) and it is used to store cargoes that are only partially sensitive to moisture such as lumber , drums and even woodpile , and paper.

For more sensitive cargoes, the shed is enclosed with walls and roll-up doors. In the typical arrangement, the shed has two large doors on its short sides for trucks or forklifts, and several smaller doors for smaller forklifts leading to loading ramps on its long side. Port warehouses are usually equipped with sprinklers for fire protection, and with a lighting system for night operation. The structure itself should desirably have large free spans or even be column-less to allow easy maneuvering of forklifts and trucks inside the sheds. The internal height is about 6 meters , though for some cargoes(paper rolls, palletized cargo) it can go as high as 10 meters. In some special applications the temperature and moisture inside the shed are controlled . (for fresh cargo).

Gate and land transportation accesses

The function of the gate and related facilities can be divided into:

(a) Cargo and equipment exchange;
(b) Traffic control;
(c) Parking;
(d) General security.

Not all the above mentioned gate functions can be found at all the inland terminals. The gate activities are performed under cover, each of them at a separate booth. There are booths for security check, for cargo check, and for equipment check. The entire gate area is lighted for night processing and connected to the terminal office by telephone, and sometimes by document-moving(container terminal). The gate and terminal entrance should include a two lane road(in/out)with traffic bumps to slow down the terminal traffic.

An important component of the gate complex , especially at large terminals, is the parking lot both in front of the terminal entrance and next to it on the inside. The parking lot is provide mainly for trucks but also for passenger cars, in some cases, especially at general cargo terminals with direct loading or unloading from trucks, the parking lot can take up a large area.

The transportation accesses are the rail and road. The rail access is usually provided not through the main gate but through a special gate whose location is dictated by the alignment to the rail trackage. Unlike the truck gate, the only function of the rail gate is simply to let trans in or out. Cargo processing is performed in the terminal rail yard or at the truck gate.

Electrical Power, fresh water supply and communication.

Any terminal needs electrical power, fresh water supply and clear communication to support the operation of all the equipment and all the people there.

There are two kinds of terminal handling equipment, one is electrical machine, another is fuel (gasoline or diesel) machine. If the operation is the same for the two kinds of handling machines, the cost of electrical machine will be half of the fuel machine. So for developing countries , except for the transport on roads or in yards, trucks or trailers, forklifts, all other handling equipment including cranes, truck loaders or unloaders, ship loaders or unloaders, should be electrical machines. The use of the electrical equipment not only saves the fuel cost but also saves the downtime and repair cost and repair time. If the capacity of the two kinds of machines is the same, the repair cost of fuel machines will be 3 times of electrical machines, and the repair time will be 5 times. This is the many years' experience of Nanjing Port Authority. The terminals, without fresh water, could not operate. If the terminal is not close to the city, and the fresh water pipeline cannot be connected a fresh water maker is necessary. There are three fresh water makers in Nanjing Port, one is at the coal terminal producing 1000 tons per day, one is at the liquid terminal, producing 5000 tons per day, and another one is at the Xinshengwei terminal, producing 20000 tons per day, supplying fresh water for vessels, as well as for domestic use.

Clear communication is important for terminal operation. At present , computer terminals, telex, telefacsimile ,etc. are very popular.

2.3 Cargo Handling Equipment

As already mentioned , a common division of cargoes handled by inland ports is based on their operational form. Consequently, the two generic cargo groups , are general and bulk cargoes. In line with this operational cargo classification , cargo handling equipment can also be divided into:

(a) General cargo equipment;
(b) Bulk cargo equipment.

General cargoes (bags, bundles of steel, paper reels, etc.) are defined as cargoes which are is handled in batches or in discrete units. Their handling method is lifting and moving the cargo units, or loads, in a cyclical, repetitive fashion. Bulk cargoes(grain , coal, etc.) are composed of a multitude of small and homogenous units. They are handled in a continuous fashion and their main handling methods are based on conveyance.

The basic characteristics of any handling equipment can be defined by answering three basic questions:

What is to be moved?
From where to where?
How fast?

Indeed , cargo handling machines are characterized according to their

(a) Capacity--the size (dimensions and weight) of cargoes units;
(b) Distance or reach--the distance (horizontal and vertical) between loading and unloading points;
(c) Speed-- the traveling, swinging and hoisting speeds(acceleration and velocity) of the various moving components and the resulting overall rate or productivity.

Moving cargoes in the inland port setting is not different from moving cargoes in any industrial setting which is a part of the broader discipline of material handling, which, in turn, is a hybrid of Mechanical and Industrial Engineering. According to "Material Handling", cargoes can be moved in three principal ways:

(a) Trucking -- by rolling the cargoes on wheels;
(b) Lifting-- by picking up and moving the cargoes in the air;
(c) Conveying--by carrying the cargoes on a continuously moving chain, belt , chute, or pipe.

Each cargo handling machine(or system) includes a combination of the above-mentioned principal methods. For example, a forklift combines limited lifting with trucking while a crawler crane combines limited trucking with lifting.

The following sections will briefly review the most popular machines used in inland ports, mainly the general cargo equipment and container equipment as well as bulk cargo equipment.

General cargo equipment

General cargo equipment are the most basic handling machines at the inland waterway terminals. In the simplest terminal configuration, the equipment loads or unloads a vessel directly to or from the truck, railcar or another vessel. In the more-common, indirect operation, the cargo is first transferred between the vessel and the dock, held or stored at the terminal for a short period, and later trucked or railed to the final shipper's place.

These general cargo equipment are tyre cranes, portal cranes, fixed cranes, forklifts, trailers, platform wagons, etc.

Tyre cranes

The type crane is a real multi-purpose handling machine, and can be found almost in any inland ports. Within the marine terminal the crane is not limited to vessel handling but can be used for handling trucks and railcars as well. In the common tyre crane configuration, the carriage system is on rubber tyres. In China's inland pots, the boom of most tyre cranes is fixed from 10 to 15 meters high (only boom length). Another tyre crane is truck crane, whose boom is usually telescopic (by hydraulic), so the crane can drive freely on public roads without need to dismantle the boom as is the case of fixed boom tyre crane. All tyre cranes are equipped with outriggers including wooden supports, and truck crane can be equipped with a separate crane driving cab. The capacity of a tyre crane is usually somewhat limited, allowing it to lift about 5 tons to 25 tons in the most popular case.

The tyre crane can move to any place easily and fast , and that is the merits; but the operations is slow and lift capacity is lower than that of the portal crane(in the same working radius), and that is the demerits.

Portal Cranes

In China's ports including seaports and inland ports, portal cranes are extensively used on docks, including small inland ports whose throughput is less than 3 million tons .

The configuration of portal crane in inland ports is based on pedestal support structure and an elevated turntable. In some design the support structure is based on a 4-leg gantry (bridge or portal) design with four sets of steel wheels at each corner, which enable the crane to move on tracks along the dock. The driver cab in most of these cranes is also elevated to enable an unobstructed view of the entire vessel hold. The pedestal configuration allows the crane to stand closer to the vessel, and use shorter boom and smaller swinging radius.

As a result, the cargo path is shorter and cargo control and staging is more accurate. Another improvement in boom design, called level-luffing, is based on an articulated boom, which allows through counter movement of the two boom segments for leveled traverse travelling, because the level movement is more energy-efficient, and also allows the use of less hoisting cable and the accuracy is better when working in small ranges.

Portal cranes usually have a higher productivity and a better reach than tyre cranes; if the capacity is the same, the price of one set is lower than that of the tyre crane. In China market, the lifting load is 10 tons and the reach is 30 meters, and the price of one set is about 380 thousand US dollars. All of these portal cranes are powered by electricity, so the cost of operation is lower, and that is important for developing countries.

Fixed cranes

The fixed crane can not move, as its name indicates it can do any activity except travel. So we can say it is a crane without legs, because it has no traveling gear, this crane is cheaper and lighter than the traveling crane. Its elevated structure is usually the same as the portal crane's, but only smaller and lighter.

Because of the price consideration, in China, small inland ports like to use the fixed crane. It can be located on the pontoon or on the dock, powered by electricity. If the port throughput is less than 3 million tons, the fixed crane will be chosen first, because the investment is comparatively low.

Forklifts

These are very extensive cargo handling machines, suitable for any ports. The forklift combines trucking and lifting of cargo units, and the lifting is usually realized by way of a fork moving along a vertical mast through a hydraulic cylinder and a chain-driven fork attachment. The mast can be extended by using up to three telescopic sections(triplex). The capacity of a forklift is measured by the maximum weight it can lift at a stated distance from the face of the forks (60 cm in common applications). The smallest forklifts, where the cargo is hand pushed and lifted, have a rated capacity of about 0.5 ton, but usually inland ports use forklifts of a capacity of 3-5 tons, at larger inland terminal maybe 10 tons. The largest can be found at container terminals, and the rated capacity is about 40 tons.

At terminals forklifts are mainly used for cargo loading or unloading from trucks or railcars, or storage in the yard or warehouse. Forklifts are not used to transport the cargo, beyond 50 meters.

Trailers and platform wagons

Cranes and forklifts are mainly to handle cargo vertically; in cargo transportation on land trailers and platform wagons will be used. A trailer is like a truck, but without packing box, and each trailer will trail 3-5 platform wagons, a group to transport cargoes. The cargo is put on to the platform wagons, each wagon can take 5 tons, or 10 tons, and the largest can take 40 tons, travelling from vessel to yard/ warehouse or from yard/warehouse to vessel.

In China's inland ports, for the inside terminal transportation this system is used for general cargoes, but this system can not run on public roads.

General Cargo Handling Process

General cargoes unitized and palletized

General cargoes will involve different sizes and different weights, so it is difficult to handle the cargoes efficiently and quickly, therefore, in order to handle general cargoes efficiently and quickly , they must be unitized and palletized, that is the dispersive units of cargoes must be unitized and palletized. The dispersive units of cargo will be unitized in large bags, or bundled up by slings, however, the single unit of cargo from several kg to hundreds kg will be unitized to a larger unit, maybe 5-10 tons, depending on the capacity of the handling crane.
For the forklift to pick it up, the cargo should be mounted on pallets or skids. Pallets are usually classified according to their engagement system(one-way or two-way pallets), their dimensions and carrying capability.

When the general cargo is unitized cranes or forklifts can be used and transportation by trailer and platform wagons, however, in transport or storage, the attachments(bags, slings, pallets) can not be separated from the cargoes.

Handling attachments

In handling the cargo, the cranes or forklifts, from the hatch of the vessel or truck , need special tools--handling attachments, which can be divided into two groups:

(a) Crane attachments;
(b) Forklift attachments.

The crane attachments are very simple. They hook on to the hook of the crane, and can pick up the cargo. They are of different sizes and types for different cargoes.

Forklifts are probably the most common cargo handling and moving machine . Their versatility is achieved through various attachments which either go over the forks or simply replace them.

The most popular of them include a side shifter for better positioning; clamps handle baled cargo, paper reels or large carton, grip and backrest devices to handle drums; hanging beam for handling cargoes with hooks; centrally mounted ram for handling reels. Likewise, there is a whole range of spreader attachments for handling containers.

Container Equipment and Handing Process

In inland ports, container handling is gradually becoming more and more, on the Changjiang River, there are more than 10 ports handling containers. Last year, the container throughput of Nanjing Port was 150 thousand TEU.

Portainer--Container Crane

Maybe the portainer is the largest machine in inland ports, its weight is about 600-800 tons, so the dock must be constructed with reinforced concrete. On the superstructure mounted is the railtrack, on which the portainer moves .

At inland port terminals , the configuration of the portainer is like a grab gantry crane. The container movement is conducted by way of a trolley inside the boom. The trolley travels in straight line, and it can be cable-powered. The boom crosses over the vessel to handle the containers, and the gantry can be moved along the dock to the container. So the handling efficiency is very high . The portainer is powered by electricity, and its total power may be as large as 450 HP.

Transtainer--tyre gantry crane

The portainer is only for handling container from vessel to yard or from yard to vessel, while the transtainer, handles the container from storage to truck or from truck to storage. Usually , the inland port transtainer is the same as the seaport transtainer.

The transtainer configuration is divided into 4 legs, 2 seal beams on the top on which the trolley travels and 8 rubber tyres for gantry travel. The span is 23.5 meters, and the power is a diesel engine of 200 HP.

Straddle Carrier

This is a combined handling and trucking machine specially for container. The moving distance can be longer than that of the forklift. As mentioned above, a forklift can not move for a long distance when it is loaded, but a straddle carrier can move for a long distance (only at the terminal, not on public road), so it can pick up and transport the container. However, the efficiency is lower than that of the forklift.(moving slowly).

Trailer and Chassis

The trailer is special for container transportation in the storage yard or on the public road for long distance transportation. The container is put on the chassis and then the trailer can trail the chassis . From the uses, trailers can be classified into two species:

(a) Yard trailers;
(b) Road trailers.

The yard trailer cab is small, only for one driver for short distance running , the power is smaller than that of the road trailer, and the speed is lower. The road trailer cab is large, with two seats special for long distance running; at the back of the cab there is a bed room , and one driver can sleep here. It is more powerful than the yard trailer, and the power may reach 300 H.P.

The chassis is a storage and transport means special for containers, whose length is 20 feet or 40 feet. At the front of the chassis there is a support for storing the container for a long time, during travel the support is shortened.

Toplifter and sidepicker

Toplifters are a version of forklifts, but with lifting performed by a hinged boom instead of a straight mast. In a way, toplifters are a combination a truck carne and a frontlifter. Usually, the toplift is equipped with a hanging spreader which can pick up and put down the container from the yard on to the chassis, so handling containers with toplifters is typical to low volume terminals.

The toplifter is specially for handling full containers, to deal with empty containers, we can use the side picker . In fact, the sidepicker is a regular forklift, the only difference lies in the attachment: the sidepicker attachment engages the machine only to two corner castings.

Container handling process

The system of container handling is a special system which is different from the general cargo or bulk cargo handling, because each container has a lot of cargo inside, and needs to be transported and delivered quickly, on the other hand, every full container is heavy, reaching up to 30 tons for a 40 feet long container, or 20 tons for a 20 feet long container. Therefore, how to process the container is a very important problem.

There are three system:

(a) Chassis system;
(b) Straddle carrier system;
(c) Transtainer system.

Chassis system--This system was first operated on Sea-Land liners in the world. All containers were put on the chassis, and at any time, the trailer can trail them it to the vessel or to the owner. This system is simple, its operation is easy, and the efficiency is high.

But the utilization rate of the yard is low and the container can only be stored in one layer and this is the defect.

Straddle carrier system--This system does not need a trailer to move the container. The straddle carrier can pick up the container and travel to the storage yard. This system was operated first by Matson Liner, the characteristics are ; high mobility, a long distance moving and handling(only inside terminal) high efficiency of operation and good utilization rate of yard.

But the straddle carrier is expensive and liable to damage, and the cost of maintenance is high.

Transtainer system-This system is better than the chassis and straddle carrier system. At present, the most ports have used this system; in China, several ports on the Changjiang have been equipped with the transtainer system. Usually, it can store 6 rows and 3 layers as well as a trailer road inside of the span. The yard use rate is high, the handling efficiency is high but the system can not transport the container.

Bulk cargo equipment

Bulk cargo handling methods and related equipment can be divided into two categories:

(a) Batch handling equipment;
(b) Continuous handling equipment.

Batch handling equipment are essentially general cargo equipment adaptable for bulk handling, such as grab cranes. Continuous handling equipment are based on specialized bulk handling machines and are geared to the more voluminous terminals , handling up to several million tons a year.

Continues handling equipment is usually a low cost system on a per-ton handled basis.

Other advantages of continuous bulk handling equipment are that the machines pose lower infrastructure requirements due to lower loads, and enable better environmental control due to easier containment options.

Grab cranes

As mentioned in the previous section on general cargo cranes, almost all these cranes can be fitted for handling bulk cargoes. The conversion to bulk cargo handling is quite simple: replacing the hook by a clam-shell or grab attachment and installing additional power(mechanical or electrical). The grab can be attached to any crane system but most commonly it is used with crawler and portal or gantry cranes. Usually, crawler cranes fitted with grabs are very versatile machines, they can both load and unload vessels, and can also load and unload trucks and trains. However, portal and gantry cranes are usually limited to vessel operation.

The productivity of a grab crane in handling bulk cargo is determined by the capacity(tonnage) of the shell, the path it has to cover and the speed of hoisting, swinging and opening/closing the grabs.

The size of the grab itself is a function of the density of the material it carries; smaller grabs are used with denser and heavier materials. Common inland ports. For example, many ports on China's Changjiang have been equipped with portal or gantry cranes fitted with grabs to unload the vessels. At present, it is the main method to unload the bulk cargo from vessels in China inland ports.

The use of the grab crane, though it is classified as a batch and not a continuous system, can be found in many continuous large-volume terminals. The crane is mostly of a gantry configuration, though sometimes the whirley boom is used as well (it is usually less expensive). A typical terminal layout includes one or two cranes, each feeding a hopper which, in turn, feeds a side belt conveyer leading to the storage pile or silo.

At the bulk terminal (iron ore terminal) of Nanjing port , the dock is equipped with two grab cranes, specially for unloading the iron ore vessel (25000 tonnage oceangoing vessel). The capacity of the crane is 16 tons, the volume of discharge is 500 tons/per hour each crane.

Screw unloader

The first screw unloader in the world was operated in 1975 in Holland. After that the development of screw unloader has been very rapid. Recently, in the world many countries have used the screw unloader at common or industrial terminals, only specially for unloading vessels. Depending on the material and the tonnage of vessel, the diameter of screw varies from 260 mm to 790 mm, and the capacity from 100 tons/per hour to 2000 tons/per hour.

At port terminals , the screw unloader discharges the cargoes from the vessel and its operation has the following characteristics. It can unload coal, grain, cement, fertilizer and allowance powder, granular, and lump no more than 300 mm.

High efficiency of operation, due to the screw unloader fitted a feed gear that the filled up ratio can be reached 70-90%.

Its pollution is less than any type ship unloader, because the screw rotates inside the vertical pipe, and the material is inhaled into the screw pipe, so there is no dust pollution.

The configuration of screw unloader is simple so it is light in weight and low in price.

The defect is that it needs more power and the damage caused by friction of the screw is rapid.

In China, the Yanyeng Electrical Power Station terminal, located at the Dongting lake is equipped with the screw unloader.

Chain bucket unloader

In China, this type chain bucket ship unloader is specially designed for barge to discharge cargo from cargo hold, but in the world, the inland terminals were first equipped with this chain bucket ship unloader on the Mississippi of the U.S.A. In 1987, totally 65 berths equipped with the chain bucket ship unloader were in operation on the Mississippi, unloading the coal barges, the unloading capacity being from 3000 tons/per hour to 4000 tons/per hour.

In China, the Wuhan University of Communication Science and Technology researched and designed the chain bucket ship unloader in 1979 , the first one was put into operation in 1984 on the inland terminal in Zuzhou city, and the capacity is 200 tons/per hour, the second one was out in operation in 1985, in Wuhan city, and the capacity is 500 tons/per hour.

The main section in the chain bucket ship unloader is the suspensory chain buckets, inside which is the belt conveyor. In operation, the chain bucket moves in the direction shown, the lower chain bucket excavates the material and carries it up around the top wheel and then dump the material onto the belt conveyor which carries the cargo to the land.

The characteristics of the chain bucket ship unloader are as follows:

(a) High efficiency, the average efficiency can reach 0.7-0.75, higher than that of the grab crane, which is below 0.5;
(b) The energy consumption is lower than that of the grab crane. If the capacity is the same, the energy consumption of the chain bucket ship unloader is only half of that of the grab crane;
(c) Its weight is light, 20% less than that of the grab crane;
(d) The cleaning of barge hold is good. When the ship unloading is finished, the cargo remainder is only 1%;
(e) The dust control is easier than for the grab crane, because the unloading is continuous and it is easy to cover the chain bucket and belt conveyer.

As mentioned above, the chain bucket ship unloader is a better machine for continuous unloading in inland ports.

Belt conveyer

The belt conveyer is probably the most common piece of equipment in material handling. The main advantage of the conveyer is that it usually offers the lowest cost alternative for horizontal movement of cargo. This is an important property in inland areas. For example, at many China's coal inland terminals, the storage yard is located behind the levee, far away from the berth. When combined with the stockpile conveyer, the overall length of conveyer at such a terminal can reach several km. The length of conveyer at the coal terminal in Nanjing port is more than 4 km. The main disadvantage of conveyer stems from the fact that it provides only a point-to-point connection and requires fixed support structures, unlike dump trucks and loader, which can move anywhere.

The belt conveyer consists of a belt and idlers, or rollers, which support the belt. The idlers and the belt are usually arranged either "flat" or "troughed", depending on the properties of the material to be conveyed. Flat belts fit materials which have a steep repose angle(e.g. damp sand) while troughed belts fit lumpy materials(e.g. coal ,ore). In addition to the belt and idlers, each conveyer has a support structure, a feeder and discharge device(for loading and unloading), and a tension-maintaining arrangement.

The capacity of the conveyer is the function of the belt width, speed and of course, the specific weight of the conveyed material. The speed is mainly determined by the size of the particles. The speed is adjusted to avoid dust in powdery material and spillage in bulky material. Energy consumption, a function of both density and speed, is another consideration. For example, the typical speed of a grain belt is about 2 meters/per second, while a coal belt, 3.5 meters/per second.

In Nanjing port, the capacity of the belt conveyer at the coal terminal is 2500 tons/ per hour, the speed is 3.5 meters/per second, and the belt width is 1.4 meters.

It is important to note that the conveyer is only a means to move materials between machines. Therefore, the conveyer capacity is not only a function of its speed but also a function of the end-point capacities where the material is fed onto/ from the belt.

Vessel loaders

In the typical layout of inland waterway bulk terminals the vessel is lower than the storage yard. Therefore, the loading of vessels is done almost exclusively by gravity, usually by using chutes or inclines. As already mentioned, at the low-volume, simplest bulk terminals , the trucks can dump their cargo directly into the vessel hold. At the continuous , high volume terminals , the loader is fed by a conveyer either from storage (bins or piles), or directly from truck/traincar dumper. The capacity of gravity-based loader, as described above, is dictated not by the loader itself(which has almost unlimited capacity) , but by the forementioned feeding belts.

Fixed ship loader-- At inland terminals, this fix ship loader is fixed on a pillar column dock, itself can not move but the boom can be rotated around left right and luffed, the belt conveyer inside the boom, depending on the loading position can be extended or shortened. This type of ship loader is simple in configuration , low in cost and reliable in performance, so many small or middle inland ports like to use this kind of ship loader.

Except on the pillar column dock, it is also fixed on a pontoon(floating dock). This model is the simplest, the cost is lowest, and it is suitable for terminals whose throughout is under 3 million tons.

Moving ship loader--unlike the fixed ship loader, this ship loader can be moved along the dock to load the cargo to the ship hold. In operation , the vessel does not need to move; the ship loader can move so the operation is better than that of the fixed ship loader.

The moving ship loader is mounted on a travel gantry ,and the conveyer is connected. The section above the gantry is the same as for the fixed ship loader, the boom can be rotated around the left and right as well as extended and shortened, in addition, the gantry can move . The efficiency is higher than that of the fixed ship loader.

In China , Harbin port and Jiamusi port have been equipped with this kind of ship loader, whose capacity is 500 tons/ per hour for coal.

Arc line ship loader-- This kind of ship loader can not move along the dock, but the boom can move by means of a bogie which moves on an arc track mounted on the dock. The stern of the ship loader is fixed on a rotary center, when the bogies is moved on the arc track, the stern of the ship loader is rotated around the center and then the boom moves around the left and right. The conveyer is inside the boom, conveying the cargo to the vessel.

The configuration of the arc line ship loader is simple and its itself-weigh is light, the cost is more than that of the fixed ship loader but lower than that of the straight line ship loader. In China , many ports on the Changjiang have been equipped with this kind of ship loader.

Straight line ship loader-- The straight line ship loader is different from the arc line ship loader:

(a) The arc line ship loader used an arc line track, while the straight line ship loader uses a straight line track;
(b) The arc line ship loader is on a bogie (one track), while the straight line ship loader is on a gantry(two tracks).

The common point is that the stern of loader is on a rotary center and the conveyer inside the boom. The track of the straight line ship loader is the same as the track of the moving ship loader, but the stern is different.

This type of shiploader is better than other types .In loading the vessel the loading point is easy to reach the vessel hold, and the coverage area is large, specially suitable for high volume terminals. The coal terminal of Nanjing port was equipped with the straight line ship loader in 1985, it was the first in China, whose capacity is 2500 tons/per hour.

Boom stacker and reclaimer

At continuous bulk terminals, the loading onto the storage piles is done by stackers and the discharge by reclaimers. Stackers are simply an inclined conveyer on a crane boom, and the crane structure is supported by a rail-mounted gantry. Usually the stacker travels along the rail track covering a large stocking area. A large stacker can stack piles of 10-15 meters high and 35-50 meters wider, about 100,000 tons of coal on each side. Because the stacker has such a large capacity, most inland terminals , only need one stacker.

The reclaimer is a large bucket wheel, mounted on the end of the boom carried (like the stacker) on a track-mounted gantry. The wheel digs into the stockpile and throws the cargo onto a conveyer. Usually, both the stacker and the reclaimer use the same trackage, gantry basis, and main conveyer (in reverse direction). The common usage is a very cost effective arrangement, at the expense of limited flexibility of usage, one machine can either stack or reclaim. This is a combined boom stacker and reclaimer.

A stacker or reclaimer or combined stacker and reclaimer must be connected with a main conveyer. The cargo will be conveyed from the stockpile or traincar by the main conveyer, and then to stockpile or the vessel. The main conveyer is connected with the boom conveyer which is mounted on the gantry. However, a stacker or a reclaimer only does a single operation, either stocking or reclaiming.

But the combined stacker and reclaimer can do two operations(not at the same time) stocking or reclaiming. The key factor of this machine is the boom conveyer running direction: forward direction for stocking or reverse direction for reclaiming.

In China's inland ports, most terminals use this type of machine for bulk cargo transfer. The coal terminal and the iron ore terminal of Nanjing port have been equipped with the boom stacker and reclaimer.

Gantry stacker and reclaimer

The gantry stacker and reclaimer and boom stacker and reclaimer are handling and transfer machines in the inland ports, their characteristics and operations are the same , but the configuration is different. We can say that the gantry type is more efficient and economical than the boom type;

First, the weight of the machine is lighter than the boom type. It is one fifth to one fourth lighter (at the same capacity), because no balance weights needed.

Second , the configuration is rational. There is no need for the balance weight to increase its stability, the conveyer beam can go up or down to charge or discharge the cargo and two bucket wheels are mounted on it.

Third, the reclaiming area is large, the stockpile can be discharged by one machine.

The gantry stacker and reclaimer is composed of the main gantry and conveyer beam, two legs mounted at the two ends of the top beam, under which is the bogies on the track , and two gears of the bucket wheel mounted on the conveyer beam, it is powered by electricity. The two bucket wheels can move along the conveyer beam to discharge the bulk cargo from the stockpile.

The coal terminal of Nanjing port was equipped with a gantry stacker and reclaimer ten years ago. Its span is 50 meters, its capacity is 2500 tons/per hour, the belt of conveyer is 1.4 meter wide and the speed is 3.15 meter/per second.

Railcar loader and unloader

All the above mentioned are ship equipment. This section will discuss the railcar equipment, because at the bulk terminal two kinds of transfer are operated either from railcar to vessel or from vessel to railcar.

At the continuous high volume bulk terminal, the majority of cargo on the land side is brought in or sent out by rail. Indeed, the rail loading/unloading equipment and support system constitute between one fourth and one third of the entire terminal investment. The common way of loading railcars (or trucks) is through an elevated hopper and a gravity chute. Loading of the hopper from the piles is done by elevators and/or inclined conveyers.

Unloading of railcars can be done either through the bottom (bottom drop cars or side open cars) or through the top, by turning them around using a rotary dumper(open gondolas with rotary rings).

Both systems allow for continuous discharge and high productivity ranging from 1000 tons/ per hour to 2000 tons/ per hour.

Railcar screw unloader--This machine is only for rail gondolas (both side doors are open). In developing countries most rail cars are made of timber (except for the chassis), sometimes, unload these cars are unloaded by manpower. In China's inland ports, in 1960's many coal terminals were equipped with the railcar screw unloader for discharging the coal from gondolas.

This machine is very simple. A screw is mounted on a vertical beam which can go up or down, depending on the operation of discharge. When the screw is rotated and inserted into the coal, the coal will drop down to the hopper and then onto the conveyer. Usually, it takes 6 minutes to unload a railcar(50 tons) .

The screw unloader is cheap, it is easy to use and maintain, and it is suitable to bulk terminals whose annual throughput is 1-3 million tons.

Railcar rotary dumper--This unloader discharges the gondola by turning the car from 0 degree to 180 degrees, and the cargo drops down through the hopper onto the conveyer. The capacity of the rotary dumper is high, and it can unload 60 cars per hour. It suites the high volume bulk terminal. If one railcar can be loaded with 50 tons of cargo, the productivity of a rotary dumper will reach 3000 tons per hour. It is very high for an inland port. In fact, this high productivity does not depend on the rotary dumper, but depends on the "car-feeding system", that is to say, the high productivity of that rotary dumper depends on a good "car-feeding system".

Bulk cargo handling process

General

The bulk cargo handling process at bulk terminals involves two systems, one is land-to-water, another is water-to-land. The land-to-water system is for the unloading of the railcars (or trucks) to storage or direct shipment, and this system is the case at most China's inland terminals. The water-to-land system is unloading the vessel to storage and then loading the trucks or railcars.

The large volume handled by bulk terminals justifies the so-called "whole system design" or "general arrangement" , i.e. , designing the entire terminal as if it were one large, continuous machine. The underlying concept is to insure efficient flow of cargo and to optimize investment by adjusting the capacity of the various terminal machines. In fact, at many terminals, the handling machines are already physically connected together through a network of conveyers . The apparent need to balance the various terminal components, however, is not evident at some bulk terminals where bottlenecks of capacity can be mainly identified on the land side operation, mainly in rail handling .

The components of the bulk cargo terminal can be divided into three groups:

(a) Railcar-unloading system;
(b) Storage system;

(c) Shipment system.

However, the low volume or large volume throughput terminal will also involve the three systems, the difference are the machines. The following presents several bulk cargo handling terminals in Nanjing port.

Coal terminal

This is a land-to-water terminal. The coal was transported by railcars which stop at the entrance of the rotary dumper. The dumper discharges the coal for either storage or shipment. This terminal involves railcar-unloading system, storage system and shipment system.

The shipment system involves two berths , berth No. 37 and berth No.35. Berth No.37 is constructed of reinforced concrete pile structure and two fixed shiploaders are mounted on the open piled structure. The belt conveyer is mounted on the boom of the shiploader, the width of the belt is 1.2 meters, the speed is 3.15 meter/per second, and the capacity is 1200 tons/per hour. The transport conveyer is connected with the shiploader, and the other end connected with the loading conveyer inside the under ground tunnel. The coal stockpile is on the tunnel, and two stackers travel along the tunnel. Over the tunnel is a V-type hopper, and the coal is stored inside the bigger hopper which is constructed of concrete. A transport conveyer is connected with the stacker and the other end connected with the railcar unloading system.

The railcar unloading system involves two rotary dampers and two railcar pusher systems. The pusher can push the railcar up an 11% slope into the dumper. The working cycle of the pusher (from first railcar to second railcar) is 3 minutes. Under each dumper is a big hopper, to which a conveyer is connected. When the railcar reaches the dumper, it turns 180 degrees, and the coal drops down into the hopper, and through the conveyer it goes either to the storage or for direct shipment.

Another stockpile is equipped with two stacker and reclaimers. The coal is stored on the ground. In this case, the boom conveyer runs ahead; in case of shipment, the bucket wheels of the reclaimer will run and the boom conveyer runs reversibly, the bucket excavates into the coal stockpile and through the boom conveyer the coal goes for shipment.

The handling process of berth No.35 is the same as that of berth No.37, but the handling machines are different. On the dock is a straight line shiploader, and two tracks on the platform. The belt width of the conveyer is 1.4 meters, and the capacity is 2500 tons coal per hour. The boom can be luffed , extended or shortened. When the shiploader is in operation, the range of loading points is wide than that of the No.37 berth shiploader.

The storage yard of number 35 berth is different from that of the No. 37 berth. It is equipped with a gantry stacker and reclaimer, and the coal is stored on the ground by the conveyer beam. There is no tunnel, therefore, no worker works in the tunnel. That it improves the working environment, and reduces dust pollution. The span of the gantry stacker and reclaimer is 50 meters, and the stockpile can be 10 meters high . There are two conveyers connected with the gantry stacker and reclaimer , one is the store conveyer, connected with the dumper (railcar-unloading system) , one is the out-of-store conveyer, connected with the shiploader. The coal in railcars is dumped through the dumper into the hopper and then, through the conveyer goes either to storage or shipment.

This railcar-unloading system is different from the number 37 berth railcar unloading system. Here the railcars move on a horizontal rail. The pusher is different , here the pusher pushes 20 railcars.

The efficiency of No. 35 berth is higher than that of the No. 37 berth.

Iron ore terminal

The main function of the iron ore terminal is water-to-land transfer. The iron ore comes from Australia and Brazil by 25000 tonnage ocean-going vessels, and it is either transferred to the barge or stored on the yard. The dock is constructed of open piled reinforced concrete structure. On the platform, there are equipped two portal cranes with hopper, only for unloading ocean-going vessels. This is the unloading berth; near it is a loading berth for loading barges. Two shiploaders were equipped on the platform and the two portal cranes and two shiploaders can travel along the dock. The storage yard was equipped with a boom stacker and reclaimer. A conveyer system is connected with the unloading system and storage system. In fact this system is a water-to -land (only for storage), or land-to-water, or water-to-water (ocean-going vessel to barge) terminal.

The machines are two portal cranes (with hopper fixed on the crane), two shiploaders (only for barge), one boom stacker and reclaimer and several hundred meters belt conveyers. The width of belt is 1.2 meters, speed is 2.5 meters/ per second, the capacity is 1000 tons/per hour and the annual throughput can reach five million tons.

Sand terminal

As mentioned above, the function of the sand terminal is only water-to-land transfer. The general arrangement of this terminal is very simple, because the function is unloading barges and then storing , and loading the trucks from the stockpile by bucketlift.

Two grab cranes are fixed on the platform of the dock that is an open piled reinforced concrete structure. The two grab cranes feed a conveyer at the same time. A boom stacker stores the sand on the stockpile . The annual throughput can reach one million tons.

2.4 Environmental protection

At present, environmental protection is a very important issue. Because of the dust pollution at coal terminals, the handling and storage of coal at bulk terminals is also a major concern to port authorities. Air pollution here depends mainly on the dust-making properties of the material and the method of handling employed. It is important to choose the method of handling and storage suitable to the material, and to prevent dust explosions.

The handling of coal is environmentally problematic in many cases; handling creates dust (especially gravity loading), the equipment is noisy and the dust of coal is inflammable.

The reduction of environmental hazards at coal terminals can be achieved by:
Minimizing the depth of drop--Dropping the coal as close as possible to its final surface of rest can both reduce dust and noise; in the loading of vessels the boom can be lowered and the chutes extended. Likewise, in certain cases, the vertical drop can be altogether eliminated by using slides or inclines.

Enclosing the handling system--it is easy to enclose the parts of handling machines used for moving cargoes or the drop point where dust explosion may take place, such as the conveyer, connecting points, railcar dumper-hopper connecting point, and etc.

Wetting the material--This is an efficacious method to reduce dust pollution. Showers can be installed at all the connecting points of conveyer, and all drop points, and the material on stockpile or railcar can be wetted for unloading to avoid dust explosions.

Wind shelter board--In the port area, special stockpiles can be surrounded with shelter green belts (trees 30-50 meters wide) , and this can suppress dust flying.