general\sfart2 Conference on Transportation Management, Sate University of NY, Maritime College, May 1995

STOCK AND FLOW METHODOLOGY FOR CALCULATING CAPACITY OF CARGO TRANSFER TERMINALS

A. Ashar and G. Ayzanoa

I. GENERAL

The recent Intermodal Surface Transportation Efficiency Act of 1991 urges states to launch comprehensive planing efforts, focusing on integration of all modes of transportation. A comparison between the capacity of existing transportation infrastructure and future needs is the centerpiece of this planning effort. Cargo terminals, where the intermodal transfer takes place, are widely considered as the most critical component of the transportation infrastructure. This paper discusses the capacity of cargo transfer terminals at the level required by state or regional planners.

The paper begins with a brief review of commonly used capacity calculation methodologies. It proceeds with a description of a proposed methodology, based on a stock & flow (**S & F**) approach. Then it provides an illustration taken from the recent Louisiana's Statewide Intermodal Plan (1995), where the methodology was applied to about 50 marine and rail terminals, handling a wide array of cargos. The paper concludes with a timely observation on terminals' capacity during a sudden surge in demand.

II. CURRENT CAPACITY CALCULATION METHODOLOGIES

Module-Based Methodologies

Terminal capacity has been a recurrent subject in professional port literature in the U.S. and worldwide. A major research effort in this area was conducted by the U.S. Department of Transportation, Maritime Administration (MARAD).[1] MARAD's methodology is based on defining 9 terminal "modules", based on the type of cargo and annual throughput. Each module has a prescribed set of facilities which yield a respective range of capacities.

There is nothing wrong with MARAD's system except that it is too broad for state-level planning purposes. Each state has its peculiar set of terminals (or modules) that cannot be fitted into MARAD's standard modules. For example, MARAD's coal module, defined as "dry-bulk, open-storage, high-density" terminal, has a typical throughput of 1 million tons/year. This is well below the throughput of Louisiana's high-density coal terminals with annual capacity ranging from 8 to 21 million tons. Another problem with MARAD's modules is that they do not relate to terminals which transfer cargo between barges and ships, a prime operating practice of Louisiana terminals. Finally, the determination of the

---

[1] See: (1) U.S. Maritime Administration, Port Handbook for Estimating Marine Terminal Cargo Handling capability, 1979 and the updated version in 1986, by Moffat & Nichol Eng.

capacity in MARAD's methodology is based on *actual* (average) figures as reported by a small sample of U.S. ports. MARAD does not provide guidance on *potential* capacity which is key to the planning process. The methodology suggested by UNCTAD is similar in essence to MARAD's except that it is even more general.[2]

Simulation Based Methodologies

While a MARAD-like, module-based system seems too rough for state-level planning purposes, an alternative methodology, based on operational simulation, seems too detailed for this purpose. The problems with a simulation of terminal operations are: (a) the input required for a meaningful simulation is massive and may include on-site Time & Motion studies; and (b) the need to hire programming professionals (consultants) to develop and update it. Simulation is geared to dealing with stochastic phenomena where simple algebraic manipulation becomes intractable. Simulation may be useful to analyze capacity of specific terminal components such as berthage handling random ship arrival, or crane serving yard tractors with random cycle time. Developing an operational simulation for a large number of terminals handling a wide variety of cargos, as is the case in state-level planning, is way beyond the needs of the planners (and also beyond their budget).

Intermediate-Level Methodology

The proposed S & F methodology is an intermediate level system. It is more detailed than MARAD's modules and can be adjusted to cope with the specific population of terminals in a given state. But, it is much less demanding than a simulation in terms of data collection and computation. A S & F capacity model be developed and maintained by the regular staff of a state's planning department. Most importantly, perhaps, is the fact that despite the rudimentary nature of the proposed methodology, it can still provide a clear insight with regard to deficiencies and required improvements. This insight will be demonstrated in the conclusion of the case study presented later on.

III. THE STOCK & FLOW METHODOLOGY

A Network of Stock & Flow Components

The proposed Stock & Flow (S & F) methodology decomposes a cargo transfer terminal into two types of components:

- **Flow Processing Components** -- the facilities that transfer cargos from/to vessels, barges, trains and trucks (loading/unloading); or as

---

[2] See: UNCTAD, Port Development, New York, 1978, TD/B/C.4/175. Other relevant publications on Port Capacity: (a) Brum, Per, Port Engineering, Volume 2, 1990, pp. 9 - 21; and (b) Frankel, Ernest, Port Planning and Development, Chapter 6.2, 1987, pp. 344 - 362; (C) Ashar, Asaf, "Capacity Modeling for Container Terminals, WWS/World Ports, January 1986.

• **Stock Holding Components** -- the facilities that store the cargo in-between flows (storage).

A terminal component includes both the facilities and the operations that take place by them. The capacity of the flow-processing facilities is defined as *dynamic capacity* and is a function of their *productivity*; the capacity of the stock-holding facilities is defined as *static capacity* and is a function of their *utilization.*[3]

The simplest terminal is called *direct transfer* terminal and involves only one component, a flow processing one. This is the case, for example, with a marine terminal where the cargo is moved directly from ship to barge, or a in rail terminal where the cargo is moved directly from rail to truck. In both cases, the terminal does not include intermediate stock (buffer). Most terminals include at least one stock and mainly perform indirect transfer. Direct transfer between ship and barge, as will be seen later, is an important feature of Louisiana terminals.

The methodology has three steps: (a) the terminal is "converted" into a network of S & F components; (b) the capacity of each component is calculated using algebraic formulation; and (c) the capacity of the most limiting components is identified and determined as the capacity of the entire terminal (the "weak link").[4]

Stock & Flow Diagram

Constructing a S & F diagram is a valuable pre-requisite to the S & F analysis. The diagram is, in essence, a schematic layout of the terminal, using symbols to identify the S & F nature of the various components and, especially, unravels their inter-relations. The diagram uses circles to depict flow components; rectangles for stock components; and diamonds for flow splitting (intersections). For simplification, the diagram only includes the major terminal components. This mandates consolidation of components either through horizontal integration of parallel components (e.g. 2 shore cranes are represented as "crane" component), or through vertical integration of serial and tightly connected components (e.g. the cranes, berth and dock alongside are represented as "berth").

While constructing the diagram, the planner should make sure that no processing

---

[3] The S & F approach was originally developed by MIT's Jay Forrester (1961) under the name Industrial Dynamics that later on became known as System Dynamics. The application of S & F for calculating terminal capacity is described in: (a) Ashar, Asaf, "Productivity, Capacity and Equity in the Port of San Juan," WWS/Worldwide Shipping, May 1991, pp. 46 - 52; and (b) Ashar, Asaf, "On-Off Terminal Ship-to-Rail Transfer," Ports '92, American Society of Civil Engineers / PIANC, 1992, pp. 108 - 120.

[4] The actual calculation involves a *deterministic simulation* driven by a set of *difference equations*(not be confused with stochastic, Monte Carlo simulation). The deterministic simulation explores, through a series of sensitivity tests, the constraining dynamic or static components and calculates their so-called *critical capacities*.

components are linked serially (redundancy). Also it is desirable to separate different storage functions in case of a jointly-used facility (e.g. a container yard that store both loaded and empty containers).

Capacity of Flow Processing Components

The formula for calculating the dynamic capacity of the processing components is the product of two basic elements:

- **Effective Transfer Rate**

- **Effective Time**

The effective transfer rate is usually expressed in tons/day and relates to the gross productivity during work time. The effective rate is calculated by taking the *nominal* rate as given by the manufacturer (tons/hour) and modifying (reducing) it to reflect discontinuities and interruptions *during* work. For example, in calculating the capacity of vessel loading in a coal terminal, the nominal loading rate is reduced to account for preparations before and after loading (open the hatches, positioning of equipment) and interruptions during the loading (blending, end of piles, vessel trimming, vessel survey, hatch shifting, operator change, equipment breakdowns). Effective rates are usually 60 - 70% of the nominal rates.

The effective time, usually measured in days/year, relates to number of days that the terminal component is expected to work at the effective rate. For example, in the case of vessel unloading (berth), the calculation is based on defining typical *vessel cycle time* which usually includes 3 components:

- **Working Time** -- the time that the vessel is at berth and working (actually unloading cargo);

- **Preparations** -- the time that the vessel is at berth but not working because of non-cargo activities, mainly before/after working time. Typical preparations include berthing/unberthing, customs, immigration, open/close hatches, inspection, equipment staging/removal, etc.

- **Inter-Vessel Time** -- the time when there is no vessel at berth or the berth is idle. This time stems from the irregularity in ship arrival due to unexpected delays.

The effective time is calculated by taking the total available time (e.g. 365 days per year) and subtracting from it the preparations and inter-vessel times. *Berth utilization* is defined here as the ratio between work time and cycle time.

Estimation of the inter-vessel time is the key for the calculation of effective time and with it, the capacity of the entire component. As the Queuing Theory advocates, the allowance for inter-vessel time mainly depends on the relative values ($/hour) placed on ship and berth times. More practical considerations relate to the type of service (liner or tramp), location of terminal vis-a-vis access channel and anchorage and, especially, length of working time. For example, in the case of coal terminal, the inter-vessel time was assumed as half of the effective time, but no less than half a day.

Figure 1 presents the formulas and factors used for capacity calculations of stock & flow components.

Figure 2 presents a schematic illustration of vessel cycle and its elements.

Capacity of Stock Holding Components

The formula for calculating the capacity of the stock holding components is the product of two basic elements:

- **Effective Static Capacity**
- **Effective Turnover Rate**

The effective static capacity is usually expressed in tons (or TEUs) and relates to the physical capability of the component to store (hold) cargo. The effective capacity is calculated by taking the *nominal* capacity and modifying (reducing) it to account for reserves (empty storage space) required for efficient operations. The reduction is usually on the order of 10 - 20%.

The effective turnover rate is the inverse of the effective *stock (dwell) time*. Effective dwell time is calculated by taking the *average* dwell time and multiplying (inflating) it by a *peak factor* to account for fluctuations in cargo flows and temporary on-terminal accumulations. Average dwell time varies between cargos and trades, ranging between 2 days for containers and 30 days for coal. Peak factor values usually range between 1.1 and 1.5.

Weak Link

The S & F methodology, like many other network systems, identifies the most restrictive terminal component and stipulate its capacity as the capacity of the entire terminal. The unstated assumption in this weak link approach is that each of the terminal components is independent, so that its capacity does not infringe on the capacity of the other components. However, sometimes two or more components may share the same facilities and their capacity is inter-dependent. For example, in coal terminal, ship loading and barge unloading use the same yard equipment whereby the same stackers, reclaimers and conveyors are used to load vessels and unload barges. In this case, the calculation is more complex and is based on *prioritization* (e.g. vessel is more important than barge).

Figure 1. Port Capacity in Stock & Flow Framework

Dynamic Capacity of Flow Component (Tons/Year) =

Effective Transfer Rate (Tons/Day) X Effective Working Time (Days/Year)

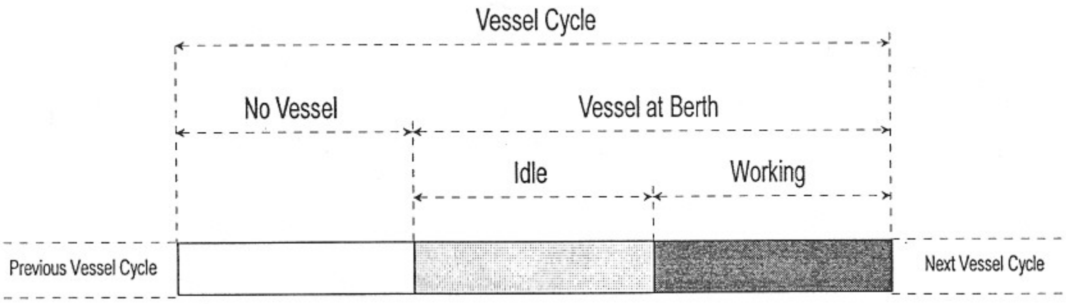
Affecting Factors:
[Preparations & Interruptions] *[Interval between Vessels]*

Dynamic Capacity of Stock Component (Tons/Year) =

Effective Static Capacity (Tons) X Effective Turnovers (1/Year)

Affecting Factors: *[Operational Flexibility]* *[Peaking]*

Figure 2. Vessel Cycle Analysis



Inter-Vessel Time:

- Delays in arrival
- Cargo unavailable
- Planned maintenance
- Bad weather

Preparations:

- Tie In/Out
- Open/Close Hatches
- Inspect Vessel
- Setup/Remove Equipment

Interruptions:

- Start-up & Finish
- Blending & Cleaning
- Shift Loaders
- Trimming
- Change Operators
- Meals
- Breakdows

IV. The Capacity of Louisiana's General Cargo Terminals

Louisiana's Cargo Terminals

A comprehensive capacity assessment of the Louisiana's cargo terminals, including all deep-draft ports and intermodal (rail) terminals, was an essential input to Louisiana Statewide Intermodal Plan. The terminals were categorized by commodity and operational form (type) of cargo. The capacity analysis was based on the S & F methodology and encompassed 50 terminals. The terminals were divided into 5 generic groups:

- Coals terminals -- handling bulk coal;
- Grain terminals -- handling bulk grain;
- General Cargo terminals -- handling neo-bulk, breakbulk and some containers;
- Container terminals -- handling containers and trailers; and
- Intermodal yards -- handling containers and trailers between trains and trucks.

This paper only presents one group of terminal, the general cargo terminal.[5] This terminal was selected to illustrate the methodology because of its complexity. In Louisiana, the terminal is involved both in transfer between ship and barges (direct transfer) and ship and shore (indirect transfer). Also, the terminal handles heterogeneous cargo with a wide range of productivity and storage densities.

Cargo Composition

The breakbulk terminals of Louisiana handle 4 types of cargos: steel, forest products, bagged cargos and mixed cargos. The terminals also handle small quantities of containers, usually carried on multi-purpose ships. The containers, however, are not discussed here.

Steel mainly includes imports of slabs, plates, pipes and coils. Forest products include exports of woodpulp and linerboard, in bales, and import of plywood, on pallets. Bagged cargo mainly includes export of flour and rice, brought in by rail and truck. Mixed cargo mainly relates to Ro/Ro (roll on/roll off) services that bring in and take out various types of cargos. Other cargos, not detailed above, have similar handling systems (and capacity) to one of the above cargo categories. For example, handling of import baled rubber resembles that of forest product; handling import coffee bags resembles that of rice bags.

---

[5] This terminal is sometimes called "breakbulk" terminal. This term is erroneous since the terminal mainly handles neobulk and containers. There is almost no breakbulk cargo left in the U.S.

Fixed and Floating Terminals
Louisiana's general cargo terminals are scattered in 4 ports, New Orleans, Baton Rouge, Lake Charles and South Louisiana. The terminals are of two types, fixed (land-based) terminals and floating terminals. Altogether there are about 20 separate terminals, with each can handle any one of the cargos listed above.

FIXED, LAND-BASED TERMINALS
Stock & Flow Approach
The terminal main components include the berth, open and covered storage (shed and yard), and the loading ramps for truck and rail. The general cargo terminal handles cargo in two directions, inbound and outbound. The main cargo handling equipment is cranes, for vessels, and forklift trucks for trucks and rail.

Direct & Indirect Transfer
A unique feature of some of the general cargo terminals is the ability to work simultaneously direct and indirect transfer. In this mixed operation, common in steel import, some of the cargo is handled to the land-based terminal, and some overboard to a barge, using floating cranes. The same floating cranes are also used in floating terminals.

Ship Loading/Unloading
Effective Transfer Rate
The effective transfer rate varies according to size (weight) of the lifted unit and the difficulties in attaching/disattaching it to the crane. Steel, the heaviest cargo, has an average transfer rate of 375 tons/hour; loose bags, the smallest cargo unit and most labor intensive, averages 50 tons/hour. The number of gangs per ship varies, averaging 2 in steel (landside) and 4 in bags. General cargo is usually worked only during day light, with the shifts frequently extended to 10 and 12 hours. Sometimes, 2 shifts are used, but rarely 3 shifts (24 hours). This is mainly the result of labor agreement regarding overtime, lack of fresh gangs and insufficient lighting. The capacity calculation here assumes no change in the number of hours worked per day. Under these assumptions, the daily transfer rate per berth varies from 1,900 tons/day for bags to 7,200 tons/day for steel. Accordingly, handling of a 25,000-ton bag ship takes 13 days while handling of a 30,000-ton steel vessel 4.2 days.

Figure 3 presents a layout of a typical general cargo terminal in Louisiana.

Figure 4 presents a respective stock & flow diagram of the general cargo terminal above. The symbols in dotted lines denote non-restricting components.

Inter-Vessel Times
Most of the general cargo is served by *semi-liner* services. Semi-liner services follow the same

Figure 3. Conceptual Layout of General Cargo Terminal

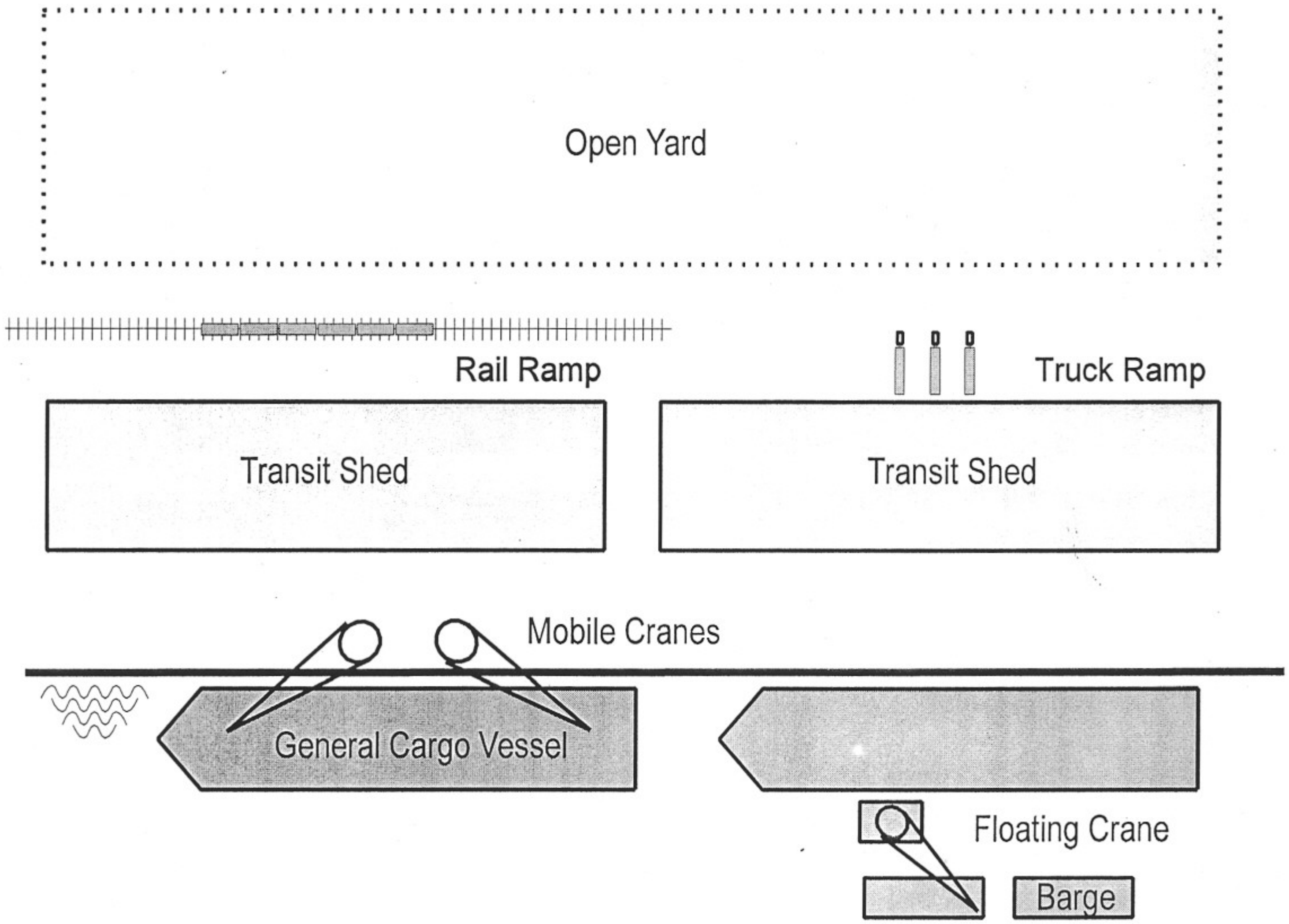
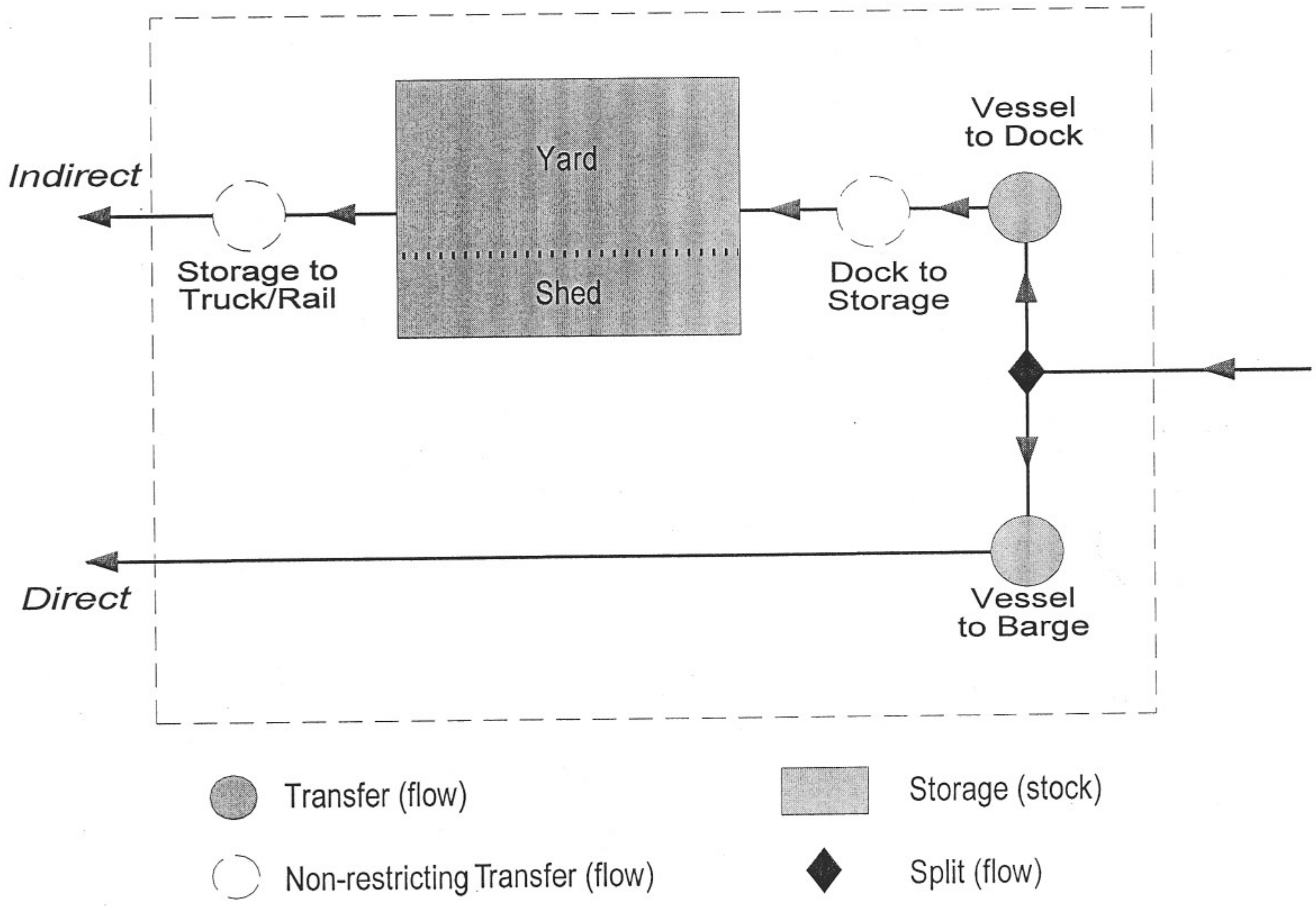


Figure 4. S&F Diagram for General Cargo Terminal



itineraries with some variations based on cargo availability.[6] Typical service frequencies vary from 10 days to a month. Steel and bags are usually served by *tramp* shipping, similar to bulk cargos. However, ship arrival of tramp ships is planned with quite a tight "window", and their handling is conducted according to an agreed-upon schedule. Still, ship arrival is distinguished by irregularity and inter-vessel times are relatively long. The assumption on inter-arrival time here is 0.5 of working time but no less than a day. The resulting times are 6.7 days for bags, but only 1.7 day for steel.[7] This means, for example, that a steel berth working at full capacity, can handle a 30,000-ton vessel every 5.9 days (4.2 + 1.7).

Ship Handling Capacity
A steel berth has the largest capacity, at about 1.7 million tons/year while a bagged cargo berth has the smallest capacity, at less than 0.5 million tons/year. These capacity figures are highly dependent on the number of cranes serving the vessel and hours worked per day. For example, if steel unloading is performed by 4 cranes (2 fixed and 2 floating), and the gangs work continuously, the capacity of a steel berth can reach 4.4 million tons.

Figure 5 presents a range of handling rates for typical general cargos and resulting capacities per berth.

Storage

Effective Holding Capacity
There are two types of storage in a general terminal, a covered storage in a shed, and an open storage in a yard. As was the case with vessel handling, each cargo category has its own specific weight, packaging unit and stacking height, resulting in a different storage density (tons/sq ft). Since the terminal can store several categories of cargos, the nominal capacity has to be reduced to account for internal circulation and separation between different batches of cargos. Steel has the largest static storage capacity of about 0.3 tons/sq ft and mixed cargo the smallest, at about 0.1 tons/sq ft. It is estimated that about 50% of the steel, 20% of the forest product and 20% of the mixed cargo but none of the bagged cargo can be stored outside.

Turnovers per Year
A common practice in general cargo terminals is to allow 30 days free time. Usually, most cargos take full advantage of this period but not exceed it. Interviews with operators suggest that the required dwell time averages about 15 days. Peak factor is estimated at 1.3.

Storage Capacity
The dynamic storage capacity is calculated per storage unit of 1,000 sq ft of shed or open area. The results vary according to the cargo categories, from 923 tons/year for mixed cargo to 2,769 for steel. The storage capacity relates to indirect transfer. To convert these figures into

[6] This is in contrast to a full liner service that calls always the same port at exact, pre-determined dates.

[7] The unstated assumption here is that the bagged cargo needs a long accumulation period.

equivalent terminal capacity, a percentage has to be added to reflect the direct transfer that usually takes place in *parallel* to the indirect transfer (see S & F diagram). Based on interviews with terminal operators, it is assumed that about half of the steel is going directly to barges (while the vessels are at berth).

Truck and Rail Handling

This component was found to have much larger capacity than the rest of the components. Therefore, no capacity calculations are included for landside handling of truck and rail. Landside handling was found critical only for receiving export of bagged cargos. However, the capacity restrictions there were not due to inadequate facilities, but due to insufficient switching and availability of labor to man second shifts.

Figure 6 presents storage densities for a range of typical general cargos and the resulting (dynamic) capacities per storage area.

Total Terminal Capacity

For illustration, only the capacity calculation of one terminal, Nashville Ave. in New Orleans is included here. The terminal berthage, which can accommodate 6 ships, has an annual capacity of about 10.6 million ton, including direct transfer. The shed and yard, with a total of 1.2 million sq ft, have capacity of only 5.2 million tons/year (when adjusted for the direct transfer which does not require storage). The berth capacity is thus more than twice larger than that of the storage. There is a clear imbalance between the capacity of the flow and stock components in this terminal, as well as in most of the State's terminals. This indicates a consistent problem in terminal planning which may be attributed to misunderstanding the S & F nature of the terminal.

Figure 7 presents the terminal capacity calculations. Note that the calculation is based on berthage and storage capacity calculations presented in previous figures.

FLOATING TERMINALS

Ship Loading/Unloading

Effective Transfer Rate

The facilities involved in direct transfer of general cargo are based on a barge-mounted crane and a set of buoys to restrain ship motions. Direct transfer of general cargo is common in Louisiana only for steel though it can also be conducted for forest products and bags. Typically, the ship is served with the average of 2 cranes but can be served by up to 4 cranes. Nominal transfer rates are similar to that of shore-based facilities since both use the same cranes. However, because of difficulties in moving the floating crane along ship and getting labor in/out of barges, the effective rate is lower. The lower rate is reflected in reducing the rate modifier assumed here at 0.6 vs. 0.8 for land-based terminals.

Figure 5. Capacity of Terminal Berthage

Component	Unit	Cargo Category: Bagged (Export)	Woodpulp Prod. (Export)	Steel Prod. (Import)	Mixed (Imp./Exp.)	Steel Prod. - Floating (Import)
Berthage:						
Nominal Transfer Rate per Crane	Tons/Hour	50	250	300	120	300
Rate Modifier [1]		0.8	0.8	0.8	0.8	0.6
Number of Cranes per Ship		4	3	2	2	2
Working Hours	Hours/Day	12	12	16	12	12
Effective Daily Transfer per Berth	Tons/Day	1,920	7,200	7,680	2,304	4,320
Vessel Load	Tons	25,000	12,000	30,000	5,000	30,000
Vessel Loading Time	Days	13.02	1.67	3.91	2.17	6.94
Vessel Preparation Time	Days	0.3	0.3	0.3	0.3	0.3
Vessel Berth Time	Days	13.32	1.97	4.21	2.47	7.24
Inter-Vessel Time Coefficient		0.5	0.5	0.5	0.5	0.5
Inter-Vessel Time	Days	6.66	0.98	2.1	1.24	3.62
Vessel Cycle Time	Days	19.98	2.95	6.31	3.71	10.87
Berth Utilization		0.65	0.56	0.62	0.59	0.64
Effective Working Time	Days/Year	235	203	223	211	230
Capacity per Berth	**Tons/Year**	**450,422**	**1,464,407**	**1,711,738**	**485,803**	**993,865**

Note: (1) Rate modifier to account for interruptions during work.

Figure 6. Capacity of Terminal Storage

Component	Unit	Cargo Category: Bagged (Export)	Woodpulp Prod. (Export)	Steel Prod. (Import)	Mixed (Imp./Exp.)
Storage:					
Nominal Area	Sq. Ft.	1,000	1,000	1,000	1,000
Utilization Modifier [1]		0.5	0.8	0.5	0.5
Effective Area	Sq. Ft.	500	800	500	500
Storage Density	Tons/Sq.Ft.	0.15	0.13	0.30	0.10
Effective Static Capacity	Tons	75	104	150	50
Average Dwell Time	Days	15	15	15	15
Peak Factor		1.3	1.3	1.3	1.3
Turnovers	1/Year	18	18	18	18
Capacity per 1,000 Sq. Ft.	Tons/Year	1,385	1,920	2,769	923
Direct Transfer					
Portion Transferred Directly		0%	0	50%	20%
Equivalent Capacity per 1,000 Sq. Ft.	**Tons/Year**	**1,385**	**1,920**	**5,538**	**1,154**

Note: (1) To account for space used for traffic circulation and separation.

Figure 7. Capacity Calculation of a General Cargo Terminal

Component	*Unit*	*Nashville Ave. Terminals*
Facility Characteristics:		
Berth Length	Ft.	4,545
Shed	Sq. Ft.	897,600
Open Area	Sq. Ft.	424,578
Cargo Composition:		
Bagged (Export)		0%
Woodpulp Products (Export)		20%
Steel Products (Import)		60%
Mixed (Import/Export)		20%
Berthage:		
Weighted Capacity Per Berth	Tons/Year	1,417,085
Number of Berths		6
Effective Transfer Per Terminal	Tons/Year	8,502,510
Utilization Multiplier [1]		1.25
Berthage Capacity	**Tons/Year**	**10,636,924**
Storage:		
Weighted Capacity Per 1,000 sq.ft.	Tons/Year	3,938
Storage Area	Sq.Ft.	1,322,178
Storage Capacity	**Tons/Year**	**5,206,208**
LIMITING CAPACITY	**Tons/Year**	**5,206,208**

Notes: (1) To account for higher utilization in case of multiple beths.

Effective Working Time and Total Terminal Capacity
Ship arrival to floating terminals is less regular than to land-based terminals. This, in turn, reduces the effective work time and total capacity. The total capacity of a floating terminal is calculated at 1.2 million tons/year (vs. 1.4 million for a land-based berth).

STATE CAPACITY VS. DEMAND

Statewide Terminal Capacity
The total capacity of the land-based general cargo terminals of State of Louisiana to handle general cargo was estimated in 1993 at about 9.0 million tons/year. It was also estimated that once the process of development of the Up-River complex in New Orleans is completed (in 1996), the capacity will increase by about 2 million tons/year. Some of this added capacity will be reduced if older New Orleans' terminals are discarded.

The floating terminals of Louisiana were estimated to have the capacity of 3.6 million tons/year. It was also observed that development of a floating terminal, unlike a land-based terminal, is a relatively short and inexpensive process, allowing capacity to quickly adjust to demand. This should be contrasted with the lengthy and tedious process of developing a land-based terminal.

Capacity vs. Need
As stated at the outset of this paper, the capacity analysis served as a key input for developing the Statewide Intermodal Plan. In Louisiana, as well as in other states, the Plan revolves around the need to expand capacity in response to future needs through construction of new terminals or expansion of existing ones. The demand forecast was prepared in a traditional fashion, taking 1993 as a base year and inflating it with a set of growth coefficients.

In the case of Louisiana's general cargo terminals, the comparison between capacity and forecasted needs indicated that the State had a comfortable margin of about 30 - 40% of over-capacity. This margin was expected to absorb the growth rate well into the next decade.

Response to Demand Surge
Reality, however, has an annoying tendency to refute forecasts. While the Plan was still unfolding, Louisiana witnessed an unpredictable surge in demand with an overall increase in general cargo of about 40% in 1994 over 1993 (base year). Steel imports, Louisiana's main cargo, rose 180% with a strong indication of continuing growth trend in 1995 and beyond. Demand apparently was about to outstrip supply even with the 40% capacity margins identified by the Plan.

Louisiana's planners were not driven into a frenzy looking for sites for new terminals, however. A quick review of the S & F capacity model revealed that only 50% steel is stored on terminal. Steel, especially in time of demand surge, is handled directly to barges either while the vessels are berthed at land-based terminals or, mostly, by floating terminals. Louisiana's terminals, with berthage capacity of 3 or 4 times the storage capacity could easily cope with practically any demand surge. Moreover, if needed floating terminals can be added in a relatively short time and ease the pressure off the land-based terminals. In short, Louisiana planners rest assured that the needed capacity will be easily provided by existing terminals.