that a gang is actually *handling containers*, excluding all other activities and interruptions.

By definition, the gross times are larger than the net ones for both the ship and the gang. There is no clear correspondence between Gross Berth Time and Gross Gang Time. Gangs can be waiting for a ship while the ship is not at berth, or a ship can be waiting for gangs while at berth. There is a direct correspondence only between Net Berth Time and Net Gang Time; Net Berth Time is equal to Net Gang Time divided by the average number of gangs.

Figure 1 illustrates the various times and activities related to the ship handling process.

**Container Moves**

While serving a ship, a gang may perform a series of direct and indirect activities. The activities are usually quantified by "moves", the four common types of which are:

- ***Load/Unload*** -- the transfer of domestic (import & export) and transshipment boxes between ship and yard;
- ***Re-Handle*** -- the transfer of transshipment boxes between ship and dock for a later transfer from the dock to the same ship;
- ***Shifting On-Board*** -- the transfer of boxes in-between bays (cells) without staging them on dock; and
- ***Hatch Opening/Closing*** -- the transfer of *hatchcovers* between ship and dock.

Only the first and the second types of moves are usually being charged. Therefore, only these two are counted for the purpose of measuring productivity, with re-handles counted twice (once each way). If needed, the two other moves can be expressed as a percentage of the counted moves. Altogether, a "move" is counted every time a box crosses the imaginary line between ship and dock.

**Ship and Gang Productivity Measures**

Six productivity measures are suggested for specifying the performance of ships and gangs. Five measures are based on divisions of moves by times; the sixth is based on time difference.[5]

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[5] These measures are part of a broader system of performance indicators that define the productivity profile of a terminal. The system relates to a terminal as a stock & flow system: ship and berth handling productivity measures relate to flows (rates); yard dwell time and space utilization measure relate to stocks. For a discussion see Ashar, Asaf, "Performance Indicators for Intermodal Freight Terminals", LSU National Ports & Waterways Institute, for U.S. Department of Transportation, Office of Intermodal Transportation, 1993.

Ship productivity includes three measures:

- ***Port Accessibility*** -- the difference between Port Time and Gross Berth Time. This measure reflects: (a) the geographical situation of a port, mainly the distance and navigation conditions of the access channel; (b) availability of pilot and tugs; (c) availability of governmental agencies responsible for clearing ships, crews and cargo; and (d) availability of berthage.

- ***Gross Berth Productivity*** -- moves (boxes transferred between the ship and the dock/yard) divided by ship's Gross Berth Time (the time between the first and the last line). This measure reflects the shift structure and labor situation.

- ***Net Berth Productivity*** -- the same as Gross Berth Productivity, but using Net Berth Time. This measure reflects the number of gangs (cranes) assigned to the ship and the Net Gang Productivity (see below).

Gang productivity also includes three measures:

- ***Gross Gang Productivity*** -- moves divided by Gross Gang Time. This measure reflects labor contract, especially regarding idle ("stand-by") times at the beginning, during and the end of shifts (early finish).

- ***Net Gang Productivity*** -- the same as Gross Gang Productivity, but using Net Gang Time. This measure reflects necessary, although non-productive (do not produce moves), activities such as handling hatch covers, shifting boxes on-board (cell-to-cell), inserting/removing cones, etc.

- ***Net/Net Gang Productivity*** -- the same as above but using the Net/Net Gang Time. This measure, also called "pick-rate", reflects the technical capability of facilities and equipment, along with the proficiency of the labor in operating them and the competence of terminal management in planning and controlling them.

Since all times are usually measured in hours, the productivity measures are all expressed in moves/hour. Figure 2 presents a summary table of the above definitions of times, moves, and productivity measures.

**Factors Affecting Productivity**

Factors affecting productivity can be divided into those that are controllable and uncontrollable by terminal operators. Controllable factors relate to the proficiency of planning, organizing, operating, and maintaining terminal labor, facilities, and equipment. Uncontrollable factors are, first, ship-related: the type of ships (TEU capacity, cellular/non-cellular) calling at the terminal, number of moves per call and per

bay, type and number of hatchcovers, dimensions of the ship (especially width and depth that determine the box path), and stowage plan. Second, terminal-related: the type of facilities and equipment available at the terminal, including type of cranes employed for handling ships, whether they are shore-based gantries, shore-based mobile cranes, ship-based gantries or ship-based whirley (stick, jib) cranes, type of yard machines, etc. Other uncontrollable factors that affect productivity such as weather conditions, time of the day, etc.

**Selected Productivity Measures**

The most comparable productivity measure is the one that is the least affected by the uncontrollable factors listed above, the Net/Net Gang Productivity. However, this measure, while being the most important to terminal operators, is of little interest to lines.

The most important productivity measure for lines is Net Berth Productivity. This can be shown through a simple algebraic manipulation. Lines are most interested in shortening port time. Port time can be formulated, using the above-defined productivity measures, as:

$$\textit{Port Time} = \textit{Port Access Time} + \textit{Terminal Preparation Time} + \\ + \textit{Terminal Handling Time}$$

Waiting for berth is quite rare in modern terminals. Hence, port access time mostly consists of the navigation time in the access channel, with the terminal operators having only limited influence over it. Access time can be viewed as fixed for all practical purposes.

Assuming waiting for berth and major delays during work are rare, ship preparation time, which is the difference between Gross and Net Berth Time, also can be viewed as fixed. Under these two simplifying assumptions, the line's main concern is:

$$\textit{Terminal Handling Time} = \textit{(Container Moves/Net Berth Productivity)}$$

Consequently, if the recent trend in port pricing is for a single, all-in box handling charge to be accompanied by a single productivity measure, Net Berth Productivity is probably the best choice. The terminal operator, in turn, should focus on the comparable productivity measure of Net Gang Productivity (not Net/Net), since:

$$\textit{Net Berth Productivity} = \textit{Net Gang Productivity x} \\ \textit{Average Number of Gangs}$$

## III. Comparative Productivity Data

### Net/Net Gang Productivity

Thirteen terminals in the Caribbean / South Atlantic region were visited, including meetings with local terminal operators and shipping line representatives. As already noted above, no organized data on productivity was available. Nevertheless, through gathering bits and pieces of data from various direct and indirect sources and by adjusting the data to comply with definitions, a set of productivity measures was calculated. Figure 3 presents a summary of productivity data gathered and estimated for some of the terminals.

As seen from the data, the Net/Net Gang Productivity is almost uniform across all terminals, with larger ships handled at larger terminals having a slightly higher performance. This seems reasonable; on a per-single crane basis, and while the crane is working loading/unloading boxes, there not much difference amongst terminals. Moreover, Net/Net Gang Productivity mainly relates to crane driving skills, which should not differ much across countries. Likewise, the technological difference between modern and older cranes has a "natural" offsetting mechanism. Older terminals equipped with older and slower cranes usually handle smaller ships, which have shorter crane paths.

### Net Gang and Berth Productivity

There is a wider difference among terminals in Net Gang Productivity, which accounts for delays during work and indirect activities. Here, larger terminals with well-organized yard and ship-planning procedures, which usually handle larger ships with longer crane "runs", have higher performance. An even wider difference is in Net Berth Productivity, which reflects the number of cranes per ship. The larger terminals, MIT, Miami and Kingston have 3 gangs working simultaneously when handling large ships, with a combined Net Berth Productivity of up to 90 moves/hour. At this rate, a ship with 1,000 moves, needs about 11 of Net Berth Time, and an overall Port Time of 15 hours (assuming 1 hour for ship preparations and 3 hours for port access time). Such a terminal can handle a 1,800-move ship within 24 hours. These handling rates are beyond the reach of the smaller regional terminals, with smaller facilities geared for handling smaller ships.

### Three Groups of Container Terminals

As seen above, the type of facilities and equipment are critical in assessing terminal productivity. These, in turn, reflect the trade segment that the terminal is targeted to serve. In the Caribbean / South Atlantic region, terminals can be roughly grouped into three categories:

- ***Large-size terminals with transshipment orientation*** -- including the terminals in Miami, MIT and, Kingston, each having 6 - 10 gantries of the latest model and a

large, dedicated yard.

- ***Medium-size terminals with local-cargo orientation, along with limited transshipment*** -- including the terminals in Rio Haina West (SeaLand) and Cristobal, each with 2 old gantries. Cartagena's terminal may also be placed in this category, assuming that its combination of a mobile crane and a modern gantry is equivalent to two older gantries.

- ***Small, semi-containerized terminals with local-cargo orientation*** -- including the Eastern terminal in Rio Haina with its single, old gantry. The rest of the Colombian terminals (excluded in Figure 3) may also be placed in this category.

Each of the above terminal categories is oriented toward serving different trade segments. Figure 4 presents the main characteristics and trade orientation of the three terminal categories.

A meaningful productivity analysis should first identify the objects for comparison. Only then, observations can be made regarding needed changes in operational procedures, pricing system and future facility development plans.

## IV. Final Observations and Recommendations

Following the recent wave of port privatization, the attention in the shipping and port industry has been focused on port pricing, with the price defined as an all-in ship-handling charge. Such a charge is meaningless unless what it is paid for, ship-handling productivity, is clearly defined. Despite years of extensive dealing with port productivity, there is no uniform terminology and methodology to measure productivity.

A uniform definition, such as that presented in this paper, is a prerequisite for a well functioning market for port services. It is thus recommended that the industry develops and adopts a *standard ship handling (stevedoring) contract*, similar to the standard Bill-Of-Lading and other uniform instruments of trade used in the industry. The contract should include clear description of times and activities (and delays) involved in the ship handling process, along with a definition of a set relevant productivity measures. To monitor actual productivity, the contract should include a *standard ship operations report* for recording times and activities according to the contract's definitions. The intention undertaking the proposed standardization is not to regulate the industry and stifle competition; on the contrary, better communication should facilitate negotiations among parties and enhance competition. The standardization initiative can be headed by one or a combination of existing international trade bodies, such as UNCTAD, ICHCA, IAPH, etc.

Figure 1

## Break-down of Ship and Gang Times

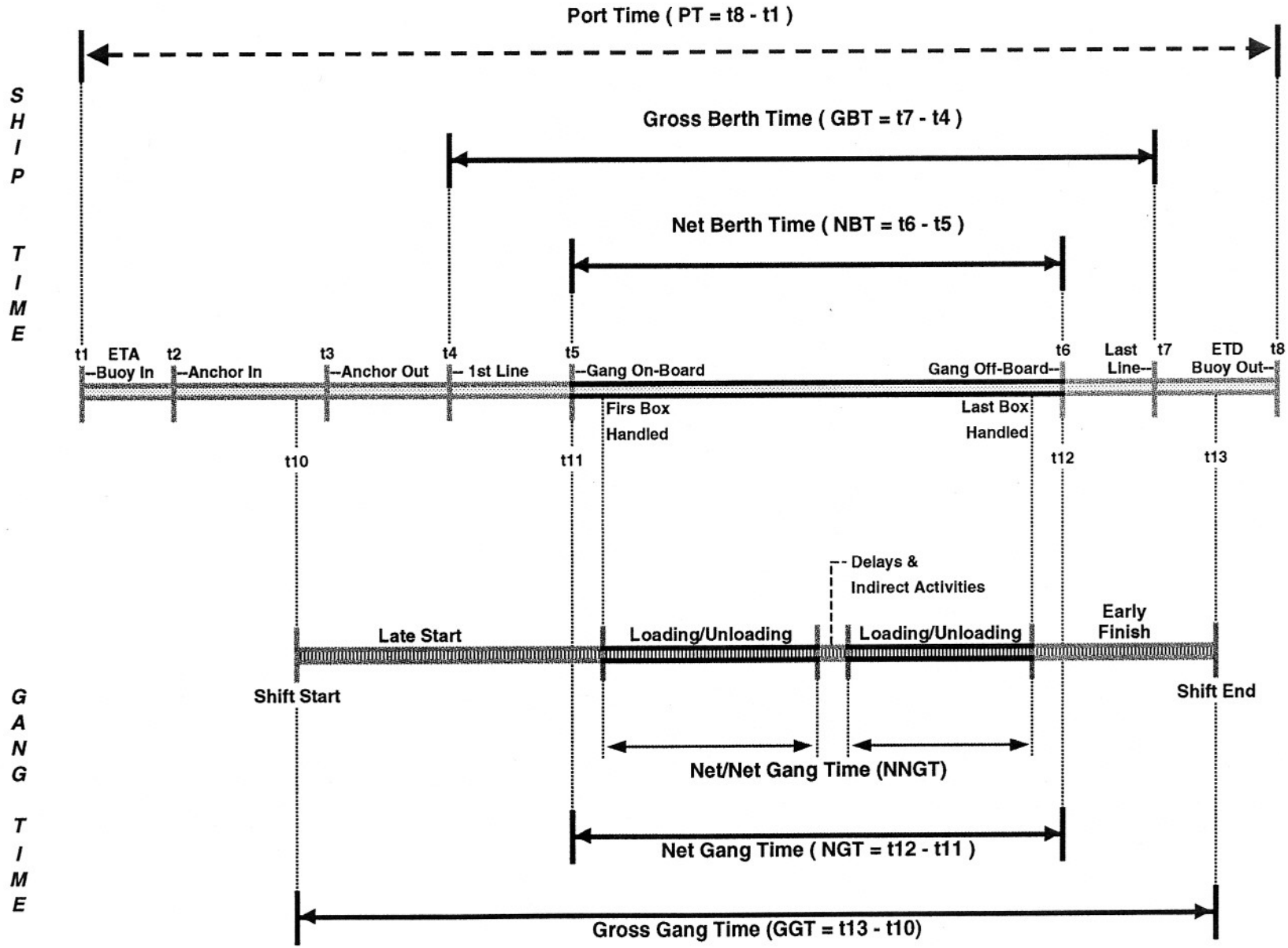

Figure 2

# Definitions of Ship Handling Indicators

| Parameter | Notation | Unit | Description |
|---|---|---|---|
| ***Ship Times:*** | | | |
| Port Time | Tp | Hour | Buoy-to-buoy |
| Gross Berth Time | Tbg | Hour | First-to-last line |
| Net Berth Time | Tbn | Hour | First-to-last box |
| ***Gang Times:*** | | | |
| Gross Gang Time | Tgg | Hour | Assigned (paid) time |
| Net Gang Time | Tgn | Hour | Working time (first-to-last box) |
| Net Net Gang Time | Tgnn | Hour | Handling boxes only |
| **"Moves"** | **Mv** | **Box** | **Ship / Dock (Yard)** |
| ***Performance Indicators:*** | | | |
| Port Accessiblity | Ba | Hours | Tp - Tbg |
| Gross Berth Productivity | Pbg | Moves/Hour | Mv / Tbg |
| Net Berth Productivity | Pbn | Moves/Hour | Mv / Tbn |
| Gross Gang Productivity | Pgg | Moves/Hour | Mv / Tgg |
| Net Gang Productivity | Pgn | Moves/Hour | Mv / Tgn |
| Net-Net Gang Productivity | Pgnn | Moves/Hour | Mv / Tgnn ("pick" rate) |

Figure 3

# Gang and Berth Productivity of Caribbean Ports

| Terminal (Crane Type) | Ship Size | Moves per Call | Productivity | | |
|---|---|---|---|---|---|
| | | | Gang Net/Net | Gang Net | Berth Net |
| **MIT** | 4,000 | 1,200 | --- | 30 | 90 |
| (Gantry) | Feeder | 150 | --- | 20 | 20 |
| (Ship's Gear) | Feeder | --- | --- | 11 | --- |
| **Cristobal** | 4,000 | 500 | --- | 25 | 50 |
| (Gantry) | Feeder | 350 | --- | 16 | 16 |
| **Miami** (Gantry) | 350 | --- | --- | 25 | 25 |
| | 3,000 | --- | 30 | --- | --- |
| | 2,000 | --- | 25 | --- | --- |
| | 3,000 | 165 | 30 | --- | --- |
| | Feeder | --- | 22 | --- | --- |
| | 4,000 | 1,000 | 27 | 24 | 73 |
| **Kingston** (Gantry) | 4,000 | 650 | 24 | 22 | 66 |
| | 3,000 | 16 | 21 | 19 | 16 |
| | 1,000 | 160 | 17 | 15 | 15 |
| | 1,500 | 16 | 20 | 18 | 36 |
| | 1,000 | 16 | 23 | 21 | --- |
| | 3,000 | 650 | 22 | 16 | 35 |
| | Feeder | 150 | 22 | 16 | |
| | 400 | 90 | 17 | 15 | 35 |
| | 1,200 | 65 | --- | 15 | --- |
| **Rio Haina West** | 1,300 | 600 | 27 | 20 | --- |
| (Gantry) | Feeder | --- | 20 | 15 | --- |
| **Rio Haina East** | Feeder | 300 | 9 | 7 | 16 |
| (Ship's Gear) | Feeder | 184 | 10 | 9 | 16 |