tainer handling rate per hour of vessel time at berth (h_b) is given in Table 3. Assuming that a container crane is capable of handling 30 container moves per hour, then allowing for lost time, number of cranes, crane interference, ratio of working time to berth time, and restow moves, results in handling rates of 5 to 41 containers/hr of vessel time at berth. This explains how the wide range of values for container handling rates occurs; by comparing this range of values with data in Table 1, the model is to some degree verified.

NEED FOR FURTHER RESEARCH

In Table 3 certain ranges of values have been assumed for the independent variables. These were arrived at through consultation with terminal operators and from the literature. The ranges are believed to be realistic, but more data and research are needed to improve the prediction of values of these variables for specific cases.

One variable that is of particular interest and is by itself a candidate for modeling is R--the proportion of restow moves. More specifically, $R = N_R/(N_R + N_{DL})$, where N_R is the number of restow moves and N_{DL} is the number of containers discharged and loaded. In earlier work (5), the percentage of restow moves was assumed to vary linearly with the number of ports of call as follows: $R\% = 3\ (n_p - 2)$, where n_p is the number of ports of call on a vessel (round trip). Data for modeling R, although undoubtedly in existence, have not been available.

Summarizing the need for further research, the following tasks are identified:

1. Develop a model for the percentage of restow moves (R),
2. Develop a model for predicting base crane efficiency (h),
3. Develop a crane assignment model [i.e., number of cranes assigned (n)], and
4. Develop a model for the ratio of working time to berth time (w).

Other variables such as proportion of containers that are 40-ft boxes (P), time spent entering and leaving port (t), and number of containers discharged and loaded per port visit (c) are specific to the kind of trade and the itinerary of the vessel.

REFERENCES

1. Moffatt and Nichol. Port Handbook for Estimating Marine Terminal Cargo Handling Capability. Office of Port and Intermodal Development, U.S. Maritime Administration, Sept. 1979, pp. 68-161.
2. J. Al-Kazily. Choice of Technology for Containerized Shipping--A Study of Interaction Between Vessels and Ports. Univ. of California, Berkeley, Dec. 1979, pp. 66-117.
3. Technological Changes in Shipping and its Effect on Ports: The Impact of Unitization on Port Operations. United Nations Committee for Trade and Development, New York, Rept. TE/B/C.4 129, 1976.
4. C.H. Plumlee. Port Performance Index--1979. Public Works Consultants, Carmel Valley, CA, 1979.
5. J. Al-Kazily. Modeling Containerized Shipping for Developing Countries. Transportation Research, July 1982, pp. 271-284.

Handling and Storage of Empty Chassis

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The reasons that intermodalism is growing and will continue to grow are briefly outlined, and the problems inherent in current designs are discussed. One problem—the handling and storage of empty chassis—is identified. Current methods of handling and storing chassis are discussed, and new equipment, which places the chassis in a vertical position, is presented. The methods shown indicate that 65 to 700 ft^2 of land can be used per chassis. Thus, the use of land for chassis storage can vary from 60 to 650 chassis/acre. Brief reference to the economics of this new concept, and the capital investment required, is made.

The intermodal industry comprises several definite and separate individual operating sections. Air transport is an important part of intermodalism, but the intermodal industries considered in this paper are railroads, trucking firms, and water shipping; i.e., where containers and their empty chassis exist.

Each mode has its own functional and mechanical operating problems, and because an individual unit usually operates within its own forum, it often does not come in contact with the other segments. In fact, domestic intermodalism is extremely competitive and often deliberately separate.

There have been efforts at cooperation, such as through the National Railroad Intermodal Association and the Uniform Intermodal Interchange Agreement, but generally it has been each mode--rail, truck, or ship--solving its own problems. And if by chance another mode was helped, it was more by accident than by design. However, in intermodalism, sooner or later each mode comes into contact with other modes, and in doing so is forced to handle an identity that is not compatible with its original terminal design or equipment capabilities.

INTERMODAL GROWTH

The overall industry is a true material handling industry, and because the material is assembled into larger container forms, the physical problems of weight and dimensions necessitated, and still require, the recognition of specialized handling equipment. This industry, despite its rapid expansion, is young in its hardware technology.

There are many internationally recognized manufacturers of material handling equipment, such as LeTourneau, Hatachi, Drott, Raygo Wagner, and Paceco. This list does not cover the entire industry, but it does point out that many capable and competent suppliers are involved.

Thus, tools have been developed and are available to fit into the intermodal segments of the various modes. By rapidly passing over the other individual advances in this industry (i.e., container ships, larger trailers) to arrive at what is happening today virtually ignores an intense period of material handling development by the individual segments of this industry and the various manufacturers. From this development comes material handling equipment used by rail, truck, and ship that is efficient and relatively economical, which has allowed the industry to expand. This expansion is natural because of the economic values this method of material handling offers; however, expansion has been accelerated by the energy crises. Deregulation has also stimulated some innovative ideas and interchange agreements; the land-bridge, minibridge, and microbridge concepts are prime examples.

All indicators point to continued growth. This industry grew rapidly in the late 1950s, and even had a steady increase during the 1981 to 1982 depressed era. However, today some major problems have arisen, such as space, room, and area in which to operate the intermodal business in interchange areas.

NECESSARY STEPS TO EXPANSION SOLUTIONS

The intermodal industry has to grow, yet it is tied to the transfer points of packages--primarily railroad terminal yards and ports. Most were originally built to solve the problems of the individual modes, with no real understanding of other modal problems or foresight of the expansion that has taken place.

It is recognized that a new terminal design in a new location can meet many of the problems of logistical space construction. However, it is also recognized that this can constitute some capital investment problems that are in some cases almost insurmountable. Thus, current terminal designs, if possible, should be modified. Also, all modes need new tools in order to increase efficiency and allow for continued expansion. Therefore, it is imperative that management seek and recognize these new technocracies for immediate profitability and possibly survival.

EMPTY CHASSIS PROBLEM

Tens of thousands of containers and trailers are handled every day. When a container is put aboard a ship or on a railroad flatcar, its chassis or undercarriage is left behind. Within the railroad industry today there is a massive program of development of specialized railcars to handle these containers. An example is the "double pack" of the Southern Pacific Railroad and the "10-pack" of the Santa Fe Railroad. In fact, it is believed that domestic containerization is inevitable, which will compound the storage problems at these interchange points, including the problem of storing the empty chassis.

In theory, the use of a container requires a chassis at each end of the haul or, on a worldwide basis, at each port. Many approaches are being taken to handle cargo and empty container problems, yet few terminals can handle the storage problems of empty chassis.

An empty chassis is an undesirable item: it does not produce any income, is easily damaged, needs to be repaired often, takes up space, and, when one is wheeled out of the way or stacked on top of another one, it creates continuous operational labor problems.

If customers are pressured to move a chassis out of the yard before they are prepared to do so, a customer-relations problem is created, and the problem of what to do with the chassis is intensified. Increasingly, the owner or shipper is asking that this problem be faced by the actual intermodal unit itself, whether rail, truck, or ship.

CURRENT APPROACHES TO EMPTY CHASSIS HANDLING AND STORAGE

Some firms have reached the conclusion that, because of the logistical problems of empty chassis and delivery practices, when the container is off-loaded from the ship and in domestic use it should be locked to the empty chassis. When the terminal storage area is large enough, there are many advantages to this method. However, there are also some major disadvantages, which will continue to create the same operational problem of storage space. Ultimately, the storage of the empty container, whether or not on an empty chassis, has to be approached and looked at in a method other than that of the single horizontal technocracies that exist today. Even so, there must be a group of empty chassis, usually no less than 300, in order to start unloading a ship. And 300 empty chassis in a single horizontal position take up 210,000 ft^2, or 5 acres.

The owners' approach to the handling of empty chassis is usually influenced by the number that they are responsible for or the size or location of the fleet. Many owners have so many chassis that they operate their own terminals for empty chassis storage and repair. Others depend on what are known as satellite or privately owned storage yards, which operate in most port areas. Thus, an owner can have the container, trailer, or empty chassis handled by a third party. Bear in mind that the problem of space, although it is accentuated at the terminals (whether rail or port), also exists at the privately owned third-party yard. The use of these satellite yards is a common method, yet it is puzzling that the owners of chassis are not more aware of the problems of the handling by some of these private yards from the standpoint of chassis repair costs.

The technology of handling chassis in most areas consists of putting them in the air in a highly unsafe manner by a front-end forklift truck and stacking them on top of each other. In addition, chassis owners will send a truck to get a chassis and tolerate as much as a 3- to 5-hr wait while a chassis is dug out of storage.

Basically, what takes place today, whether it is in a private satellite yard or in a large owner's yard, is that chassis are stacked on top of each other by forklift trucks in a horizontal plane or parked in a single horizontal system with random access.

In the discussion of storage, it is beneficial to have some knowledge of the physical characteristics of empty chassis. There are at least five major chassis manufacturers. Commonalities of measurements include the same frame heights and widths. However, frame depths vary by as much as 100 percent. There are other factors related to the empty chassis that affect storage, no matter what method is used. The primary one is axle setting, which is the most variable factor. Although axle setting is not too important when using the horizontal-type storage system, it is of major importance for some mechanical systems when chassis are stored on top of each other. Basically, there are some chassis that are so specialized that there is only one way to handle them, and that is to leave them flat on the ground. There are also variations in chassis lengths: the basic 40-ft chassis down to the basic 20 ft, with 24- and 35-ft chassis in between, and also the new 45- and 48-ft chassis. However, the chassis used today are usually 20 and 40 ft and are easily handled by the mechanical devices described in this paper.

Following is a study of current conventional storage systems used for empty chassis, both 20 and

40 ft. All of the examples have allowed for working room and use a 40x8-ft chassis in the diagrams.

System 1: Conventional Random-Access, Ground-Level, Horizontal System

The advantages of system 1 are as follows:

1. No lifting (handling) equipment is needed,
2. It is sometimes possible to have owners park and pick up their chassis,
3. There is minimum chassis damage, and
4. It is relatively safe.

The disadvantages of this system are as follows:

1. It uses a great deal of space,
2. Inventory control is difficult,
3. Hostling search time is high, and
4. Security is poor.

The space used for system 1, based on 40-ft chassis (which are generally used throughout the industry) with access and roadways also accounted for, is 677 ft²/chassis. Figure 1 shows system 1, which is for 48 chassis and uses 32,500 ft².

System 2A: One-on-One Stacking and Side Pick

One-on-one stacking and side pick are horizontal systems. The advantages are as follows:

1. It reduces the space requirement of system 1 by at least 50 percent or more,
2. It is relatively safe when compared to stacking higher,
3. No stickers are needed because of reduced weight, and
4. There is better security.

The disadvantages of system 2A are as follows:

1. More labor and equipment are needed;
2. There is some damage to chassis; and
3. Three chassis may have to be moved in order to get to one.

Side pick uses a standard 15,000- to 20,000-lb forklift. The space used for system 2A is 430 ft²/chassis. Figure 2 shows system 2A, which is for 96 chassis and uses 41,300 ft². (Note that in Figure 2, each line represents two chassis, one on top of the other.)

System 2B: End Pick

System 2B, like the one-on-one concept, is horizontal. It is necessary to have a chassis flipper for this method (the flipper is illustrated later), and to move only one chassis to get to any other one. This system allows the possible use of land that is not normally accessible. The space used for system 2B is 313 ft²/chassis. Figure 3 shows system 2B, which is for 96 chassis and uses 30,000 ft².

System 3: Two-on-One

System 3 is also a horizontal system. It has similar space requirements to systems 2A and 2B, except that in system 3 the chassis are stacked in a two-on-one configuration (see Figure 4). [System 3 is subdivided into 3A (side pick) and 3B (end pick).] The main advantage of system 3 is that it takes up 33 percent less space than either system 2A or 2B. The disadvantages of the system are as follows:

1. Stickers are needed (dunnage);
2. More damage is done to chassis;
3. It is more dangerous;
4. More time is spent on operations; and
5. Five chassis may have to be moved in order to get to one chassis in 3A, and two chassis may have to be moved in order to get to one chassis in 3B.

Therefore, system 3A (side pick) needs 270 ft²/unit for stacking chassis three high and system 3B (end pick) needs 200 ft²/unit for stacking

Figure 1. Diagram for system 1.

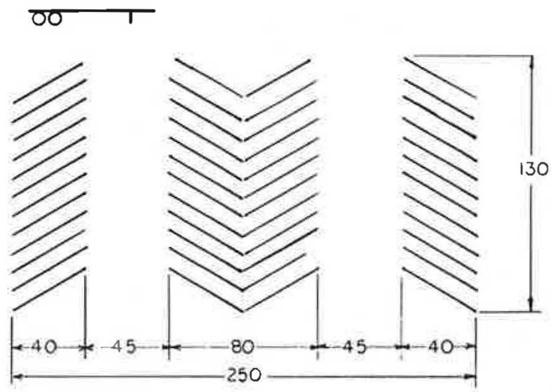


Figure 2. Diagram for system 2A.

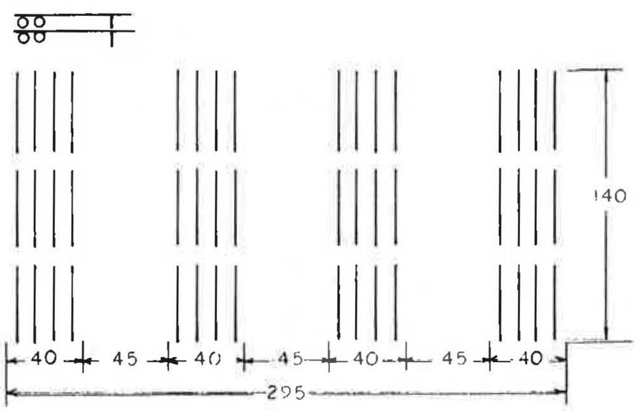


Figure 3. Diagram for system 2B.

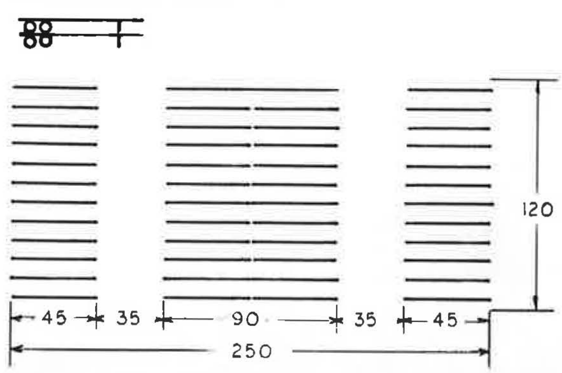
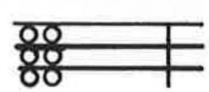


Figure 4. Diagram for system 3.



three high. Sometimes the procedure of stacking chassis four high is used, but it is not recommended because it could be damaging and dangerous.

Discussion of Systems

The manpower required in all three examples is approximately the same. The only capital equipment required to get chassis on top of each other is the aforementioned 15,000- to 20,000-lb forklift truck. There is a damage factor that increases proportionately, and there are time and labor factors, depending on density.

By placing chassis in a tighter density, there may be situations in which as many as 30 to 40 chassis may have to be moved in order to get to a particular one. In general, the practice of seeking a specific chassis is not common. It is common for a general storage yard to keep an individual customer's chassis together in one group, which is the sensible procedure. Therefore, in using an acre of land as the criterion--whether it is leased land or land that is needed for the horizontal method--count on 60 chassis (40x8 ft) to an acre; when stacked two high, 120 chassis; and when stacked three high, 180 chassis.

With respect to the application of land costs, obviously costs vary in different areas. On the East Coast, an annual rental of $17,000/acre is common, and on the West Coast, and in Seattle in particular, it is $47,000/acre. Thus, if all factors were maximal--if there was the ability to store 180 chassis/acre, the annual rental was $47,000, and the requirement was for storing 1,000 chassis--there would be probably about 6 or 7 acres involved, 2 or 3 forklifts, and an annual rental cost of $300,000 to $350,000 for the land. On the other hand, by using system 1, as much as 17 acres and $900,000 in rental costs could be involved.

In most port areas, putting chassis one on top of the other is not acceptable because of the time factor involved in getting them up and down, and also because of the search and storage requirements. In most port areas the single storage system is used. However, as ports become more crowded, chassis have to be placed on top of each other.

NEW EMPTY CHASSIS STORAGE CONCEPT

The mechanical system described in this section is an improved method from the standpoint of land use and least damage to chassis. The value to customers of this system is based entirely on how they view the acquisition of new land. If, for example, a major railroad wanted to put more volume through a

Figure 5. Chassis flipper system.

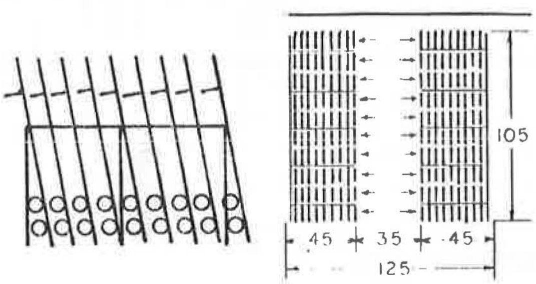


Figure 6. Chassis flipper attachment.

Figure 7. Flipper picking up a unit.

Figure 8. Placement in storage rack.

Figure 9. Chassis in a bundler.

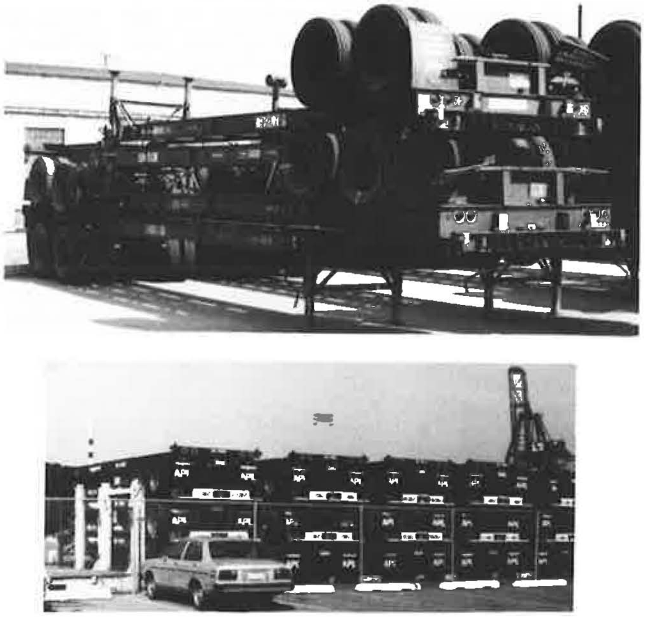


Figure 10. Rotator or uprighter at work.

piggyback terminal, this could mean new business for the company. But for a stevedoring company, it could also mean a reduction in the amount of land needed for handling chassis.

With respect to labor, the farther the traveling distance (if using a single system) and the more hostling tractors used, the more time that is needed to search because of inventory control. In putting chassis on top of each other, there is the factor of labor in hoisting them up by the lift trucks and then taking them down. Also, although there may be savings on a hostling tractor, more will be spent on labor for the forklift truck operator, and there will be a higher damage factor.

The turnover time, or the ratio of time spent taking a chassis from storage to its final use, varies immensely--from as much as four or five months between uses to four or five times a month.

The system described below is the chassis flipper system, which is manufactured by Multi-Sort, Inc., of Portland, Oregon. The advantages of this system are as follows:

1. It has the best possible land use,
2. It is the best system for safety reasons,
3. There is reduced hostling time,
4. There is no stacking damage, and
5. There is better security and inventory control.

The disadvantages of the system are the costs for the storage racks and the requirements for moving several chassis in order to get to a specific one.

The space used for this system, which is designed for 8- to 10-ft-wide front-axle forklift trucks with a T-bar rack design, is 74 ft^2/chassis. Figure 5 shows the system for an 8-ft-wide lift truck. It can handle 180 units and uses 13,000 ft^2.

Figure 6 shows the chassis flipper attachment, which will fit on any standard forklift truck of 30,000 lb or more, as it approaches the chassis when the chassis is in the horizontal position. Figure 7 shows the flipper picking up the unit, and Figure 8 shows the chassis being placed in a storage rack.

In this system, each individual chassis in the upright position takes up 55 ft^2. However, to allow for the open working space needed to get the chassis in and out of storage, an estimate of 650 chassis/acre is used. For example, in Seattle a little less than 2 acres is used as compared to 17 acres, and at $47,000/acre, this is a significant factor. On the other hand, there is a capital investment required for the larger lift truck, the flipper attachment itself, and the storage racks. The storage racks operate automatically, so that ground personnel are not needed. The racks should be good for many years, and probably can be amortized on a 7-year schedule. They also are movable; however, this would necessitate the building of new footings for the next location. The advantages of this system from the standpoint of inventory control are obvious. However, capital investment is considerably greater when compared to other systems.

Some operators need to move chassis from one location to another because of an imbalance, and they usually move the chassis in bundles. Rotating or turning over a chassis can present labor and damage problems. The following figures depict the rotator or uprighter that helps alleviate these problems. Again, these are manufactured by Multi-Sort, Inc. Figure 9 shows the chassis in a bundler, and Figure 10 shows the rotator or uprighter in action.

CONCLUSIONS

The handling and storage of chassis are factors that have been greatly neglected in the planning and thinking of most operational entities, whether by the owner or the operator. Extra efforts in this area can be of material advantage to the company that seizes the opportunity to use the available tools to enhance its own position in the field of intermodalism, whether for obtaining new business, reducing current costs, or supplying customers with needed facilities.

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