

Design of a Public Distribution Center

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A public logistics network (PLN) is proposed as an alternative to private logistics networks for the ground transport of parcels [1]. Using the analogy between the packages transported in the network and the packets transmitted through the Internet, a package would be sent from a store and then routed through a sequence of public distribution centers (DCs) located throughout a metropolitan area and then delivered to a home in a matter of hours, making a car trip to the store to get the package unnecessary. The DCs, functioning like routers in the Internet, could also be located at major highway interchanges for longer distance transport. Currently, it is common for a single logistics firm like UPS and FedEx to handle a package throughout its transport. In a PLN, the different functions of the network would be separated so that a single firm is not required for coordination. This would enable scale economies to be realized in performing each logistics function since each element of the network has access to potentially all of the network's demand. The increase in scale would make it economical to have many more transshipment points. Each transshipment point, or DC, could be an independently operated facility that serves as both a freight terminal and a public warehouse, and could be established in small cities and towns that would never have such facilities if they were served as part of a proprietary, private logistics network.

This paper will describe a proposed design for the DCs in a public logistics network. In order to be cost-effective, the loading/unloading, sortation, and storage activities at each DC in the public logistics network must be highly automated since each load might visit a dozen or more DCs while it's in transit. Since existing automation technologies do not provide the flexibility needed to allow any size load to move to any location at anytime, new DC, load, and trailer designs are needed that integrate sortation with storage and allow for a variety of different size loads to be handled. A goal of the proposed design is to make it as cheap or cheaper to ship a single item than it is to ship a larger consolidated unit load. In addition, the minimum efficient scale of operation for each DC should be low. Equipment that requires a large capital expenditure can only be able to be justified for high demand volumes. In order for it to be economic to locate a fully automated DC in a small town and dozens of local DCs in larger towns, the capacity of each DC should be able to be specified in small fixed-cost increments so that the cost of the DC is proportional to its size.

The proposed design for the DCs meets these requirements by using as its primary material handling device a small square module with orthogonal pop-up powered wheels (see Figure 1). Arrays of the modules are used to form a planar surface. Loads are transported on this surface using a series of orthogonal translations (reminiscent

of the Tetris computer game, but without rotation). The wheels of the module in one direction are at a fixed height; the wheels in the other direction are raised and lowered to three heights relative to the wheels in the other direction (see Figure 2): (a) level, when a load is at rest on the module; (b) lower, when the other wheels are transporting the load across the module; and (c) higher, when the raised wheels are transporting the load across the module. Turns are accomplished without rotating the load by simultaneously lowering the wheels in one direction and raising the wheels in the other direction once the load has covered the module. The load then travels in an orthogonal direction. Each module has guides on two of its sides (the guides for the other two sides are provided by the adjacent modules). The guides are raised and lowered as needed in order to constrain and direct the movement of a load (see Figure 3). The length of each module is 8.5 in. Loads with a length greater than this would occupy several contiguous modules (e.g., a 24×16 in. or 60×40 cm carton would occupy six modules). These modules would operate in unison in order to transport the load.

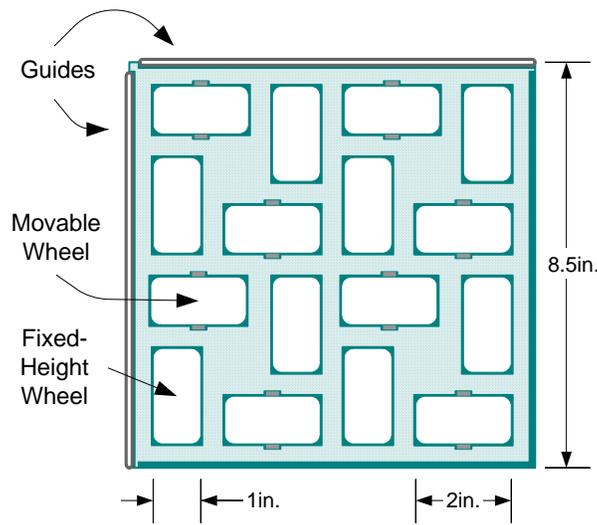


Figure 1. Single material handling module with guides on two sides.

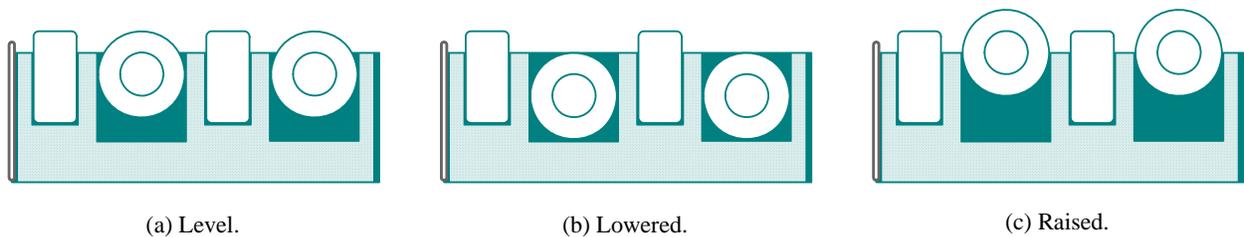


Figure 2. The movable wheels are raised and lowered to three heights relative to the fixed-height wheels.

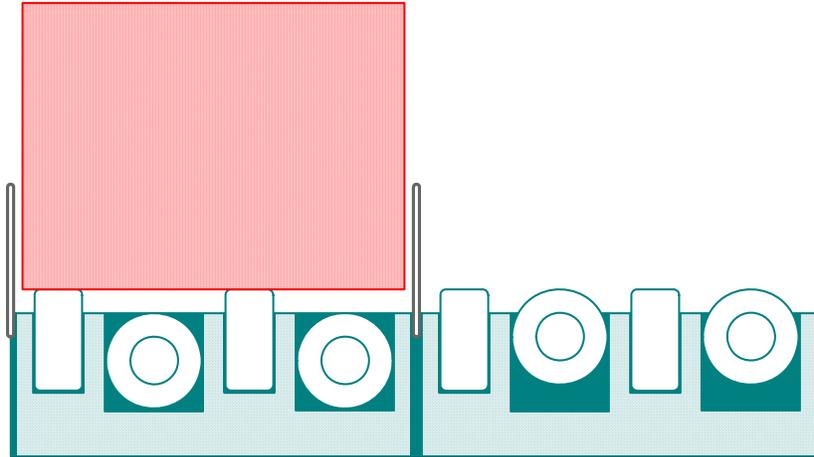


Figure 3. Guides in raised position.

Figure 4 shows a top view of one level of a four-bay DC and Figure 5 shows a side view of the DC. All loading/unloading, sortation, and storage operations are performed on a large open surface composed of arrays of pop-up wheel modules. Only individual arrays are visible in the figure, not the individual modules. The individual modules are visible in Figure 6 and Figure 7. The loads in transit in the sortation area typically move in clusters comprised of all of the loads traveling from the same origin to the same destination. In Figure 4, trucks are at three of the shipping and receiving (S/R) bays. The DC has 14 levels: four levels for S/R and sortation and ten levels for longer-term storage. Three elevators are used to move loads between levels. All three of the elevators are operate together if a load is as large as an entire array. Each truck has the same number of levels of module arrays as the number of S/R and sortation levels of the DC. At each S/R and sortation level, loads are automatically loaded and unloaded by positioning a movable array at each bay to provide a flexible interface between the array onboard the truck and a standard array in the DC used for staging (see Figure 6).

In Figure 4, two areas of the DC are used for the temporary storage of loads in transit. During storage, loads can be densely packed together while still allowing each individual load to always be accessible because all of the other loads can simultaneously move to open a free path for the load (see Figure 7). As compared to a design that uses traditional sortation and storage equipment (e.g., conveyors or an AS/RS), the proposed module-based design provides complete load accessibility at all times. The design differs from traditional designs by trading mechanical complexity for control complexity: each module is a simple mechanism, but each load in the system must be continuously controlled (even when it is in storage, since it will be continuously moving to provide clear paths for other loads (see Figure 7)).

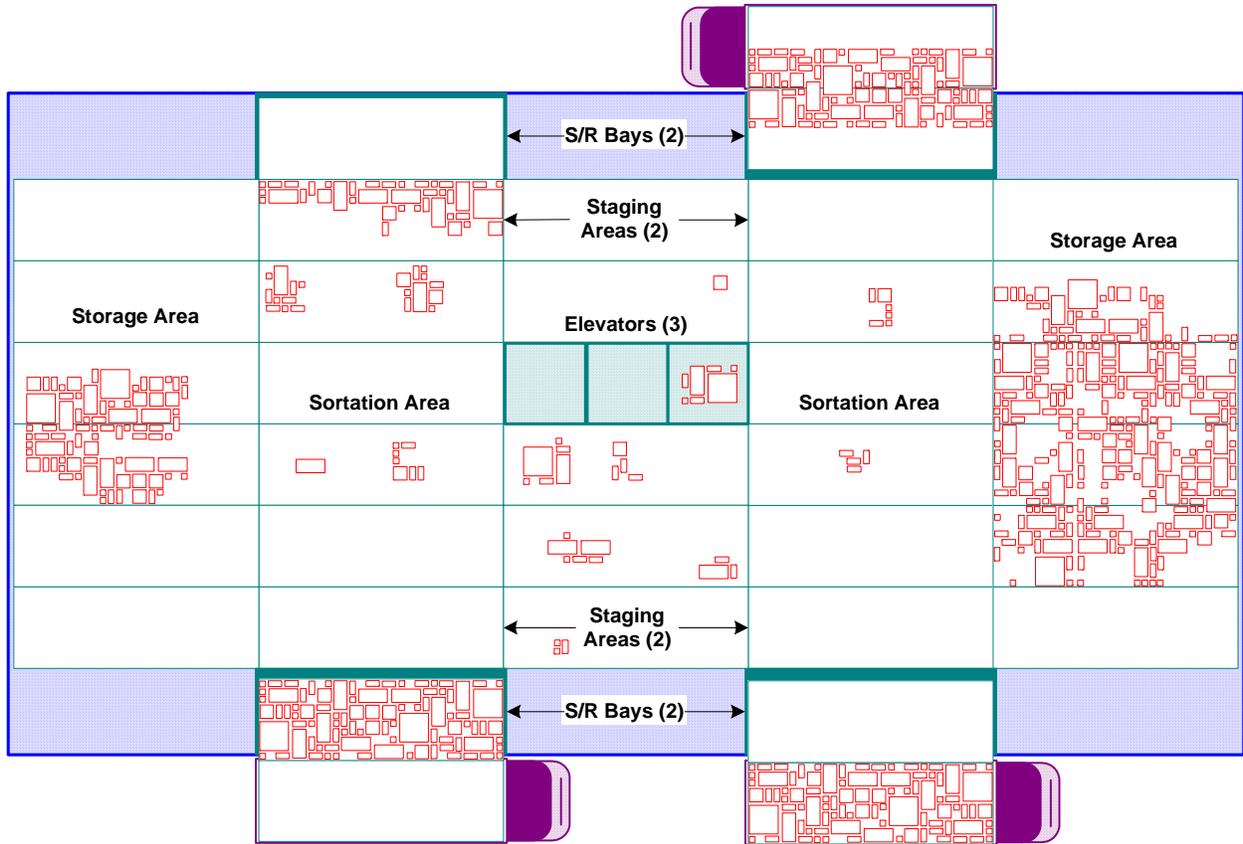


Figure 4. Top view of one level of a four-bay DC, where all loading/unloading, sortation, and storage operations are performed on a large open surface composed of arrays of pop-up wheel modules.

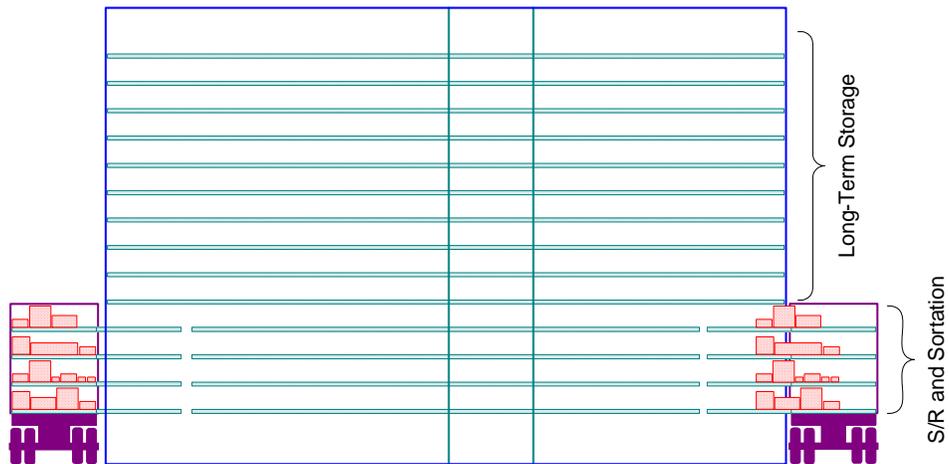


Figure 5. Side view of the DC showing four S/R and sortation levels and ten long-term storage levels.

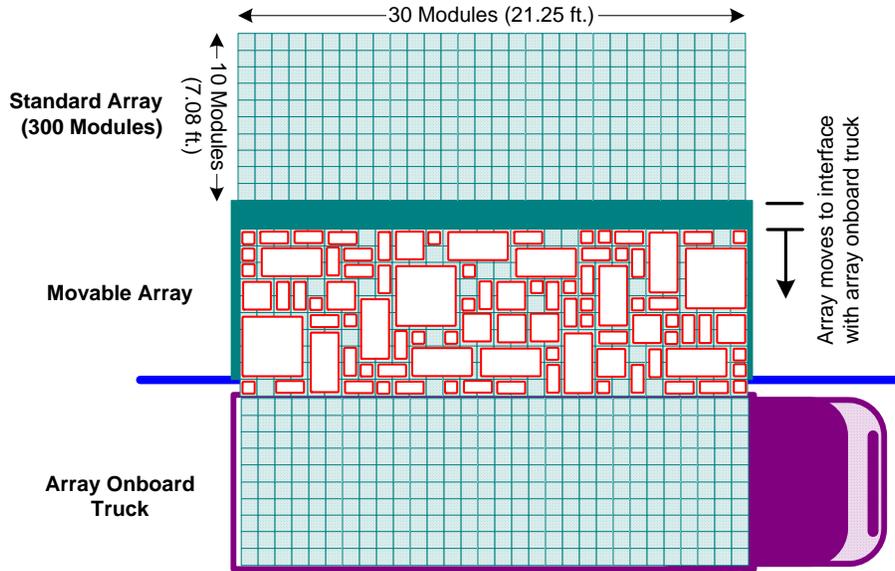
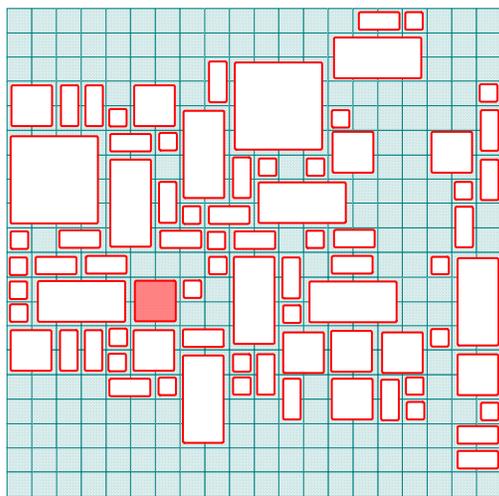
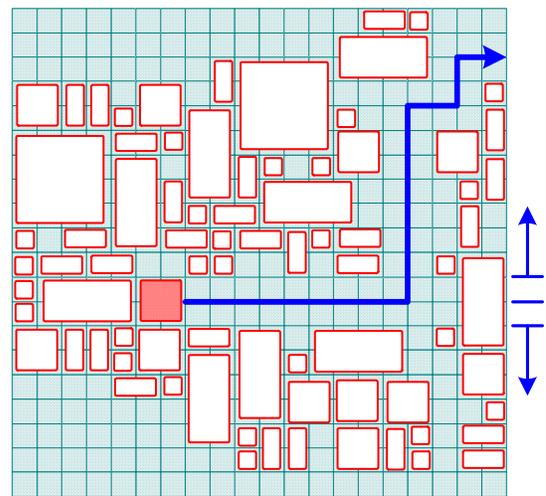


Figure 6. Detailed view of Figure 4 showing how loads are automatically loaded and unloaded from a truck by positioning a movable array at each bay to provide a flexible interface between the array onboard the truck and a standard DC array.



(a) Storage area prior to retrieval of shaded load



(b) Storage area after path cleared for shaded load

Figure 7. During storage, loads can be densely packed together while still allowing each individual load to always be accessible because the other loads can simultaneously move to open a free path.

The simple actions required for each module along with using a single standard configuration should allow them to be produced in high volumes at a low cost. The major limitation on load size is the height of the load, since the levels of arrays in the DC and onboard each truck are separated by a fixed distance. Due to a maximum height restriction for a truck trailer of 110 in., a 4 in. height for each module (including the wheels in the raised position), and 2 in. gap, the maximum height of a load would be 21.5 in. The maximum length of a load would be same as the length of an array, 21.25 ft.

The proposed design provides the flexibility needed to allow any size load to move to any location at anytime by integrating sortation with storage using arrays of low-cost modules. It allows for low-cost fully automated loading/unloading of a variety of different load sizes—currently, automatic loading/unloading requires uniform load sizes or, for non-uniform sizes, expensive robotic devices. It enables high cube utilization during sortation and storage together with full accessibility to different size loads. High cube utilization reduces the amount of space required, while full accessibility provides the flexibility needed to re-route packages at any time and it reduces the time and cost associated with retrieving items from storage. With other types of storage, there is always tradeoff between cube utilization, accessibility, and load uniformity. While conveyor-based automated sortation systems can handle different load sizes by making their conveyors wide enough to handle the widest load, the loads are only accessible when they pass a limited number of switching points. When a load is at rest on a conveyor, it cannot be individually accessed. Similarly, achieving high cube utilization using an automated storage/retrieval system (AS/RS) usually entails either requiring uniformity in load sizes, the use of large consolidated unit loads, or the use of deep-lane storage, which makes individual loads inaccessible. The modules in the proposed design could be produced at a low cost due to the scale economies associated with using only a single uniform module design and the fact that each individual module would not have to be designed to handle the heaviest load because the larger loads would occupy more modules and have their weight spread over these modules, thus lowering the cost of producing each module. Also, it is likely a small, single-module load will be as cheap or cheaper to transport and store as a larger, multi-module load because it would be easier for the smaller load to find space available on a truck and in a storage area, while other handling costs would be directly proportional to the size of each load; thus, there is no benefit associated with shipping larger consolidated unit loads.

References

1. M.G. Kay and A.N. Parlikad, “Material flow analysis of public logistics networks,” in *Progress in Material Handling Research: 2002*, R. Meller, M.K. Ogle, B.A. Peters, G.D. Taylor, and J. Usher, Eds., Charlotte, NC: The Material Handling Institute, 2002, pp. 205–218.

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