

Pallets 103: Pallets & Material Handling Equipment

Interactive Design for Cost Savings and Performance Optimization

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As a pallet designer, I'm often called into a warehouse to troubleshoot a pallet "issue." One of my first such projects was a warehouse that manufactured and stored bottled antifreeze. Figure 1 shows what we walked into and why the warehouse manager was upset – they had antifreeze leaking all over the floor from racked pallets!



Figure 1: Leaking Antifreeze on Racked Pallets

We found that the pallets were overloaded, deflecting up to 2" in the racks. But we also found that this same pallet design had been used for many years to store the same product. The reason they had leaks this year was that the unitized pallets were now stored in a drive in rack system that the warehouse manager had purchased in the used market at a bargain price. The bargain equipment would now require a stronger (more expensive) pallet. At the end of the day, this equipment "upgrade" cost the warehouse a significant amount of money in new pallets, lost product, and cleanup. Unfortunately, this type of experience is not uncommon. New Equipment can transform a warehouse, but if the pallets used in this equipment don't work, someone will

have to solve expensive retrofits and time consuming headaches. These costs and headaches are avoidable if designers understand how pallets and equipment interact.

This paper is the third in a series. The first paper, **Pallets 101** (Clarke 2004), was an overview of the pallet industry and pallet design options. The second, **Pallets 102** (Clarke 2007), discussed cost savings for packaging and pallets. This paper, **Pallets 103**, discusses interactions between Pallets and Material Handling Equipment, again with a goal of optimizing cost savings and improving performance throughout our supply chains.

Dr. Marshall White (White & Company and Virginia Tech) was an early proponent of the systems based design approach to packaging, pallets, and material handling equipment. He worked with the Material Handling Industry (MHI) association to identify pallet quality levels required for automated systems. A standard was developed: *MHI MH1 Part 10 - Performance Specifications for Pallets Used in Automated Unit Load Material Handling Equipment*. This is available free from the MHI website (see references at end for site), and is suggested as a starting point for pallet designs that will be used in automated systems.

Pallet and Packaging Sourcing Teams look for a few % savings on annual spend. There are opportunities for much higher % savings on pallets and packaging when Material Handling Equipment is upgraded. The next few years are a great time to capture these savings. A recent survey by Modern Materials Handling (Levans 2012) found that 50% of companies planned to spend \$250,000 in 2013, primarily to upgrade racking and forklift fleets. An additional 16% planned to spend \$1 million or more for major facility upgrades, generally for higher levels of automated material handling. These are capital expenditures, usually considered separately than the Packaging and Pallets spend. But the equipment we install can have a significant impact on the cost of Packaging and Pallets. Packaging and Pallet Teams should request a voice with Equipment decision teams.

The goal of this paper is to highlight the interactions between Packaging, Pallets, and Material Handling Equipment – interactions that will help your company reduce costs and improve overall supply chain performance.

Equipment Overview

The following is a basic overview of the Material Handling Equipment we use to load, store, ship, and handle our packaged products on pallets. For the purposes of this paper, we discuss the equipment, system constraints that cause higher costs (either equipment or pallets), and how these constraints might be modified to lower overall costs.

The major types of equipment that interact with pallets are:

- **Forklifts, Pallet Jacks, AGV's**
- **Conveyors**
- **Palletizers**
- **Racks**
- **Transportation**

We'll look at an overview of each of these, what equipment characteristics to record when evaluating options, and opportunities to improve designs and reduce costs between the equipment and pallets.

Forklifts

A forklift (also called a lift truck, a fork truck, or a tow-motor) is a powered industrial truck used to lift and transport materials. Two examples are given in Figures 2 and 3. There are many different types of forklifts, but most forklifts designed for pallets will lift with forklifts inserted under the pallet top deck.

Forklifts and Pallets: Key Components and Opportunities

- Forklift dimensions (Length / Width / Thickness)
- Tine spacing, ability to adjust spacing?
- Are fork extenders an option for longer pallets? Will they really be used?
- Number of forklifts (usually 2 but wider pallets may have more)
- Guidelines for general forklift use:
 - Typical tine lengths are 42" - 36 and 48 also common
 - Typical tine widths are 4 to 5"
 - Typical tine thickness is 1.5"
- In general, pallet top leadboards are most frequently damaged during forklift handling. For longer pallets, the bottom leadboards and top board at the end of the forklift tips are damaged. These pallet areas may need reinforcement.
- Forklifts with operators allow more pallet design flexibility than any other equipment. Most pallets only need 2" tall openings for forklifts. If all pallet handling is with forklifts, pallet options like lower profile pallets, 4 stringer pallets, reversible pallets, etc. may be options.
- Forklifts with operators also cause more pallet damage than any other equipment. More forklift handling requires more durable pallets.
- Some pallet materials, like plastics, are more susceptible to slip on forklifts. Operators may need to make speed or other adjustments when handling slicker pallets.



Figure 2: Counterbalance forklift with longer tines – used for longer pallets



Figure 3: Side Loader Forklift with 4 forks – used for wider pallets

Pallet Jacks

A pallet jack usually has 2 tines, and these tines have wheels mounted inside the end of the forks that are lifted with a hydraulic jack (Figures 4 and 5). When the wheels are lifted, the pallet is only lifted enough to clear the floor for subsequent travel. Since the tines have internal wheels and hydraulics, they are larger dimension than forklift tines. The more automated the pallet jack tines, the larger dimension the tines.



Figure 4: Typical Pallet Jack tines – the near one is designed to lift 2 pallets at once. This shows wheels in the lowered position.



Figure 5: Electric Ride On Pallet Jack. Note tight fit of tines in pallet opening

Pallet Jacks and Pallets: Key Components and Opportunities

- Tine dimensions (Length / Width / Thickness)
- Tine Spacing (not adjustable)
- Guidelines for general use automated pallet jacks:
 - typical tine lengths are 42" - 36 and 48 also common
 - Typical tine widths are 8"
 - Typical tine requires 3.5" tall pallet openings
 - Space between tines – 11" inside to inside
- Pallets cannot have bottom deckboards where the front wheels extend to the floor. These wheels will damage any pallet bottom deck, even very durable pallets, if they are opened over a bottom pallet component. Most pallets for pallet jacks leave 9" minimum bottom deck openings for these wheels.
- Enables only two-way entry into a four-way notched-stringer pallet, because the forks cannot be inserted into the 2" tall side notches.
- Requires pallets to be taller (min 3-1/2" opening height) for pallet jack tines. No opportunity for low profile pallets.
- Smaller pallets may need captive pallets underneath to facilitate pallet jack use.
- Thicker bottom boards may need to be chamfered to facilitate pallet jack use.
- Can Pallet Jacks be eliminated from the Supply Chain? If so, lower cost pallet designs are possible.

Automated Guided Vehicles



Figure 6: Typical AGV with forklines to move pallets

In general, AGVs either carry the pallets on a flat platform or use forklift tines like a forklift - they just have no operator. Since there is no driver to make tine adjustments, they will require a higher quality pallet design.

AGVs and Pallets: Key Components and Opportunities

- If they use tines, the above criteria for forklifts and pallets jacks will apply.
- Also measure how the pallets transfer onto and off the AGV. Most will use some type of conveyor at this transfer (conveyors discussed next).

Conveyors

The primary types of conveyors used with pallets are:

- Roller Conveyors (Figure 7)
- Chain Conveyors (Figure 8)
- Skate Wheel Conveyors (Figure 9)



Figure 7: Roller Conveyor. Usually rollers are full pallet width but can be 2-3 rows of shorter rollers. The close roller spacing on this conveyor allows a marginal quality pallet bottom deck to flow. Better pallets, or bottom boards oriented perpendicular to rollers, would require fewer rollers for same performance.



Figure 8: Chain Conveyor (3 strand). Most bottom deckboards run perpendicular to chains, but parallel deck flow like here can work if pallet quality is consistent.



Figure 9: Skate Wheel Conveyor (4 rail). Note that skate wheel conveyors (and many chain conveyors) are similar to a pallet “rack” and pallets will deflect. Also note the potential for loose stretchwrap and other debris to interfere with flow on this conveyor.

Conveyors and Pallets: Key Components and Opportunities

- Roller Conveyors – measure roller diameter, spacing between rollers, length of rollers, distance between roller support beams.
- Chain Conveyors – measure chain width and span between chains.
- Skate Wheel Conveyors – measure wheel diameter, wheel width, and span between rows of wheels. Skate wheels are less forgiving of poor quality pallets or debris than other conveyors.
- Pallet deflection greater than ½” on conveyors may cause issues.
- The bottom deck of the pallet is the interface between pallets and conveyors. Make sure the bottom deck is compatible with the conveyor design.
- Note direction of pallet bottom deck travel on the conveyor. Usually works best if pallet boards are perpendicular to roller length, but some conveyors are more forgiving of bottom deck direction. Perimeter base pallets roll better on conveyors.
- Broken boards are the worst pallet quality issue on conveyors.
- Nails that protrude from the bottom deck are another big problem with conveyors. Make sure your nail quality is adequate for the conveyor design.
- Many conveyors are essentially short term Racks. We see many applications where a short conveyor is the critical design factor that increases the cost of a pallet design throughout the supply chain. Can that short conveyor be modified to increase pallet support and save ongoing pallet costs?

Palletizers

A palletizer is used to automatically stack packaged products on pallets, but for pallet purposes we are interested in the handling devices that move the pallet into and out of the palletizer location. These are usually some type of lifting tine or device. Some examples are below:



Figure 10: This automatic lift uses 5 small forks that are 10" long. These forks require every pallet to have a 6" wide second board. If the palletizer forks were longer (one time modification), we could reduce the ongoing price of this pallet by 5% per pallet. This particular palletizer creates greater top deck stresses on this pallet than any other equipment throughout the supply chain.



Figure 11: This palletizer uses fork tines in the pallet notches. The spacing is not easily adjusted. Although the pallet is only here a few minutes, any potential change to a pallet design would need to be compatible with these forks.

Palletizers and Pallets: Key Components and Opportunities

- How does the palletizer position the pallet? It will use forklifts, conveyors, etc. to do this. The criteria listed in those sections would also apply here.
- If some feature of the palletizer is a limiting factor in the pallet design, can that feature be modified? Often a one-time modification to equipment is often lower cost than a higher ongoing pallet cost.
- Palletizers are automated, so pallet quality needs to be consistent with palletizer requirements.

Pallet Racks

Pallet racks are designed to more efficiently store palletized products. The main types of racks used with pallets are:

- Single Deep / Double Deep
- Drive in / Drive Through
- Cantilever Rack
- Flow Rack
- Push Back Rack



Figure 12: Single Deep rack with longer product. Pallet is supported by rack beams (blue) in the front and back of the rack position. Each pallet is also supported by 4 cross beams (orange) perpendicular to the blue beams. This allows more flexibility in pallet design and price. It is also increases rack / pallet safety.



Figure 13: Drive in Racking. Pallet is supported by Angle Beams on each side of the pallet. The pallet deckboards are supporting the load in this rack. A captive warehouse pallet was needed to support the lighter shipping pallet in this rack. Would another rack / pallet system be more economical for this warehouse?



Figure 14: Cantilever Racking. Pallet is supported by I beams under the bottom deck. Note pallet stringer location – bottom pallet has stringers located over the rack arms and transfers no stress to the bottom deck. Top pallet requires the bottom boards to help support the load.



Figure 15: Push Back Rack. Each of the carts is loaded and pushed back starting with the top cart. The last pallet is loaded on the track rails. Each pallet in this rack will be supported by a different rack span, since each cart is different.



Figure 16: Single deep rack with wire decking support. In this case, the addition of the wire deck support allows the use of a pallet that would not be safe on the beams alone.



Figure 17: Another common support for beam racking. The additional cross beams allowed the use of a smaller pallet, and caught the pallet when the bottom boards failed.

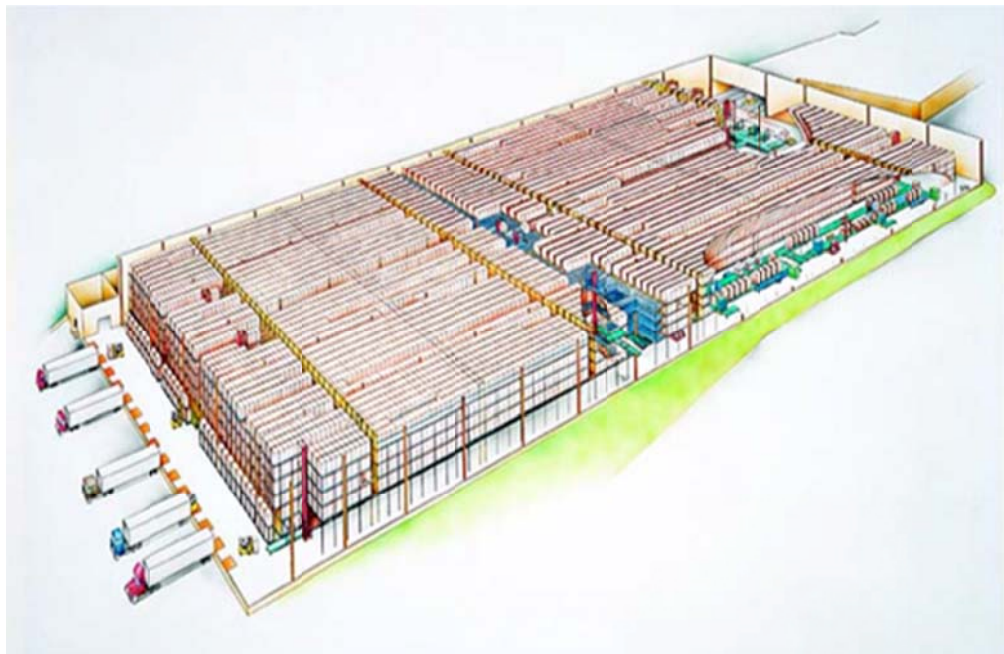


Figure 18: Highly Automated Racking Systems. These systems will have many types of equipment and racking. Pallet quality requirements are very high due to the high level of automation, critical location of pallet components, and safety issues inherent with people entering the deeper rack locations to fix pallet issues.

Racks and Pallets: Key Components and Opportunities

- Record the distance between rack supports and rack beam width. Record distance between vertical rack components that might interfere with pallets.
- Pallet Support Mode – Are pallets supported across the width or length, or both?
- On a new rack installation, would a different rack span allow a lower cost pallet?
- Can additional support be added to the rack system (wire deck or cross beams)? What is the cost of this one-time rack support vs. ongoing pallet savings?
- Broken boards are the worst problem in automated pallet systems.
- Racks require higher levels of pallet quality (safety) since failure from heights are unsafe and can result in more catastrophic results.

Transportation

Transportation is the mode that takes our products the longer distances. According to Accenture (Bentz 2012), “today not only are supply chains more extended, global, complex, and demanding, but transportation costs now exceed 63% of total supply chain costs.” A review of the latest issue of Logistics Management (Jan 2013) shows the major transportation modes all forecasting rising prices through 2014. Given these high costs and trends, anything we can do with the pallet to reduce transportation costs should be evaluated.

The primary modes of long distance transportation used to move palletized loads are:

- Vans, Flatbeds, and Curtainsides
- Containers
- Rail
- Air Freight

The internal usable dimensions of each of these modes are listed in a separate paper (Clarke, Nelson Tech Center, 2013). The usable internal dimensions between transportation modes is variable, no one size fits all. The key pallet measure that affects transportation “fit” is the pallet footprint, or length and width. The chart below is from a paper presented by Sanders (IBM) and Clarke (Nelson Company) in 2001. The “fit” of pallet sizes into standard transportation modes was evaluated. In general, no pallet size was ideal for all modes, but of the internationally recognized sizes, the 48x40 and 1.0 x 1.2m pallet sizes were relatively efficient across the options. It is interesting that the Euro pallet size (0.8 x 1.2m) was not a good fit for most transportation equipment.



Floor Space Analysis



Pallet Dims (LxW)	Air	Ocean	Surface	Average	Rank
40 x 46"	91	92	90	91	1
40 x 48"	91	89	92	91	2
40 x 44"	92	90	88	90	3
1.0 x 1.2m	89	87	93	90	4
45 x 48"	79	95	93	89	5
40 x 42"	92	86	84	87	6
0.9 x 1.1m	80	86	85	84	7
44 x 44"	71	92	86	83	8
0.8 x 1.2m	71	81	90	80	9

Notes: **Good Fit (90%+)**, **Average Fit (<90%)**, **Poor Fit (<80%)**

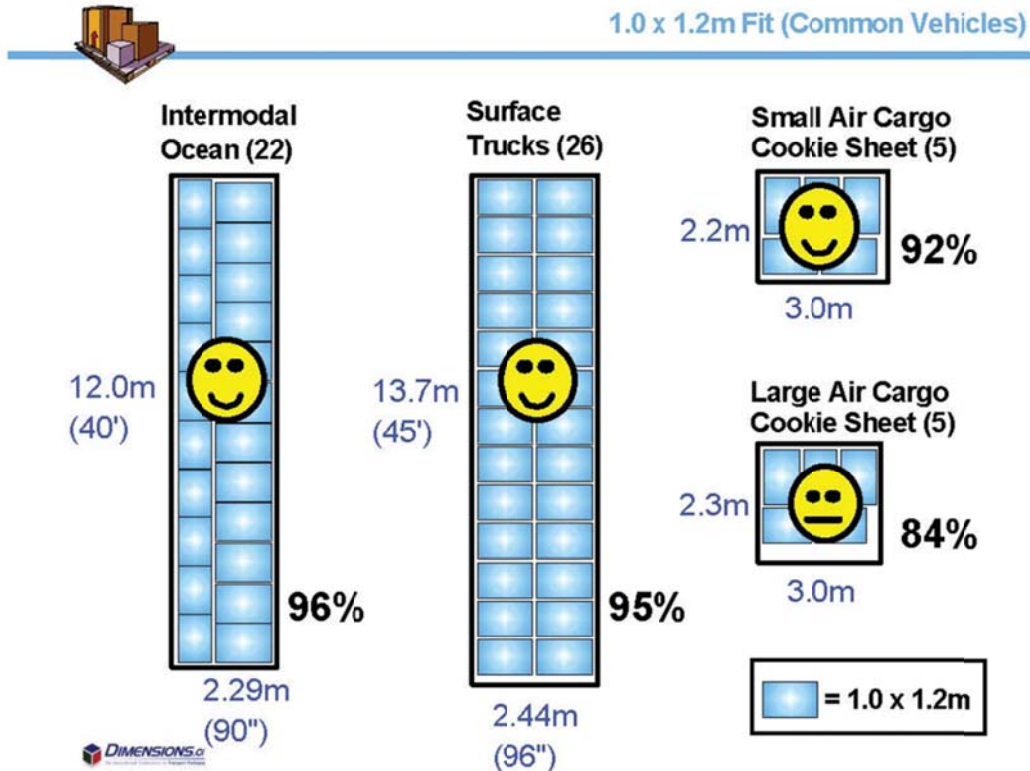
Air: Avg. on two most common "cookie sheets" (88x125" and 96x125" O.D.) less 4" trim

Ocean and Surface: **Avg. of 7** different intermodal containers from CAPE 99 and Maersk-Sealand data

Bottom Line: There is no single set of dimensions that is optimal for ALL modes



Below we can see the "fit" of the 1.0 x 1.2 m pallet footprint in the various modes. This also highlights the advantages of a rectangular pallet shape vs. a square pallet shape. A 48x40" pallet can be loaded in the 40 or 48" wide direction. This allows 2 pallets side by side to be 80", 88", or 96" wide. A square pallet, such as the common 44x44" size, can only be loaded 88" wide. Since interior dimensions of equipment will vary, rectangular pallets allow better cubing of a wider variety of transportation equipment.



Transportation and Pallets: Key Components and Opportunities

- Record the width, length, and height of transportation options. The usable dimensions will be a few inches less than the full dimension. Does your pallet “fit” the more expensive parts of your supply chain transportation?
- Does your product ship by weight or cube? If weight, is it possible to reduce the pallet weight? If by cube, can you adjust the pallet footprint, or use a low profile pallet?
- LTL freight – does the pallet design have any impact on the LTL class? A heavier pallet might actually lower your LTL rate. Would a smaller pallet lower your LTL rate?
- Airfreight – most expensive transportation mode. Is your load dimensional or weight based? Would a different pallet have any impact on airfreight costs? We have seen cases where a lighter \$15 plastic pallet is much lower “cost” than the heavier but lower priced \$5 wood pallet.
- Would a rectangular pallet size be more efficient than a square pallet?
- Would a block style pallet be more efficient than a stringer style pallet?
- Some of the greatest opportunities for cost savings lie within the transportation modes. In very few companies are supply chain decisions and pallet sourcing decisions made together. ***This is one of the MOST overlooked opportunities for cost savings today.***

Summary

Both Material Handling Equipment Designers and Pallet Designers are tasked with lowering costs to remain competitive. In many cases, Equipment and Pallets are designed and purchased by different design teams. Since pallets and equipment are interactive, changes to one will affect the cost and performance of the other. Most companies are planning equipment upgrades in the next few years. These upgrades will create excellent opportunities for designers with a knowledge of Packaging, Pallets, and Material Handling Interactions to improve performance and reduce costs for the overall system.

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