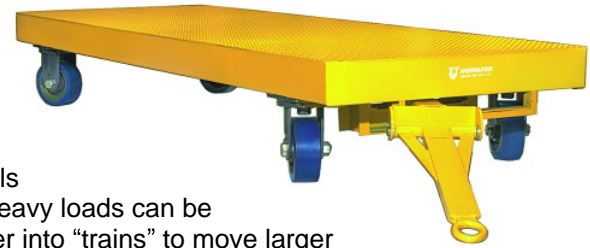


## ***Design Principles of In-Plant Trailers***

By Dave Lippert & John Yater



In-plant trailers represent a “tried and true” method of moving materials through plants safely and efficiently. Since these are power towed, heavy loads can be moved with little ergonomic risk. Trailers can also be coupled together into “trains” to move larger material volumes economically. Often more important, trailers are easily adaptable to changes in product line or plant layout, unlike fixed conveyance systems that are more expensive and lack flexibility.

Current buzzwords such as “manufacturing cells”, “kanban”, “material presentation”, and “JIT” (Just In Time) all require interaction with efficient transportation. Competitive production depends on minimal waste, and on having the right materials at the right place in the right quantities at the right time. Everyone is working hard to reduce costs. Emphasis on ergonomics argues for judicious handling of parts, particularly heavy ones. Frequently, the best solution to material handling challenges includes the use of industrial trailers.

While trailers look alike at first glance, there are some significant differences that greatly affect performance and cost. The wise purchaser will study the differences and select the system that makes the best sense for the specific application. Obviously, there is no universal right answer.

### ***Design Load Factors***

When specifying a trailer, the intended load is the primary consideration. If all loads are about the same, the selection process is easier. If not, then one must work with worst-case scenarios or “typical” loads.

The size of the load surface, or deck size, is usually the first choice to be made. The load or loads to be carried will factor heavily in the determination of a deck size. And the size of the deck will impact required aisle widths and practical length of trains that can be safely pulled. Anyone involved in the layout of a warehouse understands the importance of aisle width in the cost of storage equation. Clearly there are tradeoffs in this process. Wider aisles permit wider trailers and longer trains yielding potential reduction in handling costs, but they cost dearly in terms of space remaining for storage racks or systems.

The total weight of a load unit is important, but the center of gravity must also be considered. While most loads are presumed to be uniform (load distributed evenly within the container), some may have a significant portion of weight concentrated at one point. Load size and quantity or number of units to be carried combine to determine optimum deck size. If varying loads will be transported, consider the potential combinations when determining deck size. Also, will loads be stacked? Stacked loads and very tall loads require caution due to a much higher center of gravity. While turning presents a serious risk for taller loads, the presence of ramps or uneven floor conditions may completely rule out stacking loads.

Design engineers may project likely load combinations and limitations in “ideal” conditions, but they should try to anticipate how trailer systems might actually be used by the operators. “Creative” employees have been known to stack extra loads beyond the ends of trailers, and even place them over the couplers! Welded end racks or more appropriately sized trailers may reduce the likelihood of such misuse.

The capacity rating of a trailer is based on the running gear and the frame or structure. This rating considers the maximum load as a uniform load spread over the entire deck area. Besides the maximum weight of the anticipated loads, consider the possibility of shock loading due to abusive loading or unloading techniques and obstacles on the floor. Large floor imperfections or debris will transmit significant shock to trailers and their loads, as will dropping cargo from a lift truck or overhead hoist.

## Basic Designs

The deck is important, but what's underneath it is even more important. The "running gear", or wheel system including the steering portion, is crucial to performance and life. Stability, tracking, and pulling force are some of the factors affected by running gear.

There are at least five basic categories of steering systems: caster steer, fifth wheel steer, four wheel steer, auto steer – two wheel, and auto steer – four wheel. All of them share the inherent capability requisite for trailers – they "track" in a consistent pathway (each trailer tracks roughly in the preceding one's footprint). As one might guess, the differences are in both cost and performance.

**Caster Steer Trailers** have two swivel casters at one end and two fixed load wheels or rigid casters near the other end. Placement of the fixed wheels is critical to the trailing characteristic. Typically, each succeeding trailer tracks "in" slightly from the preceding one, making slightly wider aisles a necessity. This type is the most economical due to its inherent simplicity.



Caster Steer

**Fifth Wheel Steer Trailers**, like a child's wagon, feature a single pivot point for the front axle/wheel assembly and fixed rear wheels. Again, placement of the rear wheels is critical to trailing performance. The steering axle is "pinned" along the centerline of the trailer, and typically contacts the trailer body through a fifth wheel plate assembly. The trailer width and load capacity determine the appropriate size of the plate assembly. Typically there are "stops" (that limit the degrees of available turning) to prevent oversteering the trailer. These trailers will track "in" from preceding ones, requiring slightly wider aisles for turns.



Fifth-Wheel Steer

**Four Wheel Steer Trailers** have no fixed axles. Both axles pivot for steering, and they are connected to each other by a steering rod. This arrangement enables a tighter turning radius and more accurate tracking than two wheel steer models. Cost is higher than for single fifth wheel trailers, and there may be a slight decrease in lateral stability. One quality feature to look for is proper coupler structure. Optimal tracking and strength is achieved when the rear coupler is tied to the frame.



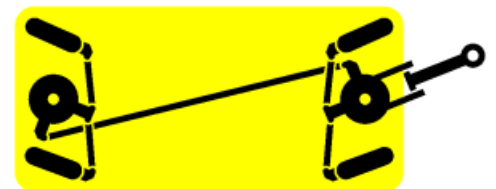
Four Wheel Steer

**Auto-Steer Trailers (Two Wheel Steer)** have a steering system that mimics an automobile. The turning wheels pivot similar to automobile wheels, maintaining more front corner stability than the fifth wheel steering trailer. As before, the rear wheels do not steer but must be located precisely for accurate tracking. Due primarily to the complexity of the steering mechanism, these trailers are considerably more expensive than caster steer trailers.



Auto-Steer (2 wheel steer)

**Auto-Steer Trailers (Four Wheel Steer)** have both front and rear steering as described above, connected by a steering rod to coordinate turns. Tighter, more accurate turns result while maintaining solid lateral stability, albeit at a price. A trailer with this steering type can cost 2-1/2 times a caster steer trailer of the same deck size.



Auto-Steer (4 wheel steer)

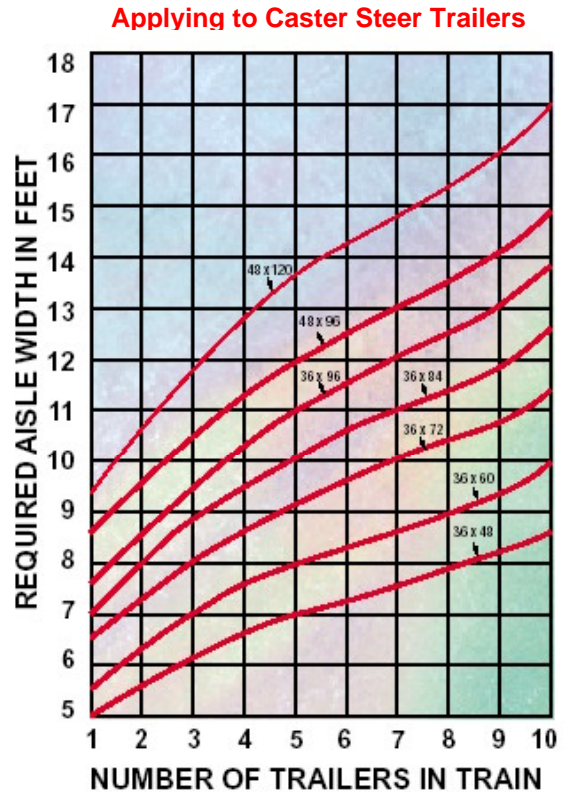
## Trailability

Accurate tracking is crucial to an effective trailer system. The benefits are numerous, ranging from minimal aisle space (cost savings) to fewer collisions and corner damage during turns (more cost

savings). Generally the accuracy in tracking coincides with the steering type and complexity. Caster steer and fifth wheel steer trailers track least accurately, while four wheel steer trailers track the best.

Depending on how a system of trailers is used, the maneuverability of any one trailer may be important. Interestingly, the ranking order of maneuverability is opposite to that of tracking. That is, the more accurately a trailer tracks when being towed, the less maneuverable it is when handled individually. Caster steer trailers are by far the easiest to steer manually, while four wheel auto-steer are the most difficult. System engineers may elect to compromise somewhat on trailability to achieve a more maneuverable trailer. This approach might be useful when a train will be towed to a general area and individual trailers will be disconnected and moved into specific positions for loading/unloading. When uncoupling and moving manually is expected to be a rare event, the auto-steer design may be most efficient.

The number of trailers that can be safely towed is another significant factor. There is a mathematical interdependency between trailer length, width, aisle width requirements, and number of trailers. Hamilton Caster has developed a nomograph to assist in using these factors for good planning for caster steer trailers (see graph). Hamilton's Engineering Department has developed models for determining the appropriate ratios for other steering types. High productivity normally demands maximum loads be towed in longer trains. On the other hand, longer trains require wider intersecting aisles, and wider aisles reduce available storage space in a warehouse. For this reason there is seldom a "right" or "wrong" answer, but there are certainly better and worse approaches. For general safety and everyday practicality, Hamilton normally recommends a maximum of five trailers in a given train.



The trailability factor is dependent on the length of the trailer from connecting point to connecting point. The points where the couplers connect to adjacent trailers determine the towing length. The type of coupler used is an important factor. An imprecise coupler, such as an automatic coupler, permits lots of movement between trailers. The relatively wide "bail" on an automatic coupler affords significant lateral movement of the adjoining trailer jaw. This can degrade the trailability and cost in extra aisle width or reduced train length. Of course, automatic couplers bring some benefits to the material handling equation and may be the simplest solution despite their negative impact on trailability.

One other facet of trailer design impacts trailability and trailer deck size: corner design. The distance from the front coupler to the rear coupler is a key dimension. The actual deck length must lie between those two points. One way to maximize the deck length while conforming to the width requirement is to round the outside corners. During tighter turns, trailers may actually "pinch" at the corners. Rounded corners permit tighter turns or reduce the likelihood of contact between trailers. Two additional advantages of rounding corners are personnel safety and reduction of property damage vs. sharp 90-degree corners.

## Stability

Safety is paramount in every trailer application. Cutting corners in this area can be costly in both human and economic terms. Design determines trailer stability, and towing operators should be instructed in these characteristics.

Running gear placement or orientation is the first determinant of stability. Any trailer with fixed running gear poses a stability risk during loading. For proper trailing, the fixed running gear must be set well forward of the rear edge of the deck. The risk here is that someone may overload the rear deck overhang and create a tipping situation. Much like a restaurant server loading drinks onto a carrying tray, everyday physics tells us that loading a trailer first at the unsupported end causes problems. Likewise, unloading the unsupported end last can have the same deleterious result. All personnel involved in loading trailers must know the proper sequence, and understand the consequences of improper loading.

Trains of trailers will be pulled around corners as they weave through plants. Loads stacked high raise the center of gravity of a trailer, creating a tipping tendency during turns. Soft wheels such as pneumatics are particularly susceptible to this. Production pressures might motivate material handlers to stack loads too high and/or travel too fast. The combination of the two is particularly hazardous. Training and supervision can prevent either of these from happening. The size, configuration and weight of loads determine appropriate stacking practices. In-plant speed limits and even towing equipment governors may be appropriate to address excessive speed.

Ramps pose problems for fifth wheel, auto-four-wheel-steer trailers, and for trailers connected with automatic couplers. It is possible for automatic couplers to twist in such a fashion as to become disconnected, posing an obvious safety risk. Connecting steering rods are vulnerable to ramps and may bind against the pavement in extreme cases. If ramps must be negotiated, consider employing only “straight on” approach and departure routes, and strict enforcement of slow speeds during travel up or down. Experimentation may be necessary to determine how steep a grade can be safely negotiated.

Finally, fifth wheel trailers, particularly those with four wheel steering, pose their own unique stability challenge. Despite the obvious fact that the wheels are at the outside edges, the axle assembly is essentially “pinned” along the centerline of the trailer. A single fifth wheel plate assembly located on this centerline, regardless of its size dictated by the trailer’s size and capacity, provides the only lateral support for the front end. For four-wheel steer trailers, lateral stability comes only from a fifth wheel at both ends. Users must employ extreme caution in loading (maintain low centers of gravity), traveling (slow considerably in all turns), and ramps (best to avoid these completely with this running gear arrangement).

## ***Structural Considerations***

To a casual observer, the size of side and end frame members may seem to be the most important aspect of the “strength” of a trailer. But only by checking the entire bolstering structure underneath the deck can one discover the truth.

Considering the longitudinal pull on any trailer, a center rail is an absolute necessity. There must be adequate support to withstand the tremendous longitudinal pulling forces at both ends of a trailer. Extraordinarily heavy loads may warrant two center rails, located at or near the centerline. The absence of a center rail is a recipe for serious failure problems down the road.

Side loads represent another potential problem. These may be imposed during loading and unloading. Forklift operators may occasionally misjudge the height of their load and the trailer deck height, and hit the trailer side rail with either their forks or the load itself. This puts incredible force on the axle supports, or the plates on either side of the wheels. Caster steer trailers do have at least one advantage here. If this happens at the swivel end of the trailer, the swivel casters will turn to align with the side load, and probably avoid damage. But the end with the rigid casters remains at risk.

Actual movement of trailers, particularly when loaded, may also introduce side forces. Simply turning a corner creates lateral forces on a loaded trailer. In some instances, corner posts designed to protect rack uprights at the ends of large warehouse aisles become “rubbing posts” for trailer trains, and extreme side forces suddenly emerge.

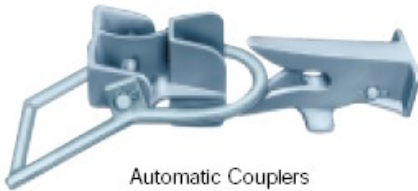
Axle supports, or steel plates welded between cross members, are generally more resistant to these forces than rigid casters. Casters may be strengthened with gussets, and even axle supports may have lateral reinforcing members to add strength. Prudent planning normally involves “worst case” scenarios, and the wise planner anticipates stresses such as side forces and designs accordingly.

Fifth wheel plate size, particularly in four wheel steer trailers, impacts lateral stability. Smaller diameter fifth wheel plates may be adequate for a given load in static conditions, but they can become woefully inadequate when trailing a full capacity load. Generally, a larger fifth wheel plate translates into more lateral stability.

Rigidity can be described as the trailer’s resistance to twisting and flexing. Construction of the deck and undercarriage plays the largest role in rigidity. Open frame trailers (no deck) typically employ structural tubing in the frame for both strength and aesthetic purposes. Steel deck trailers, the most laterally rigid design, more frequently use structural channel in their frames. Wood deck trailers feature structural angle frame members, although the heavier duty versions typically use channel frames with the deck boards bolted on and secured with angle hold-down strips. Different sizes and placement of structural members can cause key differences in competing trailer bids, although not apparent to the eye. Inadequately designed trailers are subject to twisting and flexing during use, and risk premature failure.

## **Ergonomics**

At first glance, a system of trailers pulled by a tugger appears to be a perfect ergonomic choice. After all, the only exposure to ergonomic problems seems to lie with the driver. Actually, there is much to consider: coupling and uncoupling trailers; lifting the tongues, including unguarded jaws; and moving trailers manually into position.

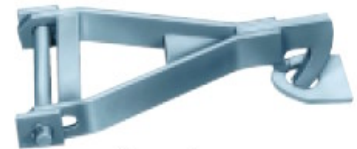


Automatic Couplers

By definition, trailers have the capacity to be coupled together and then uncoupled as required. The physical effort required for these activities varies by coupler design. The automatic coupler, as its name implies, allows trailers to be coupled “automatically”. The loop or bail, as it is known, can actually engage the “jaw” of the adjacent trailer simply by pushing the two together. Uncoupling involves stepping on a jaw pedal and simultaneously pushing the two trailers apart. It is the manual pushing or pulling of a trailer that carries the risk of injury.

Manual couplers require a person to raise or lower a wishbone tongue into or out of an “eye” mounted on an adjacent trailer. Jockeying trailers into position while lowering the tongue can create an ergonomic problem. Manual couplers typically have an “over center” position for stowing the disconnected tongue in an upright position, and can be fitted with spring-loaded stops to prevent the tongue from dropping to the floor. Additionally, attaching convenient handles to tongues permits easier grasping by personnel.

When disconnected, the jaw end of a trailer can be a real hazard to shins. For this reason, optional toe/shin guards around the coupler jaw are available to minimize likelihood of injury.



Manual Couplers

Finally, manually positioning trailers around the factory or warehouse floor can be difficult. Caster steer trailers have the advantage of a handle at one end, while other trailer types are unlikely to have a superstructure available for pushing leverage. All else being equal, caster steer trailers are easily the best choice for manual maneuvering. Obviously, the best situation is moving unloaded trailers.

## **Wheels**

Arguably, proper choice of wheels may be the most important aspect of everyday trailer performance. Wheels affect noise, pulling force required, floor and load protection, and longevity of the investment.

Efforts to economize in the selection of wheels may result in extra maintenance costs as premature failures lead to unplanned downtime and additional costs. Perhaps it is unfortunate in some ways that there are so many choices to make when selecting wheels!

Load capacity and maximum speed are the primary factors to consider. Additionally, noise, anticipated side loads, usage, floor and load protection, and shock loading are important, too. Constraints usually include deck height and cost.

Trailers by definition are intended to be towed. For this reason, we expect higher speeds and longer travel distances with trailers than with manual carts. Straight roller bearings are typically inadequate. They provide virtually no resistance to side forces, present in every trailer application. Also, they are generally not intended for continuous duty and higher speeds in conditions typically experienced by trailers.

Tapered roller bearings are the best choice for trailer wheels. As with automobiles, tapered roller bearings have a long history of capable service on trailers. They are designed for both higher speeds and the rigors of impact loads and side loads encountered when cornering. These are the best choice for severe towing conditions.



**Tapered Bearing**

Precision ball bearings feature the ergonomic advantage of minimal rolling resistance. Like the tapered roller bearings, they are suitable for both horizontal and vertical loads as well as higher speeds and sustained use. For trailers that may see manual movement, these bearings offer the least rolling resistance although their capacities are more limited.

Available tread types for wheels are numerous, and offer a myriad of both advantages and limitations. Softer treads, either pneumatic or solid rubber, provide load cushioning, quieter running, and better traction. Harder treads like polyurethane provide more capacity while still protecting floors and offering some noise reduction over the hardest materials. Solid materials, such as forged steel, have the maximum load capacity and are virtually indestructible. But they also damage floors unless a system of tracks is employed.



**Precision Bearing**

Disadvantages of each major tread type can complicate the selection. Rubber tread wheels have reduced capacities. Polyurethane is susceptible to heat buildup during sustained speeds. Steel wheels are noisy, abusive to plant floors, and have a greater tendency to slide around corners (particularly when the trailer is unloaded).

Desired deck height impacts the wheel selection. Generally, larger wheels are preferable for trailer applications. Larger wheels turn fewer revolutions per unit of distance, and therefore bearings run cooler and treads last longer. Also, larger wheels are less affected by debris on the floor and other obstacles.

Floor conditions, intended speed, anticipated running time, load requirements, rollability and acceptable noise level comprise the major considerations for wheel selection. One may expect some trade-offs, with no "perfect fit". Experienced trailer manufacturers know the right questions to ask and bring the value of others' experiences to the table.

## **Options**

There are limitless opportunities to customize trailers for specific uses. Most of these involve the superstructure, or features above the deck. But two "below deck" options are noteworthy.

Reversible steering is available on four wheel steer trailers. Importantly, trailers are not designed to be "backed up" or reversed while connected. This is particularly true of four wheel steer trailers, which will suffer serious damage to the steering connecting rod. Reversible steering enables the operator to disconnect the towing tongue from one end and reattach it to the other end. This feature probably argues for hitches at both ends if the trailer is to be used in trains.

A parking brake is available on fifth wheel steer trailers. Typically this engages a bar to secure both wheels on one axle, and is activated through the tongue. Brakes are most effective on softer tread wheels, and are designed to hold a trailer in a stopped level position, not to stop it when moving or to hold a trailer on a ramp or sloped surface.

Superstructure options are limited only by the imaginations of those designing them. Load configurations usually drive these choices. Examples include cradles for rolls or tubes, tie down rings, wood cross rails on decks for lift truck access to loads, fork pockets for proper trailer lifting by lift trucks, stake sockets, shelves, tool cabinets, conveyor sections, ball transfer tables, and special deck materials. Customizing trailers can play a significant role in the utility and efficiency of the trailer by improving material handling.



## **Maintenance**

Industrial trailers have few routine maintenance requirements. But total neglect can be counterproductive, so a basic PM plan is well-advised.

The parts that turn require the most attention. Wheels should be checked periodically for tread condition and proper bearing operation. Most wheels with tapered roller bearings will be equipped with lubrication fittings. Precision ball bearings are normally considered “lubed for life”, depending on effectiveness of the seals. Fifth wheel assemblies, auto-steering assemblies, and swivel casters have lubrication points. All of the above should be lubricated at least annually, depending on the usage and environmental conditions.

Wheel tread wear may reveal some problems. Softer treads, particularly rubber, may pick up considerable metal chips or other debris from the floor. These will result in reduced tread life or even damaged floors. Any flat spots indicate a dragging wheel, and a locked wheel bearing is an immediate suspect. Uneven tread wear suggests a bent axle, or if always on the outside, excessive cornering speeds. Tread separation from the center usually signifies failure of the bond, while chunking out of tread material may be more difficult to diagnose. Whether caused by excessive heat buildup, abusive side forces or manufacturing defect, any significant tread failure seriously compromises performance and safe operation, demanding immediate replacement. In bond failure, the separated tread may be shifting from one side of the wheel to the other, held on only by the axle supports or caster “legs”.

At least annually the swivel action of the steering assembly should be checked and lubricated (swivel casters, fifth wheels, or auto-steer assemblies). Any looseness indicates excessive wear or possibly shock loading. Trailers exhibiting looseness should be pulled from service for tightening and more thorough checking. Missing steel balls from the main bearing raceway are often a sign of shock loading. Contact the manufacturer for assistance.

Excessive wear of bearing raceways is rare, but possible in unusually demanding applications. Heavy loads and continual steering, especially in multi-shift service, may be the cause and may be normal in the circumstances. Hamilton recommends heat-treated swivel raceways for caster and auto-steer mechanisms when facing such rigors. In some cases where assemblies were not heat treated, it may be possible to repeatedly re-tighten them. A better long term choice, however, is replacement of the worn parts with new heat treated ones.

Excessive side forces become evident in several ways. Serious rub marks on either or both sides of the trailer indicate dragging around obstacles. Wheel treads separating from the centers or exhibiting significant cross-tread scuff marks are signs of extreme side forces. Finally, structural damage - typically bending of the axle supports or rigid casters - points to a serious problem. While special stiffeners can be applied to a trailer’s running gear, first check the application to be sure there is no abuse (such as rubbing posts or rack uprights during turns or improper loading techniques). Damage to axle supports or casters requires parts be replaced with stronger or reinforced frames. Simply bending parts back close to their original shape only invites further failures.

Couplers normally require only a visual inspection. Since couplers make contact with one another as part of their design, wear can be expected. The loop, or bail, may show wear on the inside radius. The jaw assembly typically shows wear on the “dog”, or the part that engages the loop. When 1/8” of material (from the original dimension) is worn away, the part should be replaced. Perhaps the most serious sign of trouble, though, is actual deformation of the loop which indicates some binding or other problem occurring during towing. Any part that is not symmetrical is suspect.

Finally, a general inspection of the complete trailer and all its parts is recommended at least annually. During this inspection, look for broken welds, loose deck, and loose or missing bolts. Be particularly cognizant of the welds around couplers and center support rails.

### **Conclusion**

Selecting any kind of material handling system can be challenging, especially when everyone is attempting to meet increasing production demands with limited space and budget. This is why every successful operation is taking a close look at factors beyond initial cost to total costs of ownership: maintenance, downtime, efficiency, flexibility and life. A trailer system inherently offers economy and flexibility. When that system is professionally designed and built from quality components selected to fit a specific application, it can offer much more.

Hamilton Caster & Mfg. Co. has been designing and building industrial trailers and their running gear for over half a century, and stands ready to help any company with its material handling needs.

### **Examples of Various In-Plant Trailers:**

