Hamilton Caster

No. 13

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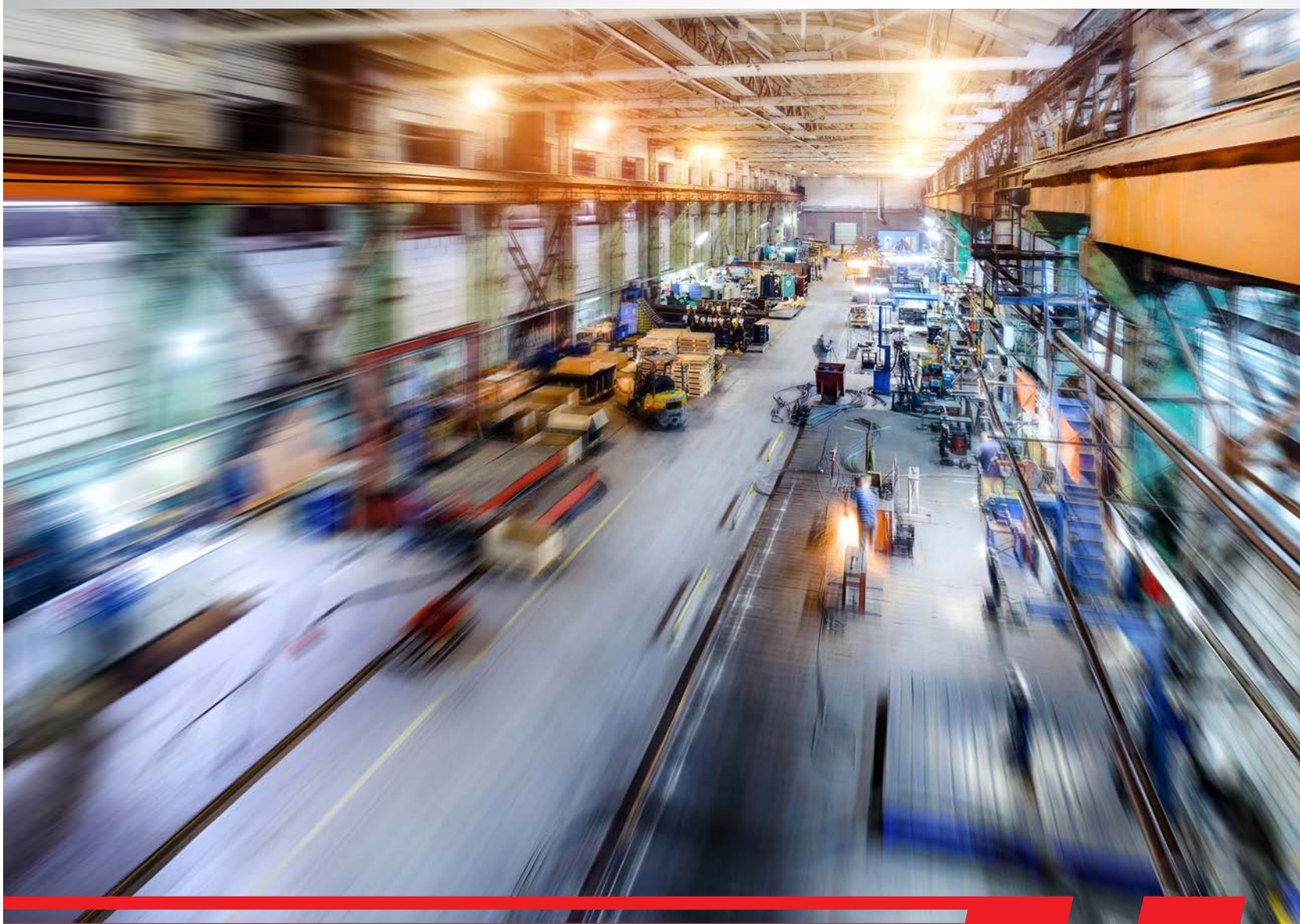
Steering Systems | In-Plant Trailers



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Truck Steering and Trailability

Industrial trailer applications come in many forms. The common use is efficiently moving as many parts as possible from one place in a factory or warehouse to another. It may well be thought of as internal logistics. Industrial trailers, and particularly trains of more than one trailer, often top any cost/benefit analysis. Yet the kind and arrangement of wheels and steering system can dictate success or failure in an application; there is no "one design fits all." Consider the following different scenarios:

Scenario #1: *Susie waited near the delivery station while Stan dropped the last trailer of his train of five. She always lamented her "turn" to move the loaded trailer into position. Sure, it was easy for Stan to pull five of them with his tugger. But at 5'4" and a trim 125 pounds, she struggled to maneuver the loaded trailer into position. She did it only two or sometimes three times each day, but it was her least favorite part of being an assembler.*

Stan left it in the middle of the aisle, and with a quick wave of his hand, was off to the next station. He might have offered to help her move it, but his route didn't afford him time for that. Susie grasped the handle, planted her feet, and pulled with all her might. Slowly, almost imperceptibly, the trailer began to move. A long minute later, the trailer was in position and ready for use. She breathed a sigh of relief, and took her spot back on the assembly line.

Scenario #2: *Ben climbed onto the tugger, wondering how the trailers from "B" Warehouse would handle in his "A" Warehouse aisles. Normally he pulled three trailers, collecting cartons of product along the way to shipping. But his regular trailers were somewhat shorter, and he had no problems avoiding the concrete safety columns at the end of each aisle. He had a few minor scrapes in his first month, but since then had "rubbed" no paint onto the trailer sides. Night shift, however, was a different story.*

The "B" warehouse had wider aisles, and often towed four trailers in a train. But not in "A" Warehouse, where the narrower cross aisles made that impossible. Ben's "A" trailers were offline for maintenance. So, for one shift, he had the longer "B" trailers. With his pull orders in hand, he accelerated cautiously and approached the first turn. It was a 90 degree turn to the right, from a wider main aisle into a narrower cross aisle. Following his training techniques, he hugged the left

side of the aisle, turning "wide" and favoring the left side of the cross aisle. He kept his speed well below walking, and closely monitored the trailers as each passed by the safety column. The last one cleared by only an inch or two. It was going to be a long day!

Scenario #3: *Jane paused as she prepared mentally for the next maneuver of her tugger. Last hour she had borne the brunt of her co-workers' jeers as she attempted to back a loaded industrial trailer up to the assembly workstation. While not hitting anything, it had taken several "adjustments" as she pulled forward, then back, to get it even close to the desired spot.*

Narrow aisles and production floor overcrowding had made most assembly-line trailer drops back-in events. The company simply couldn't find the extra space to have pull-through opportunities. Pulling one trailer at a time was easy, and navigating aisles safely without hitting anything was a piece of cake. But backing was the tricky part. Even when she was well-positioned to back straight into a space, the trailer could take an unpredictable turn and suddenly a routine maneuver became a challenge.

Caster Steer Trailers

A caster steer trailer is essentially a platform with swivel casters at one end and a form of non-steering wheels at the other. Proprietary formulas are used to position the running gear in the optimal position to maximize both stability and tracking. Applicable design factors include trailer length, trailer width, coupler lengths, number of trailers in the train and location of the rigid wheels.

The fixed wheels that maintain straight-ahead direction are either axle-mounted or in rigid casters at the rear. Axle-mounted wheels are typically larger than the caster wheels and are mounted between wheel brackets (steel plates welded to the frame). Due to their higher capacity, these wheels can be positioned closer to the load-bearing center to carry more of the load than the swivel casters. Such an arrangement also has the benefit of lowering the overall push force required because a higher percentage of the load will be carried by a larger diameter wheel. Compared to rigid casters, the axle brackets of a load wheel design will generally be more structurally robust and resist side forces better. Rigid casters make more sense in lighter duty applications and represent a more economical choice.

Couplers are mounted directly to the trailer frame. The towing stresses are passed from coupler to coupler along the center longitudinal frame members. When considering the maximum carrying capacity of each trailer and the total number of trailers to be towed in a train, and the stress on the lead trailer (connected to the tow vehicle), one will gain appreciation for the importance of these center frame members. Trailers can be equipped with either manual or automatic coupling systems. The automatic type couplers engage when the tow vehicle is backed into a trailer or trailer train equipped with a mating coupler. They are manually disengaged. Manual couplers are coupled and uncoupled by hand.

Caster steer trailers that will be maneuvered by hand typically have a removable push handle for manual operation. Such "convertible" trailers may warrant some form of protection for the shins of the manual operators, such as an effective bumper or frame around the coupler at the handle end.

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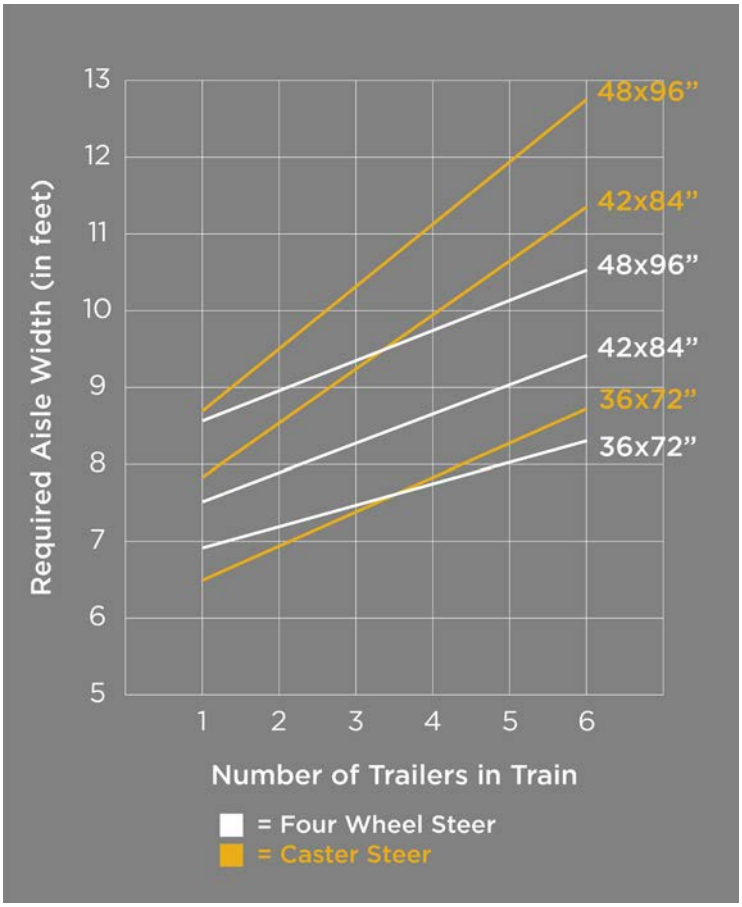
Fifth Wheel Steer Trailers

Fifth wheel steer trailers have front and rear wheels mounted on axles, and employ a design in which a pivoting tongue attached to a running gear assembly at the front rotates on a "fifth wheel" plate around a kingpin. The famed little red wagon (kid's toy) uses this design! Positioning of the non-steering axle-mounted rear wheels determines the relationship between stability and trailability. If the rear wheels are too close to the longitudinal center, fore/aft stability is compromised when loaded. If they are too close to the rear of the trailer, trailer maneuverability is reduced. This design is well suited for power towing, singularly or in trains, and can be towed at higher speeds than the caster steer trailers. Rear couplers, if so equipped, are directly mounted to the frame.



Primarily for stability reasons, most fifth wheel steer trailers have steering "stops." Steering stops are physical limitations on the steering range, physically limiting the degree of turning available. Absent these stops, a sharp turn would cause loss of support under the front corners as lateral front wheel spread diminishes (again, think little red wagon with tongue turned 90 degrees).

Four Wheel Steer Trailers

The four wheel steer trailer has a pivoting assembly (fifth wheel) at both ends of the trailer connected via a tie rod so that the rear running gear turns in the opposite direction of the front. Precise location of running gear components is paramount for peak performance. This arrangement causes the rear wheels of the trailer to follow in the track of the front wheels, permitting tighter turns.

The four wheel steer trailers shine when it comes to pulling longer trains of trailers through tight aisles and intersections, or where space considerations dictate maximizing storage capacity

and minimizing aisle widths. Tracking means that each successive trailer in a train follows approximately the same path as the preceding one. Generally, the longer the trailer train and/or the narrower the aisles, the more advantageous is the four wheel steer design. Optionally, the four wheel steer trailers can be outfitted with tongues at both ends to allow them to be towed in either direction (reversible). The more sophisticated four wheel steer is a design challenge for the novice trailer manufacturer. Therefore, for peak performance, care should be used to select a trailer manufacturer with expert design engineering capabilities.

Four-Wheel Steer Trailer

Compared to four wheel steer trailers, fifth wheel steer trailers are more economical and work very well when pulled solo. Also, these trailers can be backed up more easily than the four wheel steer version but only when solo. Trains of more than one trailer of any steering type should never be reversed, or "pushed." When a train is reversed, it places opposite forces on some of the steering components and can quickly result in structural damage.

Two Wheel Auto-Steer Trailers

Automotive steer trailers mimic the steering system in an automobile. The two wheel auto-steer trailer has fixed wheels at the back end that maintain straight-ahead direction. In front, a pivoting tongue is attached to a "hound" assembly that rotates around a kingpin. Tie rods span the distance between the hound assembly and the wheel assemblies. Each wheel assembly rotates on its own axis. The inside wheel needs to turn tighter (smaller radius) than the outside wheel to reduce the amount of tire/wheel "scrubbing" resulting from different turn radii. The biggest benefit of auto-steer trailers is maximum stability. The running gear stays under the corners of the load as the steering assemblies turn, as opposed to the fifth wheel design where the entire axle assembly turns. From a trailability standpoint, the two wheel auto-steer performs similarly to the fifth wheel steer trailer.

Four Wheel Auto-Steer Trailers

Four wheel auto-steer trailers replicate the design of the front steering in the back, replacing the fixed wheels. Both front and back steering assemblies are linked together, and all four wheels turn appropriately during turns. Since all wheels remain essentially in position under the load, stability is preserved even during turns. From a tracking standpoint, the four wheel auto-steer performs almost identically to the four wheel steer.

Of the two types of auto steer trailers, the two wheel version is less expensive, easier to back up, and is the smart choice if towed solo since tracking will not matter. The four wheel auto-steer

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trailers should be used when towing long trains or when reversible towing is needed. Reversible towing means towing from either end, not backing up!

Among all the trailer types, the auto-steers require the most engineering know-how to produce and caution should be used when choosing a manufacturing source. A manufacturer with ample experience in the design, testing and support of trailer systems is the greatest assurance that your chosen system performs to your satisfaction and provides many years of trouble-free service.

Trailer Steering Matrix

	Caster Steer	5th Wheel Steer	Four Wheel	4-Wheel Auto	2-Wheel Auto
Towed & Manual					
Towing 1-4					
Towing 5+					
Tight Aisles					
Speeds to 5 mph					
Speeds 5+ mph					
Towed from Both Ends					
Loads with High Center of Gravity					
Maintenance Cost (relative)					
Purchase Price (relative)					
Key	*Best*	*Good*	*Fair*	*Poor*	*Worst*

Compare & Contrast Basic Designs in Various Applications

Combined Manual & Towed Operation

When faced with an application involving both power towing and manual positioning, caster steer trailers work very well. To help reduce the push/pull forces needed to manually move the trailer, large diameter wheels rotating on ball bearings are better. The larger diameter wheels will almost certainly have a much higher load-bearing capacity than required, but the reduced pushing and pulling forces make this a wise choice.

Along with diameter, tread type plays a critical part in wheel performance. Resilient tread wheels, including solid pneumatics and various types of polyurethane, are popular for several reasons. First, they protect the floor from wear and damage that can result when forged steel or cast-iron wheels are used. Second, they are significantly quieter than the hard wheels. Third, they provide more "grip" (friction) with the floor, avoiding any trailer skidding during turns (a phenomenon that is more likely when trailers are towed empty). Polyurethane wheels are a great choice when trailers will be moved manually as well as towed, since they provide easier rolling. They also experience less wear during use, and will last longer. Finally, they have higher load capacity ratings than similar-sized rubber tread wheels.

Load Variation & Deck Size

When it comes to loads with relatively high centers of gravity with respect to the trailer width, either an auto steer or a caster steer trailer is optimum. Both trailers' running gear remain under load during turns, maintaining stability. Additionally, tweaking the position of the rigid wheels on caster steer or two wheel auto steer trailers can improve the stability to the slight detriment of the tracking. Knowing the sizes, weights, and shapes of the intended loads is vital in making good decisions about running gear.

The fifth wheel family of trailers, both four wheel steer and fifth wheel steer, are not recommended when the required deck size is almost as wide as it is long (approaching square). The pivoting of the running gear can create interference and/or a short wheelbase problem. In these instances, caster or auto steer trailers should be chosen.

Ramps, Inclines and Slopes

Ramps and inclines create added design issues and considerations, including coupler binding, interference problems, load stability challenges and potential loss of wheel contact. These can be addressed in a general form, but each application is different and must be looked at individually.

Encountering any slope or incline with a train of trailers can lead to binding of the couplers. The tendency to bind may vary depending on the angle of the ramp. Automatic jaw and bail systems are most susceptible in applications with slopes and ramps, and these are couplers more likely found on caster steer trailers. Loops and pintle hitches are available to better handle movement and reduce binding that can occur when engaging a ramp.

Insufficient ground clearance is another potential problem with slopes. The middle of the trailer may come into contact with the peak of the slope, or the front or rear of the trailer may come into contact in a valley. This is most likely to happen with four wheel steer and four wheel auto steer trailers since they have tie rods that span the distance between front and rear steering assemblies. Ideally the ramp dimensions are known prior to trailer design or purchase, and this can be avoided. If there is any likelihood of contact, counter measures can be put into place to protect vulnerable trailer components such as tie rods and drag links.

Narrow Aisles for Space Maximization vs. Trailer Design

Most warehouse designs consider aisle space to be essentially wasted. So the narrower the aisles, the better space is utilized. An entire genre of special narrow aisle lift trucks is marketed for this purpose. But towing trailer trains through the aisles of a warehouse argues for the opposite – wider aisles. In new "greenfield" designs, the optimum solution can be worked out by balancing the cost of space with the cost of operations. When one or the other (facility and existing aisles or existing tuggers and trailers) already exists, the options shrink. From the trailer perspective, when towing a single trailer through aisles, the type of trailer does not make a significant difference to required aisle width. When pulling multiple trailers, selection is paramount.

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Caster steer trailers and fifth wheel steer trailers, when pulled solo, can turn about a smaller radius (maneuver in narrower aisles) than four wheel steer and four wheel auto steer trailers due to steering stops. One might surmise that the tighter turning radius equals better tracking, which is not necessarily the case.

> "When pulling multiple trailers, selection is paramount."

Track width is a better indicator of turning. For this discussion track width is the dimensional difference between the innermost turn radius and the outermost turn radius. These radii are those associated with the inside wheels in a "sharpest turn" scenario and the outside wheels in the same turn. Track width directly relates to the aisle width that a trailer can safely navigate.

The remaining trailability factor is tracking, or the repeatability of the leading trailer of each subsequent trailer in a train through a turn. Caster steer, two wheel auto steer and fifth wheel steer trailers "cut in" with each passing trailer of the train. That means that each subsequent trailer moves somewhat closer to the inside of the turn, requiring wider aisles as the train length grows. Four wheel steer and four wheel auto steer trailers, when properly designed, vary by a much smaller amount, so aisle widths can be narrower.

Common "Abuse" Practices to Anticipate

There are common abusive environments, that if known in advance, can be addressed by design. Knowing the planned use practices and environment in advance of design is critical . These factors include shock loading, rough floors, slick floors, debris, extreme temperatures, fluids, point loading, chemicals present, salt spray, ultra-violet light, wind, and much more. Caster steer trailers may benefit from more robust rear wheel assemblies, such as heavier axle brackets in lieu of rigid casters. Four wheel steer and four wheel auto steer trailers may need protection for the tie rods and connecting linkages between the steering assemblies. Wheel selection is heavily dependent on environmental challenges such as ultra-violet light, salt spray, and chemicals.

Safety Considerations

Trailer design should incorporate safety factors, including trailer stability, load stability, travel speeds, wheel slippage, pinch points, clearances, safety margins, ergonomics, load center of gravity and visibility. Auto steer and caster steer trailers provide the best stability among the steering types.

In view of the steering types, design considerations, wheels treads and sizes, and the varying workplace requirements, trailer selection is not always easy. When assuming that all trailers are essentially the same, workers frequently bear the brunt of the consequences. How might the three scenarios posed at the beginning have concluded to favor the worker?

Scenario #1 Conclusion: *Team Leader Bill Johnson addressed Susie's production team prior to the start of the shift. Everyone except Bill was surprised by what occurred next. Stan drove up to the group with his familiar tugger, but with a brand new trailer attached. Stepping off the tugger, he explained to the group that the trailer was a prototype for the assembly teams to evaluate. Ideally this would have happened by soliciting the teams' input prior to ordering new equipment, but at least someone in management was trying!*

Gathering around the prototype, Susie noticed immediately that it was already loaded with parts. Underneath, the wheels were different from the old trailer, and it seemed to have a different steering system. Bill Johnson, noticing her scrutiny, acknowledged that the steering on the prototype was caster steer, while the existing trailer used a fifth wheel assembly on the front end. George, one of her teammates, disconnected the trailer and pushed it back a few feet.

He made it look easy, but then George was over 6 feet tall and weighed at least 230 pounds. Bill began to point out other features that made this trailer better than what they were using. He said it was mostly about the wheels, which were considerably larger than those on the existing trailers. They also featured a colored polyurethane tread that was designed for easier rolling. Besides the wheels, the handle had three crossbars, which meant Susie and George could push or

pull from more comfortable positions. Caster steering made manual maneuvering easier than tugging on a towing tongue to steer while pushing.

Bill urged Susie to try pushing it. She wondered if she could make it look as easy as George had. Grabbing the lowest handle crossbar, she leaned into it and began to push. It moved almost immediately. She noticed that it moved quickly and easily, and steered better than the old trailers, too. She pretended to position it in an imaginary spot on the assembly line. Her teammates actually applauded! She gave Bill a big thumbs up accompanied by a wide smile, and actually looked forward to her turns to handle the trailer during the coming eight hours. Then she remembered it was only a prototype, and that the old trailers were still reality for a while. The team agreed that this was a huge improvement, and asked how soon the fleet could be replaced. Bill answered that it would likely be a couple of months, but said that it was in the budget and approval was only waiting on the team's OK. That "OK" was loud and unanimous, and the team headed to their positions on the line knowing that their future looked better indeed.

Scenario #2 Conclusion: *The first thing Ben noticed was that there were four trailers attached to his tugger. The second thing was that they looked brand new. The third thing was that they had "A" painted boldly on the sides. These definitely weren't "loaners" from the guys in "B". He asked Phil, his supervisor, what was going on. He had lots of orders to pull today, and didn't need towing problems to get in the way. Phil replied that the trailers were in fact new, belonged to "A" warehouse, and that the design should permit four trailers in a train. He even said they were somewhat larger than the old ones, meaning they could handle even more "pulls."*

Looking them over more carefully, Ben saw they looked different underneath. Phil, sensing the impending question, explained that the four-wheel auto steer design meant these would trail each other almost exactly, and that he could take turns knowing the last trailer would follow the first trailer. Also, because they were auto steer, they were more stable than the old fifth-wheel trailers. Ben had never personally spilled a load, but there were plenty of stories about those who had. Loads stacked too high coupled with sharp, quick turns had led to several accidents. Fortunately, no one had been injured in any of them.

Phil said he understood if Ben came up a bit short on his pulls tonight since he had to get used to the new trailers. He hoped that having larger trailers, and having four instead of three, would help to compensate. With that, Ben boarded the tugger and started his route. He knew that any "rub marks" were automatically his today! Approaching the first turn, always from the main wide aisle into a narrower cross aisle, he slowed and began the turn. The first trailer passed well clear of the yellow post. But surprisingly, so did the next three. Once he stopped to begin loading from his thick stack of pull tickets, he appreciated the added length and width. He began to realize that he could make many more stops before returning to unload and begin again. Add the additional trailer to the mix, and he might approach a 50% gain in productivity!

As the shift wore on, Ben noticed something else. Instead of slowing to a snail's pace to make each corner, he was able to keep a more reasonable speed. His approaches weren't as critical, and he gained confidence in his ability to lead into a turn knowing the entire train would follow without rubbing any paint off the infamous yellow posts. With more than an hour remaining on his shift, Ben had completed the entire batch of pull tickets and was able to work ahead!

Scenario #3 Conclusion: *Liza Ketter, Jane's team leader, met her at the beginning of the shift. This was normal – it happened every day at 7:00 AM. But when she asked Jane to follow her, Jane's internal warning system started clanging! Was she in trouble? Fortunately, that thought only lasted a moment as they walked up to a new trailer, conveniently parked next to the old one. Liza explained why Jane had been struggling with backing up the old trailer. "It was designed for tracking around corners, and originally was used in a train of three trailers. When our aisles shrank, we couldn't pull the train through the corners. The other two trailers went to storage, and we pulled this one solo. But if you look underneath, you will see a pretty complicated steering system. It's called four wheel steer, so all the wheels turn together. Great concept until you try to back it up, as you well know!"*

Jane looked under the new trailer. It was completely different. "It's called caster steer, and was a lot less expensive than the four wheel steer trailers," Liza explained. "The steering casters are at the front, and the rigid casters at the back end. Go ahead and see if it isn't easier to back up."

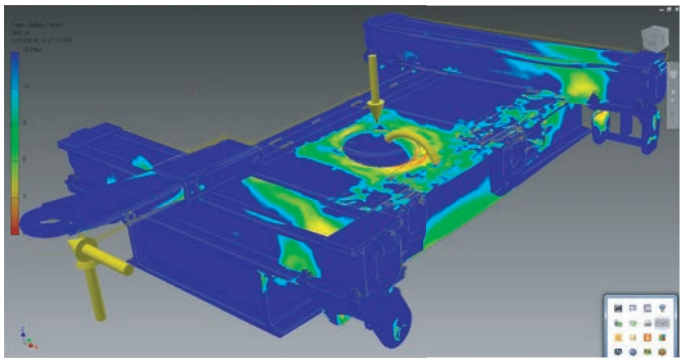
Climbing on the tugger, Jane deftly backed up to the automatic coupler of the new trailer, made the quick connection and pulled forward partway down the aisle. "See if you can back up into Ned's area" Liza called out. That would be a 90 degree turn off the main aisle. She was a little hesitant, but Jane backed into the space without needing any adjustments. "Wow!" exclaimed Ned, who was used to seeing a daily struggle with the backing up piece. "Looks like a new driver!" Jane chose to ignore that comment, nodded to Liza, and headed off to what was shaping up to be a great day in her work life.

About Hamilton Caster

For more than 100 years, Hamilton has handled the pressure in material handling's heaviest and most complex jobs. We build ultra-durable trucks to thrive under years of abuse, no matter the application. Best of all, Hamilton trucks boost warehouse efficiency, increase productivity and reduce overhead costs.

Putting Our Durability to the Test

Before any Hamilton trailer hits the factory floor, our engineers run a finite element analysis (FEA). How does it handle an oversized load? Is it stable? Is weight properly distributed? This method ensures durability and longevity.



Riding on Our Famous Casters

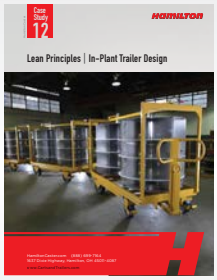
The recipe for our rugged carts and trailers starts with our famous casters. Made in our Hamilton, Ohio, factory, they help tackle material handling's heaviest and most complex jobs.

From swivel casters that easily navigate factory gridlock, to heavy-duty builds that tote 60 tons each, there's a Hamilton for the job. No matter the application.

Get Technical with Case Studies and White Papers

Design Principles of In-Plant Trailers

Hamilton carts trail better. We can prove it, too, with a white paper that features hard-hitting data from the experts who make them.



Lean Principles of In-Plant Trailers

Learn how 68 custom trailers helped a major engine manufacturer go lean, and cut costly time from assembly.

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