Designing Manual Carts: Selecting Casters, Reducing Workplace Injuries, and Improving Productivity

Tom Albin
High Plains Engineering Services
Yohann Printer
Darcor
Carts and Mobile Equipment are used in every industry

Ergonomically designed carts and casters:

- Reduce the risk of injury
- Reduce risk of damage to material
- Support productivity
- Maintain operating characteristics over time
On a typical day, an operator:

1. Lifts materials and loads them onto cart
2. Pushes cart to start it moving on path
3. Turns cart at 2 corners
4. Positions cart at production line
5. Stops cart
6. Lifts and unloads material from cart
7. Starts cart moving
8. Pushes cart back to starting point
Operating force capabilities do not overlap perfectly

75% capable for each operating force

1. Lift box and place on cart
2. Push cart to start it moving
3. Turn cart 90° at corner

~56% capable of all 3 operating forces
Standard Protocol for Measuring Operating Forces

Annex D of ISO 11228-2 (clarification)

- Measure starting force: accelerate cart from rest to velocity of 1.08 ft/s (0.33 m/s), acceleration ≤ 0.36 ft/s² (0.11 m/s²)

- Measure sustained force: maintain cart at velocity of 1.08 ft/s (0.33 m/s) over a distance ≥ 39.4 in (1 m)
## Sources

**Ohio Bureau of Workers’ Compensation**

**Liberty Mutual MMH tables**
https://libertymmhtables.libertymutual.com/CM_LMTablesWeb/taskSelection.do

<table>
<thead>
<tr>
<th>Exertion</th>
<th>Height</th>
<th>Percent Population Protected</th>
<th>Straight Exertions</th>
<th>Turning Exertions</th>
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<tbody>
<tr>
<td></td>
<td>81.3 cm (32 in)</td>
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<td>HF Limit (N)</td>
<td>Torque Limit (Nm)</td>
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<td>1 Hand Pull</td>
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<td>101.6 cm (40 in)</td>
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</table>
Cart Design: Visibility

Must see to steer!

• Avoid damage to cart and materials
• Avoid injuring other operators

Eye Height (USA)

• 55.7 inches (small woman)
• 68.6 inches (tall man)
Cart Design: Handles at Waist Height

Best push strength is at waist height!

Waist height (USA)
• ~ 35.9 inches (small woman)
• ~ 45.6 inches (tall man)

Shoulder moments?
Cart Design: Braking Force

No current guidelines

Work around:

- Use opposite force guidelines:
  - Pull force equal to sustained push force
  - Push force equal to sustained pull force
Cart Design: Caster Effects

➢ Caster material
➢ Caster diameter
➢ Caster offset
➢ Caster positioning
Debris Embedded in Casters; Increases Operating Forces

• Embedded debris affects shape of caster
• Out-of-round casters requires more force
• Caster material should resist debris embedding
Caster Diameter Affects Operating Force During Movement

Operating force: \( F = \frac{Wb}{r} \)

- \( W \) = Weight supported by wheel
- \( b \) = Rolling resistance coefficient (length units)
- \( r \) = Radius of caster

Decrease \( b \) = Lower Force
Increase \( r \) = Lower Force
Caster Offset Provides Benefit When Turning Carts

Offset is:

- The distance between the center of top plate and the center of wheel

Benefit:

- Offset provides a mechanical advantage when turning
Weight on Caster Affects Turning Force

Equal weight on all casters, Higher turning force

Less weight on swivel casters, Lower turning force
High Load Applications

Benefits of dual and triple wheels

• Reduced mobility forces (Start and swivel)
• Better load distribution for heavy loads

Benefits of a Kingpinless™ (KP) Caster

• Reduced swivel forces
• Better load distribution on bearing races
• No kingpin / kingbolt point of failure
Case Study – How Casters Affect Ergonomic Performance

Site Details:

- Several corporate manufacturing facilities in Wisconsin
- Concrete floors; many have metal debris and some unlevelled surfaces

Corporate Ergonomic Performance Targets:

- Reduce sustained push/pull forces below 42 lbs
- Caster must remain debris free
- Long caster economic life
- Durability/Longevity – maintain targeted force reduction throughout life of casters
Case Study - Casters’ Ergonomic Performance, Example 1

Distribution Carts

Starting Push Force

47 lb.

After Modification

18 lb.

~62% Force Reduction
Case Study - Casters’ Ergonomic Performance, Example 2

Metal Chip Hoppers

Starting Push Force
62 lb.

After Modification
38 lb.

~39% Force Reduction
## Case Study - Ergonomic Performance

<table>
<thead>
<tr>
<th>Plant</th>
<th>Push / Pull Forces (lbs.)</th>
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<tbody>
<tr>
<td></td>
<td>Old</td>
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<td>C</td>
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<td>42</td>
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<tr>
<td>D</td>
<td>47</td>
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</table>

### Ergo Caster Project 2017

- **Plant A**: 62 lbs (Old) to 38 lbs (New), 39% reduction
- **Plant B**: 48 lbs (Old) to 24 lbs (New), 50% reduction
- **Plant C**: 82 lbs (Old) to 42 lbs (New), 49% reduction
- **Plant D**: 47 lbs (Old) to 18 lbs (New), 62% reduction

50% Reduction in Push/Pull Forces
Conclusion

- When selecting carts, casters, and wheels considering the task requirements, operating environment, conditions, and the people that will perform the work will result in a major pay off.

- Surprisingly heavy loads and equipment can be manually moved safely, and efficiently by proactively thinking about cart and caster design.
Please subscribe to Darcor’s Monthly Blog on Proactive Ergonomic Solutions at www.darcor.com

Recommended References:

- **Liberty Mutual Tables** - Snook, S. & Ciriello, V.; *The design of manual handling tasks: revised tables of maximum acceptable weights and forces*, 1991
- https://pdfs.semanticscholar.org/e766/aaa1b65e0b449f7c9b98864251cbcd1aabde.pdf

Contact Details:
Tom Albin
High Plains Engineering Services, LLC
612-724-6978
talbinus@comcast.net

Yohann Printer
Darcor Casters & Wheels
647-951-5341
printer@darcor.com
Thank you for listening

Questions?