CARMA
(Cart in Automobile Repositioning and Maneuvering Apparatus)

Design Team
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Abstract
The loading and transport of two wheeled horse carts (sulkies) in the back of a pick-up truck can be cumbersome, dangerous, and impractical when a horse trailer is attached. The objective of this Capstone project is to design a device to lift and secure a horse cart for transport, capable of lifting the cart from the side of the truck, while allowing the horse trailer to remain attached at all times. The Cart in Automobile Repositioning and Maneuvering Apparatus (CARMA) was developed to allow a single person to safely load a 350 pound sulky into the back of their truck by harnessing power from the truck. Designed to be easily removable, the CARMA system can be completely detached from the truck with simple hand tools, allowing complete access to the bed of the truck outside of horse season. The design process included suitable material selection, as well as full FEA analysis on all subsystems of the CARMA device, ensuring acceptable stress distribution and deflections. Due to time constraints, it was decided that a full working prototype would not be fabricated, but a scaled model would be constructed instead. The full scale prototype will be produced during the next semester and will be fitted to the truck for testing.
The Need for Project

Lifting a horse cart weighing 350 or more pounds on to the back of a pick-up truck can be dangerous and cumbersome if a trailer is already attached to the truck. The bed of the pick-up truck is inaccessible to store the horse cart when the horse trailer is attached. Loading of the carts, which can weigh between 100 and 350 pounds, currently requires a large group of people to lift the cart into the bed, or else disconnecting the trailer. This can quickly become a dangerous situation should the lifter’s grip on the cart becomes compromised, environmental conditions become hazardous due to weather, or if insufficient numbers of people are available to assist with lifting.

No provisions currently exist to lift, maneuver, and secure a horse cart to a truck bed, while allowing the horse trailer to remain attached. This creates a unique opportunity to fill a niche that is currently devoid of support or consideration. A device that would drastically reduce the burden of loading and facilitate the transport of such a cart would create a novel situation that would attract much attention from both trotting enthusiasts and trainers, and could be further adapted for each group’s specific needs.

The Design Project Objectives and Requirements
Design Objectives

The objective of the Cart in Automobile Repositioning and Maneuvering Apparatus (CARMA) design is to create a system which allows a single person to load and unload the cart from the bed of a pickup truck without removing the horse trailer. The current method of putting a cart in a truck involves pushing the cart up a ramp so that it sits on the side of the truck bed. A wooden frame is used to secure the cart to the truck bed. This method requires multiple people, and can be quite dangerous due to the heavy and awkward shape of the cart.

Design Requirements

The system will have to lift a cart weighing approximately 350 lbs to a height of roughly 5 feet. The system should include a way to secure the cart to the lifting mechanism. The entire operation should be completed in less than five minutes. The apparatus should be semi-permanent, with the majority of the system being removable. A sub-frame will be bolted to the frame of the truck which would be permanent and separable from the rest of the system.

Design Concepts Considered

Two independent design concepts were considered for the CARMA system.

Two design concepts were considered for this project. The first consists of the side lifting system that the team moved forward with. This system entails a platform which slides up and down over the side of the truck. Once in the raised position, the frame holding the sliding rails on the side slides across the bed of the truck into a traveling position.

The second concept is an overhead, side loading system. This system consists of a frame mounted in the bed, from which two telescoping arms protrude over the side of the side of the truck. Attached to these arms are chains or straps, which will be used to strap the axle of the horse cart to the frame. From this, the chains will be raised by a winch, and the telescoping rails will retract, allowing the cart to be placed in the bed of the truck.

Recommended Design Concept
The CARMA system will lift, slide, and secure a horse cart into the back of a pick-up truck. The system is easily removable for full use of the truck bed when needed.

The CARMA design that was developed in depth is a platform lift system, which will lift, slide, and secure the cart into the bed of the pick-up truck.

The base frame, which serves as the foundation of the system, provides a surface to attach and slide the lifting frame on, while anchoring the system to the bed of the truck. The frame, made from 1018 steel, will bolt through the bed into four permanently installed brackets, placed under the cross braces of the truck bed, and attached to the truck frame for support.

The lift frame is integral to the lifting and reposition of the horse cart. This structure, made from 4130 chromoly steel, slides along the upper rails of the base frame via machined steel wheels. When in the lifting position shown above, folding rails are extended, providing a channel for the platform to travel through. This structure also serves as the mount to the electrical winch and pulley that will perform the lifting of the cart and platform.

Made from 4130 tubing, the lift platform provides a surface to lift and secure the sulky. The cart is rolled onto this platform, is secured by a clamping bar through the wheel spokes, and supports the long front poles which attach to the horse. This platform is lifted by the winch line attached to it, and travels through the folding rails.

A linear power screw system was designed to prevent the cart from sliding uncontrollably over the edge of the base frame during loading. This system allows effortless horizontal control of the cart, and prevents damage to the cart, truck, and human injury due to loading/unloading on uneven ground.

**Analytical Investigations**

Full FEA analysis was performed on all of the CARMA subsystems. A 700 lbs load was used for analysis, which provided a factor of safety of 2 over the heaviest sulky. All stresses were well within acceptable limits, and detailed results can be seen in the full report.

Displacements were also determined, with a maximum displacement of 1.9 inches being experienced by the tip of the lift platform under a 700 pound load. This does not create an issue for the lift system because the locking method for the cart secures it in a way that does not allow the cart to tip, and UHMW (Ultra High Molecular
Weight polyethylene) skids were added to the bottom rails to facilitate the platform sliding onto the base rails under these heavy displacements. The lifting rails experienced less than an eighth of an inch in displacement when the platform is fully loaded and extended in the loading position.

Key Advantages of Recommended Concepts

This design concept provides many key advantages over the other designs. The modularity built into the design allows a single user to install and remove CARMA with relative ease. The large area of the lift platform does not limit the user to only lifting horse carts; many large objects within the weight limit of the device (350lbs with a factor of safety of 2) can easily be lifted and secured to the platform. User safety was taken into consideration in the design of the linear motion system. Minimal user effort is required for the lifting and reposition of the cart with this CARMA design, nothing more than the push of a button.

Financial Issues

Approximate cost to develop a CARMA prototype is $2200. One obstacle encountered during the development of the CARMA system was the target budget indicated by the sponsor. Initial discussions outlined a price range of approximately $1500-$2,000. Due to the large amounts of metal needed for the structures, as well as the precision parts needed for the linear system, a prototype was estimated to cost roughly $3,000 to fabricate. Design reviews were conducted, which reduced the cost to $2,200 after the sponsor opted to remove the linear system and a few other small components in the prototype.

Recommended Improvements

Cost and size reduction could benefit the CARMA system in future designs. There are a few improvements that could be made to the CARMA system given more development time. The CARMA system currently positions the horse cart in the same position most people currently transport carts in, making the change in vehicle dynamics and stability almost negligible. The center of gravity of the system could be lowered slightly, allowing the truck to corner more efficiently during transport. The aerodynamics could also be addressed, which will provide a slight improvement in gas mileage.

Additional development time and full scale prototyping would
result in an optimized design. This optimization would facilitate further cost reduction by reducing the size of the system. This reduction would be relatively small in magnitude, since the team has already explored many options for both size and cost reduction.