Element F: Consideration of design viability

Forklift Safety Problem Statement:

"Forklifts have proven to be a significant source of accidents in warehouse working environments due to a combination of factors including lack of visibility and tip-overs."

There were several key factors involving what design to choose and pursue for both the stability and visibility aspects of this project. The team carefully analyzed copious design solutions or prior attempts (see **Element B: Documentation and justification of prior solution attempts**). Some of the solutions presented in Element B such as the "Safe Bump Protector" or the "Anti Collision Safety Device" act as passive solutions to the problem stated. The goal was to design both solutions to be active. In accidents involving forklifts a passive solution, even though it prevents some damage, it does not prevent all of it and it does not mitigate the potential to seriously injure a person. Meanwhile, an active solution can prevent the accident altogether.

Other solutions in **Element B** such as the "White Sound Alarm" and the "Fork Alert Warning System" proved not to be as useful because, as stated in the solution analysis, "safety systems which rely on audio and visual alert signals have become all too common in warehouse environments. Such systems are largely disregarded by workers and pedestrians because these alerts are a commonplace occurance." This statement is backed up by the testimonies of forklift operators at Yank Waste Co., Inc. a paper recycling located at 112 Karner Road, Albany, NY 12205 (phone number: 518-456-2345). They stated that the loud noises can be quite "obnoxious," making it more difficult to concentrate. Frank R. Benedetto, OSHA certified Safety/Personnel director of Yank Waste Co., Inc. also backed this claim during a short interview last year on May 23th, 2012 (this was also the same day the forklift operators gave their testimonies).

Lastly, solutions such as the Toyota SAS System- System of Active Stability and AGV's (Automated Guided Vehicles) included in **Element B** are the most effective solutions that the team included within this element, however even these have their drawbacks. Mr. Gorham, Executive Vice President Thompson & Johnson Equipment Co., Inc. claimed during the first conference call on October 19th 2012 that "even Toyota's SAS system cannot prevent tipovers all the time even though it is one of the best systems out there." Also, even though the AGV's prevent lack of stability and lack of visibility due to the incorporated live cameras and visibility/load capacity sensors, most small to medium warehouses will not possess such new and expensive technology and automated replacements for forklifts driven by real people are not applicable in all warehouse situations.

One thing that the team kept in mind when the specifications and requirements were created was to maintain an emphasis on small to medium warehouses. Placing a focus on the "small business owner," the team decided to target this area because, economically, it is far cheaper to buy a piece of equipment that would make a forklift safer than buy a more expensive new forklift with new safety features. As mentioned in specification seven of **Element C: Presentation and justification of solution design requirements** "a brand new forklift, like the kind which the solution will be optimized for use on, has an average cost of $23,000. The average cost of a used forklift ranges between $10,000 and $15,000, depending on the hours of total use. Because used forklifts are significantly less expensive than brand new models, a business seeking to buy and/or replace a forklift may buy an older model anyway."

Determination of Pricing for Solutions:

Bruce Campbell, owner of the Chase Electric LLC located in Albany NY, and Bob Harford, Head Technician of Thompson & Johnson Equipment Co., Inc, assisted the team in conducting an oral survey of forklift owners and forklift sales representatives. The team asked both Mr. Campbell and Mr. Harford to keep a record of how many people participated. The surveys were conducted on January 19th, 2013.

Survey Outline:

As a forklift owner, how much would you pay for a device that would prevent lateral tipovers? or how much would you pay for a device that would prevent accidents by providing better visibility?

Stability	Visibility
a)$50-250	$50-250
b)$251-400	$251-400
c)$401-600	$401-600
d)$601 +	$601 +

A total of eighteen individuals were asked this question. All eighteen of the participants answered with choice A. Then the question was re-stated to "As a forklift owner, how much would you be willing to pay for a device that would prevent lateral tipovers? or how much would you pay for a device that would prevent accidents by providing better visibility? Taking into consideration the value of the forklift, the potential property damage and injury. Especially if such device where to immensely improve forklift visibility or stability."

When the question was re-stated the way mentioned above, the results were:

Stability: Four answered A

Six answered B

Two answered C

Seven answered D

Visibility: Five answered A

Three answered B

Six answered C

Four answered D

From the second results, it was noticed that forklift owners would be willing to pay more money for designs that would eliminate most if not all potential for hazard.

Stability

The purpose of the design to be developed is to prevent a forklift from tipping over laterally. This more often than not occurs when the forklift is either turning at a high velocity, carrying an excessive load, or both. The speed at which the calculations will be perfomed is seven miles per hour, using a turning radius of 75.6 inches (“Toyota Industrial Equipment 8 Series specifications.” Toyota Material Handling, USA, Inc.2008.pdf. 19 Jan. 2013). To see the reasoning and the calculations involved please visit the "Determining Centripetal Force and Magnitude of the Center of Gravity" section of **Element E: Application of STEM principles and practices** (http://www.innovationportal.org/portfolio/2312/element/28353).

The idea behind the design is to create a moving counterweight in order to force a shift in the center of gravity of the forklift in the opposite direction of the unbalanced force. When *[redacted student name]* presented this idea ot Mr. Okamoto over a conference call he was very pleased to hear it.

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One of the key elements of the stability solution was the determination of where the device needed to be located. This proved to challenge specification six **"The solution will function, when correctly implemented, on the Toyota 8 Series Model 8FGCU20, a counterbalance forklift truck and will have the potential to be easily and quickly implemented on different forklift models as well."** (located in Element C) because even similar forklifts, in regards of load capacity and dimensions, are built sightly different. For the Toyota 8FGCU20 the team chose the underneath of the forklift as a good location. Initially the team debated whether to place the device undeneath the forklift, or inside the compartment undeneath the seat of the driver. The team chose underneath the forklift because there is slightly more room to place the device. This was approved by Mr. Harford, Head Technician of Thompson & Johnson Equipment Co., Inc and Mr. Ascoli, Albany Branch Manager of Thompson and Johnson Equipment Co., Inc.

The video link **http://youtu.be/GqZpz6EX61Q?t=8s** (http://youtu.be/GqZpz6EX61Q?t=8s) contains a short video of the underneath of the 8FGCU20.

(Picture of forklift being raised by lift)

Picture Source: Taken by *[redacted student name]* on 12/28/12.

(Picture of underneath forklift)

Picture Source: Taken by *[redacted student name]*l on 12/28/12

(Underneath the forklift)

Picture Source: Taken by *[redacted student name]* on 12/28/12

(Sketch with dimensions of underneath the forklift)

Picture source: Copy of 12/28/12 entry of *[redacted student name]*Engineering Notebook

The images above, show the underneath of the Toyota forklift. As it can be observed, there is some room available but not much. The other location that could have served as an option for the location of the device was the compartment inside the driver seat, where copious components of the forklift are located.

(Compartment under driver seat)

Picture Source: Taken by *[redacted student name]*on 11/17/12

(Compartment under driver seat)

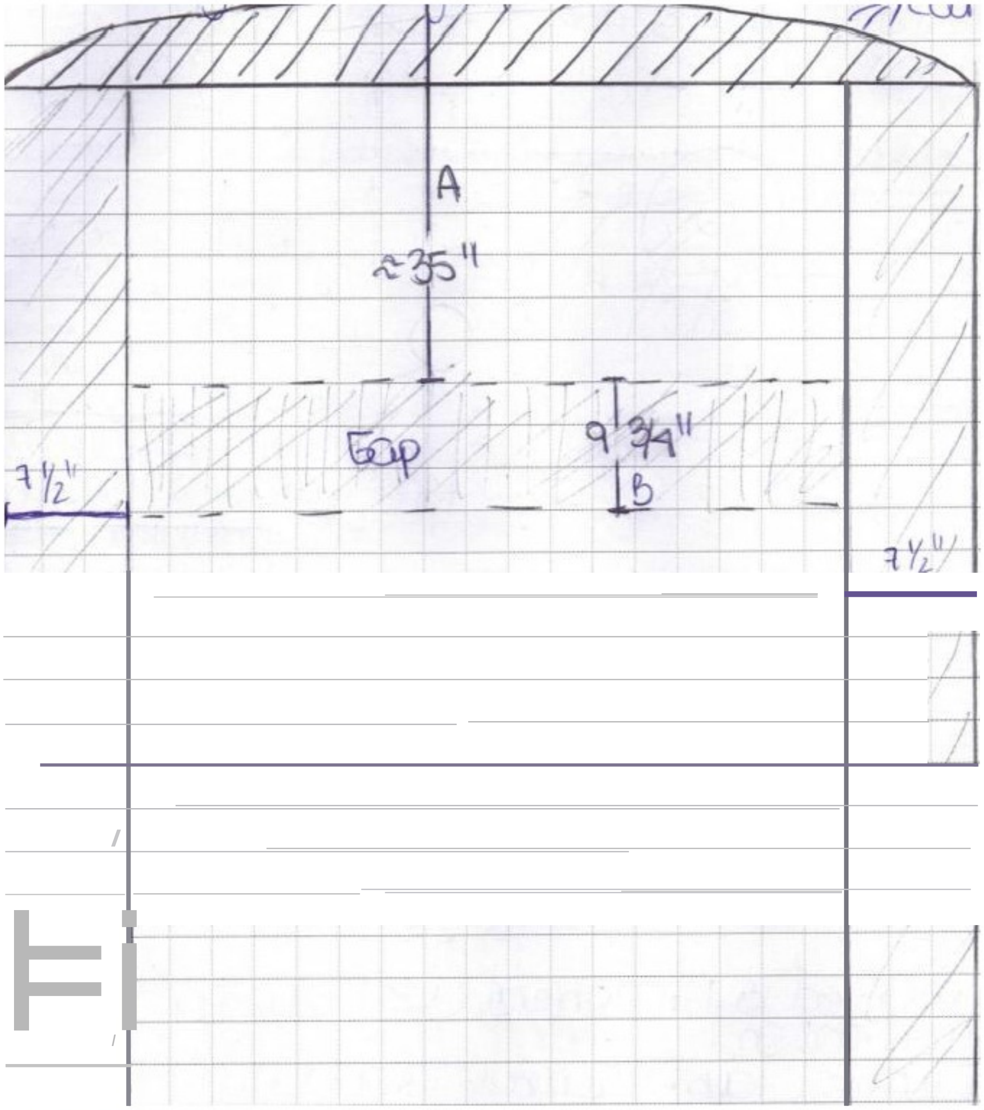
Picture Source: Taken by *[redacted student name]* on 11/17/12

The two images of the compartment under the driver seat show that there is

not much room available to place the device.

Mass of Counterweight Considerations:

As seen in the "Centripetal Force and Gravitational Force Moments: Determining the Mass of the Moving Counterweight." section of Element E, a moving counterweight with a mass of 2,489.10369 pounds (rounded to 2500 pounds) would be needed to counterbalance the centripetal force and prevent the forklift from tipping sideways. The team took a look at this number and determined this would not be feasible because of the lack of room and the fact that it goes



against specification 13 *"Each solution will not weigh more than 700 pounds."*

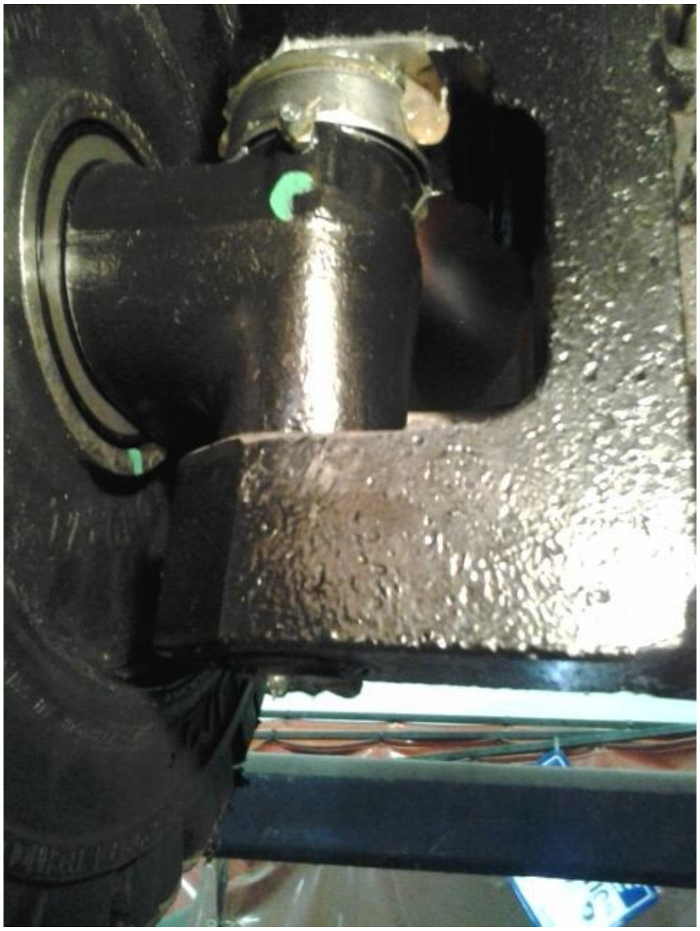
This value was derived from Mr. Ascoli's explanation that adding anything weighing more than 700 pounds behind the front wheel centerline of a forklift would have the potential to affect the load capacity of the forklift. Adding an extra 700 pounds would also unsafely increase the distance that it takes to stop the forklift.

In order to make the design work the team decided that some type of throttle back needs to be added to the system in order for a mass of five hundred pounds to be used as the counterweight. The way this throttle back needs to function is that once a certain centripetal force is reached, or angular velocity, the throttle back will activate and immediately slow down the forklift to the determined speed of 4.78609 miles per hour. The sensor with which the counterbalance system will be activated by, as well as whether a hydraulic system or a motor system will be used, is yet to be determined.

After careful consideration and brainstorming the team decided to shift directions and use a “speed and turn” detection system instead of using a throttle back and a counterweight system together. The system is intended to work in a way where speed and turning detection are used together. From this a small motor will actuate against the accelerator pedal to slow the forklift down.

Switch location:

The magnetic door switch is going to be located on the hub assembly of the forklift, which is right next to the steering axle. Please see the image below.



"Hub Assembly." It was intended for the magnetic door switch to be located on the hub assembly. One section of the switch on the cylinder that rotates the wheel (the spindle) and the other part of the switch on the stationary part of the hub assembly.

Picture source: Taken by *[redacted student name]* on 04/09/13

"Hub Assembly, Steering Axle." Picture source: Taken by *[redacted student name]* on 04/09/13

At first the magnetic switch was going to be attached by adhesive means first. The team quickly realized that this was not a durable means of attachment and it does not allow for maintenance removal. Because of this, it was decided to attached the switch via L-brackets and screws. This will then allow for the switch to be removed. One drawback to this method of attachment is that drilling may prove to be very difficult on solid thick metal. Also, magnetic door switches are not designed to handle the industrial environment that surround forklifts. In the "Deciding on a Sensor" matrix in **Element D** it was stated that a magnetic switch would be used to demonstrate the prototype as a result of a lack of budget, although the ideal switch is a limit switch. Please see **Element L** for more information on the limit switch.

The following failure analysis concerns possible problems related to a scenario wherein the motor activates without the operator's knowledge.

Speed Regulator Warning Failure Analysis.pdf

Visibility

In terms of the visibility design, one of the first things that needed to be accomplished was to obtain a forklift overheard guard. The overhead guard is the cage which encompasses the cab area to protect the operator from falling objects and objects which may protrude out and otherwise enter the operator's compartment.

"Driver's Overhead Guards." *Neon Material Handling*. Web. 06 Nov. 2012

http://www.neonmaterialhandling.com/shop/material_handling/forklift_truck_selection_guide /driver_s_overhead_gu ards (http://www.neonmaterialhandling.com/shop/material_handling /for klift_tr uck_selection_guide/driver_s_overhead_guards)

(Image of overhead guard)

Picture credit: Picture taken by *[redacted student name]* on 11/17/12

(Image of overhead guard)

Picture Credit: Picture taken by *[redacted student name]* on 11/17/12

The team contacted Mr. Gorham and Mr. Ascoli to request an overhead guard. The purpose for requesting to borrow an overhead guard for the remainder of the project was for testing purposes. Since the team received the overhead guard on Monday December 17th, 2012, the team has used the overhead guard dimensions to construct the overhead guard in Inventor to aid in the visualization and understanding of how the visibility device solution interfaces with the overhead guard that it will attach to. The overhead guard has also been a useful tool to demonstrate the solution concept to the team mentor and the engineering teacher.

The Swinging Periscopic Viewport solution concept has been approved with a great degree of confidence by several industry professionals including Mr. Ascoli, Mr. Gorham, Mr. Bovee. In addition, Mr. Gorham also saw the potential for the device to not only improve the visibility in front of the forklift, but also provide the operator with greater visibility immediately in front of tall loads. He believes that the concept is "promising and viable."

Below, are the qualifications of each of the individuals mentioned above:

Francis "Chip" Gorham
Executive Vice President Thompson & Johnson Equipment Co., Inc.

Michael T. Ascoli

Branch Manager Thompson & Johnson Equipment Co., Inc.

Richard B. Bovee, P.E.
Chief Engineer CHA ~ design/construction solutions

Mrs. Famoso, an Advanced Placement physics teacher and an alumni of

Rensselaer Polytechnic Institute's School of Engineering confirmed the team's choice of angle of the mirrors in the device, 45 degrees. Further explanation of these can be seen in **Element E: Application of STEM principles and practices**.

The following pdf file is a failure analysis which examines a scenario wherein the system that locks the device in position fails and the device swings down, colliding with the forklift operator: **Vis Device Swings Into Operator pdf.pdf**

The following pdf file is a second visibility failure analysis that concerns a scenario in which the forklift stops quickly and the forward momentum of the operator results in the operator's head colliding with the visibility device: **Operator Hits Device pdf.pdf**