Element D: Design concept generation, analysis, and selection

The first step that needed to be accomplished was to determine what type of forklift, and model, to use. This pertained to both the stability and visibility problems. A major part of choosing a forklift was not only based on technical specifications, but also on the ease of obtaining a forklift, and the availability of such forklift to use for testing.

The forklift models stated below were chosen because Thompson and Johnson, a Forklift dealer with multiple Locations throughout the Northeast, has offered to assist the team with this project. The forklifts below are some of the warehouse forklifts the company has made available.

Choosing a Forklift Matrix

Specifications regarding "Choosing a Forklift" Matrix

Forklift

Toyota 8FGCU20

Maximum Lift Height (inches)	131.5
Average Mast Height (inches)	83.1
Maximum Load Capacitiy (lbs)	4,000
Tires	cushion
Forklift Width (Inches)	37.2
Power	internal combustion

Toyota 8FGCU30

Maximun Lift Height (inches)	131.5
Lowered Mast Height (inches)	83.1
Maximum Load Capacity (lbs)	6,000
Tires	cushion
Forklift Width (inches)	43.70
Power	internal combustion

Toyota 7FGCU45

Maximun Lift Height (inches)	120.0
Lowered Mast Height (inches)	83.0
Maximum Load Capacity (lbs)	10,000
Tires	cushion
Forklift Width (inches)	53.10
Power	internal combustion

Crown SC402030

Maximun Lift Height (inches)	190.0
Lowered Mast Height (inches)	83.0
Maximum Load Capacity (lbs)	3000
Tires	cushion
Forklift Width (inches)	40.30
Power	eletric

Clark ECG25

Maximun Lift Height (inches)	188.0
Lowered Mast Height (inches)	83.5
Maximum Load Capacity (lbs)	5,000
Tires	cushion
Forklift Width (inches)	39.25
Power	electric

Click on the following link to view the excel file that contains the tabulated matrix:
Matrix #1 Deciding on a Forklift.xlsx

Stability Decision Matrices

Stability Solution Matrix

Purpose: To determine which of the possible brainstormed solutions best fits the specifications stated in Element C: Presentation and justification of solution design requirements. The winnig solution will be chosen to proceed with the project.

Brainstormed solutions with brief descriptions:

A. Bracing Wheels: wheels attached via brace to the side of forklift.

B. Tilt sensor with automated stop: sensor which detects lateral tilt and interfaces with the forklift in such a manner so as to stop it when a predefined angle is reached.

C. Counterweight system: device controls forklift stability by changing the lateral position of a counterweight.

D. Stabilizing wheels: stabilizing wheels mounted parallel to the forks, within the space between the forks.

E. Stabilizing cable: stabilizing cable fired from below the forklift, adhering to the floor in some manner.

F. Tilt prevention system: device that detects when the forklift is starting to tip and projects a beam out to the side which the forklift is leaning toward.

G. Seatbelt interlock: prevents vital functions from working on a forklift when operator is not wearing seatbelt.

H. Tire Pressure Monitor: device monitors tire pressure every time forklift is started. When pressure goes below a certain amount it warns the operator.

I. Forklift stability wheels: stabilizing wheels for forklift, wheels for forklift, similar to training wheels.

J. Weight Limiter: prohibits driver from over loading the forklift. It cannot be overridden.

K. Impact System: device that activates as the forklift reaches a certain point during a tip over. It releases a spongy material to absorb the force of impact.

L. Counter weight balance system: prevents lateral tip overs by activating when a certain turning point, angle, or distance is reached (activating mechanism has not yet been defined) in order to counterbalance tip over and bringing forklift back to its center of gravity.

M. Hydraulic Counterweight System: located underneath. It consists of two hydraulic cylinders with weights attached at the end of each piston. When the counterweight detects a certain tilt angle it activates the corresponding cylinder to counterbalance the tilt.

N. Under mounted hydraulic cylinders: the device connects to a tilt sensor which sends commands/impulses toa mechanism controlling the hydraulic cylinder, which retracts or extends based upon current levels of tilt. Should a tip over/imbalance be detected, the device will provide a stopping mechanism intended to prevent a full scale tip over.

O. Under Mounted Counterweight with Electric Motor: The device connects to a tilt sensor which sends impulses/commands to an electric motor which actuates a threaded rod, which in turn moves a counterweight. Should an imbalance be detected, the device will act to stop a full scale tipover.

Decision Specifications, with Importance Value:

(Specification Numbers Correspond to Product Specification Numbers which can be found in Element C: Presentation and justification of solution design requirements)

(DQ = Disqualified)

Product Specifications Descriptions and Criteria for Evaluation

Specification 1 (DQ)

Description: **The solution, when implemented and used according to the written assembly and operating instructions, will prevent serious injury to people in or around the forklift by solving safety concerns outlined in the problem statement.**

Positive (+): Device prevents fatal and major injury given conditions listed.

Neutral (0): N/A

Negative (-): Device does not prevent fatal and major injury given conditions listed.

Specification 2 (DQ)

Description: **The solution, when correctly implemented, will not have the reasonable potential to directly cause serious injury to people in or around the forklift by creating additional safety concerns not outlined in the problem statement.**

Positive (+): It does not and cannot injure anyone who has legitimate reason to be near the forklift.

Neutral (0): N/A

Negative (-): Device can injure pedestrians near forklift who have legitimate reason to me near forklift.

Specification 3 (DQ)

Description: **The technology necessary to implement all aspects of the solution does exist. This is a disqualifying specification.**

Positive (+): Technology utilized exists and may be implemented.

Neutral (0): N/A

Negative (-): Technology utilized does not exist or is not otherwise available.

Specification 4

Description: **The solution will adhere to both OSHA and ANSI forklift regulations. This is a disqualifying specification.**

Positive (+): Solution adheres to standard OSHA and ANSI forklift regulations.

Neutral (0): N/A

Negative (-): Solution does not adhere to standard OSHA and ANSI forklift regulations.

Specification 5

Description: The solution concept will not overwhelmingly resemble concepts of existing designs or solutions for similar problems.

Positive (+): Solution is original, unique, and does not overwhelmingly resemble other existing solutions.

Neutral (0): N/A

Negative (-): Solution bears overwhelming similarities to other solutions.

Specification 6 (X2)

Description: The solution will function on multiple models of (FORKLIFT TYPE) warehouse forklifts, provided that the forklifts have similar specifications.

Positive (+): Device functions on different models of warehouse forklifts which perform the same function but are different brands, manufacturers, etc.

Neutral (0): N/A

Negative (-): Device does not function on different models of warehouse forklifts, and problems arise with different brands, manufacturers, etc.

Specification 7

Description: The solution will be designed for implementation on preexisting forklifts, or after the forklift has been manufactured.

Positive (+): Solution may be implemented on preexisting forklifts, both past and current.

Neutral (0): Solution may be implemented on pre-manufactured forklifts.

Negative (-): Difficulties arise from attempts at implementation on past and current forklift designs.

Specification 9 (X2)

Description: The solution will not increase the width of the forklift under normal operating conditions.

Positive (+): The solution does not increase the width of the forklift under normal operating conditions.

Neutral (0): N/A

Negative (-): The solution does increase the width of the forklift under normal operating conditions.

Specification 10 (X2)

Description: No part of the solution will be located forward of the front wheel centerline of the forklift.

Positive (+): Solution is present behind the front wheel center line.

Neutral (0): N/A

Negative (-): Solution is present on or in front of front wheel centerline.

Specification 11 (X2)

Description: No part of the solution will be located to the left or right of the center of gravity when viewing the forklift from behind unless such part(s) is/are balanced on the other side.

Positive (+): Solution is not located to the left or right of the center of gravity or is appropriately balanced should it deviate from the center of gravity.

Neutral (0): N/A

Negative (-): Solution is located to the left or right of the center of gravity and is not correctly balanced, if at all.

Specification 12

Description: The solution will operate under its own power source, if a source of power is deemed necessary or optimal.

Positive (+): Device has its own self contained power source or does not otherwise require one.

Neutral (0): N/A

Negative (-): Device must draw power from outside power source such as the forklift or other source of power not originally included with the solution.

Specification 13

Description: Each solution will not weigh more than 700 pounds

Positive (+): Device weighs less than 700 pounds, reasonable tolerances considered.

Neutral (0): Device weighs within a reasonable tolerance of 700 pounds (10 pounds over).

Negative (-): Device weighs more than 700 pounds, with reasonable tolerance of weight.

Specification 14

Description: **The solution will be mechanically driven or will contain parts that can be replaced**

Positive (+): **Solution is mechanically driven or contains parts that can be replaced**

Neutral (0): N/A

Negative (-): **Solution is not mechanically driven or contains parts that cannot be replaced**

Specification 15

Description: **If the solution requires maintenance, then such maintenance will not be required more frequently than once every 250 working hours**

Positive (+): Solution does not require maintenance before 100 hours of work.

Neutral (0): N/A

Negative (-): Solution requires maintenance before 100 hours of work.

Specification 16

Description: The solution will not raise the forklift height by more than 7 inches.

Positive (+): Solution does not raise forklift height more than 7 inches.

Neutral (0): N/A

Negative (-): Solution raises forklift height more than 7 inches.

Specification 20 (DQ)

Description: **The solution designed will be an active device. This is a disqualifying specification.**

Positive (+): Device is active.

Neutral (0): N/A

Negative (-): Device is not active.

Specification 21 (DQ)

Description: **The solution will prevent lateral tip overs (versus longitudinal tip overs. This is a disqualifying specification.)**

Positive (+): Device prevents lateral tip overs.

Neutral (0): N/A

Negative (-): Device does not prevent lateral tipovers.

Defense of Design Choice:

Initially the under mounted hydraulic cylinders won the decision matrix, but after taking the team mentor's advice, the under mounted counterweight with electric motor idea was added to the matrix and it resulted in a tie between the two under mounted counterweight systems.

Both of these solutions were tied since both met the disqualifying specifications. Also, neither of these solutions is intended to protrude out on either side of the forklift. These are designed to not be located in front of the front wheel center line. Both of the brainstormed solutions are active solutions, and are designed to prevent lateral tip overs. Consultation will be made with industry professionals to decide which solution is most viable, factoring in variables such as pricing.

Click on the following link to view the excel file that contains the tabulated matrix: **Stability Solution Decision Matrix-V2.xls**

Material Choice of Weight Matrix

Purpose: To determine the ideal material of the moving counterweight.

Material List:

Steel

Wood (American Red Oak)

Aluminum

Aluminum T6061

Copper

Inconel Alloy 600

Concrete

Titanium

Lead

Criteria for Evaluation

Density (lb/in^3): A high density is desired because the more mass per volume allows for the optimization of space.

Positive (+) > 0.2990

Neutral (0) 0.150- 0.199

Negative (-) <0.1500

Price ($ per pound): A low price is needed due to the lack of budget.

Positive (+) <$3.00

Neutral (0) $3.00-$4.99

Negative (-) >$5.00

Ease of manipulation: It is ideal to work with a material that the school possesses the equipment to work with, for example welding machinery.

Positive (+) Material can be modified with the use of machinery available at school, and modification can be precise.

Neutral (0) Material can be modified with the use of machinery available at school, though modification may not be precise.

Negative (-) Material cannot be cut with the use of machinery available at school, and modification may not be precise.

Toxicity: No part of the process of working with or attaching the material creates a toxic environment.

Positive (+) No potential health hazards to those within its proximity.

Neutral (0) May cause corrosion or otherwise adversely affect surrounding materials, which may present a future health hazard.

Negative (-) Potential health hazards to those within its proximity.

Defense of Design Choice: Steel was determined to be the winner of the matrix because it provided the most cost effective solution while not presenting potential health hazards or difficulty when constructing the weight. It is also relatively cheap.

Click on the following link to view the excel file that contains the tabulated matrix: Matrix #2 Material choice of weight.xlsx

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****The "Centripetal Force and Gravitational Force Moments: Determining the Mass of the Moving Counterweight" calculations in Element E showed that the moving counterweight system would not be feasible due to the lack of space in the forklift as well as the significant amount of weight that would be required to counterbalance the tip over. Later the possibility of adding a throttle back was discussed (this was also mentioned during the team's midterm presentation). The addition of this throttle back would slow the forklift down and as a result reduce the amount of weight that would be needed. 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. Please see Element F: Consideration of Design Liability for more details.*

*Note that the following matrices pertain to the team's new stability design.****

Stability Matrix: Deciding on a Sensor

Purpose: To determine which type of sensor would be best suited to read/detect the conditions of a forklift turn.

Possible Solutions:

Laser ring gyro: Device that consists of a ring laser having two counter-propagating modes over the same path in order to detect rotation.

Mercury tilt sensor: Sensor that uses a mercury bead which connects to a terminal whenever it is tilted.

Ball in a cage sensor: Similar to a mercury tilt sensor, but with a small metal ball.

Electrolytic sensor: A system of positive/negative electrodes and an electrolyte. When the

sensor gets tilted, the magnitude of submergence of electrodes varies according to the magnitude of the tilt.

Potentiometer (linear or rotational): A resistive sensor used to measure linear displacements as well as rotary motion. An electrically conductive wiper slides across a fixed resistive element. A voltage is applied across the resistive element. Thus a voltage divider circuit is formed.

Accelerometer: Measures acceleration forces (forces can be static or dynamic). By measuring the amount of static acceleration due to gravity the tilt angle of the device can be found with respect to the earth.

Speed Regulator utilizing metal contacts with switches: When the wheel is turned the metal contact will activate a switch(es) when reaching a certain degree of rotation. When this occurs a signal will be sent to an electric motor which turns the noncircular stopper and thus prevents the accelerator pedal from being depressed any further.

Magnetic Door Switch: Similar to the "Speed regulator utilizing Metal contacts with switches" solution, however this system utilizes the steering spindles present on the steering assembly located in the rear of the forklift for triggering a magnetic door switch which controls the motor as opposed to metal contacts located on the steering wheel.

Limit Switch: This switch can be used to detect the proximity of objects or that are operated by the motion of a mechanical object. Standardized limit switches are industrials control components manufactured with a variety of operators types such as a lever or roller plunger.

Criteria

Toxicity: The device should have no level of toxicity that could cause harm to anyone exposed to it.

+1-Sensor does not utilize toxic materials that could harm a person.

-1- Sensor utilizes toxic materials that could harm a person.

Variance of output: The sensor needs to be able to detect different degrees of measurement (give an output proportional to the tilt). This is a disqualifying specification.

+1The sensor provides variance in output.

-1 The sensor provides no variance in the output. (Only ON/OFF)

Number of axis: Since the focus of this project is to deal with lateral instability, only three axis of rotation are necessary.

+1- Sensor has three or more axis of movement used in sensing direction.

-1-Sensor has less than three axis of movement used in sensing direction.

Temperature: The sensor should be able to function properly under temperatures which surround the forklift. (See Spec 16.2)

+1- Sensor functions effectively in temperatures varying from -22 °F-134°F

-1- Sensor does not function effectively in temperatures varying from -22 °F-134°F

Utilization of existing components: The sensor system will utilize existing components on the forklift in lieu of outside, independent devices which would require additional space, funds, and interfacing.

+1 The sensor system utilizes existing components present on the forklift to detect the appropriate conditions for solution activation.

-1 The sensor system utilizes independent components not present on the forklift to detect the appropriate conditions for solution activation.

Defense of Design Choice: The potentiometer, the metal contact with switches, the limit switch and the magnetic door switch all appear to be viable designs. They can work with three axes, provide accurate readings under the temperatures which a forklift may be surrounded by and they provide a variance of outputs. The limit switch was chosen as the most viable design as it utilized the least amount of components while being independent of other devices which will be needed to detect its output.

Click on the following link to view the excel file that contains the tabulated matrix: **Deciding on a Sensor.pdf**

Stability Matrix: Sensing System Analysis

Purpose: To analyze which system in a forklift would be best suited to detect a sensing signal that could be used to determine forklift instability.

Possibilities:

Engine (Engine Control Unit): This is the control system of the engine. It sends signals to the VSM. The ECU also works by reading signals in the form of voltages.

Steering System: The steering system works through hydraulic circuits. It does not have a mechanical connection between the steering wheel and the steering axle. There is a steering cylinder which makes up a major part of the steering axle. When the steering wheel is rotated in a certain direction the oil flows to one side of the steering cylinder; meanwhile hydraulic oil from the other side of the cylinder returns through the control section of the steering control unit.

VSM: This is the main computer of a forklift. It sends signals through impulses and voltages. For the purposes of this matrix, the VSM would be best utilized due to the readings it obtains from the rotational and linear speed sensors it possesses. The VSM is programmed to interpret the voltage levels and send output signals according to the voltage inputs it receives.

Criteria

Accessibility (X2): The system should be accessible to the team. Accessible, is being defined in terms of having access to the system itself. This criterion also includes having access to technical documents for the system (or being able to find them through research).

+1 The system is accessible as defined in the explanation of the criteria

-1 The system is not accessible as defined in the explanation of the criteria

Adaptability(X2): Related to spec 6"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." The design should be able to be implemented in various types of forklifts. As such, the system by which the sensor reads the signal from (if necessary) should be similar across all forklifts.

+1 The system is similar across warehouse forklift models

-1 The system is not similar across warehouse forklift models

Interface with limit switch: The system should successfully interface with the switch that was selected, the limit switch.

+1 The system can interface with the magnetic door switch.

-1 The system cannot interface with the magnetic door switch.

Defense of Design Choice: The steering system was chosen as the best design to use since it is accessible and can be used for testing. Its accessibility comes from the hydraulic steering since it is used across all warehouse forklifts. This means that there are more forklifts available to test on. Parts of individual manufacturer's steering systems vary slightly, yet the basics of the system remain the same. Also, due to this system's commonality across copious forklift models the sensor can be more adaptable to different models and manufacturers. The steering system is also able to interface with the limit switch.

Click on the following link to view the excel file that contains the tabulated matrix:**Sensing System Analysis Matrix.pdf**

Stability Matrix: Activated System

Purpose: To determine which part of the forklift will be used to slow down the forklift when the speed regulator sends a signal.

Accelerator pedal: The accelerator pedal is controlled by the operator's foot. When the operator's foot presses the accelerator pedal, the cable attached to it is pulled and a valve is opened. This allows more air to enter the system which allows the rpms of the engine to be increased. The forklift begins to lose speed immediately after this pedal is released.

Transmission: The transmission is a constant mesh transmission with one forward and one reverse speed. It has two clutches that are applied hydraulically and released by spring force.

Brake System: This system includes a master cylinder, brake shoes, wheel cylinders, an inching/brake pedal and a parking brake system. When the brake pedal is pushed, fluid pressure from the master cylinder causes the pistons in the wheel cylinder to extent.

Criteria

Speed Adjustment(X2): The system/solution chosen must have the ability to slow down the forklift.

+1 The system is able to reduce the speed of the forklift.

-1 The system is not able to reduce the speed of the forklift.

Accessibility (X2): Accessible, is defined in terms of having access to the system itself. This criterion also includes having access to technical documents for the system (or being able to find them through research).

+1 The system is accessible as defined in the explanation of the criteria.

-1 The system is not accessible as defined in the explanation of the criteria.

Adaptability: Related to spec 6"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." The design should be able to be implemented in various types of forklifts. As such, the system by which the sensor reads the signal from (if necessary) should be similar across all forklifts.

+1 The system is similar across warehouse forklift models.

-1 The system is not similar across warehouse forklift models.

Defense of Design Choice: The accelerator pedal was chosen as the most suitable system due to how accessible this part is for the team. Although accelerator pedals do vary slightly in style across manufacturers, the basis on how they work remains the same. This is also an accessible system which allows for testing.

Click on the following link to view the excel file that contains the tabulated matrix:**Activated System Matrix pdf.pdf**

Talk about failure analysis in element f!!!!!

Stability Matrix: Speed Regulator Alert System

Purpose: To determine what type of alert system to warn the operator of when the speed regulator system is active.

Possible Solutions:

Dual lights: A pair of lights located on the front vertical beams of the overheard guard. Each light is located on the individual beam as shown in Figure 1.

Figure 1 (Picture Source: Taken by Gyneth Campbell on 11 /17/2012. Last edited to show "lights" on 04/1513)

Sound Alarm: When the motor is activated, a sound is be generated to alert the operator that the system is activated.

Dual lights with sound alarm: The dual light component is the same as the one mentioned above. This system would also have a sound alarm that alerts the operator as well.

Criteria:

Obstruction of view (DQ): The system should not prohibit the forklift operator's view, this violates specification 2 "The solution, when correctly implemented, will not have the reasonable potential to directly cause serious injury to people in or around the forklift by creating additional safety concerns not outlined in the problem statement."

+1 System does not decrease the operator's field of vision.

-1 System decreases the operator's field of vision.

Specification 4 (DQ): "The solution will adhere to both OSHA and ANSI forklift regulations."

+1 System does adhere to both OSHA and ANSI forklift regulations.

-1 System does not adhere to both OSHA and ANSI forklift regulations.

Temperature: The system should be able to function properly under temperatures which surround the forklift. (See Spec 16.2)

+1 System functions effectively in temperatures varying from -22 °F-134°F.

-1 System does not function effectively in temperatures varying from -22 °F-134°F.

Warehouse Environment: The system warns the operator effectively in all warehouse environments.

+1 System warns the operator effectively in all warehouse environments.

-1 System does not warn the operator effectively in all warehouse environments.

Defense of Design Choice: The dual lights were chosen as the most suitable design since they do not obstruct the operator's view, the solution can withstand the wide range of temperatures that it may encounter and it does adheres to both OSHA and ANSI regulations. The dual lights were also chosen because they can be used in all types of warehouse environment. The sound alarms would not be as effective for a forklift surrounded by constant noise, the operator might not distinguish between the warning signal and warehouse noise. Also, research at the beginning of the year showed that sound alerts are disliked by operators due to the unwanted noise. As a result buyers are less likely to purchase them.

Click on the following link to view the excel file that contains the tabulated matrix: **Speed Regulator Alert System.pdf**

Visibility Decision Matrices

Forklift Safety Visibility Decision Matrix:

Visibility Solution

Purpose: to determine which visibility brainstormed solution is the most viable and has the most potential to solve forklift safety concerns like blind spots outlined in the problem statement.

Solutions and Brief Descriptions:

1. Heat Camera – device mounted to the side of the mast which would detect and alert the operator to the presence of any objects which give off heat, like people, in the forward path of the forklift.
2. Remote Control Forklift – device allows the operator to drive the forklift at a slow speed and operate all functions of the forklift remotely from a short distance. This would increase visibility because the operator would not be constrained to sitting behind the mast and the load.

3. Periscopic Viewport – device mounted to the mast which provides the forklift operator with greater visibility over tall loads. It uses a series of mirrors encased in a box which can raise and lower depending on the height of the load.
4. Swinging Periscopic Viewport – device similar to the Periscopic Viewport, except this is mounted to the overhead guard and can be swung over the guard when not in use.
5. Adjustable Seat – device which allows the operator to move the seat from side to side to provide visibility around the mast.
6. Stable Mirror System – system of mirrors which can be adjusted to suit the operator's perspective. The adjustable part is more resistant deform as a result of the continual vibrational motion of a forklift.

Decision Specifications, with importance value:

(Specification Numbers Correspond to Product Specification Numbers which can be found in **Element C: Presentation and justification of solution design requirements**)

(DQ means that failing this consideration disqualifies the potential solution)

Spec 1 (DQ)

+1 The device has the potential to prevent injury to people in or around the forklift by solving safety concerns outlined in the problem statement.

DQ The device does not have the potential to prevent injury to people around or in the forklift by solving safety concerns outlined in the problem statement.

Spec 2 (DQ)

+1 The device, when correctly implemented, does not have the reasonable potential to seriously injure or harm people or objects around the forklift by creating additional safety concerns not outlined in the problem statement.

DQ The device, when correctly implemented, has the reasonable potential to seriously injure or harm people or objects around the forklift by creating additional safety concerns not outlined in the problem statement.

Spec 3 (DQ)

+1 The technology to implement the device on the lift exists.

DQ The technology to implement the device on a lift does not exist.

Spec 4 (DQ)

+1 The device adheres to both OSHA and ANSI regulations.

DQ The device conflicts with either OSHA or ANSI regulations.

Spec 5 (x2)

+2 The solution concept does not overwhelmingly resemble the concept of an existing design or solution for a similar problem.

- 2 The solution concept overwhelmingly resembles the concept of an existing design

or solution for a similar problem.

Spec 6 (x2)

+2 The device will work on the Toyota Model 8FGCU20 forklift and has the potential to work on forklifts of comparable dimensions and load capacity.

- 2 The device will not work on the Toyota Model 8FGCU20 forklift or does not have the potential to work on forklifts of comparable dimensions and load capacity.

Spec 7 (x1)

+1 The device can be installed after the forklift is manufactured.

- 1 The device needs to be installed during manufacturing.

Spec 9 (x1)

+1 The device does not extend the width of the forklift under normal operating conditions.

- 1 The device does extend the width of the forklift under normal operating conditions.

Spec 10 (x1)

+1 The device is located behind the front wheel centerline of the forklift.

- 1 The device is located in front of the front wheel centerline of the forklift.

Spec 11 (x1)

+1 The device does not alter the lateral position of the forklift's center of gravity.

- 1 The device does alter the lateral position of the forklift's center of gravity.

Spec 14 (x1)

+1 the device will be simple to design, install, and maintain.

- 1 the device is very complex and is not easy to maintain.

Spec 16 (x1)

+1 The device does not, under any circumstance, exceed a height of seven inches taller than the forklift height.

0 The device has the potential to exceed a height of seven inches taller than the forklift height in some circumstances.

- 1 The device does exceed a height of seven inches taller than the forklift height.

Spec 18 (x1)

+1 The device does not diminish the operator's field of vision in any way.

- 1 The device does diminish the operator's field of vision in some way.

Spec 19 (x1)

+1 The device's range of detection of hazards is greater than five meters.

0 The device's range of detection of hazards is five meters.

- 1 The device's range of detection of hazards is less than five meters.

Defense of Design Choice:

Based on the results of the Visibility Solution Decision Matrix, the Swinging Periscopic Viewport is the most viable of the brainstormed solutions. This decision was based on the solutions adherence to a greater number of product specifications than any other solution.

Spec 1: The Swinging Periscopic Viewport will prevent injury to people in or around the forklift by providing the operator with greater visibility above tall loads. The merits of the solution concept's potential to do so was confirmed by an industry professional, Mr. Gorham, executive vice president of Thompson & Johnson, a forklift rental and sales company.

Spec 2: The chosen solution presents no outstanding risk of causing bodily injury to a forklift operator or anyone around the forklift.

Spec 3: The technology involved in implementing the solution all exists. The device utilizes mirrors and transparent panes held in place by a frame.

Spec 4: The device does not conflict with any OSHA or ANSI regulation.

Spec 5: The solution concept is original and nothing similar to it has been applied to the forklift industry or related industries. Research on this fact was conducted using several patent search engines as well as through the internet in general.

Spec 6: Because the chosen solution concept is mechanically driven, it will be able to be implemented on many different models of forklifts, including the Toyota Model 8FGCU20.

Spec 7: The solution concept allows for its attachment onto a forklift post-manufacture. It can attach to any overhead guard.

Spec 9: The chosen solution is attached to the front of the overhead guard and no part of the design protrudes beyond the width of a forklift.

Spec 10: The solution is attached to the overhead guard and therefore does not exist forward of the front wheel centerline. It enjoys this advantage over the regular Periscopic Viewport brainstormed solution.

Spec 11: The device does not alter the lateral stability of the forklift because it is centered on the front of the overhead guard.

Spec 14: The simple, mechanically driven nature of the solution concept lends to its ability to be easily understood.

Spec 16: This is the only specification that the Swinging Periscopic Viewport received a -1. It received a -1 because in its upright position, it exceeds seven inches above the forklift height. This is not disqualifying because the device can be removed in situations where the height is an issue and because the team decided that this specification was not vital

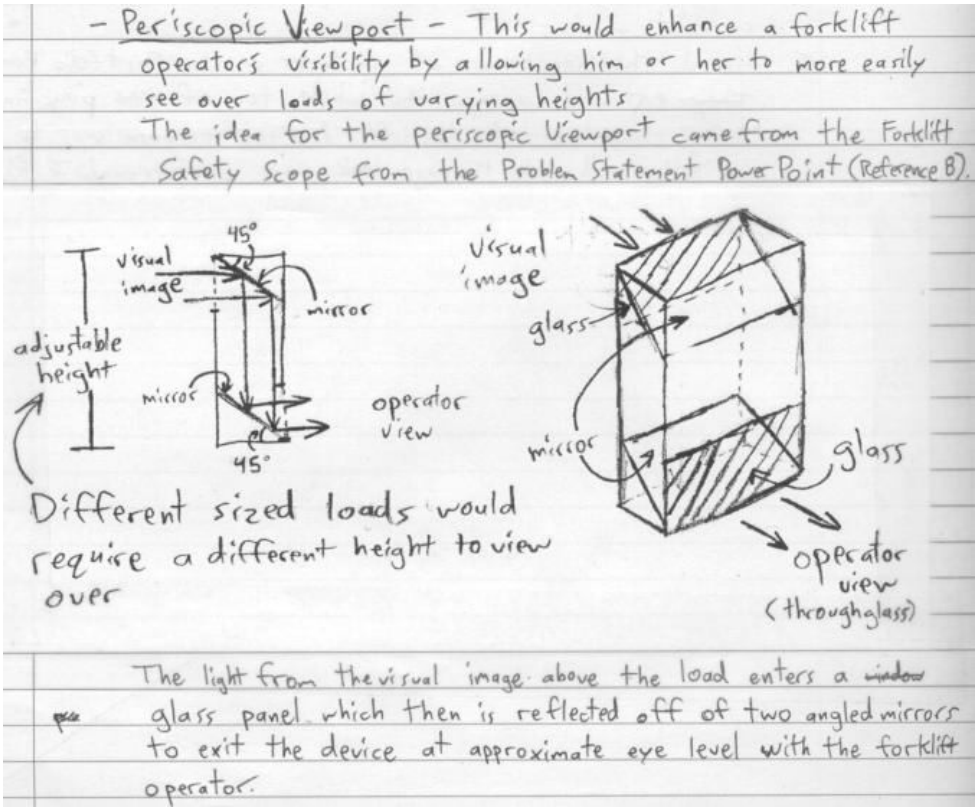
to the success of the solution at improving the safety of forklifts.

Spec 18: The chosen solution does not diminish the operator's field of vision because when it is not necessary, it swings upward to an unobtrusive position and when it is needed, it swings down to block the view of the back of a tall load which necessitated its use in the first place.

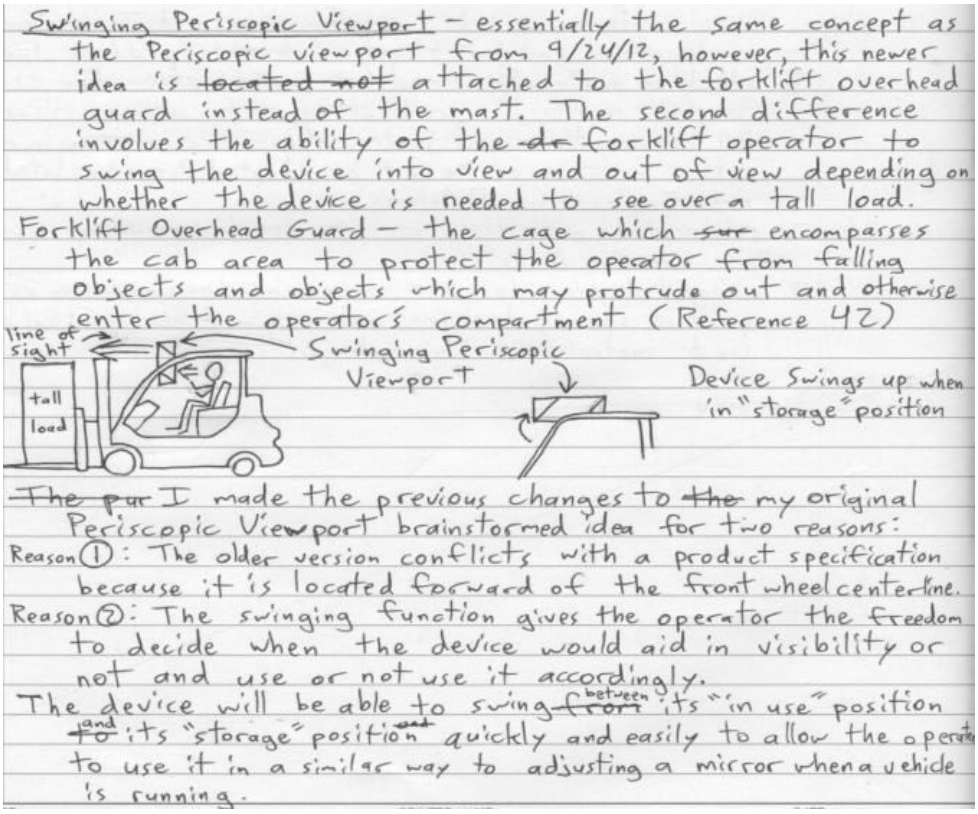
Spec 19: Because of its use of mirrors, the Swinging Periscopic Viewport will have a detection range equal to that of the eyesight of the operator. The assumption is made that the operator has clear eyesight much further away than five meters, otherwise he or she would not be allowed to operate the forklift.

Click on the following link to view the excel file that contains the tabulated matrix: Visibility Solution Matrix.xlsx

Here is more information and explanation of the Swinging Periscopic Viewport concept that the Visibility Solution Decision Matrix determined to be superior:



Picture above from *[redacted student name]* Engineering Notebook entry on 9/24/12



Picture above from *[Redacted student name]* Engineering Notebook entry on 11/6/12

Forklift Safety Visibility Decision Matrix:

Method of Attachment of Mirrors to Mirror Sections

Purpose: To determine the best method to attach the mirrors to the inside of the mirror sections of the device

Potential Solutions:

1. Pegs and stoppers- the mirror has a hole in each corner that a peg goes through to keep it from sliding and a rubber end cap is put on the end of the peg to hold it in place
2. Glue- the mirrors are held in place by a layer of glue between them and the section
3. Velcro Strips- Adhesive Velcro strips are placed on the section surface and the back of the mirror
4. Tape- Double sided tape is placed on the back of the mirror and is pressed on to the section
5. Clips- Plastic pieces with a hole in them have a screw put through the hole and into the section when the screw is tightened down the pieces hold the mirror in place and when they are loosened they can move out of the way of the mirror for removal
6. Screws- the mirror is screwed into place
7. Bolts- The mirrors are bolted into place
8. Suction Cup Idea- the mirror is held in place by four suction cups that fold down onto the corners, securing it

Decision Considerations, with importance values:

(DQ means that failing this consideration disqualifies the potential solution)

Consideration 1: Reusability(x1)

+1= The method of attachment can be reused every time the mirror is removed and reinstalled without requiring new materials

-1= The method of attachment cannot be reused every time the mirror is removed and reinstalled and does require new materials

Consideration 2: Over Tightening(x2)

+1= The method of attachment does not allow for over tightening which could result in cracking the mirror

-1= The method of attachment has the potential to be over tightened which could result in cracking the mirror

Consideration 3: Ease of Removal(x1)

+1= The mirror can be removed easily with minimal effort and time

-1= The mirror cannot be removed easily with minimal effort and time

Consideration 4: Holding Strength (x2)

+1= The method of attachment can hold 50 pounds or more.

0= The method of attachment can hold 25 pounds, but less than 50 pounds.

- 1= The method of attachment cannot hold up to 25 pounds.

Consideration 5: Obstruction of View (DQ)

+1= The method of attachment does not obstruct the light reflected by the mirrors.

DQ= The method of attachment does obstruct the light reflected by the mirrors.

Matrix:

	Considerations					
Solutions	**1**	**2**	**3**	**4**	**5**	**Total**
Pegs and stoppers	+1	+1	+1	n/a	DQ	Disqualified
Glue	-1	+1	-1	n/a	+1	0
Velcro	+1	+1	+1	+1	+1	+5
Tape	-1	+1	+1	n/a	+1	+2
Clips	+1	-1	-1	n/a	DQ	Disqualified

Screws	+1	-1	-1	n/a	DQ	Disqualified
Bolts	+1	-1	-1	n/a	DQ	Disqualified
Suction Cup Idea	+1	+1	+1	n/a	DQ	Disqualified

NOTE: The column of boxes for consideration 4 has "n/a" filled in for all of the solutions except Velcro because after the value of +1 was filled in for Velcro, it was determined that no other solution could win, even if they had +1s.

Defense of Decision: Velcro was determined to be superior because it can be re-used without having to replace the Velcro strips. Unlike screws and bolts, Velcro does not rely on a tightening process that has the potential to crack the mirror if someone over-tightens it. Velcro allows for the mirror to be removed easily. Velcro has a holding strength of 175 pounds for a piece that is two square inches. Most importantly, because Velcro attaches to the bottom of the mirror, it does not obstruct the light reflected by the mirrors.

Forklift Safety Visibility Decision Matrix:

Method of Attachment of Mirror Sections

Purpose: To find out how the device will be attached together

Solutions:

1. Tape-the device sections are taped to the box
2. Push Clips- the device is held on by push clips much like the ones that are found on most backpack cellphone pouches
3. Slot System-the sections slide into a slot in the box holding it in place
4. Zip ties- the sections are zip tied into place
5. Hinges- the sections are hinged on the device

Considerations:

Consideration 1: Reusability

+1= the method of attachment can be reused with each disassembly and reassembly of the device

-1=the method of attachment cannot be reused with each disassembly and reassembly of the device

Consideration 2: Distortion

+1= the method of attachment holds the mirror sections in so no vibration/motion the forklift under goes will distort the operators image

-1= the method of attachment does not hold the mirror sections in so no vibration/motion

the forklift under goes will distort the operators image

Consideration 3: Ease of Replacement

+1= the method of attachment is easy to reinstall back on the device

-1= the method of attachment requires new parts to reinstall each time it is remove therefore adding time to the process

	Considerations			
Solution	**1**	**2**	**3**	**Total**
Tape	-1	-1	-1	-3
Push Clips	1	-1	+1	-1
Slot System	1	1	-1	1
Zip Ties	-1	-1	-1	-3
Hinges	1	1	1	+3

Defense of Design Choice: The hinges were determined to be the most viable solution because they are reusable, have the ability to hold the sections tightly enough to stop distortion, and the sections can be easily reinstalled.

Forklift Safety Visibility Decision Matrix:

Method of Attachment of Device to Overhead Guard

Purpose: to determine the most viable method of attaching the device to the front of the forklift overhead guard in such a way that it has the ability to be attached in an "in use" and "not in use" position.

Potential Solutions:

1. Welding – The device is welded to the overhead guard.
2. Zip Ties – Zip ties are threaded through two holes in the sides of the device which connect around the front-most horizontal beam on the overhead guard.
3. Bolts – The device is bolted to the overhead guard through holes in the back of the device.
4. Screws – The device is screwed onto the overhead guard through holes in the back of the device.
5. Tape – The device is taped to the overhead guard.
6. Glue – The device is glued to the overhead guard.
7. C-Clamps – C-clamps are used to attach the device to the overhead guard.
8. Hinge System – system of four metal cylinders wherein two outside hollow cylinders are welded to the front of the overhead guard with a third inside cylinder welded to the device. The three cylinders are threaded by an inside cylinder that allows the device to have the rotational freedom of a hinge joint.

9. Carabiner System – system that allows for the device to be locked into a large "carabiner" like component on the overhead guard.
10. Overhead Guard Hole System – Holes are cut into the sides of the overhead guard. A metal axle is slid into those holes which would be secured by a cotter pin on each side. The device is welded to the center of the axle.
11. Cylinder System – The forward-most horizontal beam on the overhead guard is encased in a hollow cylinder. The device is welded to the outside of the cylinder.

Decision Considerations, with Importance Values:

(DQ means that failing this consideration disqualifies the potential solution)

Consideration 1: Ease of Removability and Reattachment (x1)

+1 The device can be removed and reattached without the need of additional tools.

- 1 To remove and reattach the device, additional tools must be used.

Consideration 2: Freedom of Motion (x2)

+2 The device can swing between the "in use" and "not in use" positions without having to remove and reattach the device.

0 Moving the device between the "in use" and "not in use" positions requires the device to be removed and reattached.

- 2 The device has no rotational freedom of movement.

Consideration 3: Need to Replace Attachment Component (x1)

+1 The device can be removed and reattached without having to replace the attachment component.

- 1 To remove and reattach the device, the attachment component must be replaced.

Consideration 4: Overhead Guard Structural Strength (x1)

+1 Implementing, removing, or reattaching the device does not adversely affect the structural strength of the overhead guard.

- 1 Implementing, removing, or reattaching the device adversely affects the structural strength of the overhead guard.

Consideration 5: Weight Held (x1)

+1 The method of attachment can hold 100 or more pounds.

0 The method of attachment can hold 50 pounds or more, but less than 100 pounds.

- 1 The method of attachment can hold less than 50 pounds.

Consideration 6: Time of Removal/Reattachment (x1)

+1 The device can be removed or reattached within two minutes.

- 1 Removing or reattaching the device takes longer than two minutes.

Consideration 7: Existing Technology (DQ)

+1 The technology necessary to implement the method of attachment exists.

DQ The technology necessary to implement the method of attachment does not exist.

Consideration 8: Obstruction of View (DQ)

+1 The method of attachment does not have any components that impede the path of the reflected light from the mirrors.

- 1 The method of attachment has at least one component that impedes the path of the reflected light from the mirrors.

Consideration 9: Device Unwanted Degrees of Freedom (x2)

+2 The device has no degrees of freedom other than the rotational freedom necessary to move it between the "in use" and "not in use" positions.

- 2 The device has degrees of freedom other than the necessary rotational freedom that allow it to move in ways that may cause the device to jostle around and make it susceptible to vibrate with the vibrational motion of the forklift, thereby disrupting the reflected view.

Matrix:

	Considerations									
Potential Solutions	1	2	3	4	5	6	7	8	9	Total
Welding	-1	-2	-1	-1	n/a	-1	+1	+1	+2	-2
Zip Ties	+1	0	- 1	+1	n/a	+1	+1	DQ	-2	DQ
Bolts	-1	0	+1	-1	n/a	+1	+1	DQ	+2	DQ
Screws	-1	0	+1	-1	n/a	+1	+1	DQ	+2	DQ
Tape	+1	0	-1	+1	n/a	+1	+1	+1	-2	+2
Glue	-1	-2	-1	+1	n/a	-1	+1	+1	+2	0
C-Clamps	+1	0	+1	+1	n/a	+1	+1	+1	+2	+8
Hinge System	+1	+2	+1	+1	n/a	+1	+1	+1	+2	+10
Carabiner System	+1	+2	+1	+1	n/a	+1	+1	+1	-2	+6

OHG Hole System	-1	+2	-1	-1	n/a	-1	+1	+1	+2	+2
Cylinder System	-1	+2	-1	+1	n/a	-1	+1	+1	+2	+4

NOTE: The column of boxes for consideration 5 has "n/a" filled in for all of the solutions because after the values for all of the other considerations were filled in, it was determined that no other solution could win other than the Hinge System even if they had +1s.

Defense of Design Choice:

The Hinge System was determined to be superior because it can be removed and reattached easily without the need of additional tools and without can be removed and reattached without having to replace the attachment component. The Hinge System can swing between the "in use" and "not in use" positions without having to remove and reattach the device. Implementing, removing, or reattaching the Hinge System does not adversely affect the structural strength of the overhead guard. The device can be removed or reattached within two minutes because all that its removal requires is to remove a cotter pin and slide out the Hinge Inside Cylinder part. The technology necessary to implement the Hinge System does exist; it relies only on mechanical parts that can be machined. The Hinge System allows the device to have no degrees of freedom other than the rotational freedom necessary to move it between the "in use" and "not in use" positions. Lastly, the Hinge System does not have any components that impede the path of the reflected light from the mirrors.

Forklift Safety Visibility Decision Matrix:

Device Locking Mechanism

Purpose: To decide which locking mechanism to use to hold the device in position.

Potential Solutions:

1. Gear Lock System- uses a gear on the end of an axle which the device swings on and a locking piece which meshes with the teeth of a gear to lock the axle in place. A spring keeps the locking piece in place, unless it is moved by the operator through the use of the string or other means.
2. Latch Lock System- a piece of metal slides into the device holding it in the upright position
3. Spring Lock- the device clips into a spring activated clip that allows for the device to be released at the push of a button
4. Hook System- a hook on either side on the section swings up and holds the device in place
5. Crank System- The device has a wire connected to it which is connected to a hand operated crank which the operator uses to lift/lower the device.

Considerations:

Durability

+1 The lock can withstand multiple locking and unlocking.

- 1 The lock's mechanisms will not hold up to multiple locking and unlocking

Complexity

+1 The lock is easy to install, build, and maintain.

- 1 The lock is not easy to install, build and maintain.

Ease of Use

+1 The lock is simple to use and allows for easy locking and unlocking for the operator.

- 1 The lock is not simple to use and does not allow for easy locking and unlocking for the operator.

Matrix:

Solutions	Durability	Complexity	Ease of Use	Total
Gear Lock System	+1	- 1	- 1	- 1
Latch Lock System	+1	+1	+1	+3
Spring Lock	- 1	- 1	+1	- 1
Hook System	+1	+1	- 1	+1
Crank	- 1	- 1	- 1	- 3

Defense of Decision: The Latch Lock System was determined to be the most viable solution because it can withstand multiple locking and unlocking,is easy to install, build, and maintain. It is also simple to use and allows for the operator to easily lock and unlock it.