Redesign of Electric Forklift

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Methodology
Understanding Electric Forklifts
- Basic Understanding
- Technical study
- Market study

Scope of the project
- operator cabin
- controls and feedback
- overall forklift

Data Collection and Analysis
- user study
- operational analysis
- problems identification
- synchronic analysis

Ideation
Forkliftunder study: Godrej GX 300 Electric Forklift

Design Brief

To redesign an Electric Forklift for better user experience

- The projects looks at a complete new dashboard designed
- Incorporate new technologies and layout necessary for improving the user interface.
- Reducing the cognitive load on the operator thereby making the operator more focused on the operations.
- Improvement in operator feedback for a better and faster sense of operation and maneuverability. Main feedback of the operator being visibility, improving the operators visibility
- Improvement in the Comfort and Safety of the operator
- Interior and Exterior styling

Thus improving the overall machine with an ultimate aim of increasing the productivity

Understanding present controls of Godrej GX 300 E Electric Forklift

Categories depending on their functions

Maneuvering controls

Steering Wheel
Acceleration
Brake
Reverse Switch/ Pedal
Speed control

Operating controls

Fork raise control (up/ down)
Fork Tilt Control (front/back)
Fork Sideways (left/right)
Neutralise switch

Other controls

Horn
Head Light
Turning Light
Emergency switch
Keying
Parking brake
Seat switch

Display

Analysis of Overall controls

CONTROL	FUNCTION	POSITION of controls with respect to the operator	INPUT given by the operator	DIRECTION OF MOTION	FEEDBACK
Maneuvering the forklift					
Steering wheel	Giving direction to the wheel	In font/to the left	One/ two hand wheel	Rotation with respect to the vehicle	No direct feedback of the position of the wheels
Accelerator	Forward movement of wheel	Base	Right leg pedal	Downwards	Movement of the vehicle
Brake	Stopping rotation of the wheel	Base	Right Leg pedal	Downwards	Stopping of the Vehicle
Reverse	Backward movement of the wheel	Switch to inverse the acceleration pedal	Left hand switch		Movement of the vehicle
		Separate reverse pedal	Right leg pedal	Downwards	
Speed control	Control the speed of the vehicle – high/low	Below steering wheel – left	Left hand switch		Position of the lever + speed of the vehicle during movement
Other Features					
Horn	Warn the presence of the forklift	On the steering wheel	Thumb press		Auditory
Head Light	Front lights for better visibility in the dark	Below steering wheel – right	Right hand switch		Visual
Turning Light	Light indicator in the direction of turn	Below steering wheel – right	Right hand switch		Visual + auditory

CONTROL	FUNCTION	POSITION of controls with respect to the operator	INPUT given by the operator	DIRECTION OF MOTION	FEEDBACK
Operations					
Fork raise control	Raising the forks – up/down	A separate operation console to the right of the steering wheel	Right hand lever/ joystick/ finger rockers	Front/back	Visual movement of the forks
Fork Tilt Control	Tilting the forks – front/back			Front/back	Visual movements of the forks
Fork Side Shifter	Shifting the forks – left/right			Front/back	Visual movements of the forks
Neutralize switch	Bringing forks to neutral position	Thumb press	Thumb press		Visual movement of the forks
Other Features					
Emergency switch	Switch to turn off machine immediately	Right of the seat	Right hand press	Downwards	Immediate switch off
Seat Safety Switch	Engine shuts off in the absence of the operator	Below seat	Weight of the body	Downward body weight	Immediate switch off
Parking Break	To manually stop the vehicle in place	Left hand dashboard	Left hand lever	Pull back	Tactile feel and final position of the lever
Keying	Key permission to start the vehicle	Below the steering wheel	Right hand	Turning	Tactile feel of turning and engine starting
Display	Display the statistics of the vehicle	Dashboard			

Insights from the table:

- The fork lever controls, positioned on the front cowl of the forklift, requires full arm movement. Continuous lever operation leads to operator fatigue.
- The operator has to look down to identify the right lever to perform the required operation. This can be achieved through experience.
- The feedback provided during the fork operation reduces with the height of the operation. At a greater height the position of the forks have to be judged by the operator by experience.
- The tilt of the forks is hard to judge when forks are at height
- The operation controls do not give a direct relation to the operation being carried out. So it is only through experience that the operator learns. This reduces the reaction time in emergency situations.
- Levers required a considerable amount of travel to operate so there was a limitation on the speed of operation.

By taking advantage of the experience of using conventional methods of operating should be taken advantage of. Simultaneously a new operator should also find the easy to understand and maneuver the forklift.

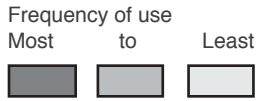
Understanding Theory behind controls of Forklift
Steering ratio
Fork operation
Turning radius

Study of Controls of Other Forklifts
Synchronic analysis of forklift control mechanisms used in other forklifts.

Frequency of controls used

Grouping of controls according to the functions performed by the forklift and the frequency of controls used for each function was studied.

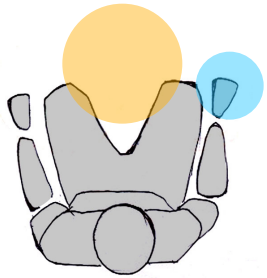
Function	Steering wheel	Acceleration	Brake	Reverse switch	Speed control switch	Horn	Turning Light	Fork Lift	Fork Tilt	Fork sideways	Neutralise switch	Headlight	Keying	Parking Break	Emergency switch	
Driving with/without load																
Loading/ Unloading																
Conditional use																



- Safety rules states that the operational controls should not be operated during maneuvering the forklift, hence the operational controls are kept separate from the maneuvering controls
- Safety controls like emergency switches, although used very frequently, should be positioned for the easy reach of the operator.
- It seen that during load operation, both operational controls and the maneuvering controls have to be used.

Based on the analysis, variations for positioning the 2 main grouping of controls, maneuvering controls and the operating controls were tried out.

Positioning of most frequently used controls

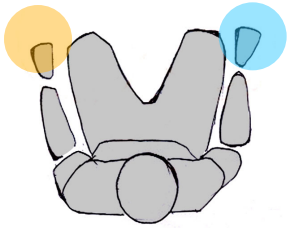


- Present position of controls of Godrej GX 300 E
- Steering in the center
- Operational controls to the side of the steering

Steering

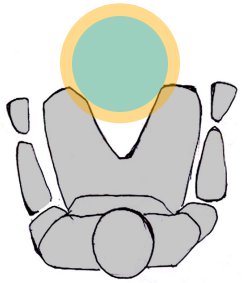
Operational controls

A



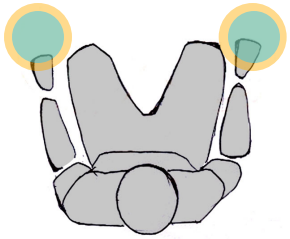
- Steering and operational controls on both sides
- hands on most frequently used controls at all time

B



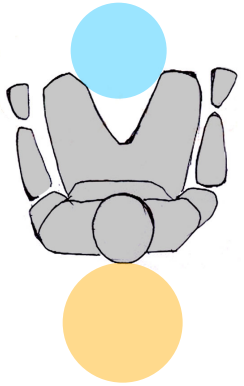
- Operational controls mounted on the steering wheel
- The operator has all the controls at his finger tips

C



- Steering and operational controls on both hands for better control
- 2 modes of controls to separate steering and operational controls

D

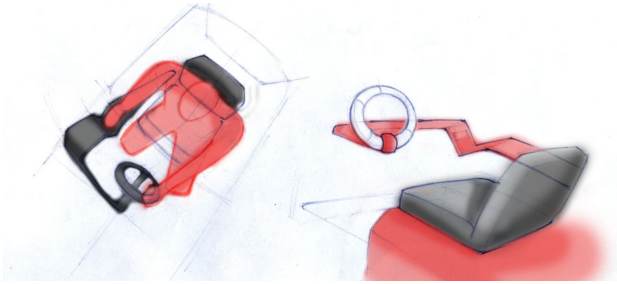


- Operational controls in the front
- Maneuvering controls behind the operator Operator seat swivels backward and the vehicle is driven in reverse

Position A was taken ahead

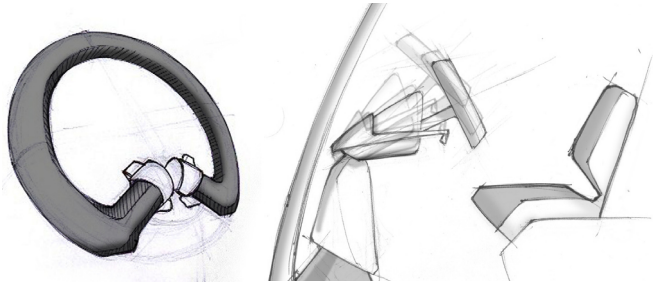
Evaluating Positions

A



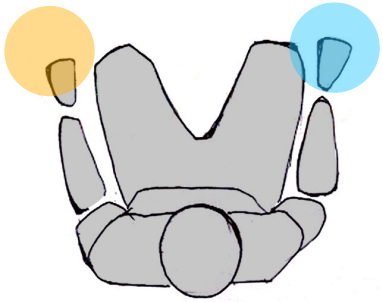
Layout A was taken ahead
Most frequently used controls at hand
operational joystick for better control
Steering follows semantics of regular forklifts
Steering wheel and operational controls placed at comfortable positions

B



C

Layout C
feature of controls attached to the seat, were added in later
allows multiple seating positions



Detailing out the Controls

1. Maneuvering controls
2. Operational Controls
3. Other controls

Maneuvering Controls

Steering Mechanism

using steer by wire mechanism

- flexibility in positioning
- adjustable steering ratio - subjected to testing

Position -

Steering as a left hand operation

Steering wheel shifted from the center to the primary reach zone

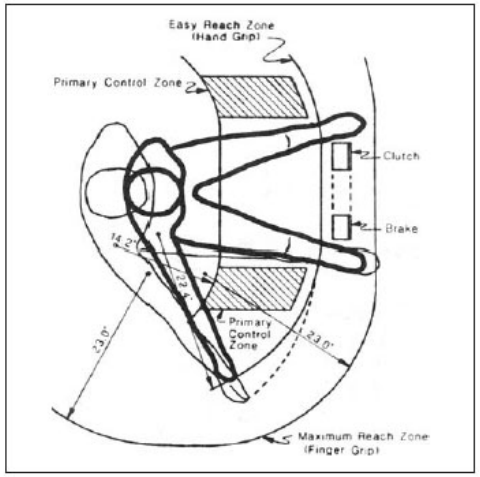


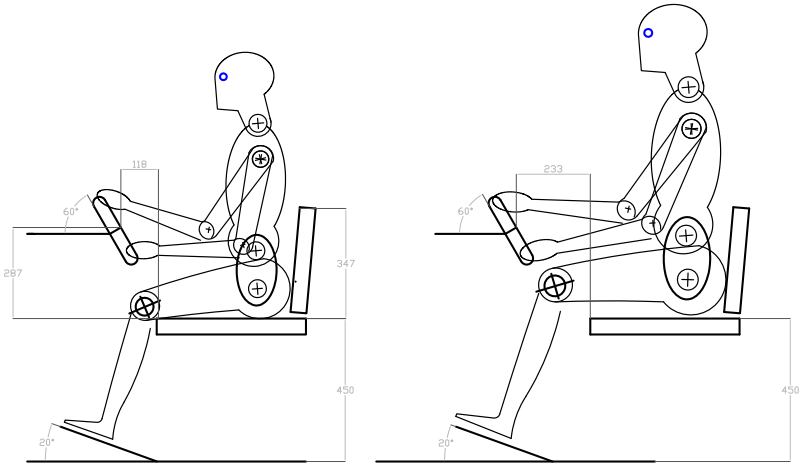
image showing arm reach zones*

*Hand Controls for agricultural equipment - http://cobweb.ecn.purdue.edu/~bng/BNG/Resource%20Center/Plowshares/ps02.pdf

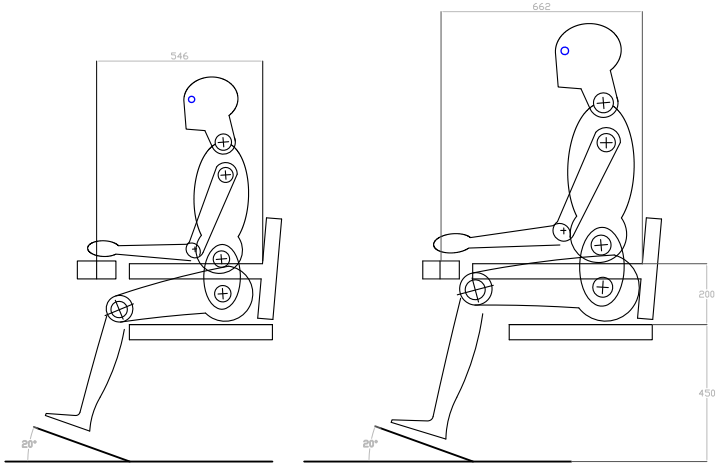
Inintial Dimensioning

Initial Anthropometric dimensions for 5th percentile male and 95th percentile male*

Seat height 450mm (50th percentile)
Height of back rest from seat height 350mm
Angle of steering wheel inclination 60 degrees
Maximum Clearance from seat height height from seat 180mm
steering knob diameter 58mm (standard)



Positioning steering wheel for 5th and 95th percentile



Positioning operational controls for 5th to 95th percentile

**Indian anthropometric dimensions, by Debkumar Chakrabarti*

Rig testing

Using the data. rig was made for testing

gradations for various heights of steering wheel from the ground

gradations for various steering wheel diameter

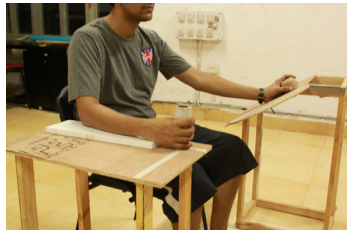
Testing
The rig was tested for most comfortable location of the controls
The dimensions tested for

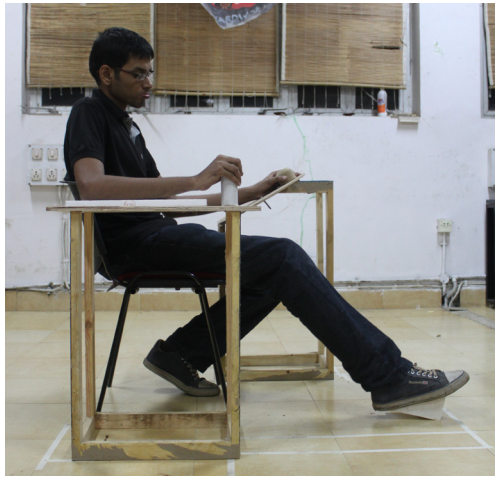
- Steering wheel distance from the seat
- Steering wheel center distance from the ground
- Steering wheel inclination
- Offset of Steering wheel from the center of the seat
- Offset of operational control from the center of the seat

Foot pedals were not tested for as they are positioned as that of the Godrej forklit GX 300 E

Testing

	Height (mm)	Distance of the steering wheel center to the seat back rest (mm)	Distance of the steering wheel diameter to the ground (mm)	Diameter of the steering wheel (mm)	Angle of steering wheel (degree)	Offset distance of the steering wheel center to the center of the seat (mm)	Offset distance of the joystick center to the center of the seat (mm)	Distance of the joystick center to the backrest of the seat (mm)
a	1860	530	670	180	30	100	250	440
b	1650	520	700	140	34	150	260	380
c	1700	570	680	220	28	220	270	410
d	1675	530	710	180	30	105	250	400
e	1630	470	670	160	32	150	250	380
f	1750	500	720	200	34	200	260	390
g	1700	560	710	180	30	170	250	390
h	1600	470	680	160	32	150	240	380





Data from testing

Conclusion

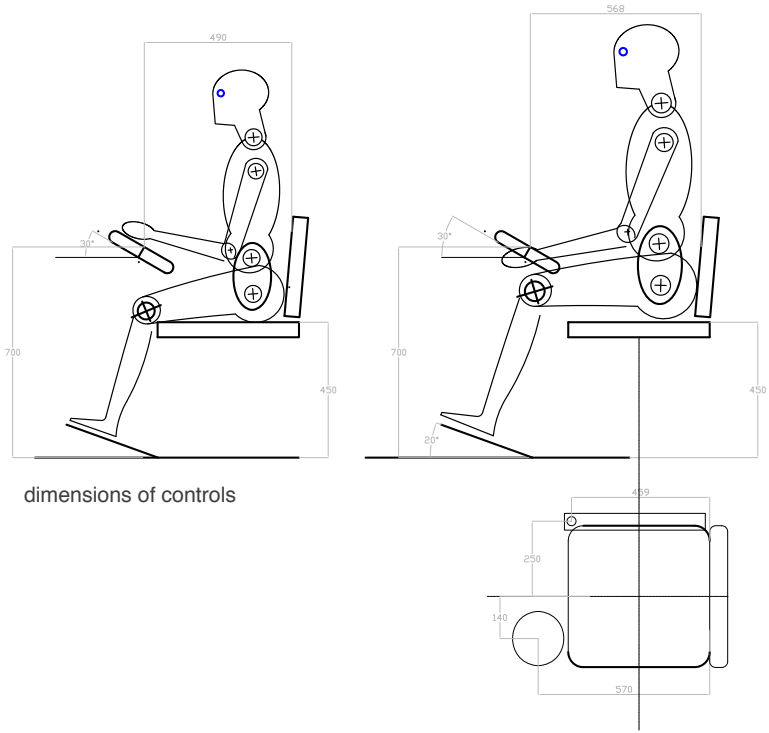
Distance of the steering wheel diameter to the ground	700mm
Diameter of the steering wheel	180mm
Angle of steering wheel	30 degree
Offset distance of the steering wheel center to the center of the seat	140mm
Offset distance of the joystick center to the center of the seat	250mm
To accommodate comfortable steering wheel and joystick distance from the seat back rest requires a seat adjust ability of	80mm
Distance of the steering wheel center to the seat back rest	490mm - 570mm
Distance of the joystick center to the backrest of the seat	380mm - 460mm

Foot pedal

Position of foot pedals have not been taken under consideration as the positions and usability is kept the same as that of Godrej Forklift GX 300 E

2 Foot pedals for acceleration and braking, both pedals are operated by the right leg

Break actuation point from the seat is 400mm and accelerator actuation point at 370mm



dimensions of controls

Operating Controls

Controls used to maneuver the forks for operation

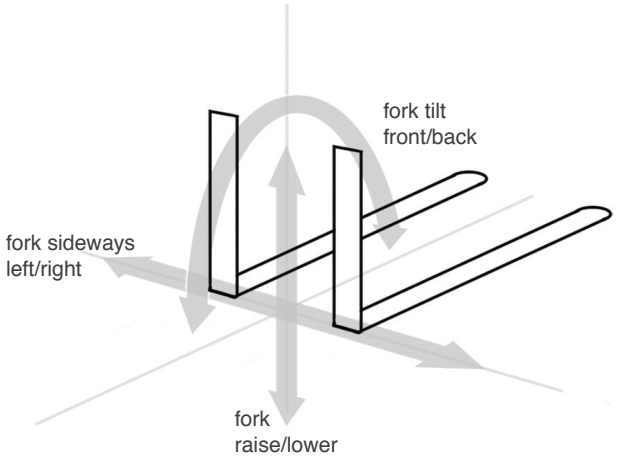
Operational Controls for Godrej Forklift GX 300 E

- 2 levers for for fork operations
- located at the front cowl

Operations performed

- Fork Raise/ Lower
- Fork Tilt front/back

- Fork sideways right/left - the additional control has been added to control the sideways movement of the forks. This helps in faster aligning of the forks, instead of moving the whole forklift for aligning.



Fork Lift Operation

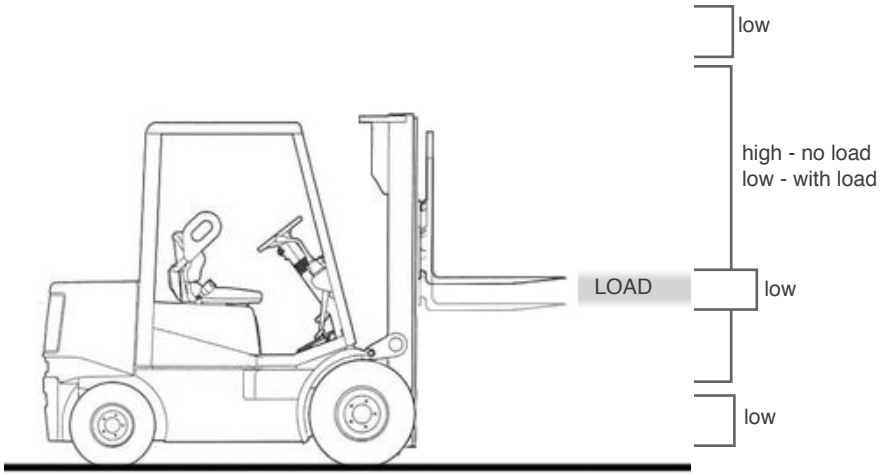
Operation: Lifting and Lowering of the forks

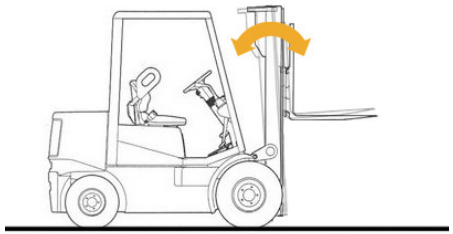
Godrej GX 300E *
Lifting load speed, with load - 0.2m/s - 0.18m/s
Lowering speed, with load - 0.35m/s - 0.3m/s

- For a more responsive system the speed of the controls should vary according to the operation conditions

Speed required of fork travel	
When no load - forks lift	high
forks lowered	high
at region of alignment	low
When load - forks lift	low
forks lowered	low
Reaching Highest point	decelerated
Reaching Lowest point	decelerated

As the height of the load to be picked up from varies, the control of fork speed should be in the hands of the operator. This helps in faster operations.
The operator can lower the forks faster when in no load condition, this helps in speeding up his operation.



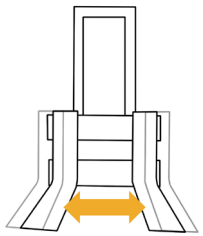


Fork Tilt Operation

Operation: Tilting of mast to ring back cg of the load

Godrej GX 300E *
Tilt angle forward 2degrees above 3700MFH
5degrees upto 3700MFH
Tilt angle backward 5degrees above 3700MFH
10degrees upto 3700MFH

- At operations at a height the operator does not get clear indication of the mast angle. Insertion of forks at wrong angles would lead to accidents.
- The angle of play for fork tilt is very less, and the operator should have a good control over the tilt. The Control response of the fork tilt control should be high.



Fork Sideways movement

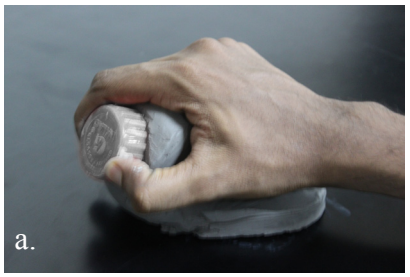
Operation: sideways movement of the forks left/right

This control helps in accurate positioning of the forks. Without this the operator has to back up and forth to align the forks.

This control is for fine positioning, so the fork displacement should be kept less.

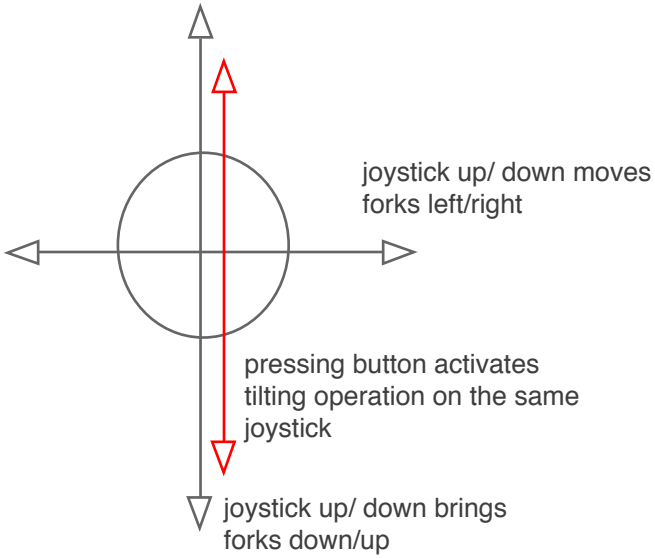
- The control response should be kept high

Ideations and Mock-ups



Controls were made in clay and evaluated with users in terms of comfort of joystick and operation comfort

Final concept of Oper



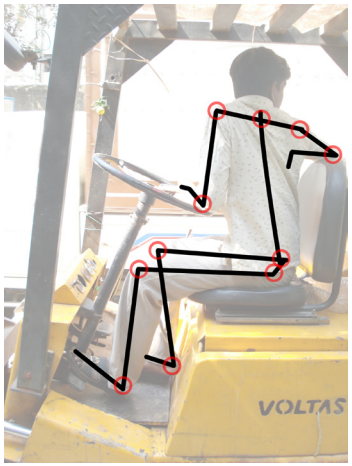
Visibility

Visibility is a most important feedback

Operator Visibility of Godrej GX 300 E forklift

The obstructions of field of vision for the field of vision are

- Front mast
- Over Head Guard
- Overhead Guard support
- Load being carried
- Blind spots



operating in reverse

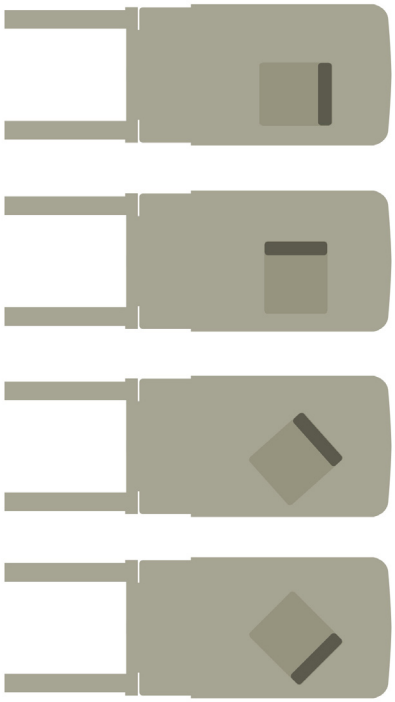
visibility of operations at a height

Visibility Problems faced by the operator

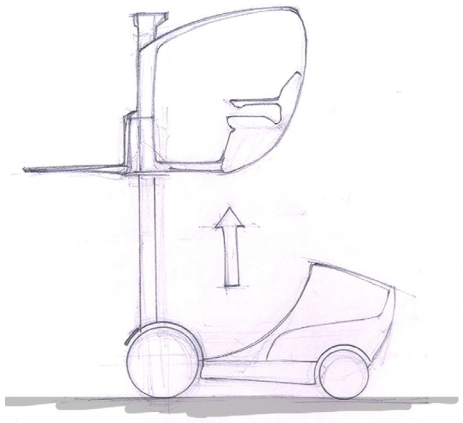
- High Load condition - Instances where high load is begin carried in front of him, blocks the vision of the operator. This can lead to accidents.
- High load conditions, operator is aksed to drive in reverse. Continuous driving in reverse lead to strain in operators back
- Performing operations at a height - operator has to lean out to get a clearer picture of the position of the forks and the Here the accuracy of the operation depends on the operator's experience. The vision of the operator is partially blocked by the overhead guard.
- Pedestrian safety

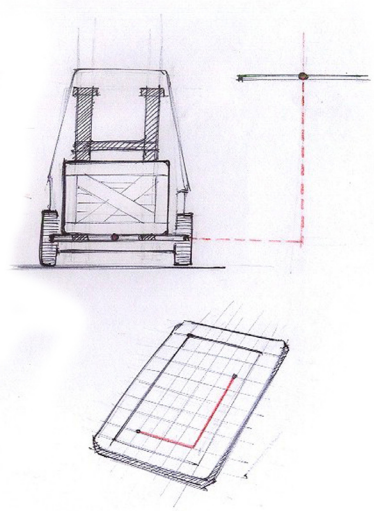
Various possibilities of Vision Improvement

Ideations

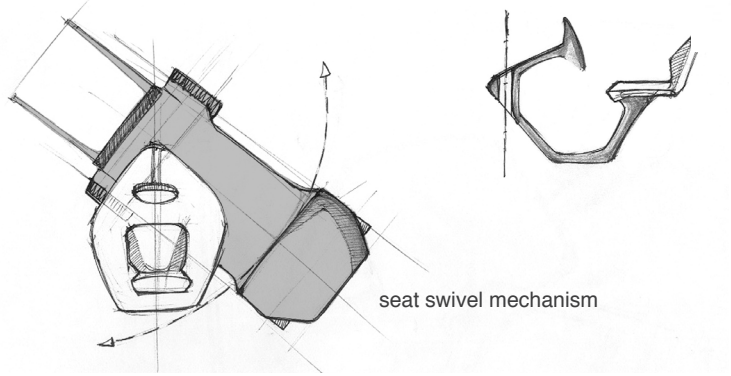


variable seat positions



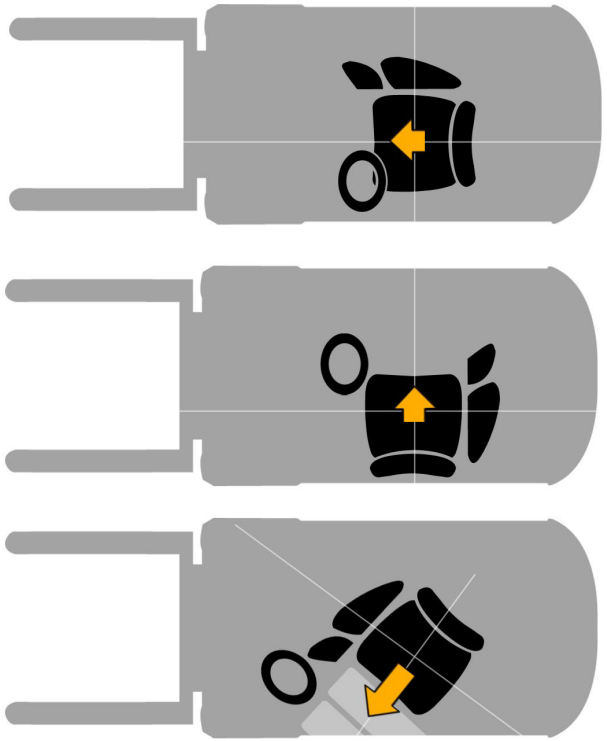


using sensors and cameras



seat swivel mechanism

Clustering and evaluation

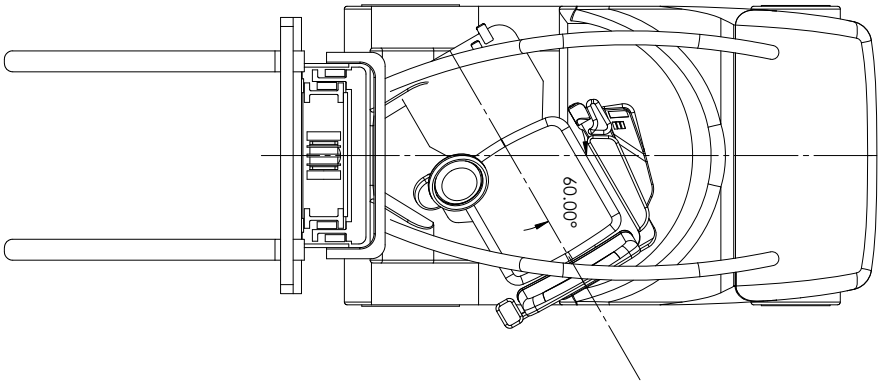


Normal Driving mode
The operator faces towards the front of the vehicle.

Operation mode
The seat swivels outward to give him a better visibility.

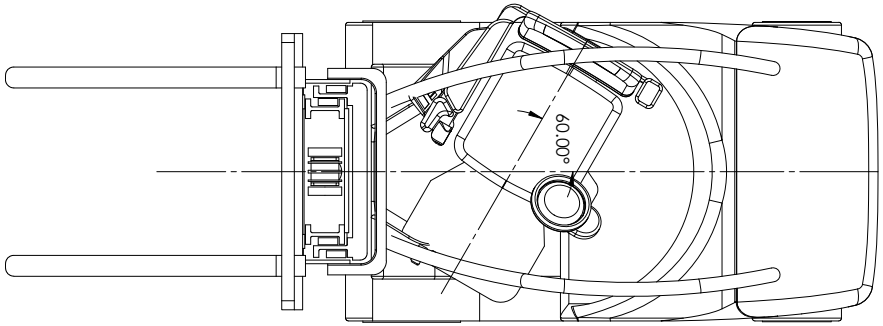
Stop mode
When the vehicle is parked, the steering swivels aside providing a comfortable and safe ingress and egress.

Detailing of swivel seat mechanism



Operational mode

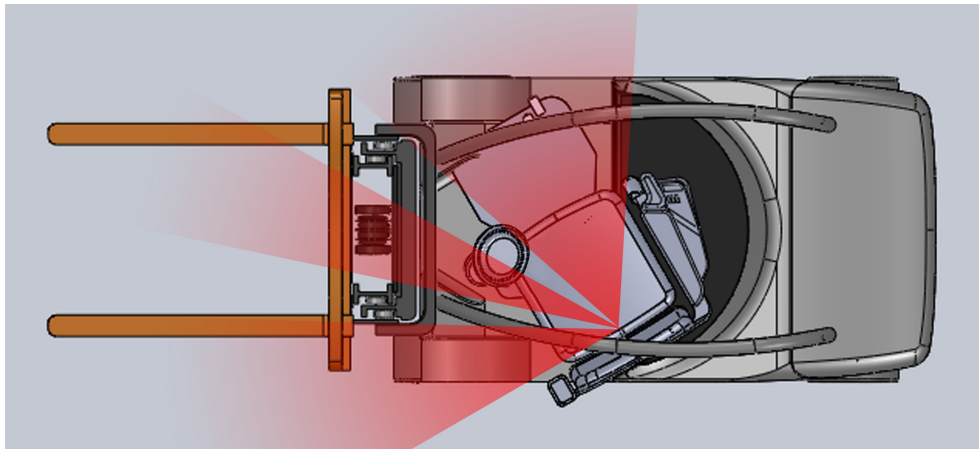
- seat swivels to 60 degree giving operator better visibility of forks at height
- while reversing the forklift operator does not have to twist his body



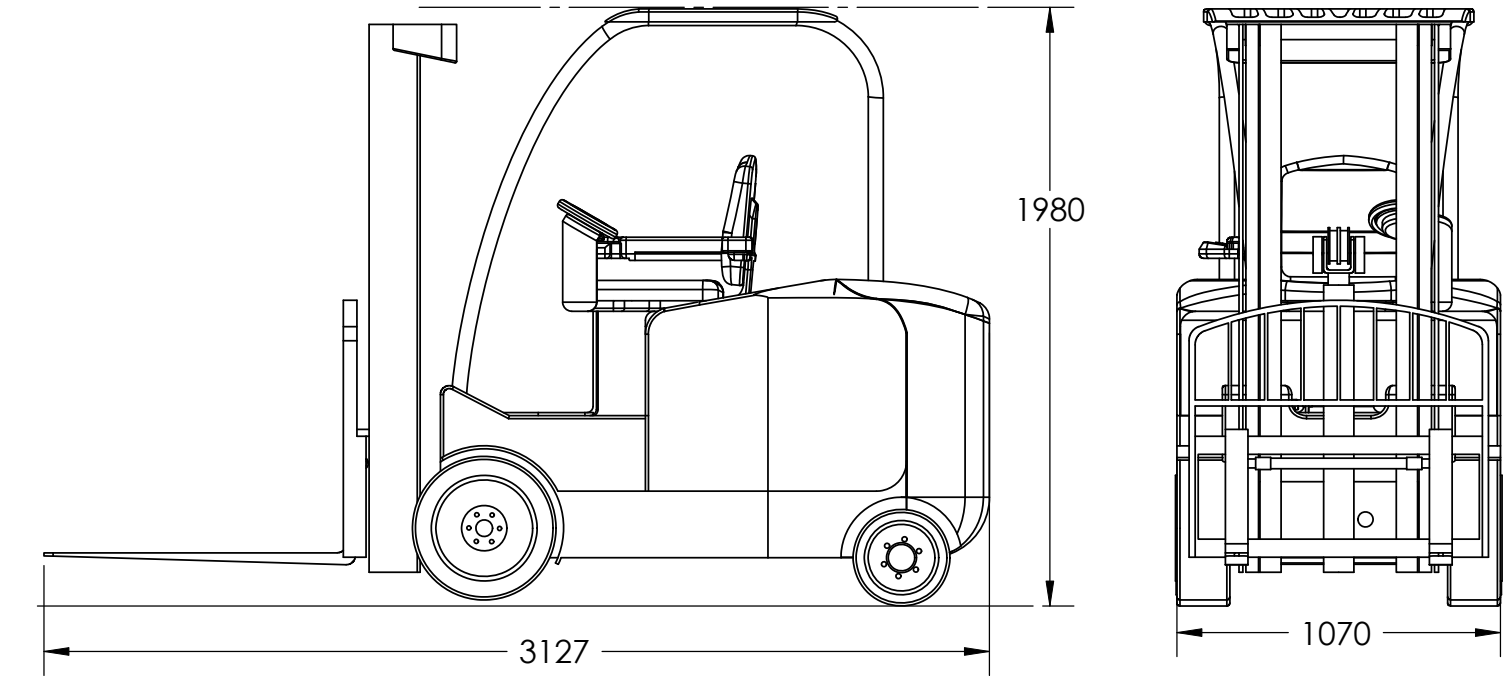
Operational mode

- seat swivels to 60 degree when forklift is switched off
- operator can get out of the vehicle with ease

Detailing of swivel seat mechanism



Overall dimensions



Final Concept