Industrial Design Project- 3

redesigning of industrial vehicle
electric forklift

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Approval Sheet

The Industrial design project 3 entitled “redesign of industrial forklift” by Vinish Janardhanan (08613003) is approved, in partial fulfillment of the requirements for Master of Design Degree in Industrial Design at Industrial Design Centre, Indian Institute Of Technology, Bombay.

Guide:

Chairperson:

Internal Examiner:

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Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsifi ed any idea/data/fact/ source in my submission. I understand that any violation of the above will be cause for disciplinary action by the institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Acknowledgment

I wish to express my gratitude to my guide Prof. Ramachandran who has always been there to support my ideas and not giving up hope during the complete journey of my project. I would like to thank Prof. Nachiketa Sadhu and all the other professors who have supported me during the project and for their critical feedbacks during the stage presentations. I would also like to thank Prof. Sandesh for being very cooperative and understanding as a coordinator for the semester project.

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Abstract

Forklift manufacturers believe that the overall economy of the forklift does not depend only on the product alone but also the operative efficiency of the operator and the efficient use .By improving the operator environment and the relation with the machine would help to improve his efficiency.

Interface is the part of a product or a system which communicates with the operator. It has become important to design suitable and functional user interfaces to remove the cognitive load of the vehicle from the operator and concentrating on the work at hand. The posture, feel and aesthetics involved of his operating cabin should give him a sense of comfort and safety provided by the forklift. To design a functioning user interface one has to know the users physical and psychic requirements and also understand how the human operates in his environment

The project deals with redesign of operator controls and its layout for a a faster and more effective response. By solving problems related to visibility of the operator, feedback was improved. Considerations were also given to the overall usability, comfort, safety of the operator.

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1.Introduction

Industrial Vehicles are operation intensive vehicles. The primary aim of these vehicle is to provide fast and consistent assistance to the operations of any industry. Material handling is one sector which utilizes machines for operation. All industries have a need to handle and transfer load.

To ensure fast and efficient productivity, industries require better and faster material handling solutions to support them. This has led the material handling manufacturers to develop and adopt newer technologies to improve the performance of the forklift. The tough competition in the material handling industry has lead the manufacturers to develop and adopt newer technologies. These developments are not only in the technical performance of the machine but also in for the safety and productivity of the operator. A commonly used material handling equipment for lifting and transferring heavy load is the Forklift. Forklift industry has been established for years and have been growing ever since.

After a basic understanding of the types and functions of the various forklifts available in the market, I chose to work on the counterbalance forklift. The counterbalance forklift is the most commonly used forklift in industries today because of its flexibility and the ability to adjust to the need of the application.

2. Understanding Counterbalance Electric Forklift

2.1.Counterbalance Electric Forklift

Counterbalance forklift is an industrial Vehicle used to lift and transport heavy loads. The counter balance forklifts are classified under various categories according to capacity, power source, function or environment.

Counterbalance forklifts are so called as they are designed such that the weight being lifted by the forks are counterbalanced by a dead weight provided in the forklift.

Counterbalance electric forklifts are powered by a battery.

Advantages of electric forklift

- lower cost per hour of operation
- produce zero emissions hence used indoors like warehouses and manufacturing plants
- quieter operation
- no fuel storage requirement

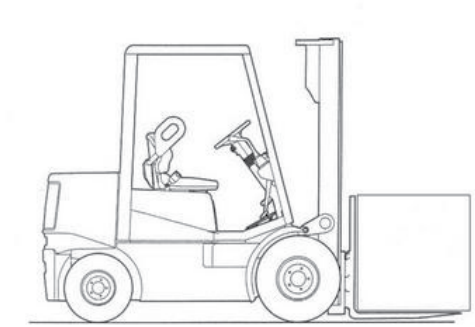


image1: counterbalance forklift

Disadvantages of electric forklift

- higher initial cost. New electric forklifts can cost 20% to 40% more than similarly-rated IC forklifts.
- batteries typically provide enough power for one standard eight-hour shift, which translates into 5 or 6 hours of constant usage. Charging a forklift battery takes 8 hours, plus an additional 8 hours of cooling time before it can be used. Due to this slow charging speed, companies buy extra batteries so one can be charged while the other one is used
- the need for a battery charging station. The chargers should be located in a dry, ventilated, and temperature-controlled location.
- using multiple batteries, will also need special cranes to change the batteries.
- not suited for outdoor use - they can be used on well-paved parking lot, but can’t be used in the rain.

Load Handled

The forklifts are classified according to the tonnage. The load carried varies according to the application. Special types of load would require specialised forks to handle them. In companies the load size is standardized by fixed pallet sizes.
A pallet is a flat transport structure that supports goods in a stable fashion while being lifted by a forklift, pallet jack, front loader or other jacking device. A pallet is the structural foundation of a unit load which allows handling and storage efficiencies

Power Source

The power source of most electric forklift is Lead-acid batteries. The output of the battery varies according to the capacity of forklift. Many manufacturers have been trying to find a better and greener energy source, like lithium-ion batteries, fuel cells and super- capacitors, to replace lead acid batteries, but till now lead acid batteries offer, by far, the lowest acquisition cost per KWh today for powering electric trucks. These bulky batteries also contribute to the dead weight of the forklift.

Usage

The low emission feature of electric forklifts allow them to be driven indoors. They are used at Manufacturing assemblies and Warehouses.

image2: parts of counterbalance electric forklift [1]

2.2.Parts of a Counterbalance Forklift

A typical counterbalanced forklift contains the following components[Ref.1]:

- **Truck Frame** is the base of the machine to which the mast, axles, wheels, counterweight, overhead guard and power source are attached. The frame may have fuel and hydraulic fluid tanks constructed as part of the frame assembly.
- **Counterweight** is a heavy cast iron mass attached to the rear of the forklift truck frame. The purpose of the counterweight is to counterbalance the load being lifted. In an electric forklift the large lead-acid battery itself may serve as part of the counterweight.
- **Cab** is the area that contains a seat for the operator along with the control pedals, steering wheel, levers, switches and a dashboard containing operator readouts. The cab area may be open or enclosed, but it is covered by the cage-like overhead guard assembly.
- **Overhead Guard** - is a metal roof supported by posts at each corner of the cab that helps protect the operator from any falling objects. On some forklifts, the overhead guard is an integrated part of the frame assembly.
- **Power Source** - most commonly used battery is the lead-acid battery. The electric motors used on a forklift may be either DC or AC types.
- **Tilt Cylinders** - are hydraulic cylinders that are mounted to the truck frame and the mast. The tilt cylinders pivot the mast to assist in engaging a load.

- **Mast** - is the vertical assembly that does the work of raising and lowering the load. It is made up of interlocking rails that also provide lateral stability. The interlocking rails may either have rollers or bushings as guides. The mast is either hydraulically operated by one or more hydraulic cylinders or it may be chain operated with a hydraulic motor providing motive power. It may be mounted to the front axle or the frame of the forklift.
- **Carriage** is the component to which the forks or other attachments mount. It is mounted into and moves up and down the mast rails by means of chains or by being directly attached to the hydraulic cylinder. Like the mast, the carriage may have either rollers or bushings to guide it in the interlocking mast rails.
- **Load Back Rest** is a rack-like extension that is either bolted or welded to the carriage in order to prevent the load from shifting backward when the carriage is lifted to full height.
- **Attachments** may consist of forks or tines that are the L-shaped members that engage the load. A variety of other types of material handling attachments are available. Some attachments include sideshifters, slipsheet attachments, carton clamps, multipurpose clamps, rotators, fork positioners, carpet poles, pole handlers, container handlers and roll clamps.

    - Side Shifters - Sideshifters are the most common additional attachment encountered on forklift trucks. The sideshifter
    - allows lateral shift of the load
    - Multi-side Shifter - they allow the pick up of two, three or even four transport units
    - Fork Positioner - forklift truck especially where the width of the load constantly changes. Adjustment of the distance between forks to accommodate different widths
    - Multi Pallet Handlers - Multi Pallet Handlers are, as with multi sideshifters, specific for transporting several pallets or transport units simultaneously
    - Rotators-Ladle Tripper - Rotators-Ladle Tripper
    - Clamps
    - Slip on Clamping Arms
    - Drum Clamps
    - Rotating Clamps
    - Reach Forks - These attachments allow loading of lorries or railway wagons from the side
    - Pantograph-pusher
    - Back Rest - Load Stabilizer
    - Push-Pull
    - Crane Jib
    - Forks

2.3.Theory behind loading

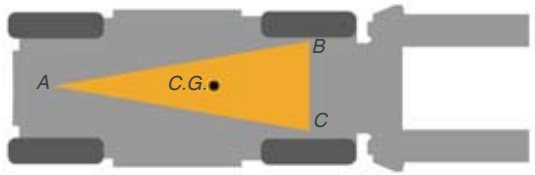


image3: Stability Triangle

Stability Triangle

The support points for the forklift are located at points A, B, and C. The triangle formed between points A, B, and C is called the Stability Triangle. The forklift will not tip over as long as the center of gravity remains inside the triangle.

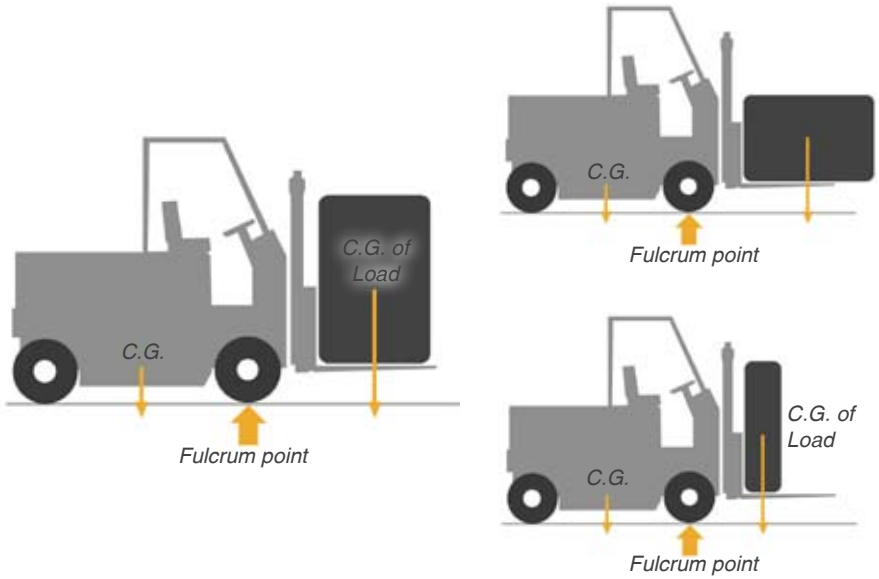


image4: fulcrum point, load center

Fulcrum Point

The front wheels of a forklift serve as the Fulcrum Point between the weight of the forklift and the weight of the load being carried. If the weight of the load is equal to the weight of the forklift, with equal distances between the centers of gravity, it is possible to “seesaw” a forklift on its front wheels.

Load center

It is the distance of the center of gravity of the load from the mast of the forklift

If the load center is farther away from the fulcrum point, this will cause the center of gravity for both the forklift and the load to shift beyond the front wheels of the forklift, and the forklift will tip forward.

On the other hand, if the load center closer to the fulcrum point, this will cause the center of gravity for both the forklift and the load to shift behind the front wheels of the forklift. With this arrangement, there is no danger of the forklift tipping forward.

2.4.The Forklift market

The modern forklift was developed in the 1920s and since then the forklift has since become an indispensable piece of equipment in manufacturing and warehousing operations. As technology grows, the face of the forklift industry grows with it to achieve a safer and productive vehicle. The forklift market was studied to understand the future evolution of forklifts.

2.4.1.Indian Scenario

- A clear picture of the Indian forklift market was understood after reading the interview with Milind M. Shahane, Vice President - Voltas Ltd and a personal interview with Vinay Kulkarni, Head designer - Material Handling Division ,Godrej and Boyce Mfg. India has always been a nation of surplus manpower. But in recent time the scenario has been changing with industrialization.
- The two main manufacturers of forklifts are Godrej and Boyce Mfg. and Voltas Ltd. Other smaller manufacturers are Jaldoot, Maini Materials Movement Pvt. Ltd., etc

Godrej Material Handling [Ref.2]
Mumbai

Voltas Ltd. [Ref. 3]
Mumbai

- With multinationals setting up manufacturing units in India and Indian companies are also investing in manufacturing plants and warehousing required for supporting manufacturing plants, a steady growth in material handling equipment can be seen.
- The buyer is different from the operator. The buyers requirement is low cost, easy maintenance, narrow forklifts for narrow aisles, less turning radius, etc. Less attention is given to the ergonomic and aesthetic part of a forklift.
- Indian equipment is rugged and reliable and is competitively priced as compared to the foreign machines. The share of Indian equipment is over 80 per cent of the total machines in the domestic market.
- The challenges faced by the companies are due to the low level of demand and volume, cost disadvantage due to economies of scale, availability of components and due to administrative and infrastructure bottlenecks.
- Compared to the international market, the Indian forklifts are behind in terms of sophistication of technology in electronic controls and the overall ergonomics and aesthetics of the equipment. But recently have been incorporating features available internationally to match with the performance and safety standards.
- The secondhand material handling equipment market is not yet structured or developed like the secondhand automobile market

2.4.2.International Scenario

There is a tough competition in the international market, with all major companies coming up with more advanced models of forklifts every year. The major forklift manufacturers are,

Linde Material Handling
Germany [Ref.4]

Nissan Forklift [Ref. 7]
USA

Crown Equipment [Ref. 5]
Corporation
USA

Yale Materials Handling
Corporation [Ref. 8]
USA

Jungheinrich [Ref. 6]
Germany

After understanding the present international forklifts the recent trends have been noticed.

- The issues companies have been aiming at is that of technology advancements to increase the productivity of the system.
- Developments in power source. All major companies have development teams working on a new power sources which can substitute the common lead acid battery system which have been running for years. Other power sources being developed are Hybrids, fuel cells, etc. But it will take time for forklifts to shift to such alternate methods.
- Other market trends in forklifts seen are:
    - better operator comfort in terms of seating, ergonomics, steering
    - better visibility to operator in operations
    - better safety
    - many safety features
    - replacement of parts with non-metal parts, thus bringing down the unladen weight of material handling equipment

2.5.Forklift Accidents

Forklift trucks although an essential part of most industries, studies show that they are major cause of accidents in the workplace. Forklift induced injuries can be severe or fatal as they are heavy and powerful vehicles. Statistical studies show that major forklift accidents occur due to various reasons such as [Ref.9][Ref.10]

- Overturn – as the vehicle has a high center of gravity, a small imbalance can overturn the vehicle
  - Carrying unstable load
  - Driving on inclined surface
  - Uneven ground
  - High speed at sharp turns
  - Heavy load at height

  Injuries to the operator can be avoided by having an overhead rollover and by providing proper seat belts to the operator

- Pedestrians – Pedestrians get injured at places where there is more movement
  - Forklifts have a high momentum being a heavy vehicle
  - Radius turnings by the operator is misjudged
  - During reversing the forklift
  - Pedestrians are not aware of incoming forklifts

  This is solved by proper pedestrian roadways and alarm systems through sensors, to alert them of a forklift in proximity.

- Stationary objects – operator often scratches objects in the surroundings due to misjudgment

  Mistakes by operator
  - by choosing the wrong control by the operator at the wrong time
  - Failure to react at the right moment
  - Slips/mistakes

3.Scope of the Project

From the understanding of the forklift so far, gave me a direction to work in. The trend in the market shows how technological developments have been introduced in a forklift to improve the performance and safety of the forklift. The performance of any machine depends not only on the efficiency of the machine but also on the relation between the operator and the machine.

My focus was turned towards improving the relation between the operator and the forklift. By keeping the operator at the center and developing the forklift around him. The further study included a closer understanding of the relationship with the forklift and its behavior in the environment. For this my focus areas were divided into four sections

- Controls

The interface through which the operator communicates with the vehicle. The interface has to be structured for providing the right inputs form the operator to the vehicle. The interface should be designed to remove the cognitive load of the vehicle from the operator and concentrating on the work at hand.

- Visibility

The feedback of the operations performed are mostly visual. During operations and during maneuvering the forklift the operator uses his visual feedback to ensure his movements. By providing better visibility to the operator can lead to faster operations and in reducing accidents.

- Comfort and Safety

The operator works for 6-7hr shifts and forklifts should be designed for long comfortable sitting operations without inducing any strain or long term injuries. The safety of the operator, the forklift and its surrounding is important. Accidents can lead to a loss of time, money and manpower. By providing safety features, the chances of accidents can be reduced and can ensure normal functioning of the workplace

- Aesthetic

The internal and external aesthetics of the forklift plays an important role in motivating and performance of the operator. With the innovation involved there is a need for a fresh look to the forklift to compete in the market.

This was done as the problems in these sections involved are different and hence needed to be solved using different tools and different methods. As each of these sections are integrated to form the final product, sections were not ignored during the design process.

4.Data Collection and Analysis

Further understanding involved seeing the forklift in operation,
interviewing operators and maintenance staff,
understanding the technical working of the forklift,
theory behind the functionality,
problems/ difficulties faced by the operators,
understanding similar products in the market and finally
analyzing the data

4.1.Places visited

- Larsen and Toubro Ltd., Switchgear division
- Metro –Jungheinrich EVT 112, EJC 110, EJC 214
  Operator name – Dutta, Prashant
- Godrej and Boyce Mfg., Material Handling Division
  Head Designer - Vinay Kulkarni
  Sr. Executive, Design – Rahul R. Jadhay
- Hindustan Crane Service, Sakinaka
  Engineer, Operator – Arun Singh

4.2.Understanding the users

Understanding the working of the forklift in the actual environment was carried out by interviewing various operators, helpers, engineers and manufacturers who have a daily interaction with the forklift. The following observations were made

- There are dedicated forklift drivers to operate each forklift. They have a daily shift of 6-8hours.
- Their age group was for 20-40yrs
- The operators have been trained and are well-versed with the operation of the forklift.
- Modifications and maintenance done to suit the needs of the company
- The forklifts seen in various companies have been worked on for years, by maintaining the vehicle regularly.
- The buyer is different from the operator. The buyers requirement is low cost, easy maintenance, narrow forklifts for narrow aisles, less turning radius, etc. Less attention is given to the ergonomic and aesthetic part of a forklift.

Other observations made has been discussed in respective sections.

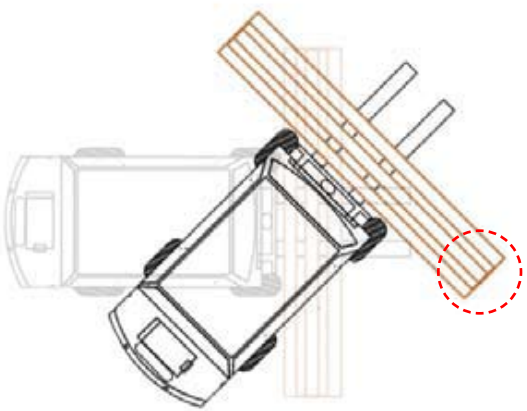


image5: outermost point of the load moves faster than the actual turning velocity of the forklift.

4.3.Insights from user study

Certain insights were obtained form the operators on the problems faced while performing their operation:

- The operators cannot estimate weight of the load being lifted. Carrying load more than the capacity of the forklift causes the forklift to tip forward.
- Fork position cannot be predicted when operations are carried out at a height. It has to be estimated and only achieved through experience. The operator has to lean out of the vehicle to get a clearer picture.
- Operator has to get an allover ground area required by a forklift and this is understood only through experience. Else lead to scratching of the forklift while taking turns. Unlike normal automobiles, forklifts work in constrained areas where they have to rotate between narrow aisles.
- Since the load carried by a Forklift is not fixed, the operator has to understand the volume of the load being carried and that of the forklift during operations. It becomes more critical when wide load is being carried, where the outermost point of the load moves faster than the actual turning velocity of the forklift.
- The operator is in a constant need of a helper to identify objects and during maneuvering.
- The operator has to look down to identify the right lever to perform the required operation. This can be achieved through experience.

5.Study of the Godrej forklift

the present model of ‘Godrej GX 300 E’ was taken as a base of analysis.

Godrej GX 300 E
Rated Capacity : 3000kg
Load Centre : 500mm

Power Supply : 48V Lead acid Battery

* Photography was prohibited in various sites of analysis, graphical representations might help to understand the situations better.

5.1.Controls

In any system it is the controls that bridge the gap between the operator and the machine. Whatever the nature of the system the basic human functions involved in its controls remain the same. Improvement in the overall performance of an operation is defined by the performance of the vehicle and also the relationship the operator has with the machine. That includes the input controls to feed the information and the feedback the operator receives form his action.

The controls of the forklift can be broadly divided into 3 parts 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

Display was considered along with the controls as it is a part of the operator console. The display provides the operator feedback of his operations and should be considered along with controls.

image6: Controls of Godrej GX 300 E Forklift

5.1.1.Controls of Godrej GX 300 E forklift

Maneuvering controls
1. Steering Wheel
2. Acceleration
3. Brake
4. Reverse Switch/ Pedal
5. Speed control

Loading operational controls
6. Fork raise control (up/ down)
7. Fork Tilt Control (front/back)
8. Neutralise switch

Others
9. Horn
10. Head Light
11. Turning Light
12. Emergency switch *(not in picture)*
13. Keying
14. Parking brake
15. Seat switch *(not in picture)*

16. Display

5.1.2.Maneuvering Controls

Forklift is an industrial vehicle used to lift and transfer heavy loads. The vehicle is unlike normal road vehicles. The electric forklift specially functions in an inside warehouses and manufacturing plants, where space is a constrain. The forklifts are designed to accommodate least space for operating and travelling.
They have a small turning radius to take fast turns.
The Steering System on forklifts is one of the most critical interfaces between the road, vehicle and driver.
The nature of this interface has remained virtually the same for most of the life of the forklifts.

Steering controls provided in Godrej GX 300 E forklift

- Steering wheel

The steering wheel is centrally located and steering is a two hand operation. The additional controls like horn, lights etc, are provided along with the steering wheel console. a knob is provided on the steering to have a better grip on the wheel.

- Acceleration and brake pedal

The acceleration and brake pedals are operated by the feet.

- Reversing pedal/Switch

A switch placed below the steering wheel is used to changes the direction of the acceleration pedal to perform as reverse.

- Speed Control Switch

The forklift has two modes of maneuvering the high speed mode and the low speed mode. Depending on the task being performed the operator has a switch, placed below the steering, with which he can control the maximum speed of the vehicle. While carrying heavy loads it is advised to drive the forklift at slow speeds as a safety measure.

image7: Truck A

image8:Truck B

image9: Turning radius

Understanding Theory

Steering Mechanism in forklifts

In a typical forklift the rear wheels are used to steer the vehicle and the front wheels are driven. This allows the vehicle to take sharper turns.
Rear wheel steering gives greater control of the truck while using the forks. Image explains forklift A, with rear wheel steering has a smaller turning radius than forklift B with front wheel steering.

Turning radius

A forklift's turning radius, also known as the turning circle, is vital information for a machine operator to have, in order to determine how much space is needed to turn the forklift around. A tighter turning radius enhances the forklift's maneuverability, allowing it to work in more congested and restricted areas. In most forklifts the center of the turning radius lies just beyond the front wheel axle. Some smaller lifts can completely turn around on the spot called zero turn vehicles.

Steering ratio

Steering ratio is the ratio of the number of degrees turned at the steering wheel to the number of degrees the deflected by the wheels. For most modern cars, the steering ratio is between 12:1 and 20:1 where as a forklift requires to take sharper turns. The Steering ratio of Godrej GX 300 E forklift is two and a half steering turns from end to end wheel position.

Types of steering mechanism

- Mechanical Steering
- Power Steering using hydraulic power Steering/ Electric Power Steering
- Four wheel steering employed by some vehicles to improve steering response, increase vehicle stability while maneuvering at high speed, or to decrease turning radius at low speed.
- Steer by wire is to completely do away with as many mechanical components (steering shaft, column, gear reduction mechanism, etc.) as possible and replacing them with wire technology.

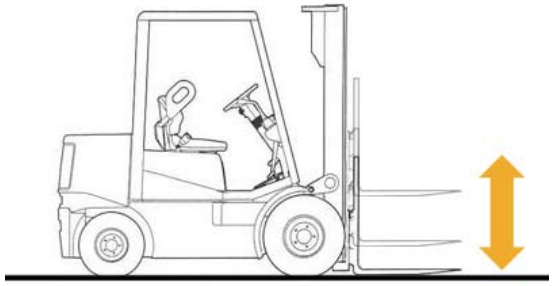


image10:Fork raise

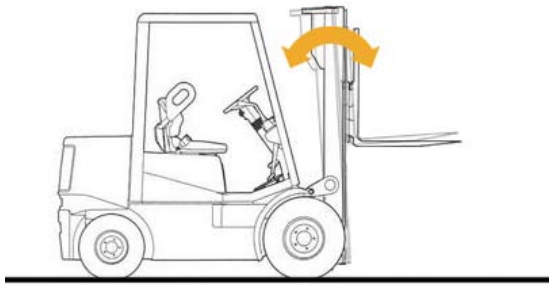


image11: Fork tilt

5.1.3.Operational Controls

These are the controls used by the operator to maneuver the forks to handle the load. The basic controls required for operation were studied.

Operational controls of Godrej GX 300 E forklift

The operation controls are lever controls. Two levers performing three separate functions:

• Fork Raise control

to control the height of the forks upwards/downwards to reach to the required height of the load.

• Fork Tilt Control

to tilt the load front/back. This operation is performed to bring the Center of gravity of the load backwards to prevent slipping off the load

Analysis of the present operational controls of Godrej GX 300 E forklift

- The levers are positioned on the dash board with the knobs reaching out to the operators arm length.
- The function of each lever is etched on to the knob of the levers. Other than that there is no relation between the operation being performed and the movement of the hand. The relation between the controls and the operation is studied only through a certain level of expertise.
- Complete arm movement by the operator was required for each operation, which caused fatigue over a long shift and increases the risk of operator error or even an accident.
- Levers required a considerable amount of travel to operate so there was a limitation on the speed of operation.

5.1.4.Analysis of Overall controls

A detailed study of various controls of the Godrej GX 300 E Forklift was carried out with respect to the position of controls with respect to the operator, the orientation of control with respect to the operation and the feedback received

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
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

table1

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 Brake	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			

table1

The analysis of the table provides various data:

- 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 operation controls do not give a direct relation to the operation being carried out.
- The speed control mode is not properly conveyed to the operator. The fast/slow mode can be figured out by the lever position or an indicator on the display
- Position of key insertion below the steering wheel is more tactile judgment
- 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.

5.2.Display

A display is provided on the dashboard of the forklift. It provides the necessary feedback of the performance of the forklift to the operator. In the Godrej GX 300 E forklift, the display is a dial indicator which supplies to the operator is the battery display indicator.

5.3.Lights

Since the forklift is used internally inside manufacturing plants of warehouses, the environment is lit up at all times. There are no disturbances from direct sunlight. But the glare from overhead lighting of the factory has to be taken under consideration. The warning lights of the forklift are

- Head light
- Brake light
- Indicator lights

5.4.Safety

Safety is a major issue considering the forklift. As the survey showed, forklifts have been a main cause of accidents in the workplace. Safety of the operator, the forklift and the workplace is important, to reduce time loss, material loss, repairs etc.
Safety features of the Godrej GX 300 E forklift:

- Overhead guard, to protect operator from falling loads
- Emergency switch, to shut off the forklift in emergencies
- Seat belts
- Head lights, Brake lights and indicators

There are important rules on how to and how not to operate a forklift. It is not only the operator who have rules to prevent accidents, it is a responsibility of the pedestrians and on the plan of the factory. The operators go through a training before they get a license and only licensed operators are allowed to operate the forklift.

5.5.Ergonomics and comfort

Comfort of the operator is an important feature of any vehicle. The operator works for 6-7hr shifts and forklifts should be designed for long sitting operations. By providing ergonomic features to the forklift reduces fatigue of the operator hence ensures higher productivity. Godrej forklifts now are designed ergonomically and come with features in terms of operator comfort such as

- basic ergonomic dimensioning
- adjustable steering console
- adjustable seat
- handle for easy ingress and egress

5.6.Visibility

Visibility is a most important feedback of most operations of the forklift. The operator has to judge according to the visual feedback he gets from the operation like position of the fork, tilt of the fork, the road ahead and behind the forklift etc.

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

Visibility Problems faced by the operator

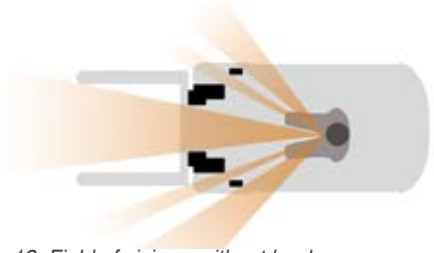


image12: Field of vision - without load

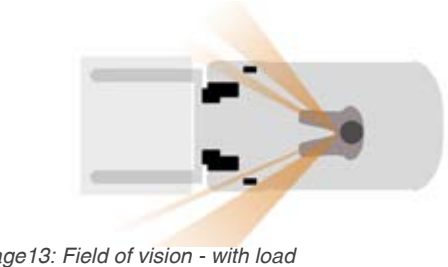


image13: Field of vision - with load

No Load Condition

The operator should have a clear view of the road ahead while maneuvering the forklift. In no load conditions the vision is partially blocked by the mast and the overhead supports.

Performing operations

The operator has to have a clear vision of the operations performed as the vehicles operate with heavy loads and a slight misjudgment can lead to an accident.

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. The operator solves this problem :

- The operator drives in reverse
- With the help of a helper who guides his way
- By leaning to a side for better visibility

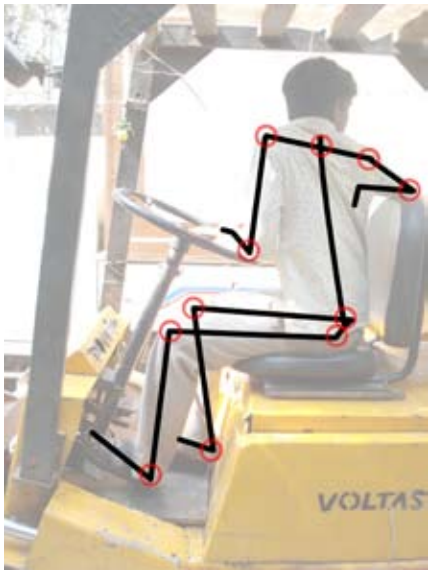


image14: operator driving in reverse

In this situation the operator is asked to drive the forklift in reverse all the way. Continuous twisting of the body to have a better vision of the back can lead to strain on the operators back

Performing operations at a height

While performing operation at a height (like loading/ unloading at a height) the operator has to lean out to get a clearer picture of the position of the forks and the load. Here the accuracy of the operation depends on the operator's experience. The vision of the operator is partially blocked by the overhead guard.

image15: Operators view of fork while operating at a height

image16: Prominent mast causes accidents

Pedestrian Safety

During operations, the operator should also be aware of pedestrians in the area. Accidents involving pedestrians are common, due to the lack of proper visibility

The pedestrians should also be aware of the forklift in the area. The mast being the most important feature of the forklifts front, the pedestrians often do not notice the protruding forks coming their way.

5.7.Ingress Egress

As the forklift is used in different kinds of industries and perform different kinds of tasks. The time required to perform the task cannot be generalized. In some jobs the operator has a fixed and repeated task to perform and some where it is flexible. It has been observed that the operator constantly gets off an on to the forklift.

Analysis of the Godrej GX 300 E Forklift, the support provided for proper ingress and egress

- The seat height of the forklift is around 1100mm
- A single step is provided at 450mm

Analysis of Current Scenario

- A handle is provided for ingress/ egress. Besides the handle the operator uses the support of the battery cover.
- The steering acts as an obstruction, which makes the operator to twist his body to position himself on the seat.
- Some vehicles have provisions for the operator to getting and out from left and right sides of the forklift.

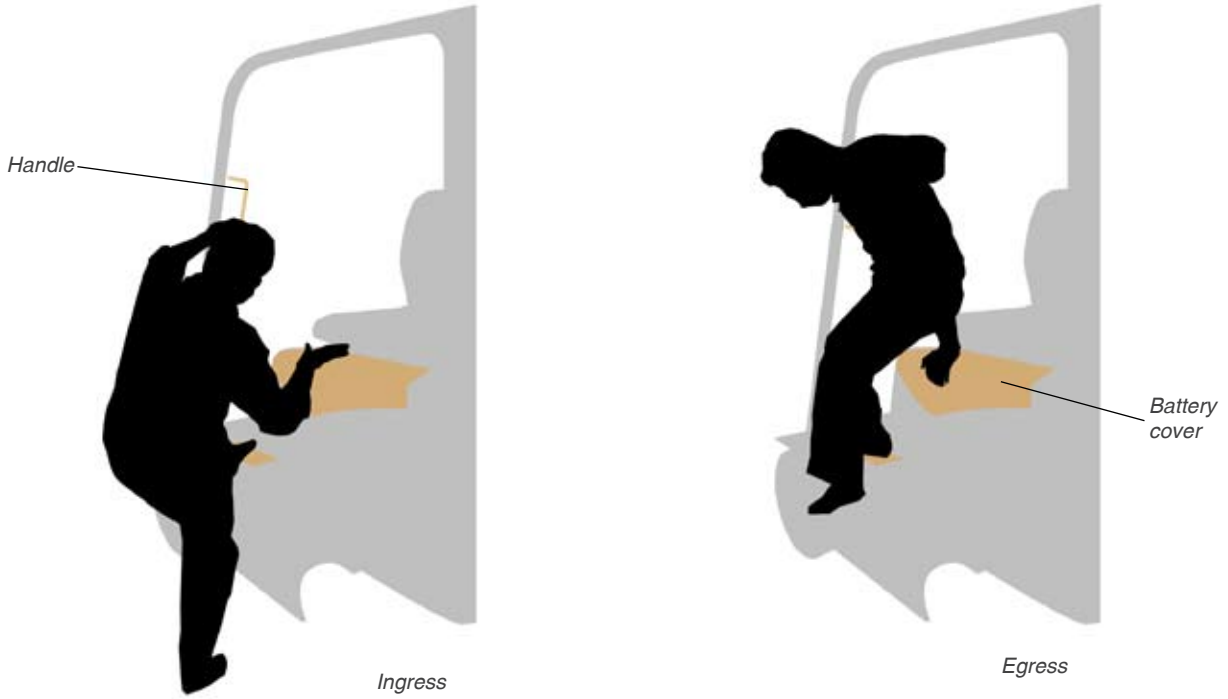


image17: Ingress and Egress in a Godrej GX 300 E Forklift

- An easy ingress and egress for the vehicle is essential for better performance without strain or injuries due to repeated twisting of body parts. By providing proper ergonomic handles and positioning the seat, a better cabin can be designed for the operator. It should provide a faster egress form the vehicle in cases of emergencies.

image18

- Instances seen in an other vehicle, where the operator uses the wheel as the handle to climb on.

- It was also noticed that due to the high seat and single foot rest, the operator tends to jump of the vehicle to balance his body weigh during egress.

image19

6.Synchronic analysis

Unlike the India Market the International Market for Forklifts is much larger as discussed before (Pg. 14). With the competition involved lot of advancements were developments were made in the forklift in the areas of forklift performance, power source, operator safety etc. A study was done on the features of the international forklifts to understand what the market has to offer.

6.1.Operator Console

A synchronic analysis of controls available on other International forklifts were studied to understand the innovations available and how it can influence the redesign of Godrej GX 300 E Forklift.

image20

Nissan Forklift [Ref.11]

- adjustable tilt steering wheel
- Allows the driver to perform simultaneous lifting and tilting operations with a single lever
- Hydrostatic Power Steering System reduce steering effort, eliminate kickback and oversteer characteristics

image21

Linde Forklift [Ref.12]

- steering wheel diameter reduced for lesser hand movement
- separate pedal for reverse
- joystick operation controls located on the hand rest

image22

Crown [Ref.13]

- left hand steering
- steering diameter reduced
- steering system with programmable control allows the operator to choose between 180° and 360° steer tire rotation to match driving conditions
- Multi-task operational control handle

6.2.Operational Controls

image23

Godrej GX 300 E - Lever controls
Complete arm movement by the operator required for each operation, which caused fatigue over a long shift and increases the risk of operator error or even an accident. Levers require a considerable amount of travel to operate so there was a limitation on the speed of operation.

image24

Jungheinrich - Finger tip rockers electronic control systems
operations performed by finger movement
rockers can be programmed to have more than just one function
requires instruction manual to understand usage of multi-functional levers [Ref. 14]

image25

Toyota - Joystick electronic control systems
operation performed by wrist and hand movement
requires instruction manual to understand usage of multi-functional levers [Ref. 15]

image26

Nissan - Single Lever
It uses a single lever for tilting and lifting operations [Ref. 16]

image27

Atlet - finger operated controls [Ref. 17]

6.3.Maneuvering of the Forklift

Different kinds of developments in mobility of the forklift was also studied

image29

Yale four-wheel modelERP030-040VF has been designed to give a zero turning radius. [Ref. 18]

image31

Bendi Forklift
The vehicle is hinged at the center giving more flexibility to the vehicle in operations in narrow aisles. It has front steered wheels and rear driven wheels. [Ref. 20]

image30

Airtrax Sidwinder uses omni-directional drive system. The forklift is designed to move in any direction forward, reverse and sideways. It has a zero turning radius. [Ref. 19]

image32

Combilif Sideloadershave maneuverability in multidirection. [Ref. 21]

Maneuvering

The new technology incorporated in electric forklifts of steer by wire completely replace conventional steering system and holds several advantages, such as:

- The absence of steering column simplifies the car interior design.
- The absence of steering shaft, column and gear reduction mechanism allows much better space utilization in the engine compartment.
- The steering mechanism can be designed and installed as a modular unit.
- Without mechanical connection between the steering wheel and the road wheel, it is less likely that the impact of a frontal crash will force the steering wheel to intrude into the driver's survival space.
- Steering system characteristics can easily and infinitely be adjusted to optimize the steering response and feel.

Synchronic analysis of steering in other vehicles

New trends in technology which have influenced steering mechanisms in other vehicles were briefly studied to understand how it might be incorporated in forklifts for better performance

image33

TOYOTA i-real uses two hand joysticks for maneuvering the vehicle. Tilting movement of the joystick is used to maneuver the vehicle. The acceleration and brake is provided on the joysticks [Ref. 22]

image34

TOKIA RIKA has introduced a steering system which uses a single joystick. The forward/backward motion of the vehicle is activated by the push/pull of the joystick and the direction is given by rotating the joystick.[Ref. 22]

image35

GMs Hy-wire has two hand grips for steering the vehicle. Acceleration is done by turn the grip (like that of a motorcycle) and braking is done by squeezing either grip. Reversing and Starting the engine is done with the help of switches.[Ref. 23]

image36

HONDA-u3-x like the Segway is a self balancing human transporter. It senses the body movements for maneuvering. The rider leans in the forward or backward direction and the vehicle moves in that direction. [Ref. 22]

6.4.Visibility

A market study of the features in the forklifts that help to enhance the visibility of the operator was done. A few of them are as follows:

image37

Toyota overhead guard - designed for safety and for better visibility [Ref. 24]

image38

Jungheinrich EFG D30 - Cabin can be rotated 180 degrees if front visibility is restricted by carrying large loads. Gives the operator a clear all-round visibility and allows load to be transported without stress [Ref. 25]

image39

Still RXX Forklift concept - Hydraulically raising the operator cabin giving the operator a better view over high loads.[Ref. 26]

image40

Orlaco provides cameras to enhance the visibility of the operator [Ref. 27]

image41

Forklift Mirror to enhance the visibility of the operator [Ref. 28]

image42

Komatsu - arrangement of the chains outside of the mast allows the inner width of the mast of 642 mm, ensure the good frontward visibility [Ref. 29]

6.5.Safety Features

With developments in technology, forklift companies have introduced various features for the safety of the forklift, the operator and that of its working environment.

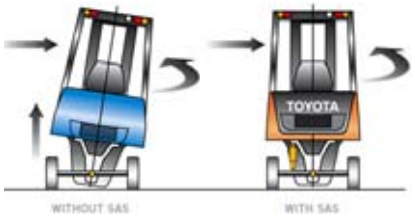


image43

System of Active Stability (SAS) technology by Toyota - sensors are used to detect instability of the forklift and stabilize the rear axle. This provides lateral stability to the forklift needed to help reduce the risk of lateral tip overs [Ref. 30]

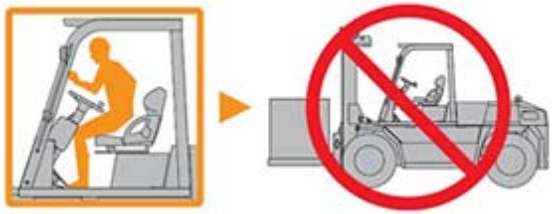


image44

Operator Presence Sensing (OPS) system by Komatsu - automatically stops traveling and lifting when the operator leaves the seat [Ref. 31]

image45

Sky-Trax System is designed to track the movement of forklifts in the warehouse. Alarms placed around the warehouse warns pedestrians and other warehouse vehicles of approaching forklifts. [Ref. 32]

image46

Toyota Load Weight indicator - It gives the operator the weight being lifted. Tipping over of the forklift due to overweight can be avoided [Ref. 30]

image47

Intrinsic Stability System by Crown – sensors are used to detect instable situations and are programmed to act accordingly like reducing speed at turns, limiting the height of tilted mast to prevent tip over [Ref. 33]

6.6.Display

International models like Nissan,Linde,etc [Ref. 34] uses advanced LED displays and provides the operator with other information like:

- Date and time display
- Hour meter and speed display
- Messages and truck direction indicator
- Mode select switch
- Parking brake reminder
- Seat belt alert
- Fault alert

image48: Display of Nissan Forklift

6.7.Comfort Features

Comfort features available in other international brands include

- Rear assist grip that enables more comfortable and easier reversing. The reverse handle integrates a horn for easier use.
- Vibration free Seating are specially designed seats for a a more comfortable ride
- Adjustable Telescopic steering. Steering with wire technology has provided an advantage of adjust ability of steering position according to the operators choice
- Specially styled cushions give the driver extra support even when driving backwards
- Adjustable lumber support

image49: Nissan - Adjustable Telescopic steering

7.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

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

8.Methodology used

The various factors were looked to solve various issues for the best user experience. And integrating it all to form a final concept was a challenge. It was seen that evaluation criteria for the various sections had to handled separately.

Firstly the controls, their position and usability had to be ideated and evaluated under parameters relating to their performance, comfort and usability.
The factors of visibility, comfort, safety and ergonomics were considered together as they were more integrated in features and the concepts had to evaluated to provide the best solution to the problems.
And the Formal aspect of the vehicle was the last part of the evaluation, depending on their parameters.

9.Ideations

Based on the analysis of the data. The ideation was a continuous phase through out the process

10.Work Space Dimensioning

Designing of the forklifts included certain basic anthropometric dimensioning which were considered before ideating. Dimensioning includes 5th percentile male to 95th percentile male. [Ref. 35]

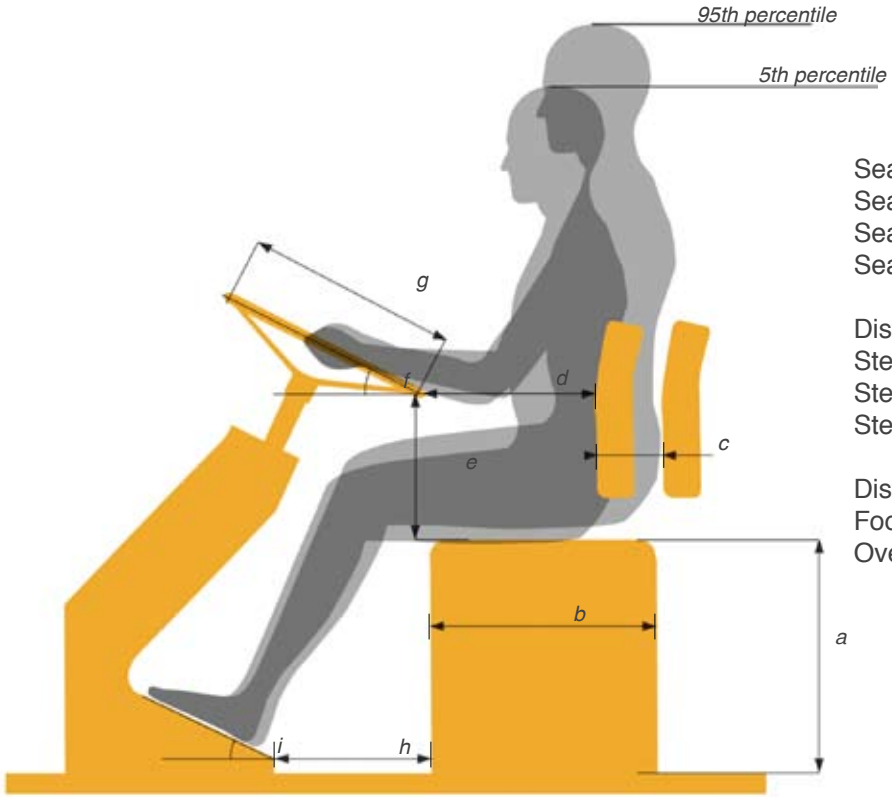


image50: work space dimensioning

Seat Height 400 - 430 mm (a)
Seat Width 470 mm (b)
Seat Breadth 330 - 390 mm
Seat Adjustable 120 mm (c)

Distance of Steering wheel from the back seat 460 mm (d)
Steering wheel height from seat 240mm (e)
Steering wheel angle 60 - 70 degree (f)
Steering wheel daimeter 400mm (g)

Distance of Foot pedal from the seat 400 mm (h)
Foot pedal angle 60 degree (i)
Overhead mast height 132mm + Clearance

11.Controls

Analysis of Controls

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																

Frequency of use
Most to Least

table2

- 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

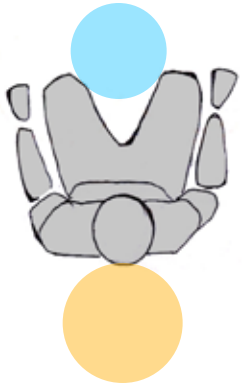
B

- 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

image51

Idea D required a full rotation of the operation to maneuver the vehicle in reverse. Although driving the vehicle in reverse has the benefits of frontal visibility without obstructions and also prevents tipping over of load on sudden breaking, the idea was dropped due to cost factor and because of the high frequency of switching between modes. Ideas A, B and C are taken ahead.

11.1.Concepts for Controls Console
Concept A

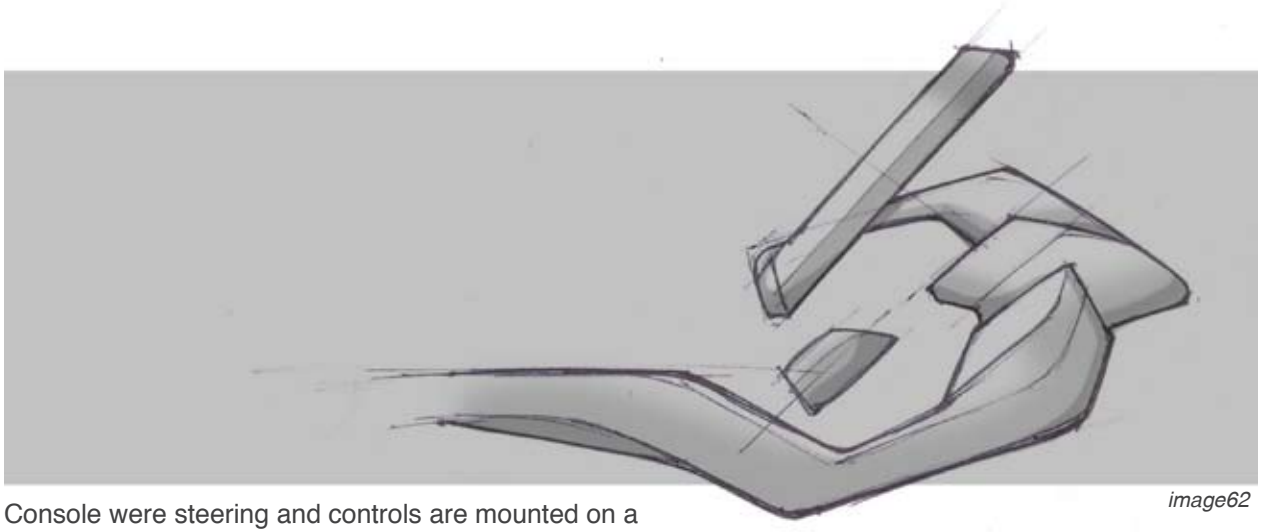


image62

Console were steering and controls are mounted on a structure

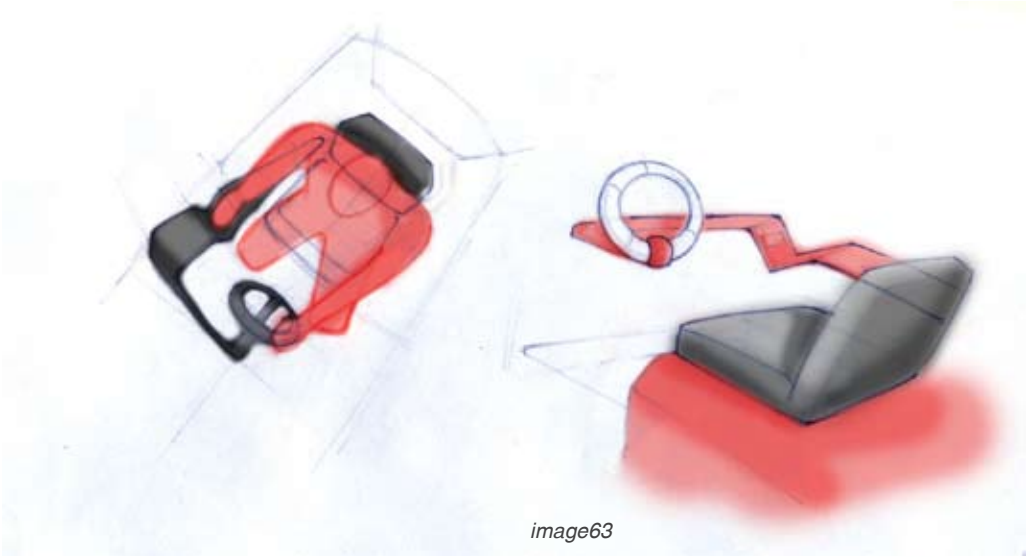


image63

Features

- The system uses wire mechanism, steering and for operations. This allows the flexibility of positioning the controls.
- This concept provides left hand steering and right hand controls. Both hands are always in touch with the main controls.
- A Steering wheel is provided which performs as a conventional steering mechanism
- The controls have been positioned base on user comfort
- The whole console provides a flexibility to the system

Dimensioning involved

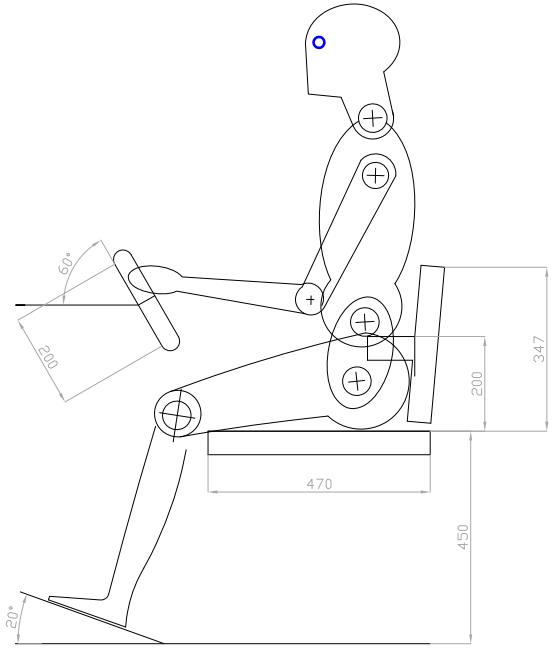


image64

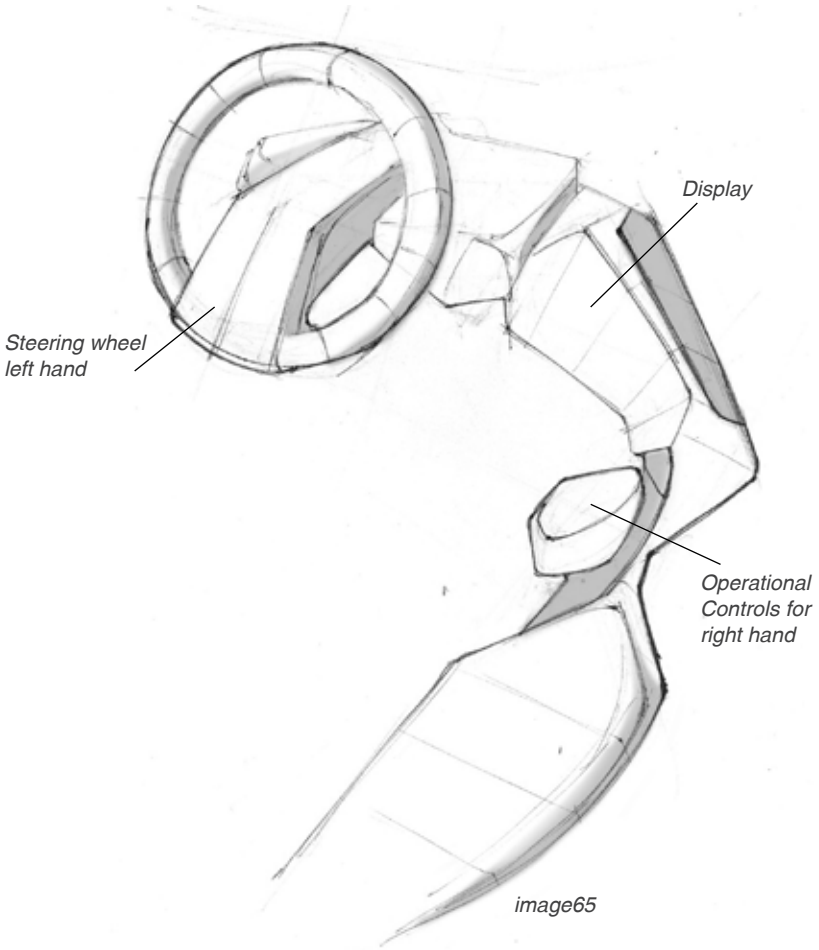


image65

Concept B

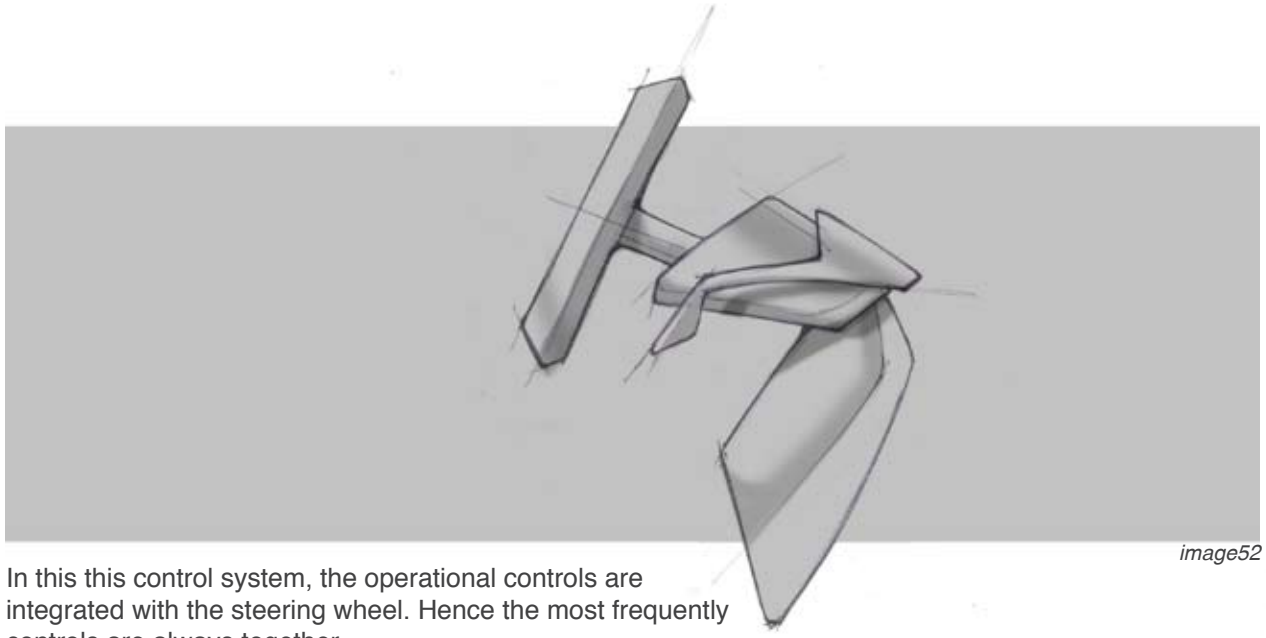


image52

In this this control system, the operational controls are integrated with the steering wheel. Hence the most frequently controls are always together.

- All controls and display integrated into a single mast console. The cowl can be eliminated for better visibility.
- The swivelling steering allows adjust ability and allows easy ingress and egress.

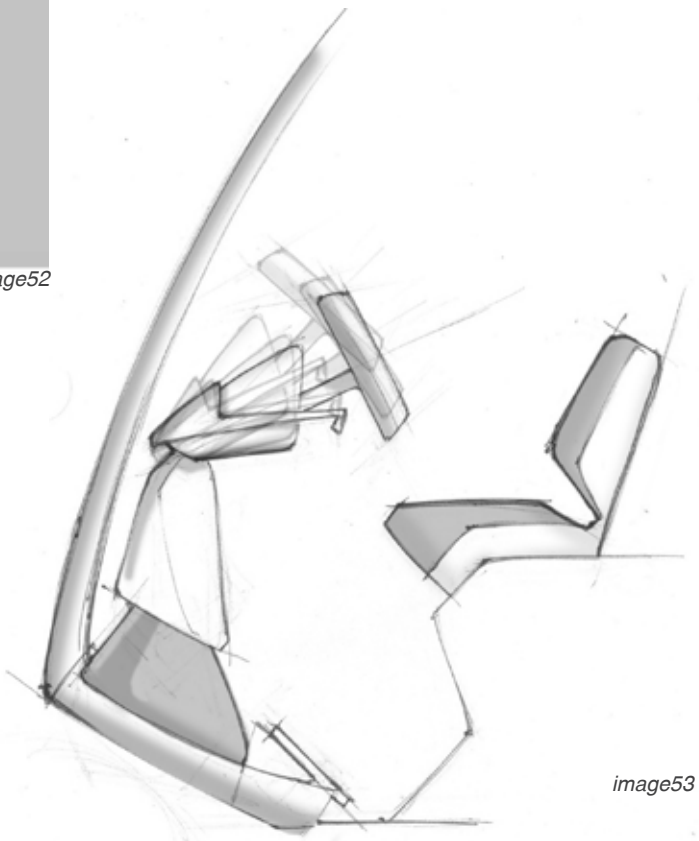


image53

image55: Steering mode

image56: Operation mode

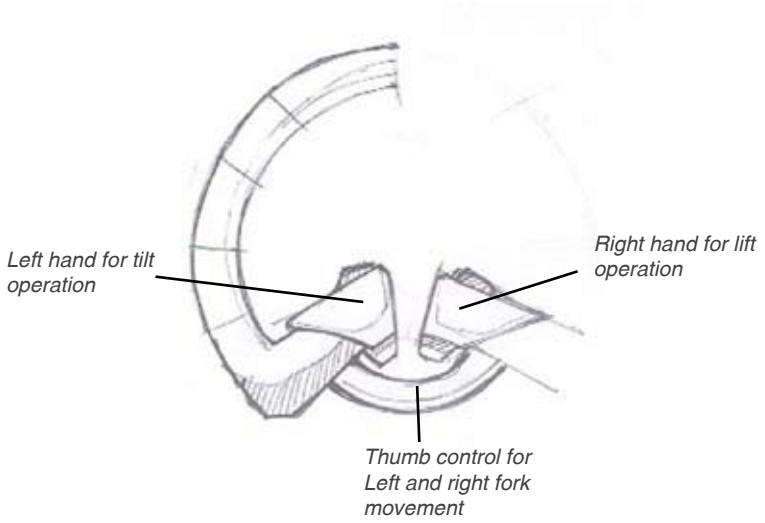


image54: position of controls

image57: Steering wheel
image58: Hand Operation
image59: Digital display integrated in the steering hub and light indicators provided below the steering, as conventional vehicles

image57

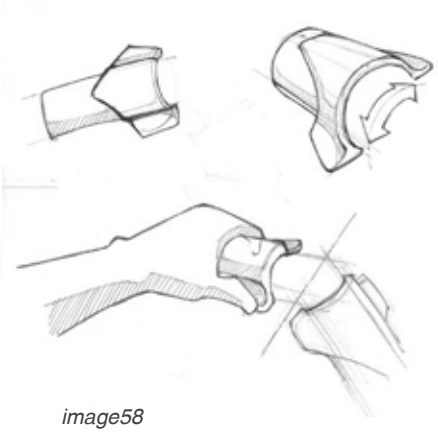


image58

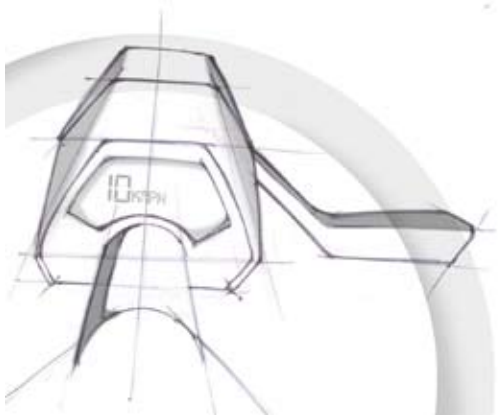


image59

Concept B

Features

- main controls are at hand at all times
- it follows conventional steering advantages
- the operation controls are always at hand
- the vehicle can be steered while hands are on the operation controls
- all controls are integrated on a single steering column

Dimensioning involved

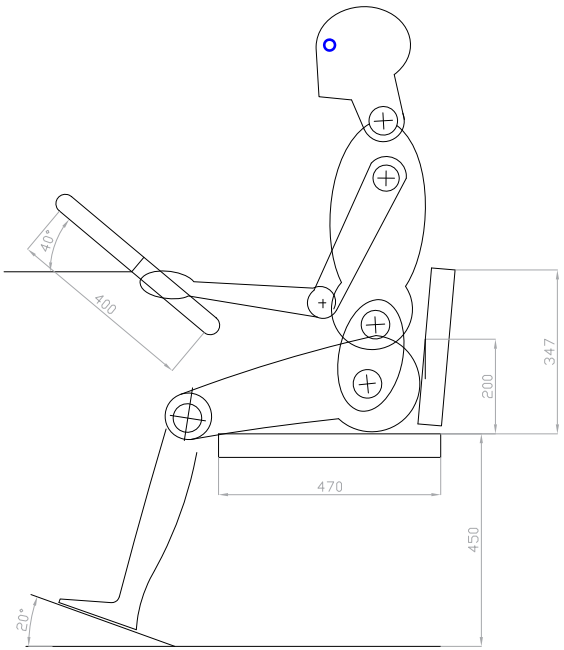


image60

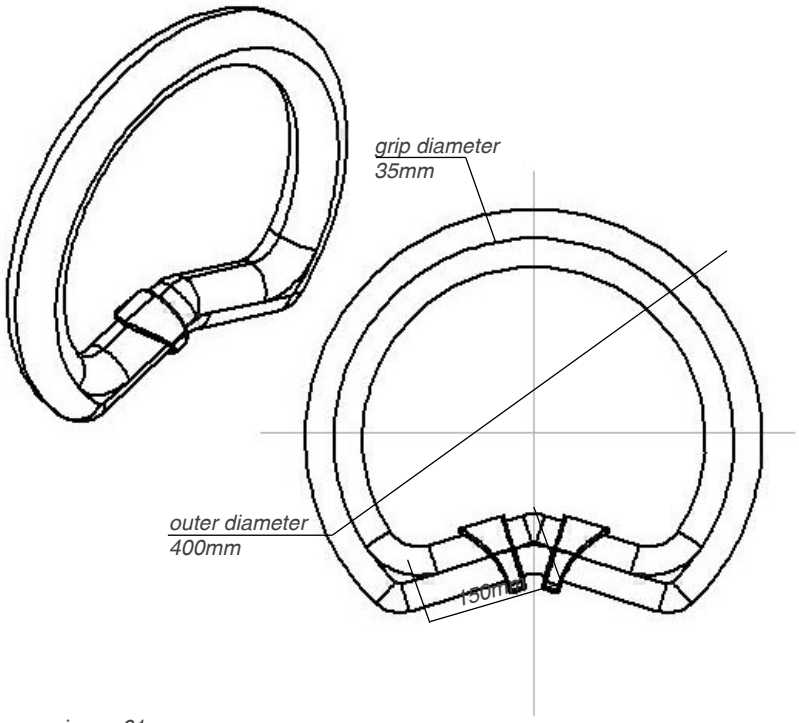
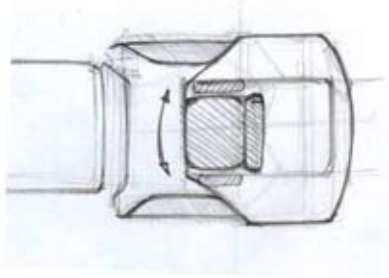


image61

Concept C

image66

Joystick controls
Gives a full view of the forklift ahead
ingress and egress can be in front direction
seat can be made to swivel along with the
controls



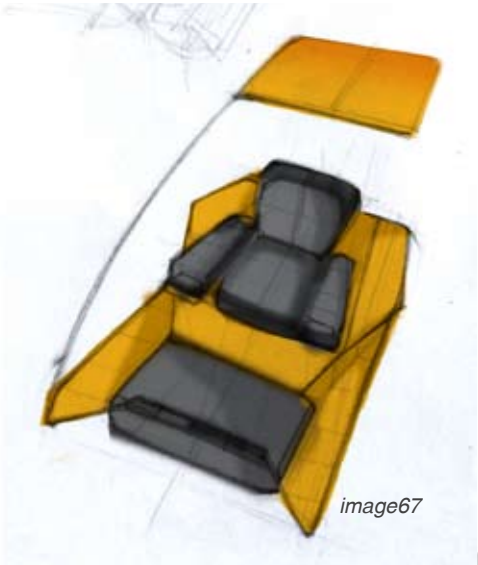


image67

Features

The concept includes 2 joystick controls on either hand. and acceleration and brakes pedals for the feet. The operation of the forklift is unlike conventional methods. It provides a better comfort and feel of operation.

Steering Mode

Steering system with two joysticks is evolved from the steering of Toyota's 'i real'. The two hands for steering implies the operator has a feel of the vehicle during maneuvering.

image68

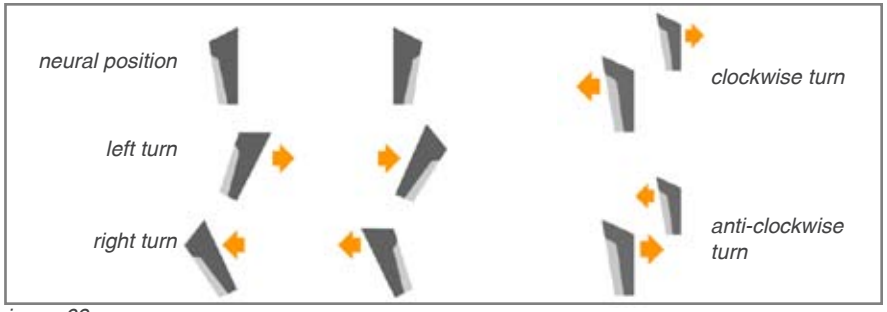


image69

Operational Mode

This mode is activated during the time of fork operations. The right hand joystick provides all movements to operate the fork, where as the left hand joystick provides forward and reverse movement of the forklift.

image70

Dimensioning involved

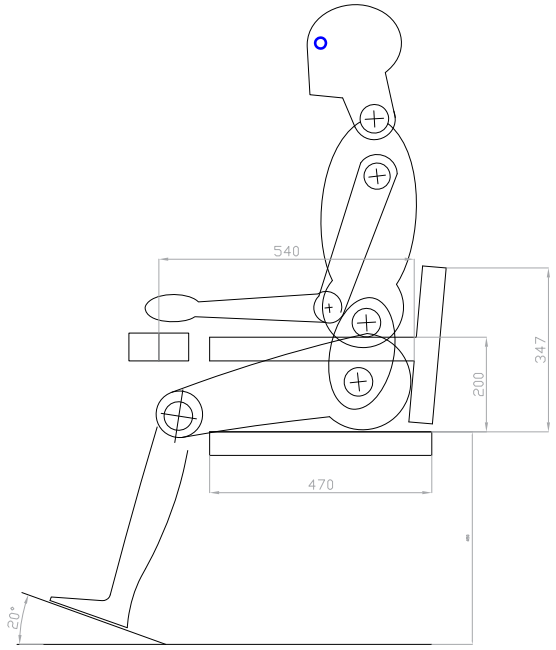


image71

11.2.Evaluation of Controls

The evaluation was done by constructing rig models of each and testing it with various users. The technology behind each concept was identified and the criteria of evaluation was user comfort and usability.

- Concept A and C has controls positioned at users comfort
- Concept C has a disadvantage being, experience operators who have been working on previous models controls might find it hard to learn. Concept A has the advantage of providing the steering system similar to the old models but integrating the new technologies for better user performance.
- Compared to the central mast concept B, there was a more possibility of flexibility in seat positioning with concepts A and C as it the controls are integrated with the seat
- Concept C has an advantage of full frontal visibility and easy ingress and egress

Concept B was considered for its positioning and usability but during testing of controls it was seen that in Concept B, since the steering was placed just above the leg there was a problem of wheel hub positioning. Due to this a combination of concept B and C was chosen, where the steering wheel is attached to the left hand rest. This combination also provides no obstruction in front of the driver giving him full visibility and easy ingress and egress.

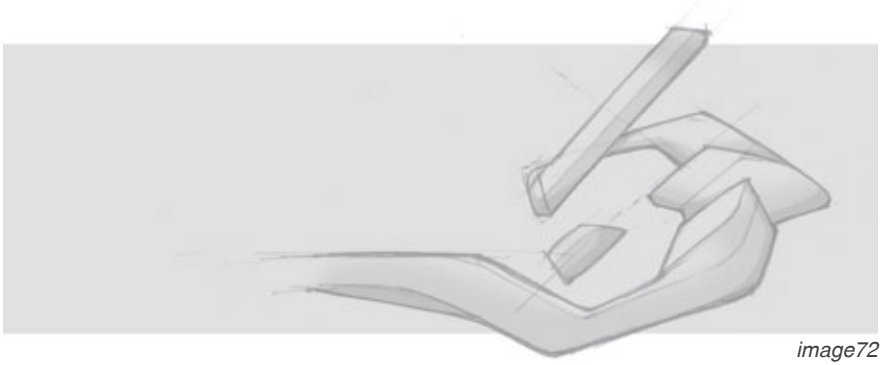


image72

12.Overall

The factors of visibility, comfort, safety and ergonomics were factors which were codependent. The relation of the operator and the forklift dependent on all these factors combined .Each factor was first looked into separately and best possible solution to provide a better overall performance was taken ahead.

12.1.Ideation - Visibility

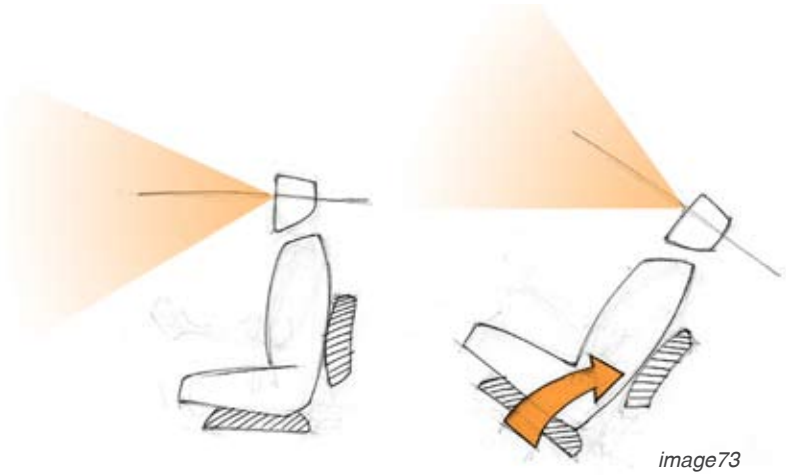


image73

Idea : By swiveling the seat upwards, gives the operator a better view of operations at a height, without straining the operators neck.

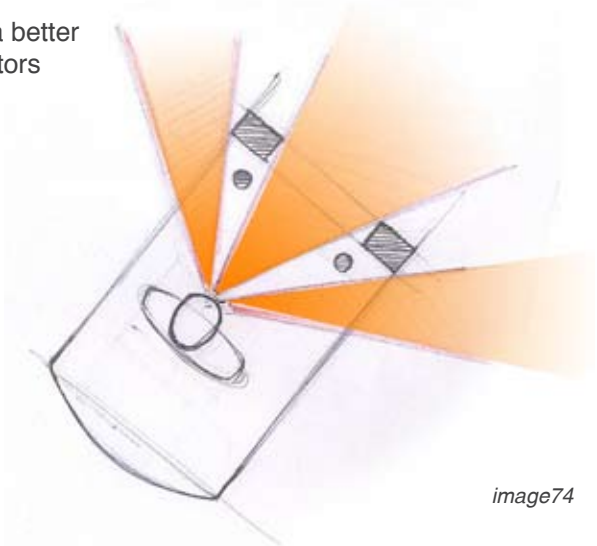


image74

Idea : Coinciding the overhead mast support with the front mast, giving the operator more visibility

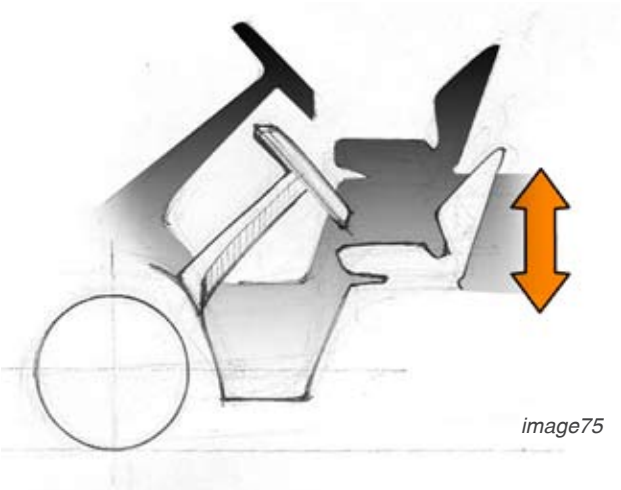


image75

Idea : The operator cabin raises up to provide a better view of the road ahead. By lowering the cabin also provides a lower height for the operator to get in and out of the forklift with ease.

Ideation - Visibility

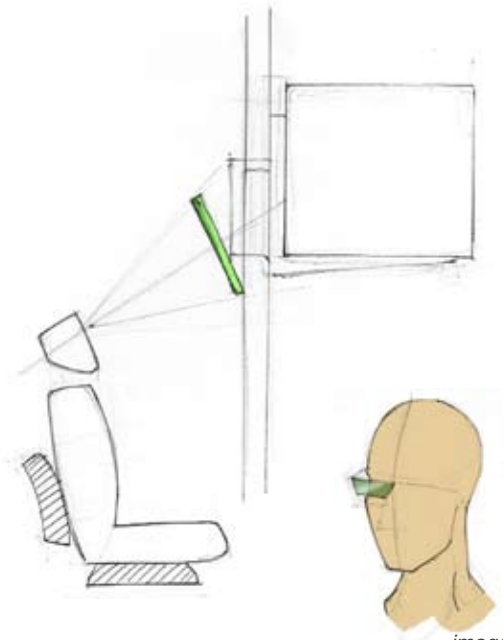


image76

idea : By providing cameras below the forks, which gives the operator a better visual beyond the load.
The visual feedback can be provided to the operator at a suitable position at the fork level or provided as an eye-piece.

idea : The operator is provided with a laser gun, with which he can aim and lock the approximate final position of the forks.
Then the forks can be activated to automatically move to the final position.
This reduce time of operation.

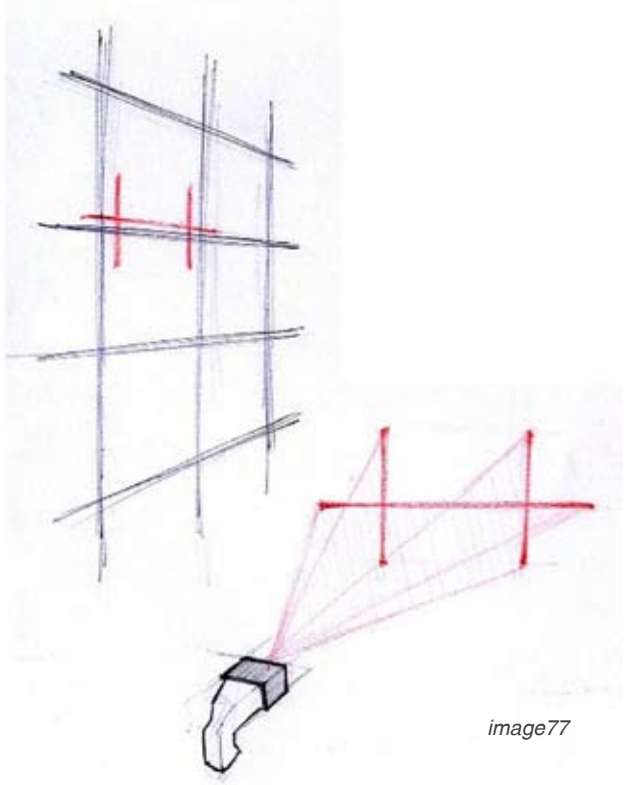


image77

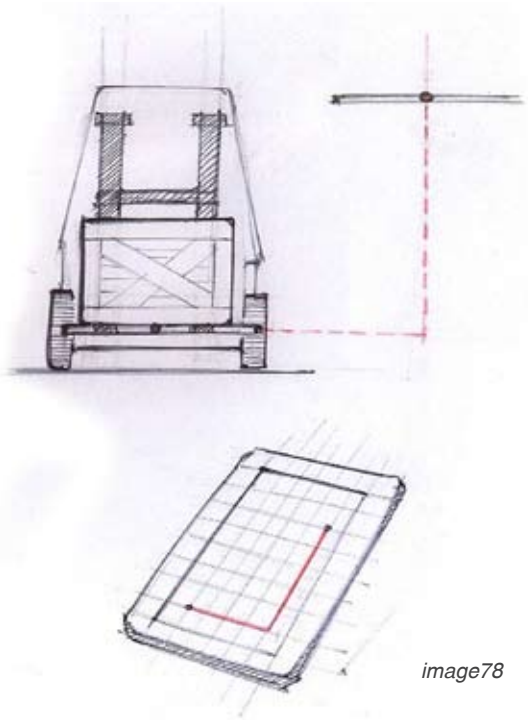


image78

idea : where the the visual feedback can be changed to a unit measure.
Sensors placed at the fork tips and on the final position of the racks. The displacement of the two sensors is visually provided to the operator. So the operator knows exactly how much to move the forks.
This reduces the operators need to rely on judgment for his operations.

Ideas of overall performance of the forklift

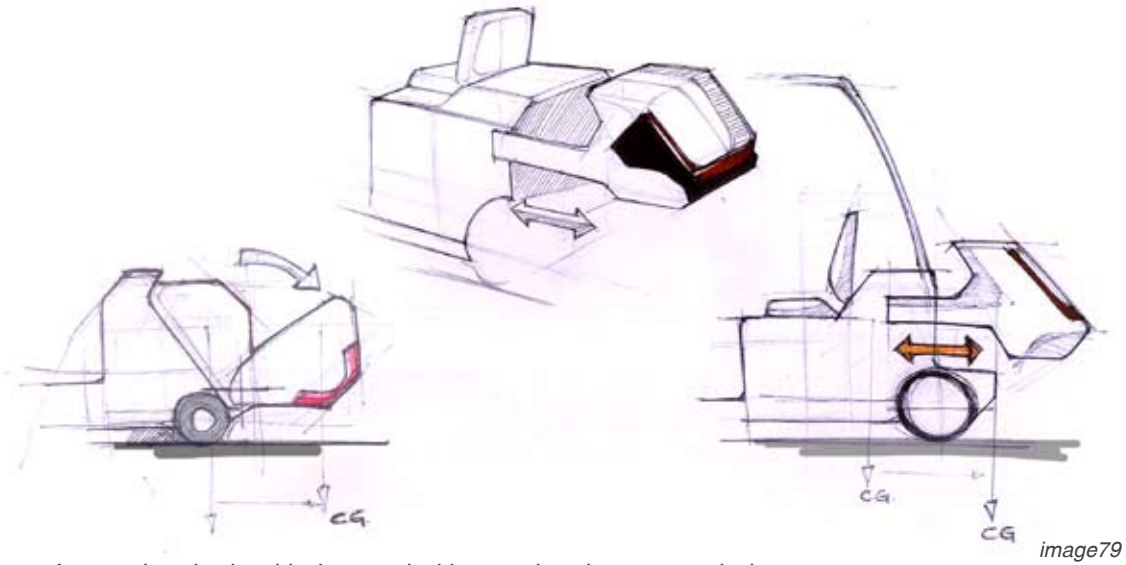


image79

Increasing the load being carried by moving the counter balance weight backwards, increasing the leverage.

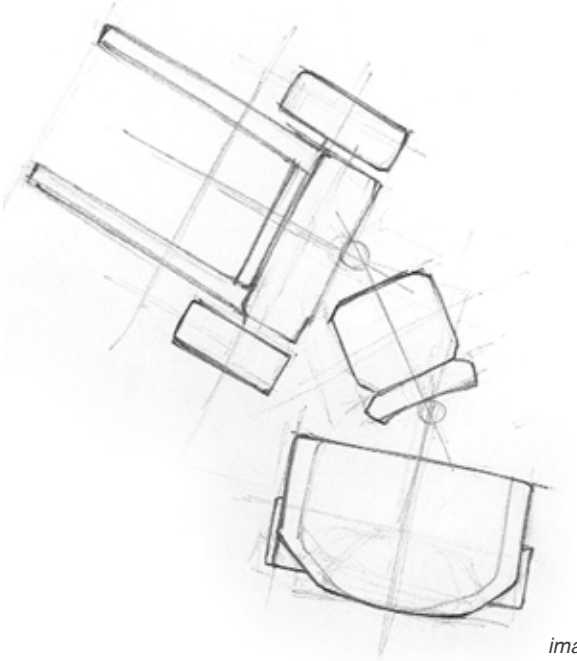


image80

Idea : here the 3 main portions of the forklift, the mast, the operator cabin and the electronic+ counterbalance, have been made to swivel with respect to each other.

- This provides a smaller turning radius, quicker turns
- better side visibility of operations at a height.

Ideas of overall performance of the forklift

image81

idea : the operator cabin is integrated along with the forks, hence the cabin lifts along with the load upward. This provides better visibility of the operation.

idea : here the operator cabin swivels along a pivot, providing the operator a greater visibility of the operations

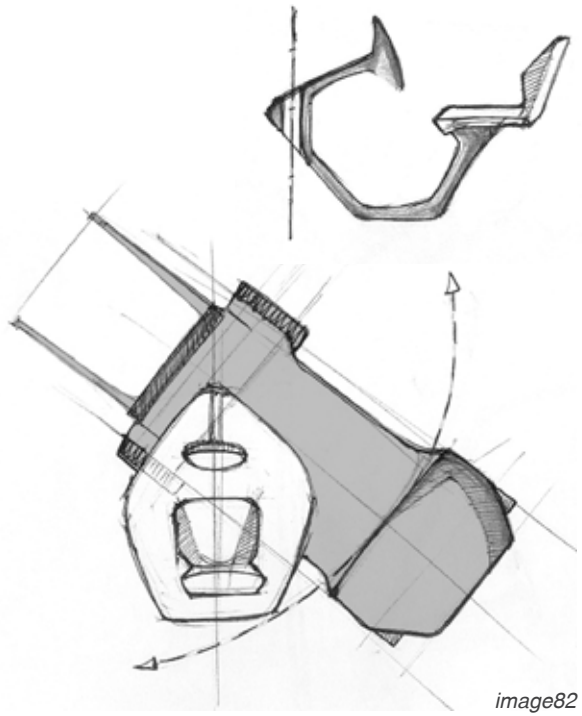


image82

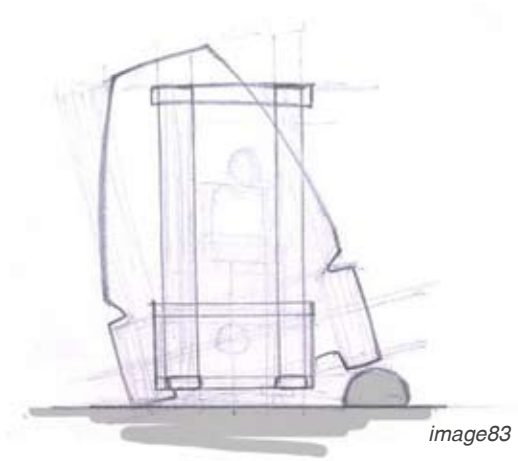


image83

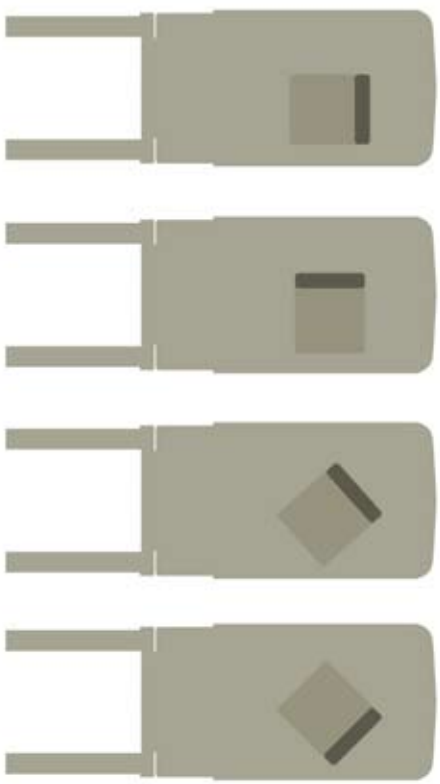
idea : here the mast and the operator seat are integrated. It is joined to the rest of the vehicle through a universal joint.

- This provides stability to the forklift in case of some obstruction.
- The load and the operator is kept stable.
- This increases comfort and reduces the chances of accidents

Ideations

The mast of the forklift and the battery size is what determines the width of the vehicle. The width has to be maintained as it is a major factor in deciding the performance of the vehicle. Narrow machines are preferred as this allows narrow aisles and more stocking in the warehouse.

The operator behind the mast provides a safe and economical position with regard to the forklift. But it is seen that, the seat does to provide all the necessary advantages required for the operation. This is seen from twisting of the operators body for better visibility overhead operations, in reversing and also during ingress and egress. Various positions of the seat with respect to the forklift was tested with the help of a rig and their following characteristics seen are as listed



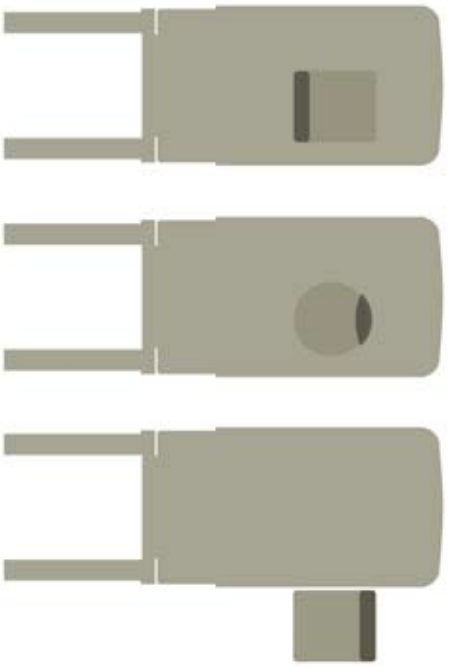
Seat positioned offset from the center
Better visibility

Seat aligned to the left of the vehicle provides easy ingress/egress

Seat aligned at an angle provides easy egress

Seat aligned at an angle provides better visibility of operation

image84



Seat facing backward
Better visibility while reversing

Round seat
no issues of alignment

Seat swivel out
easy ingress/egress

Its seen that a seat which provides adjust ability related to the operation performed is important.

12.2.Clustering

Cluster A

With innovative developments involved in controls, it makes it possible for the controls to be placed at most comfortable and ergonomic positions. As seen before, the various operations require different configurations.
One such cluster is one where the seat and the operator swivels independently giving the best seat positions and controls position for the various operations. The different modes are shown in figure.

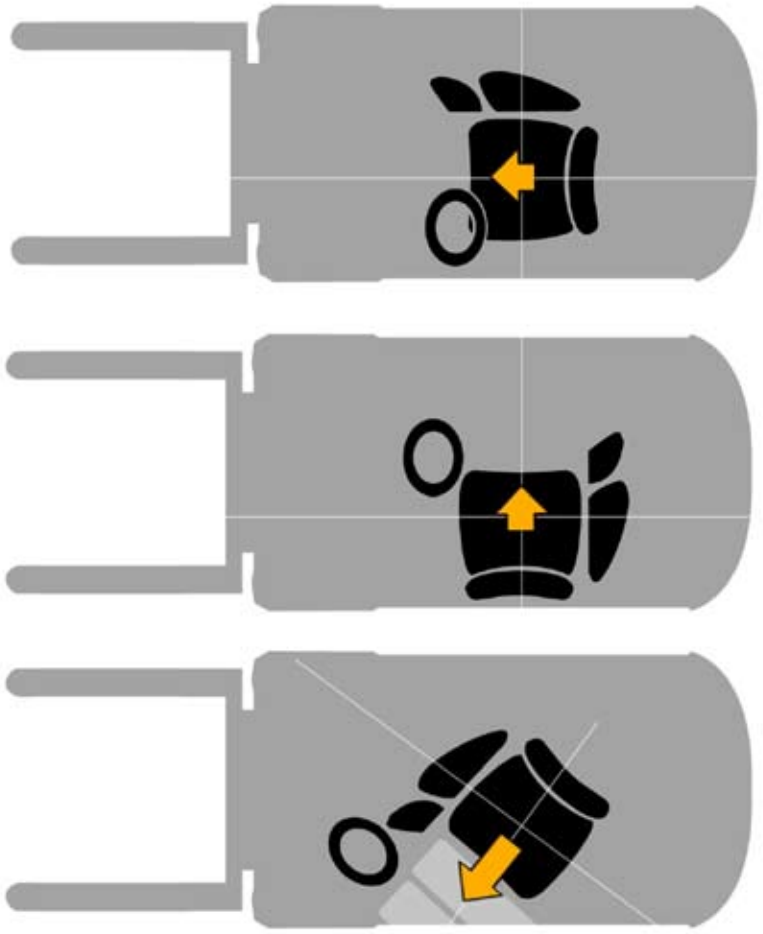


image85

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

Operation mode
In present forklifts where the operator has to twist his body to see beyond the load, here the seat swivels outward to give him a better visibility.
In the operation mode, as the operator is seated at 90 degree to the forklift, the operator has a better view while reversing the vehicle

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

Cluster B

The forklift can be divided into 3 different parts,
the front operational system - which includes the mast, forks etc.
the operator cabin which is where the operator performs his operation and
the rear part consisting of the battery, electronics and the dead weight.

In this cluster the three parts are independently connected. The operator cabin can be swivelled about the front axil according to the need of the operator.

Mode A
During high loads and the operator has to be given a greater height
This allows the operator to see over high loads and giving him better visibility.

Mode B
During no load conditions the cabin can be lowered down. This brings down the overall CG of the vehicle making the vehicle more stable.
This also allows easy ingress and egress, by lowering the height of the cabin to that of an SUV.

The added advantages is that it can prevent scratching of obstacles during turns. With the help of sensors on the rear of the forklift. The forklift can sense the obstacles and automatically collapse to avoid accidents.

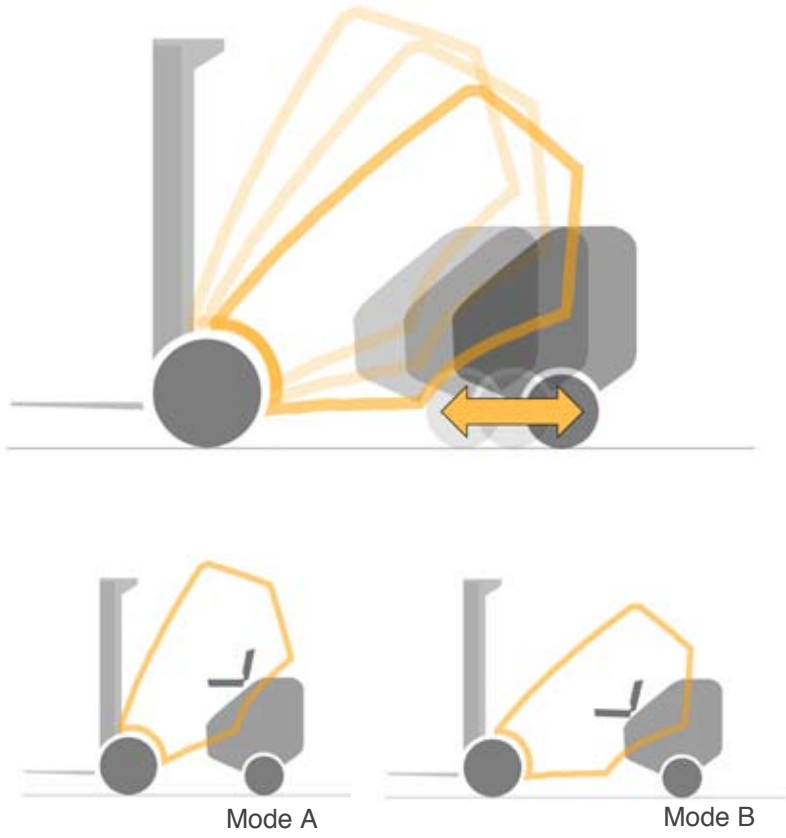


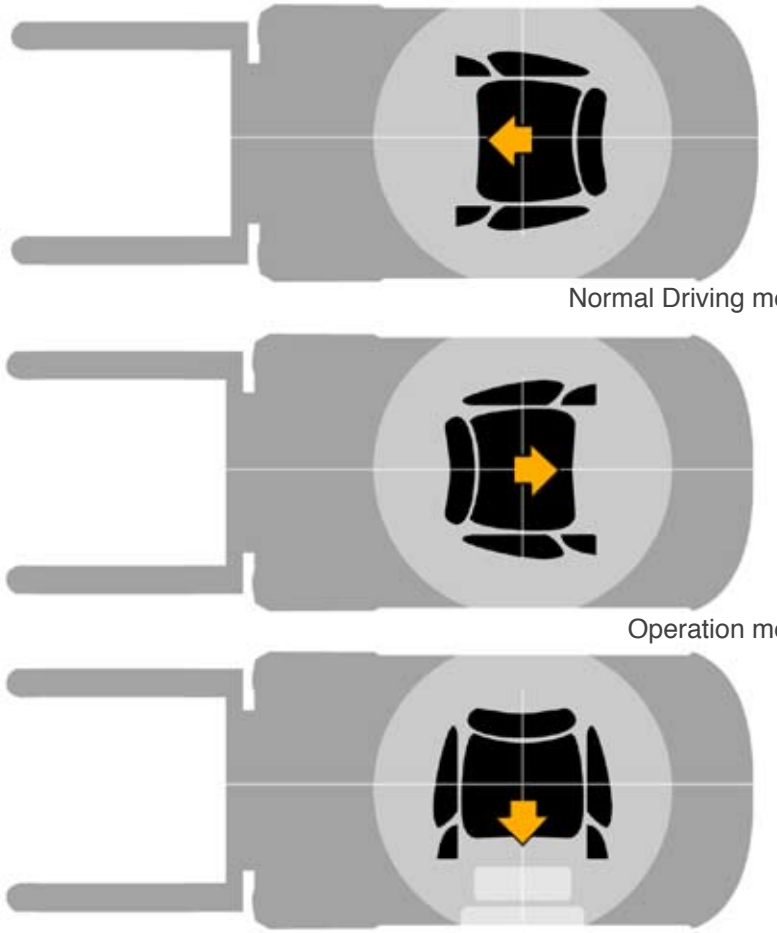
image86

A variation from the previous concept A, here the operator console rotates with the controls along the centre of the seat.

Operation Mode
During high load operations the operator rotates a 180 degree giving him a clear vision of the road ahead. This is a safe mode of operation as it does not involve any twisting of the body.

Stop mode
This also allows a easier ingress and egress as the seat rotates to the side and the operator can walk out and in without any obstructions.

image87



Normal Driving mode

Operation mode

Stop mode

image88

12.3.Evaluating the clusters

The final concept should have features which improves the comfort, safety and ergonomics of the operation. The clusters have been evaluated based on these features

- Although al three have taken care of problems with high load, cluster C and has provided the best solution to problems of visibility with high load. But physically requires more adjust ability than the rest. Cluster A has also provided a solution to providing better visibility of operations at high load by swiveling the operator seat to a side.
- Clusters A and C have provided a convenient for of ingress and egress were the operator has no obstructions in doing this. Cluster B has handled this problem in a unusual manner, which might lead to complicating the overall structure of the forklift. But this feature also has added advantages as mentioned before.
- Cluster A and C provides a better safe position in the center of the forklift whereas in cluster B, the operator might not be comfortable with the operator.
- Additional safety features have been included in the cluster B.

Cluster A was seen selected as the direction i would be working on. As it has provided the essential criteria based on the evaluation with bare minimal.

13.Final Concept

The final concept combines the features of controls and positioning of the operator , form the evaluations done. A rig of the final concept was made to test its functioning and the interrelation between the features and to get the final dimensioning of the forklift.

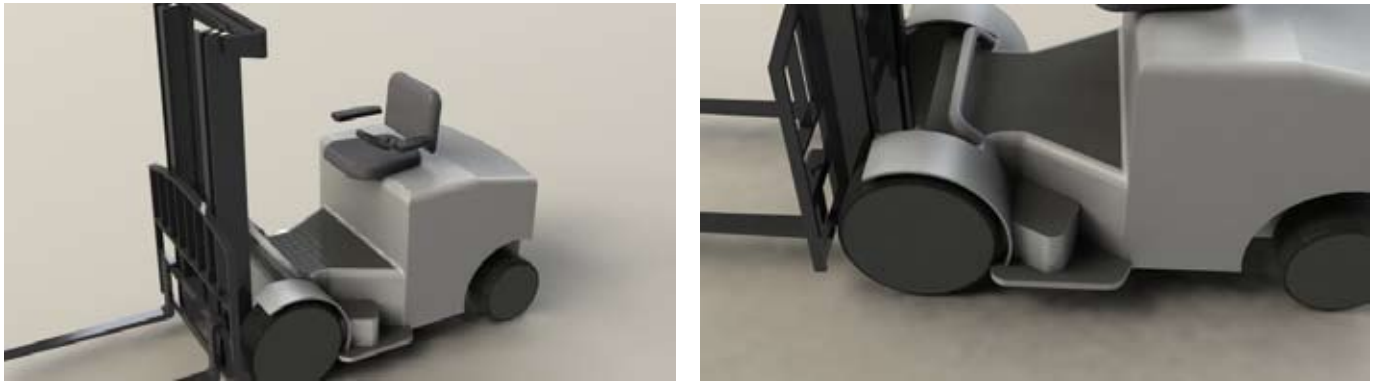


image89

Seat positions for various operations

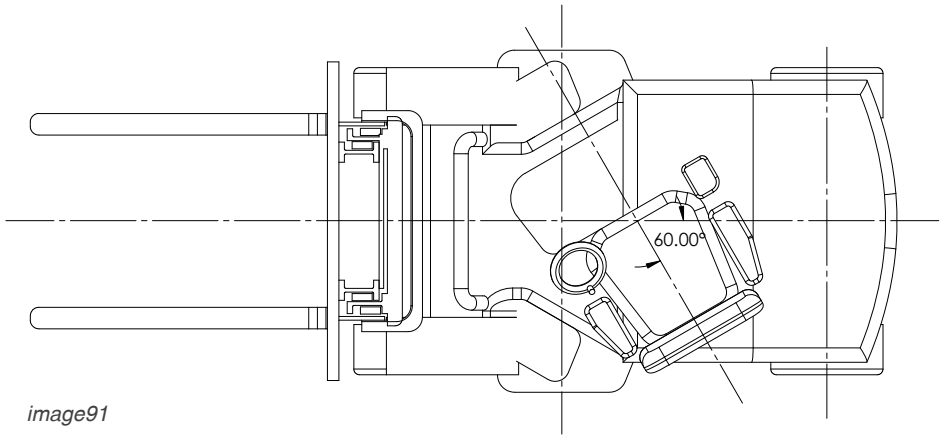


image91

Position A - During Operation, for better visibility of operations at a height and for easy visibility while reversing

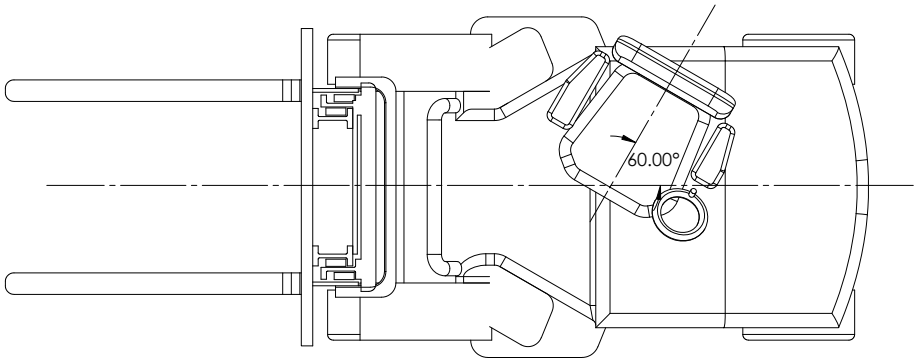


image92

Position B - Stop mode, When the engine is shut the seat automatically swivels to the left, providing easy enter and exit.

Operational Controls

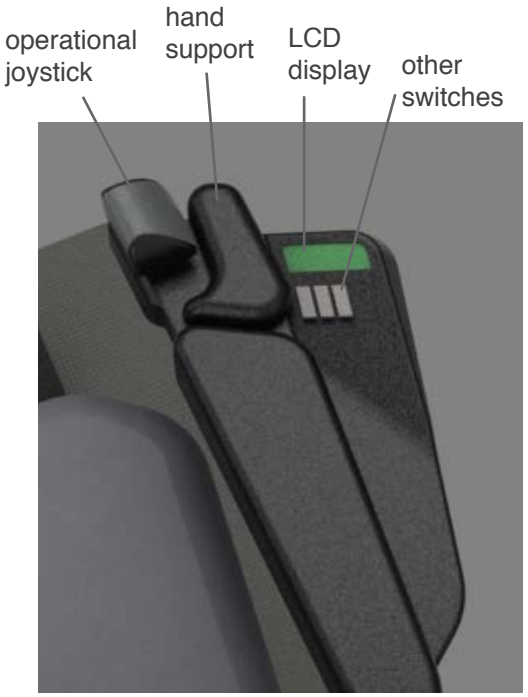


image93

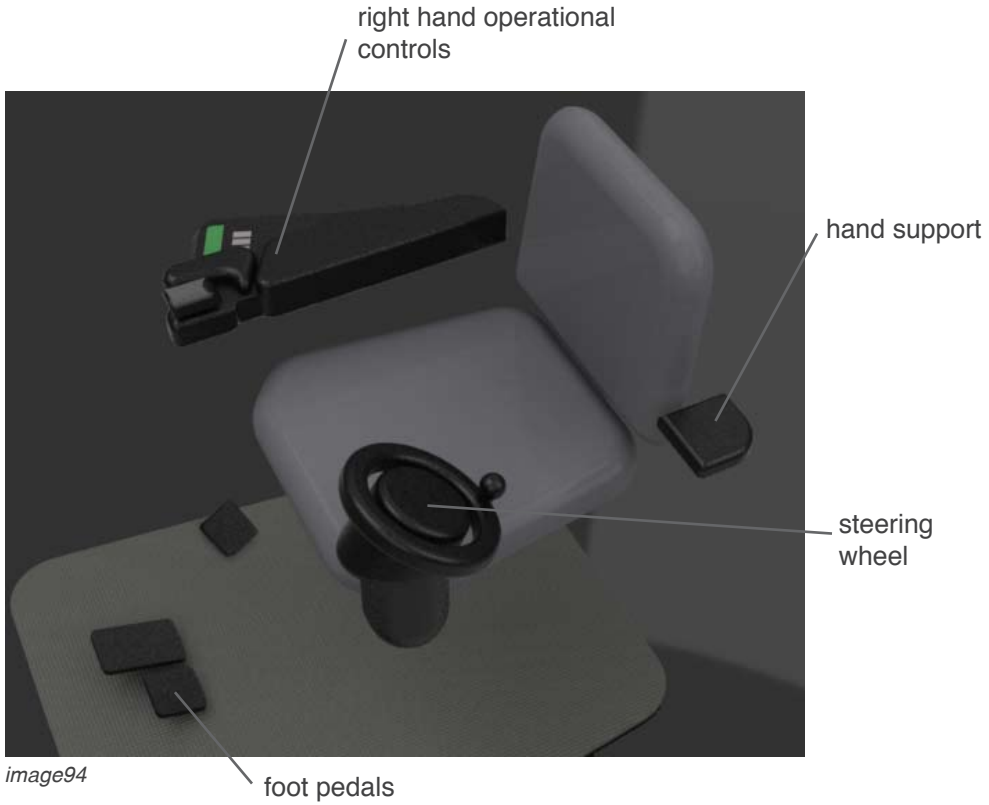


image94

14.Detailing of Concept

14.1 Controls - Steering Mechanism

The steering mechanism proposed for the concept is steer by wire technology. The advantages of this technology provides the freedom of positioning the controls at most comfortable positions. The technology also provides the adjustability in response. The force required by the operator to perform the operation and the response of the operation can be controlled.

Position of Steering Mechanism

In the final concept a left handed steering operation is proposed. The steering console is shifted to the primary reach zone for a comfortable operation. The position and dimensions of the steering wheel was concluded after a series of testing.

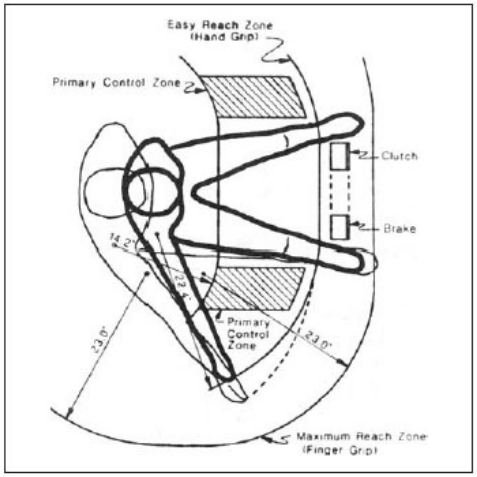


image 95[36]

Inintial Dimensioning

Initial Anthropometric dimensions for 5th percentile male and 95th percentile male* was calculated from Indian anthropometric dimensions, by Debkumar Chakrabarti [35]

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 from seat 180mm
steering knob diameter 58mm (standard)

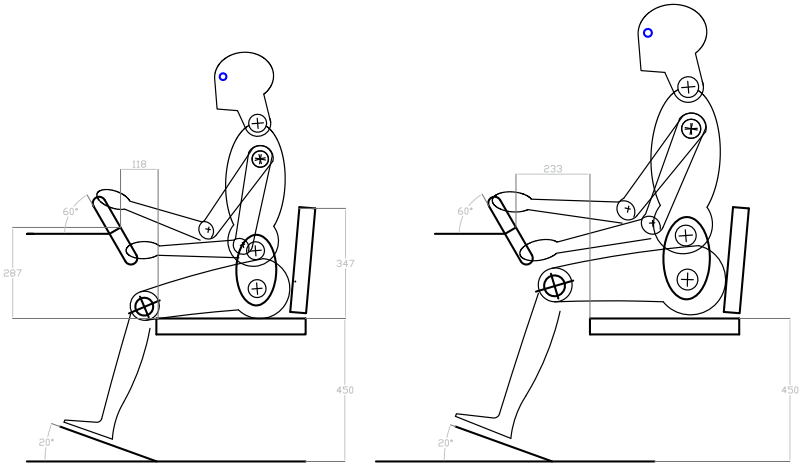


image96 Positioning steering wheel for 5th and 95th percentile

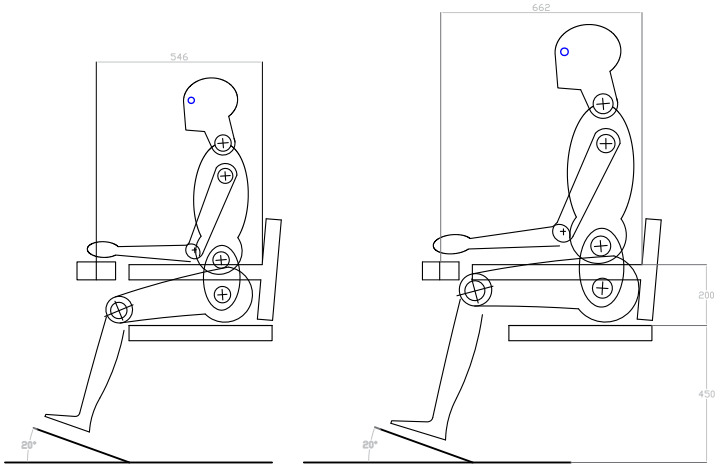


image97 Positioning operational controls for 5th to 95th percentile

Rig testing

Using the initial dimensionins a rig was prepared for testing

image98

image99 gradations for various heights of steering wheel from the ground

image100 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

image101 rig test

Data from testing

Final dimensions from table

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

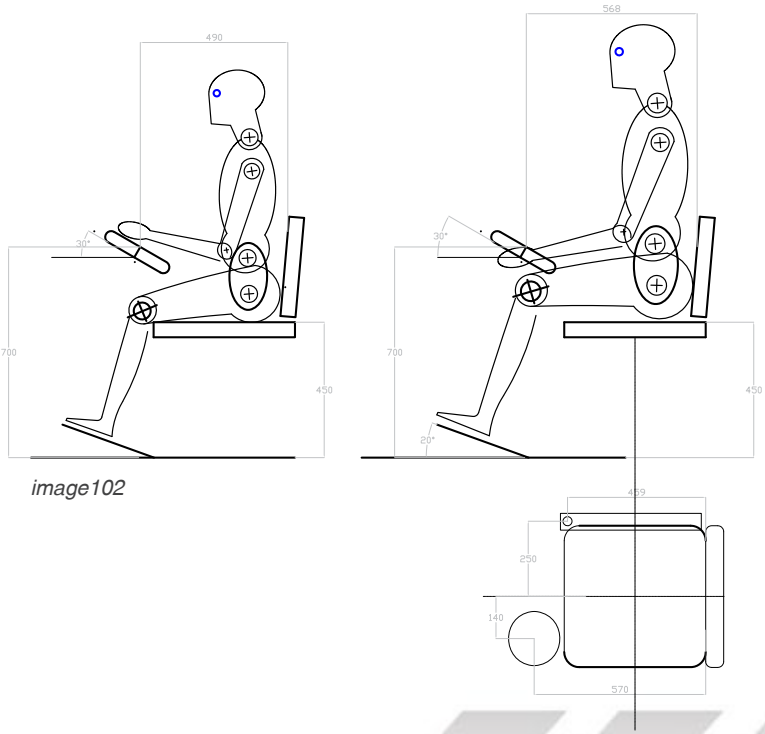


image102

14.2.Controls - Operating Controls

Controls used to maneuver the forks for operation

As seen earlier (page 25), the Godrej Forklift GX 300 E model provides two operational levers for tilting and lifting of the forks.

The final concept proposes to use an additional control sideways movement of the forks. This helps in faster aligning of the forks, instead of moving the whole forklift for aligning.

A single joystick to perform the operations

- 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.

A single joystick allows the operator to have all the controls at hand at all times. The operator does not have to locate the individual controls.

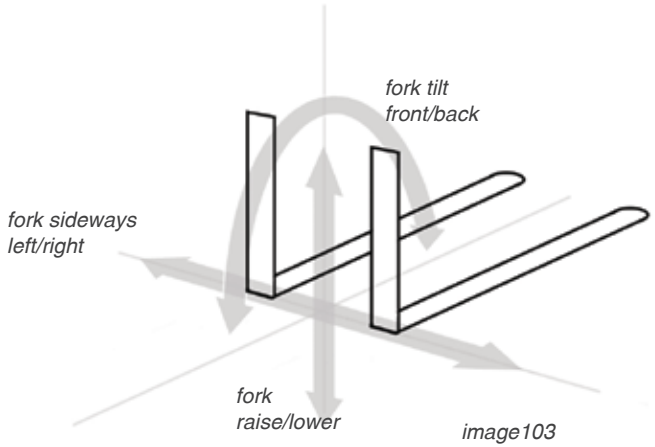


image103

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.

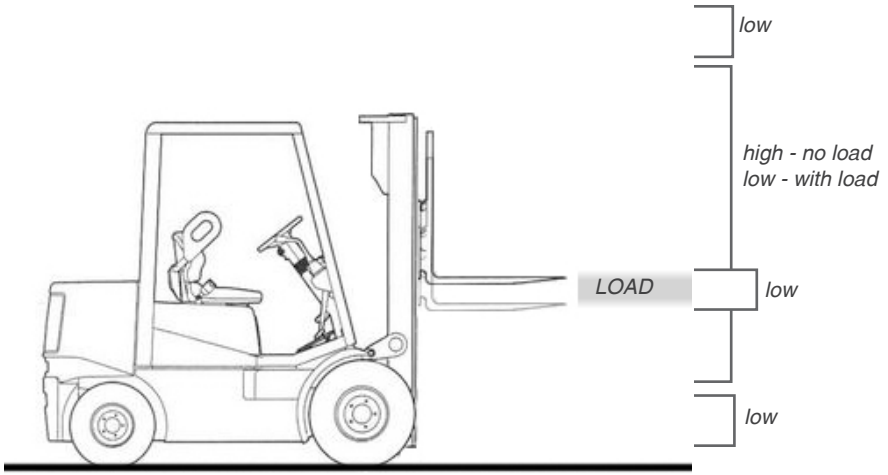


image104

Fork Tilt Operation

image105

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

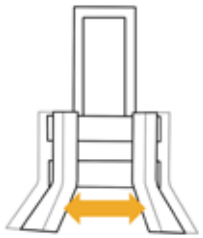


image106

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

Jostick detailing

A single handed joystick control for operational controls - fork tilt, fork lift and sideways movement
Variations were made of the joystick were made in clay and tested with users. Evaluation was made in terms of comfort of joystick and operation comfort


wrist movement for operating the controls
a full palm support was provided, the operation of lift and tilt is performed by moving joystick front and back
the fork tilt is controlled by the wheel to be operated by the index finger and thumb

User feedback:

+precise controlling of fork tilt is possible
-position of the wheel cannot be predicted by the user


a palm supported joystick similar to the previous concept.
Instead if a wheel two buttons were provided for the thumb and index finger for the tilt operation.
thumb button operates tilting the forks backward and the index finger actuates the forks forward

+position of buttons depict the operation
+comfortable button positions
-the buttons can get accidentally pressed


a hand gripped joystick
two buttons provided for forks tilting ahead and backward
The buttons are thumb operated and are placed on the top face,

+comfortable button position

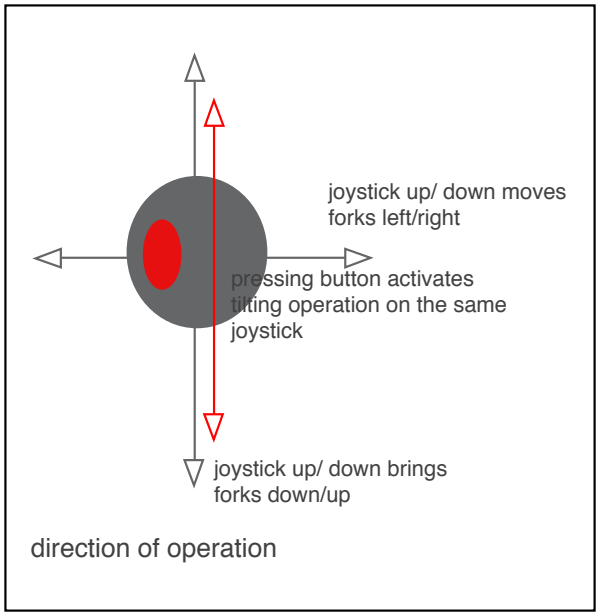

a hand gripped joystick
a single thumb operated button is provided on the top face of the joystick
pressing the button changes the operation of the joystick to tilting the forks back and forth

+comfortable grip
+redundancy is removed

image107

Final concept of Operational joystick

image108



direction of operation

15.Final Design

image109-110

Photos of the model

image111-114

Overall Dimensions

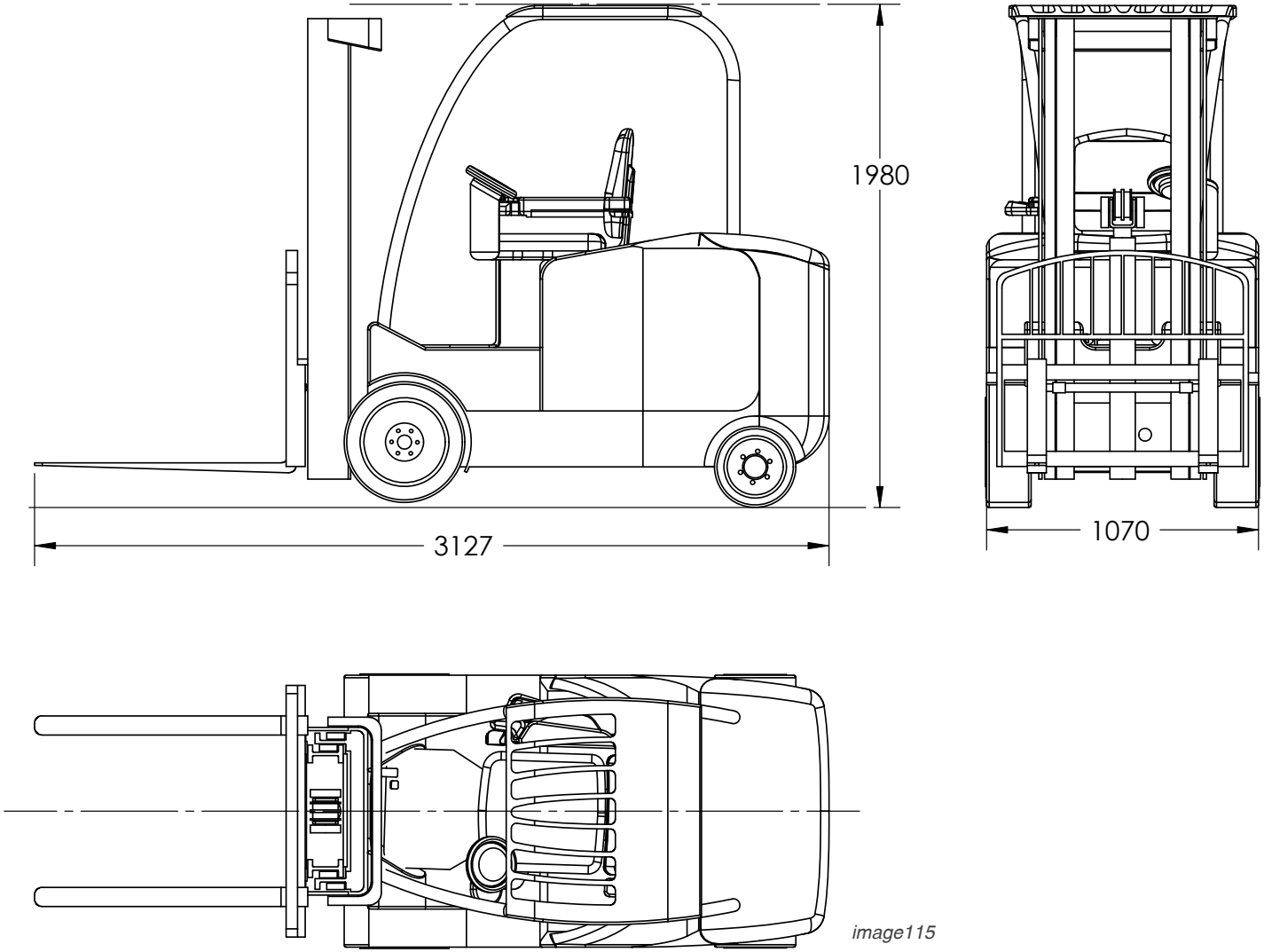


image115

Features - Operational Modes

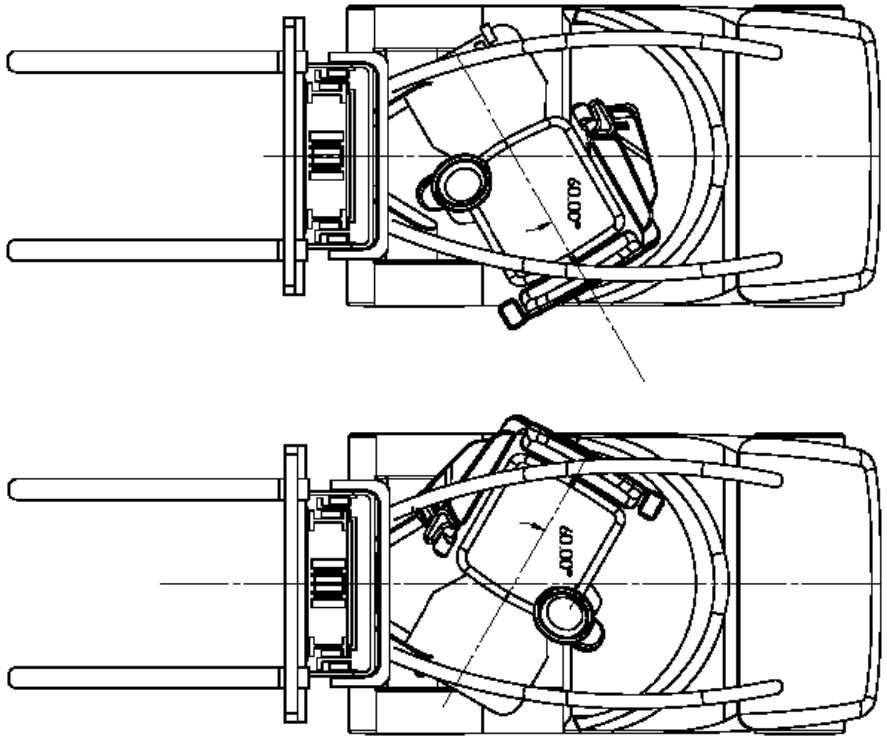


image116

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

Features of Final Concept

image117

Controls and seat swivel to provide multiple seating positions.

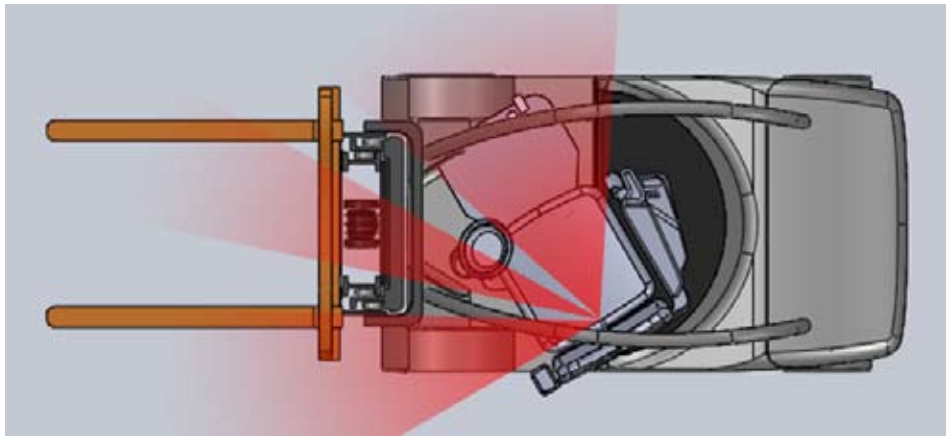


image118

Operator gets a better view of operations in the operational mode
When high load is carried and the operator has to drive in reverse, this mode provides a better visibility of the back without the operator twisting his body

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