FIRE FIGHTING VEHICLE FOR URBAN CROWDED AREAS

MOBILITY AND VEHICLE DESIGN PROJECT - III
MVD III - 38

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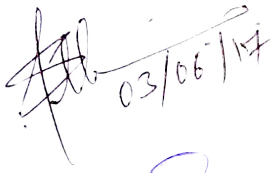
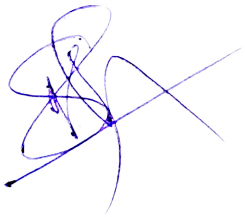
Approval Sheet

The project entitled 'Fire fighting vehicle for urban crowded areas' by Divyanshu Thakur is approved in partial fulfillment of the Master's Degree in Mobility and Vehicle Design.

Signature: 

Date: 03.06.2017

Guide: 

Internal Examiner: 

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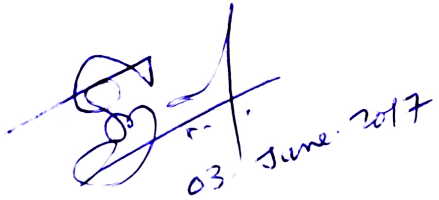
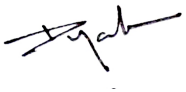
Chairman: 

Declaration

I declare that this written submission represents my ideas in my own words and adequate references and citations have been provided where required along with the original sources. I have adhered to all principles of academic honesty and integrity and have not misinterpreted or fabricated or falsified any idea or information in my submission. I understand that any violation of the above will be cause for disciplinary action by the institute and can evoke penal action from the sources which have thus not been properly cited of from whom proper permission has not been taken when needed.

Signature: 

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Acknowledgement

I am grateful to Dr. Sugandh Malhotra for giving me the opportunity of working on this project and for his expertise and technical support in the implementation. I would like to express sincere thanks to all people who provided much needed information and insights during the research phase of this project.
Nevertheless, I express my gratitude towards my parents and colleagues for their kind co-operation and encouragement which helped me in completion of this project.

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1 Introduction

The Mumbai Fire Brigade has been operating with large first responders for quite a long time. Since the dawn of overpopulation in the city, the city is becoming more crowded, roads are getting narrower due to enchroachment of settlements and it becomes difficult for emergency vehicles to pass through these roads incase of a disaster. Because the fire responders vehicles are so large, their response times are heavily affected by their own size. Most of the times, not all of the equipment which is placed on a first responder is actually needed at the scene of the disaster.

This project tries to understand what essentially can be done to tackle fire related disasters in the urban crowded streets of a metropolitan city. What causes incovenience to the current fire fighting system, the kinds of fire fighting systems in an urban fire fighting sytem and focusing on a particular kind of fire fighting system. The goal of the project is to come out with a concept of a fire fighting vehicle that can perform all the vital functions of a traditional fire fighting engine while being able to tackle the challenged of a crowded urban city.v

2 Pre research

Before arriving at the ideations and concepts, some basic groundwork needed to be completed before approaching the research phase. The methodology involved here was;

- Get a glimpse of the fire fighting system in Mumbai through internet research and visiting the fire stations around mumbai.
- Identifying the types of vehicles currently used by the Mumbai fire brigade.
- Understanding the urban scenario.
- Benchmarking against global standards.

2.1 Fire fighting in Mumbai

The Mumbai fire brigade currently has three main types of rescue vehicles. One is the first responder which is usually dispatched immediately at the call of distress, the second is a water tender which is a large water carrying vessel when there's a large fire and additional water is needed at the scene. The third is a ladder vehicle, which usually houses a hydraulic ladder that can reach heights of upto 90 meters. This is useful in rescue operations from high rise buildings where it is dangerous to enter the building from inside.

2.1.1 Ladder truck

The ladder truck used by the Mumbai fire brigade is mainly used in areas where there are a lot of high rise buildings for rescue operations. The ladder truck use a bronco ladder system which is a hydraulic operated ladder than can rise to a height of over 90 meters.
To deploy the ladder, first of all the truck needs to be jacked to the ground so that the entire system is stable and the ladder doesn't sway when it rises. The jacking requires a large space because the ladder system is self supporting. The ladder truck does not have any dedicated fire fighting equipment because it is only used for rescue missions.

2.1.2 First responder

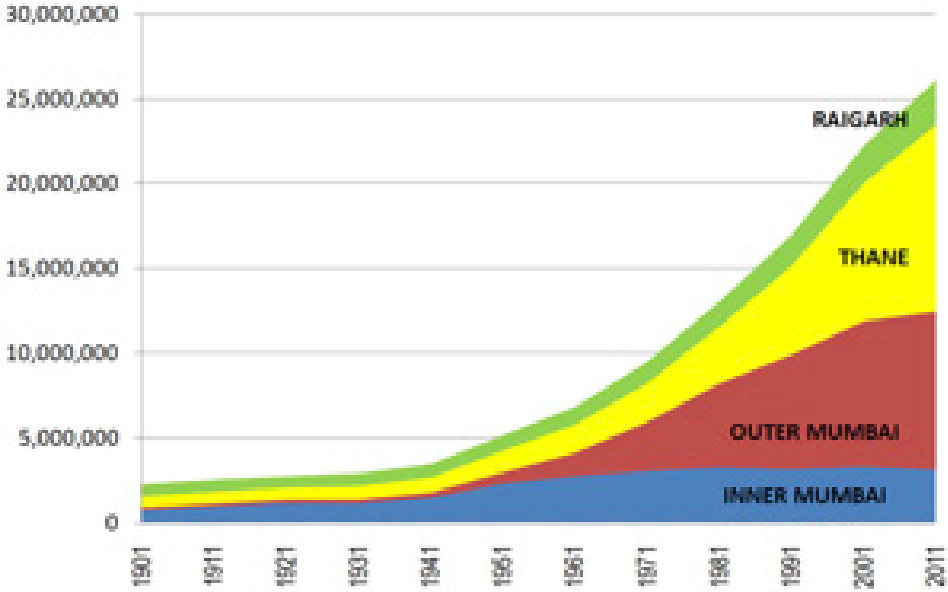
The first responder is called so because it is the first vehicle that is dispatched to the scene of disaster. Whatever maybe the situation, the first responder has all the equipment to mitigate the disaster. The first responder has a number of equipment that make it a multi purpose vehicle.

2.1.3 Water tender

A water tender is essentially a truck fitted with a high capacity water tank. It usually carries around 20,000 to 25,000 litres of water depending on the design of the tank. The tank itself is a rigid structure which has baffle plates in the tank to prevent massive load shifts while the truck is moving. Compared to a first respond which carries around 4500-5000 litres of water, the water tender carries 5 times as much as a first responder. The water tender is dispatched when there is a case of a large fire and the first responder cannot keep up with the limited quantity of water.

2.2 The urban scenario

Mumbai is a really large metropolitan city. Over the course of a century, it's population has increased by large magnitude due to which space has become a precious commodity in the city. Since the design of the fire engine has largely remained unchanged, it has suffered the most because of it's inability to adapt to the conditions of a dynamic city.



2.2.1 Over crowded spaces

One of the main reasons for crowding of the city is the ever growing population. This leads to smaller living spaces and more over, enchroachment of public land and also illegal parking of vehicles on public roads which decreases effective width of the road.

Because the design of the fire trucks in Mumbai has largely remained unchanged, it's inability to adapt can reduce it's ability to respond quickly to an emergency situation.

2.3 Benchmarking

Various solutions have been created around the world for a purpose built fire fighting system. They range from off road forest fire fighters to super mini fire fighters; all of which are designed to fulfill a purpose. However they all are quite smaller than their full sized first responder counterparts. This benchmarking will help understand what makes these specially equipped vehicles succesful in their functions.

A number of vehicles from around the world have been benchmarked and studied, mostly from densely crowded areas and places where there are no proper roads. Some modern variations of the first responder have also been benchmarked as well.

2.3.1 Mercedes Unimog

The Mercedes Unimog U400 is a small but very powerful truck that has been converted into a fire and rescue vehicle to be used in rural parts of Germany where there are a lot of hilly areas and has a risk of forest fires quite frequently.

With a short wheelbase of 3250mm, it can traverse almost any terrain with relative ease thanks to it's powerful and nimble engine. It has a 1200 liter water tank and a seperate 400 liter foam tank for chemical fires. The components are tightly integrated into the chassis so that the center of mass remains unchanged from the original vehicles. The tall cabin helps the drivers to navigate quickly and find out obstacles before they have to actually encounter it.

2.3.2 Subaru Sambar

The Subaru Sambar is an ultra small pickup truck converted to a mini fire engine. The pickup itself is based on the Kei class of small trucks in Japan. Although it does not have any water storage or heavy equipments, it is attached with an engine driven pump that can take water from a nearby hydrant and help in extinguishig fire. This is an excellent vehicle for very crowded and narrow streets.

2.3.3 Mercedes Sprinter

The Mercedes Sprinter based fire and rescue vehicle is a very versatile vehicle. It has two rear axles, one of which is a load bearing axle and the wheels can be jacked out to support heavy machinery on top of it, like a motor pump.

This vehicle is dispatched in areas where there is a water source nearby because it doesn't have a water tank of its own but it is loaded with hoses that can be clamped to form a large link along with distributing networks which are operated through relay pumps.

2.3.4 Mitsubishi Canter

Similar to the Mercedes Sprinter, Japan has the Mitsubishi Canter fire and rescue vehicle. It uses almost the same blueprint as the Sprinter which carries all of the necessary equipment of a first responder except for a water tank.

It has an extended cabin space behind the driver cabin so a total of 3 fire men and a driver can sit inside the vehicle. It has a very short wheelbase of 2800mm which makes navigation through tight spaces easy.

3 Research

To understand the system in detail, a deeper level of understanding needs to be built. The methodology involved here was a thorough study of the current system of fire fighting vehicles. Everything from the package space to the volumes actually occupied by the vehicle was thoroughly studied. The package study helped in identifying the areas where the volumes can be drastically reduced and areas which can be optimised in a better way. The second part of the research involved talking to various firemen, the station master and also the chief fire officer of the city to get their valuable inputs for creating a better concept.

3.1 Visiting fire stations around Mumbai

To study the vehicles in detail and get feedback from the firemen themselves, I had visited three fire stations in Mumbai. Namely Vikhroli firestation, Andheri fire station which also is a vehicle workshop for assembling vehicles and maintenance and finally the MIDC head office where I had the opportunity of meeting the Chief Fire Officer of Mumbai city.

Through the visits, I was able to gather a lot of vital information about the vehicles currently being used, the most used features of the vehicle and also an in depth study of the current first responder

3.2 Studying the first responder

The original first responders are based on the Tata 1516 Chassis. It has a variety of features like an Angus ladder that can reach heights of upto 46 feet. It also has a storage tank that can store water upto 5000 litres in volume. The water tank itself has baffle plates which prevent splashing of water when the truck is moving. Large shift in weight during movement of the truck can destabilise the truck and make it difficult for the driver to steer. It can also cause havoc to the vehicle in traffic. Other features of a first responder are hoses that can go upto a 1000 feet in length it also has additional hoses incase reaching the source of fire becomes difficult. The characteristic thing about first responders is their motor pump which is usually attached to the back of the vehicle. This pump can draw water from nearby water sources like lakes and ponds when the truck itself falls short of water. It is powered by the engine of the truck. Due to this, the pump can only be operated when the vehicle is stationary. It usually has two inlets and a one major outlet which can be distributed with the help of linkages.

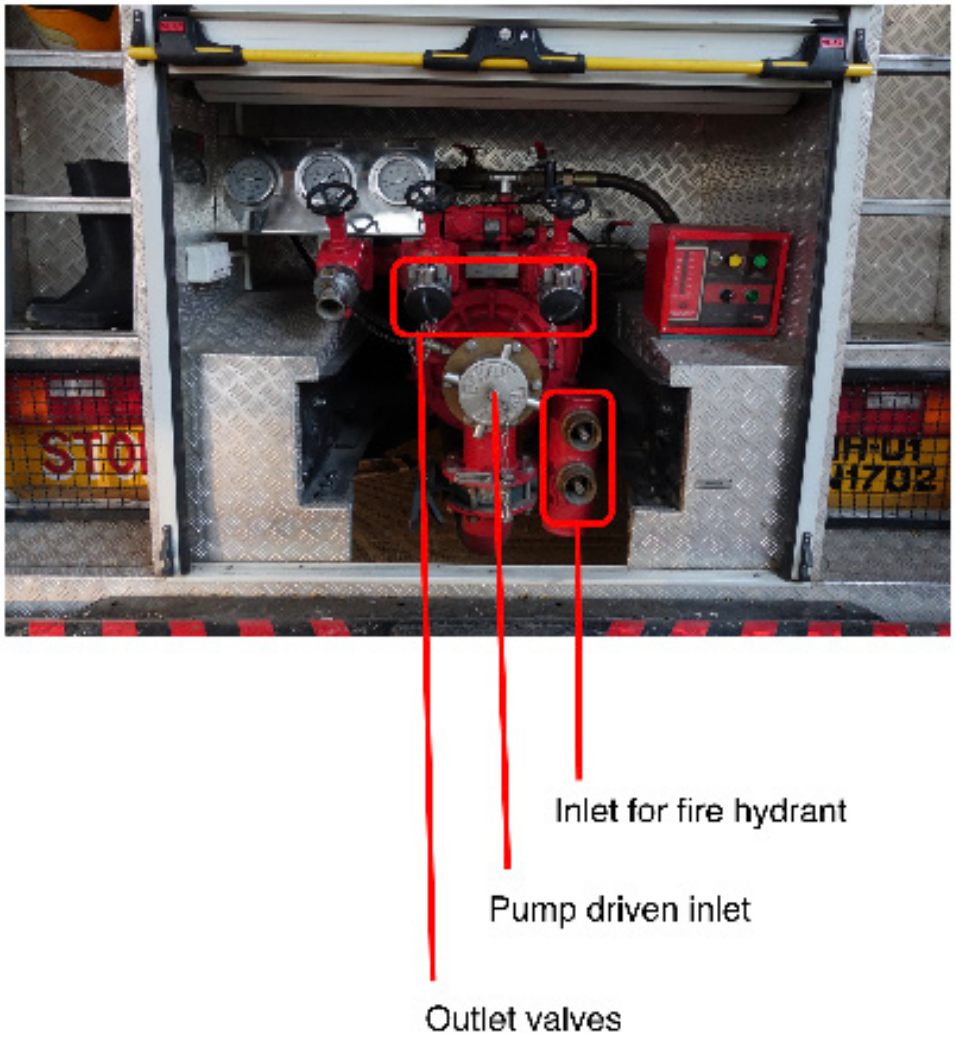
3.2.1 Features

The mini hydrant is a quickly deployed equipment which has a direct water inlet from the water tank running through a portable pump which comes as a part of the mini hydrant. This is useful in situations where small fires have to be quickly controlled.

The Angus ladder is a an aluminium ladder that can extend to upto 46 feet. It is made of aluminium to save weight and make it quickly deployable for rescue missions. The ladder is usually jacked onto the roof and since it is supported on the other end, the vehicle does not require a jacking device.

The essential features of a first responder have been studied thoroughly and it has been noticed that first responders around the city have a standard set of equipment which must be present in it to qualify calling itself as a first responder. The list of features and equipments are noted as follows;

- Angus ladder
- Motor pump
- Mini hydrant



The motor pump is what truly defines a first responder which is also called a motor pump in some cases. Usually, the pump is connected to the differential unit of the vehicle from where it draws power. Due to the high pressure requirements of the pump, it can only be operated when the vehicle is stationary so that all the power from the truck's engine can be diverted to the pump.

The pump itself has an inlet coming from the 4800 liter water tank and two other inlet lines for taking water from a fire hydrant and open water sources likes wells, lakes, ponds, etc. All these three inlets converge to a single outlet which has pressure reducing valves to reduce the pulsing of water by the pump.

A control switch is provided to quickly engage or disengage the motor pump.

3.2.2 Equipment

Oxygen tanks kept next to each seat in the cabin.

A first responder has a number of equipments. A lot of these equipments are not related to fire extinguishing but also rescue tools, lifebuoys, etc. The list of equipments is given as follows;

- Portable generator
- Power tools
- Oxygen tanks for all w
- Life buoys
- Hose with universal clamp
- Additional extension hose (around 1000 feet)
- Shovels, crowbar, hammer, etc.
- Nylon rope
- Jump sheet
- Petrol driven pump
- Spare nozzles, couplers.
- Foam jerry can (15ltr)
- Additional nylon ropes

Driver's cabin showing the radio controls and instrument cluster

The first officer responds through the radio

- Equipment is cluttered and not kept at the correct place.
- Components are retrofitted in the cabin, they do not come as standard part of the vehicle.
- Upward visibility is not very good from the driver cabin.

power generator and life buoys

Jump sheet and nylon ropes for tugging

- lifebuoys is difficult to access and not properly secured.
- cables are not tied properly and kept loose.
- portable generator is not secured properly.
- storage space is not hazard proof.

- The generator has to be kept on the ground while deployed, no special carriage is present.
- Jump sheet has no dedicated storage slot.
- Tray handles are hidden because of poor organization of equipments.

White hose: main hose with universal clamp
Blue hose: extension hoses

Towing hook incase another vehicle is stalled

- Hose reels cant't be stacked because they fall over while the vehicle is moving.
- The hose has to be manually unrolled, a slow and tedious process.

backup hoses incase a fire destroys the primary hose or another vehicle needs additional support

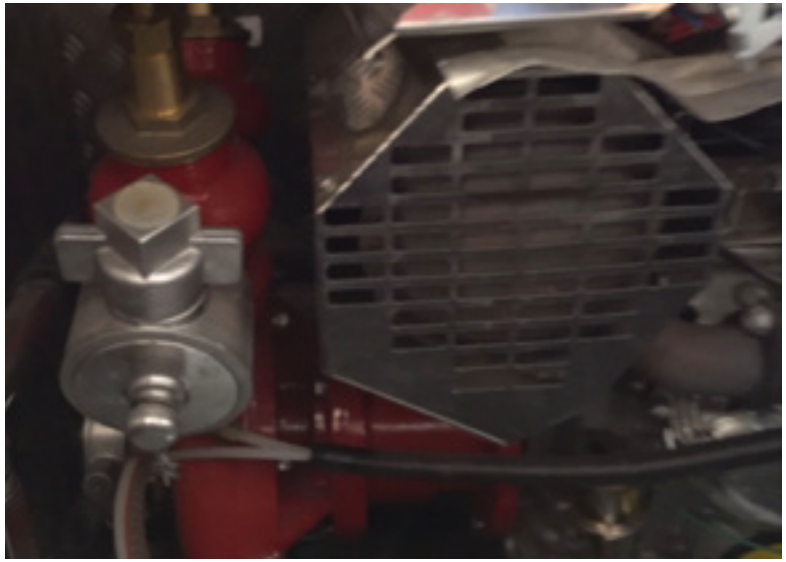
mini fire hydrant which is directly connected to the water tank through the pump. This one has a gun type nozzle.

hand tools, showel, spade, hammers, etc.

additional nozzles, couplers, distributors, etc.

nylon rope used for rescue missions

- Tools and equipments are laid out. No provision to keep them secured in one place. Movement can cause damage and wear to the tools.
- Nozzles are spread out randomly. It is difficult to organize them depending on size and type.
- Because the nylon ropes are tangled, response time gets increased due to untangling for deployment.



portable pump placed next to water tank

quick access nozzles

quick release shutter to access the main pump

- The portable pump is placed under the main storage compartment, which makes it difficult to access because it is non removable.
- The hoses are laid out over the ladder, because of lack of proper storage space.

3.3 Comparison of Tata & MAN

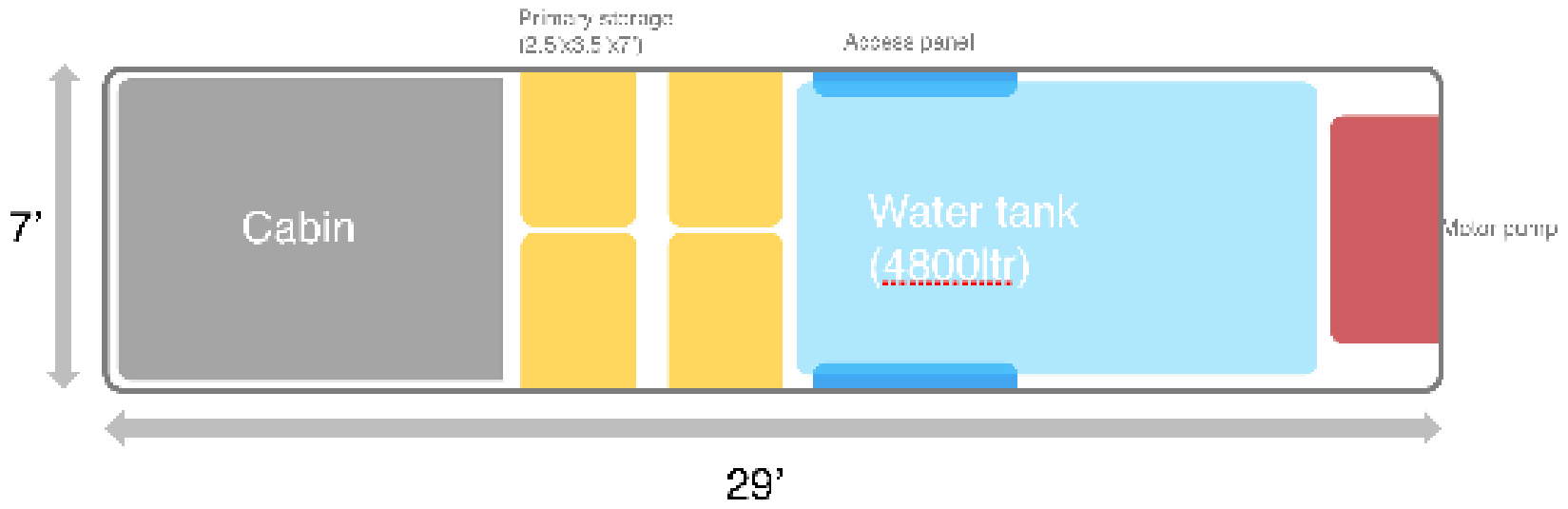
MAN CLA 16

TATA 1516

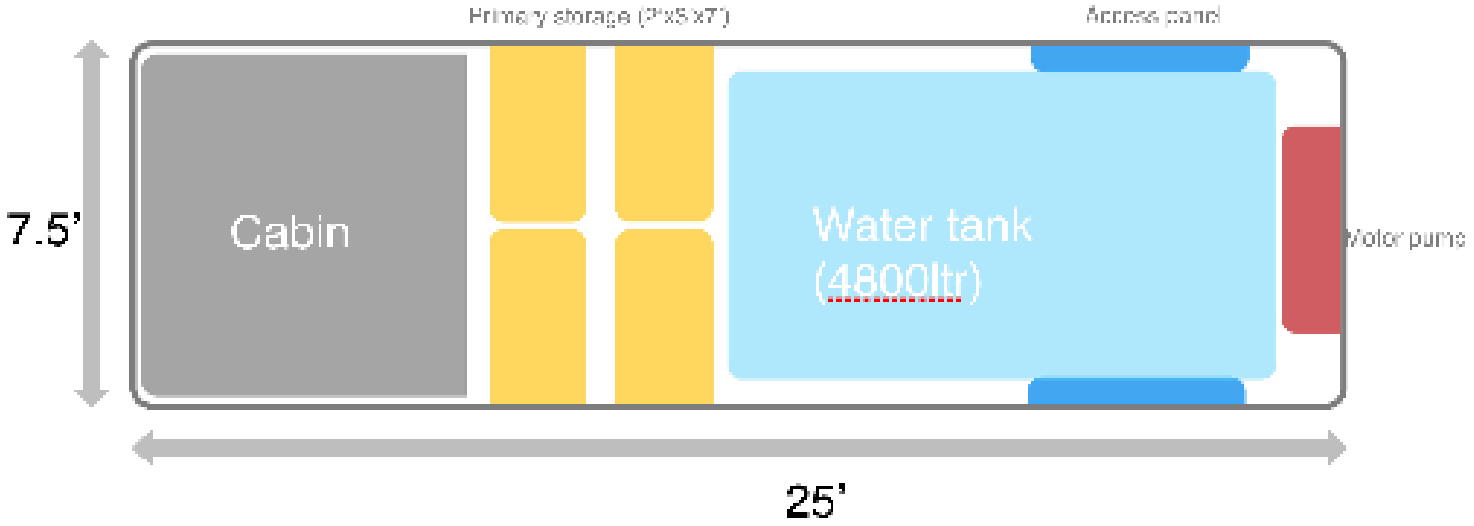
The first responders which the Mumbai fire brigade uses currently is based on the Tata 1516 and MAN CLA truck chassis. Both of them are really huge trucks on their own, with the MAN being around 30′ in length while the Tata is around 25′.

Although the Mumbai fire brigade has been using the Tata chassis for the longest time, it has now been replaced with the MAN truck model. After studying both the vehicles thoroughly, I have noticed that both of the vehicles have exactly the same features and equipments with little to no difference. The MAN truck is unnecessarily larger because it was made with European specifications.

MAN
CLA16



TATA
1516



3.4 Observations & Feedback

The drivers and the firemen at the station had given a lot of valuable feedback regarding the vehicle. Also through observation I have found out several things which can be addressed in the package.

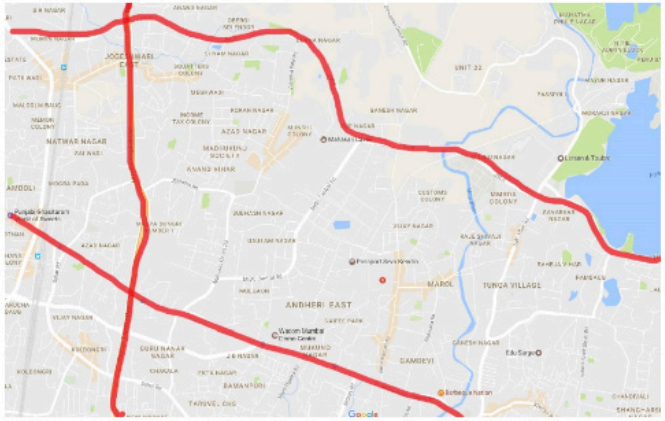
- Accessing equipment is difficult because the firemen have to run around the vehicle to reach for the hatches.
- Equipment gets easily scattered in oversized boxes.
- The storage space provided is more than necessary. Atleast 50% of the storage space is unused or poor utilised.
- Equipments do not have a dedicated storage area.
- Mixing of dirty/wet equipments along with electrical tools causes corrosion and damage.
- Equipments get tossed around because they’re not secured in a place, over time this causes damage.
- The driver has to go extremely slow in narrow lanes especially while taking a turn, to manage the long length of the vehicle around corners.
- The newer vehicles have AC, but they’ve never used it.
- The newer vehicle has several advanced features but are left unused.

3.5 Understanding the scenario

I have taken the case example of the roads around Powai. The aim was to see how the roads are used and what kind of activities occur which affect effective road use. The secondary objective was to locate for fire hydrants around the locality thorugh which the fire engines take water.

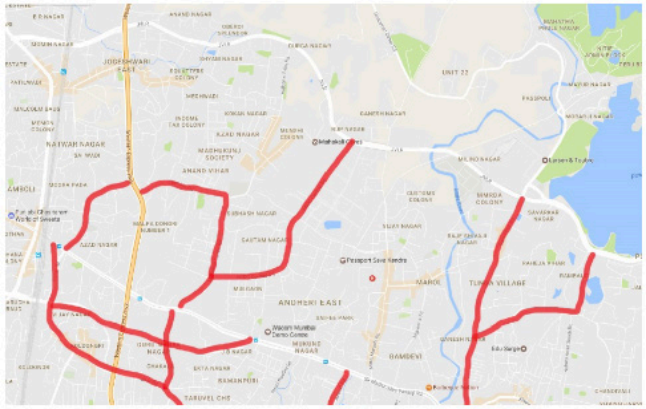
Since Powai is a good mix of crowded and cramped areas mostly inaccessible by large vehicles and large open spaces through which traffic flows freely, it was considered an ideal spot for the exercise.

3.5.1 Types of roads



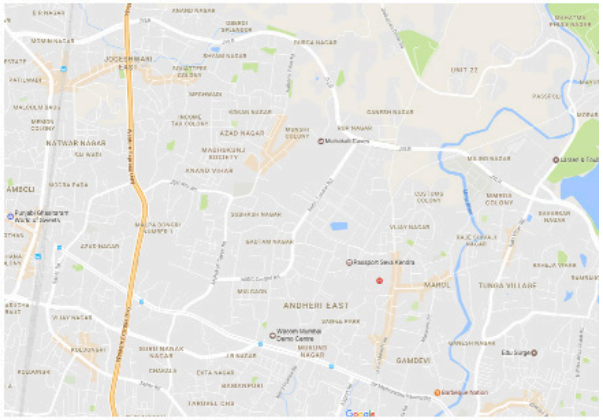
Arterial road >40’

- High vehicular volumes, expressways, highways.
- Service lanes for access to plots.
- May support mass transit infrastructure.



Sub arterial 22-40’

- Connect different wards
- High density bus routes
- Mixed use development, plot access

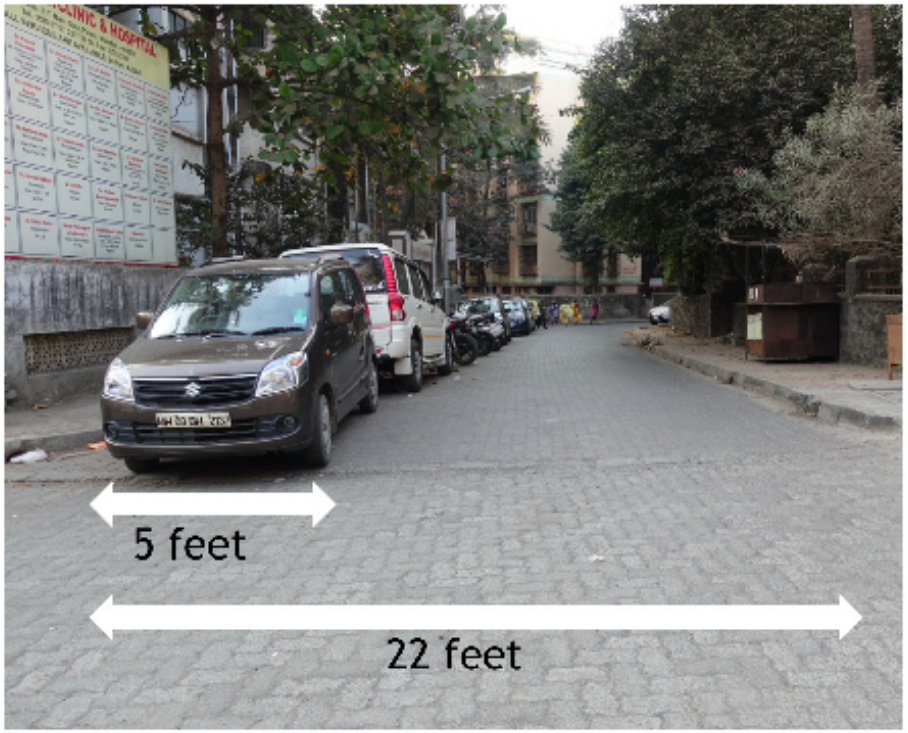


Collector roads <22’

- Collect traffic from local streets
- Fewer bus routes
- Usually single lane

Illegal parking due to lack of space is causing the effective width of roads to become lesser and narrower. Not only that, due to heavy pedestrian use of these roads, it becomes even more difficult for vehicles to pass through with ease. It is impossible for trucks to pass through such roads.

3.5.2 Effective road width



Illegal parking due to lack of space is causing the effective width of roads to become lesser and narrower. Not only that, due to heavy pedestrian use of these roads, it becomes even more difficult for vehicles to pass through with ease. It is impossible for trucks to pass through such roads.

3.6 Inferences

- Response time is of the highest priority.
- Proper organization of equipment can aid in reducing response time significantly.
- Comfort is not a requirement during a rescue and disaster mitigation mission.
- Lack of fire hydrants means its a must for the truck to have a water tank.
- The firemen are hesistant to use advanced technology, they prefer simpler operations.

4 Design Brief

To design a fire fighting vehicle (first responder) for a crowded urban area which fulfills the following requirements;

- Ability to move through narrow roads with fair ease; vehicle should not be wider than 6.5'.
- Water storage volume of at least 500 liters.
- Should have the essential features of a typical first responder, namely; motor pump and mini fire hydrant.
- Easy to operate by the firemen with bare minimum features.
- Make access to essential equipment quick and easy.
- Must be able to carry equipment in an organised manner.

5 Packaging & Concepts

Prior to generating the concepts, a packaging study was done. The bounding boxes of all the equipments in a first responder was measured and a scaled down version of the boxes were made in thermocol. A rectangular box representing the water tank was also used in the package development. Next, a few popular small pickup trucks were studied and chosen based on their size and payload capacity. The concepts were then generated and later refined to make the entire vehicle look integrated.

5.1 Packaging

For the packaging excercise, the bounding boxes of the equipments were measured and a miniaturised version was modelled in thermocol. Another volume of roughly 500 liters was made to represent the water tank. Care was taken to keep the water tank in the center of the vehicle so as to prevent weight shift and an unbalanced CG. All the equipments were kept around the water tank so as to prevent accidental damage to the tank if such an event had to occur.

5.2 Choosing a suitable vehicle

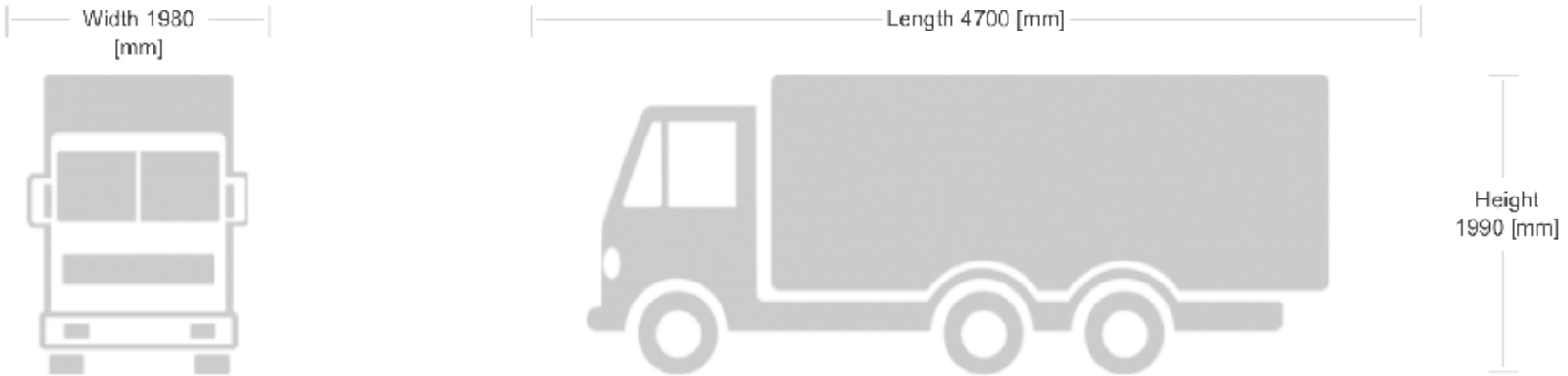
After creating the package with the smallest possible base area, I selected three vehicles on which the new platform could be built on. The criteria for selected the new platform was cargo space, payload weight and engine power. Size of the vehicle was also an important factor considering it will have to navigate through tight places.

The vehicles that were taken into consideration were Tata 407, Mahindra Maxximo and Tata Super Ace.

5.2.1 Tata 407

The 407 is a very popular and versatile vehicle in India. Due to it's rigid chassis and a 4x4 layout, it has become a popular choice for commercial vehicles in India.

It has quite a powerful engine, although it is quite wide at 2000mm will make it difficult for consideration.



5.2.2 Mahindra Maxximo

The Maxximo is a very small car meant for carrying light loads. It has very compact dimensions for it's abilities. However, it has a weak engine which displaces only 900 and hence not a lot of torque is available which is usually necessary to make it agile and also be able to run the motor pump at full loads.

5.2.3 Tata Super Ace

The Tata Super Ace ihas a very powerful engine for its size and specially modified over the standard Ace to carry large loads. It's engine has sufficient torque to run the motor pump as well as carry the payload with ease.

I have selected this vehicle platform because it is quite narrow and also long enough to extend the cabin and accomodate two more firemen at the back with enough space to spare for the equipments.

5.3 Layouts

A few layouts were created based on the platform size and the space required for the components and equipment. Using a 2d sketch layout, it is easy to visualize the overall silhouette of the vehicle and how the components would be placed on the frame. These sketches were shown to teh Chief Fire Officer of Mumbai, Mr. SS Warick who gave a lot of suggestions based on the feasability of the new concept. Using these suggestions, the final concept was built.

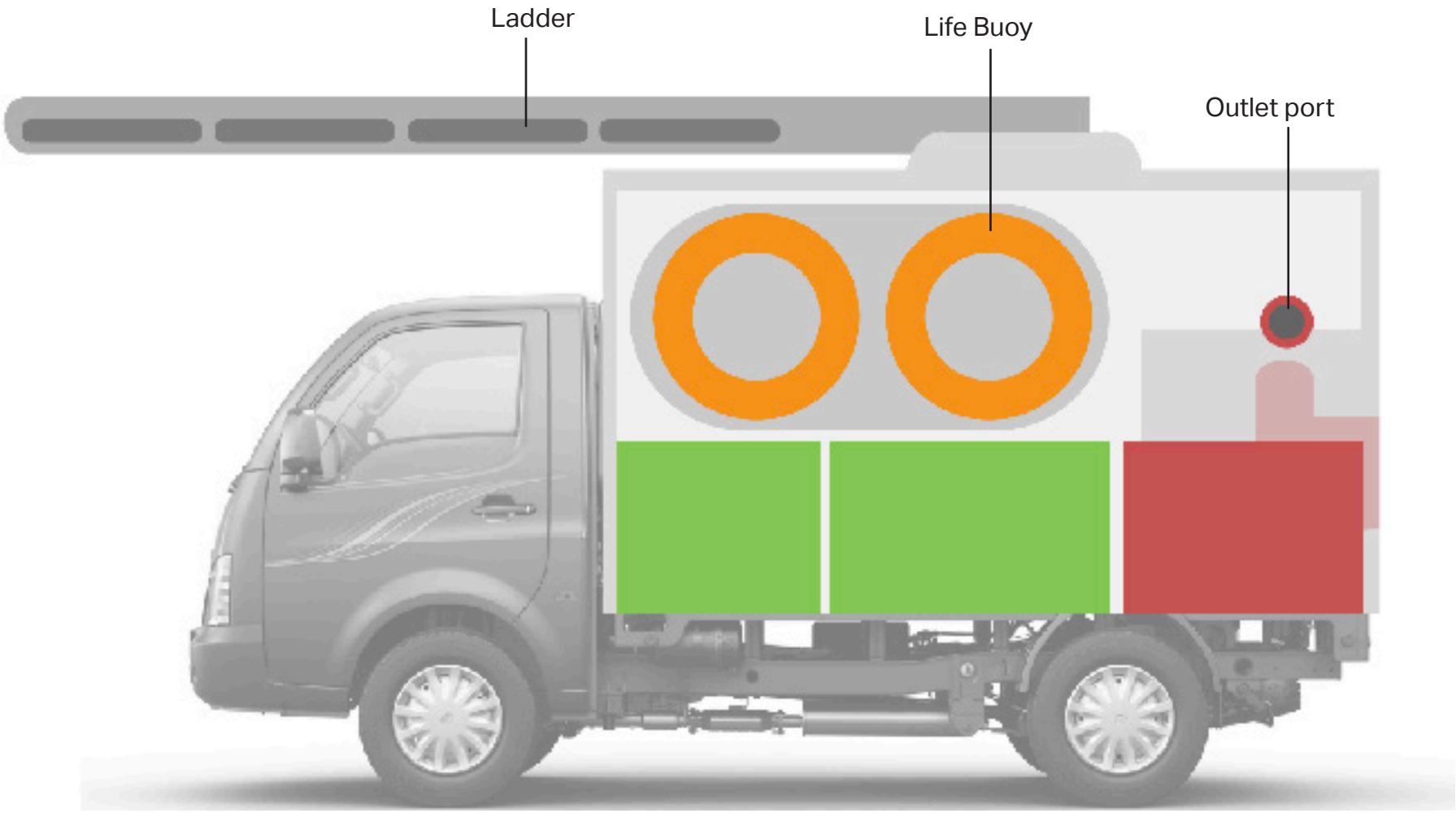
5.3.1 Layout 1

Motor pump

Water tank

Storage compartments

5.3.2 Layout 2



Motor pump

Water tank

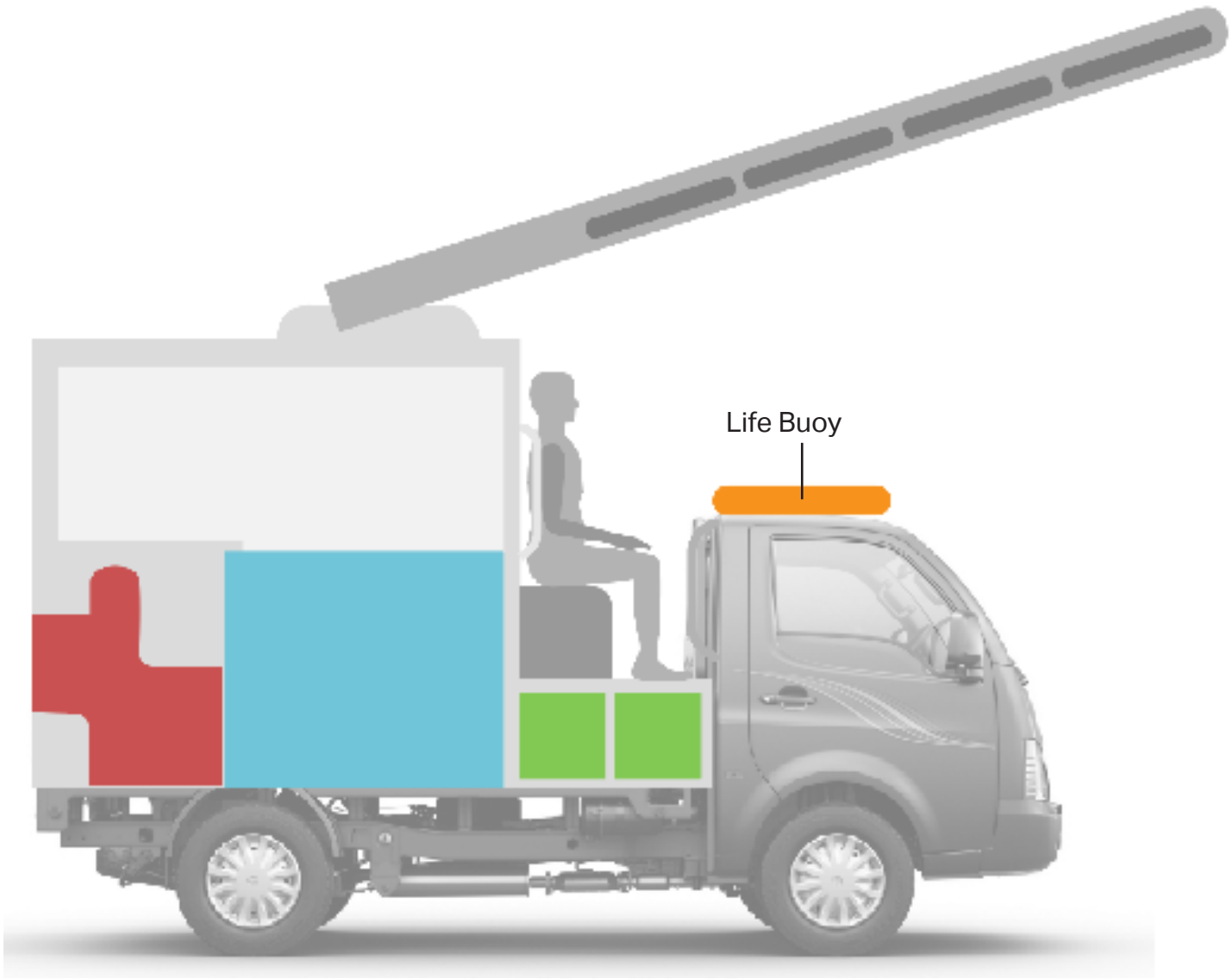
Storage compartments

Motor pump

Water tank

Storage compartments

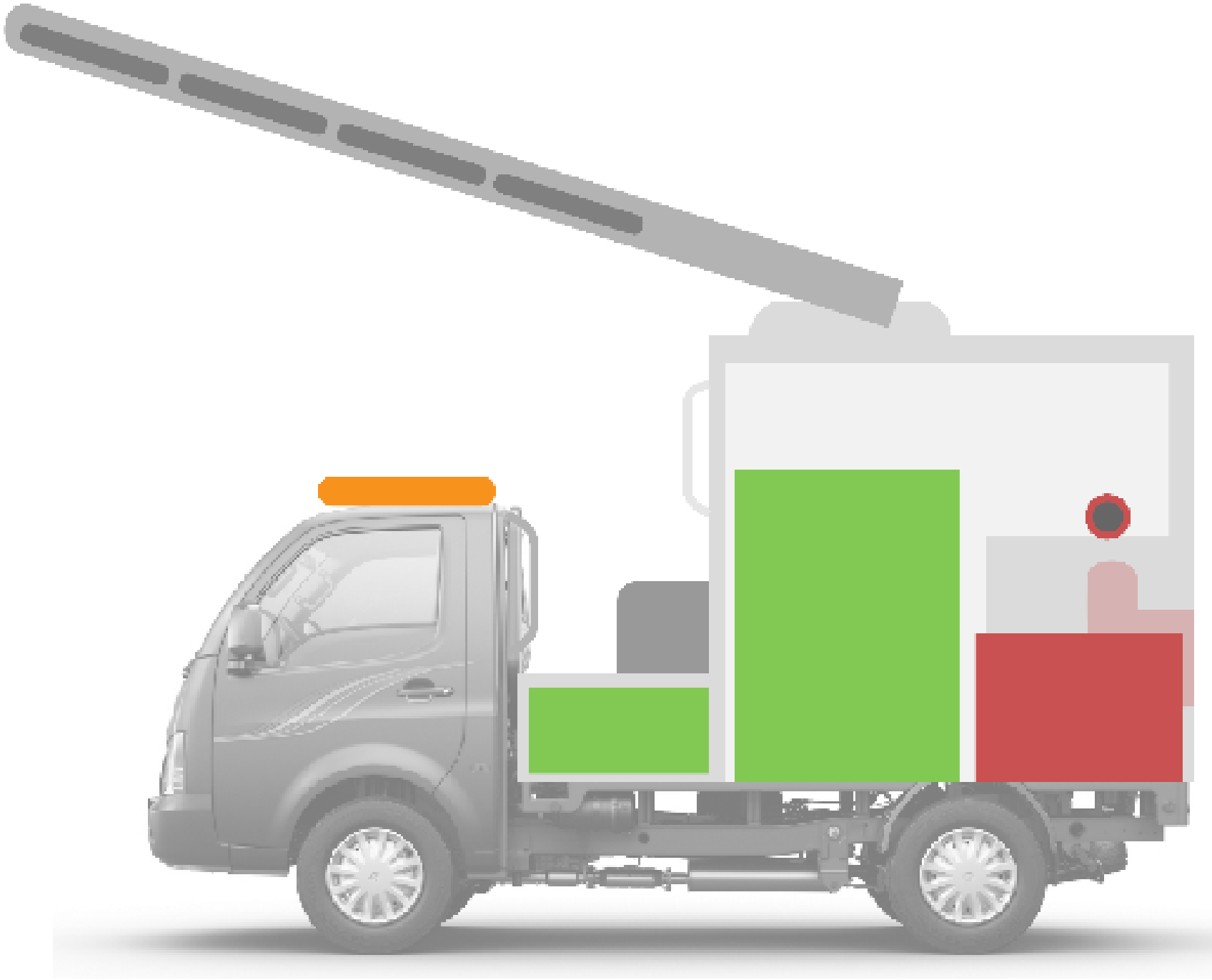
5.3.3 Layout 3



Motor pump

Water tank

Storage compartments



5.4 Concepts

After some discussion over the layouts, two concepts were made with different approaches. A 3D model was made and rendered along with all the details. Both concepts were then weighed in for their pros and cons and later one concept was chosen for further refinement and improving the overall styling and visual appeal.

The methodology involved was;

- Generation of concepts based on given feedback on vehicle layout.
- Weighing in the pros and cons of all concepts and choosing the appropriate one.
- Refinement of chosen concept, along with eliminating any disadvantages the new design has.
- Improving overall aesthetic for visual appeal.v

5.4.1 Concept 1

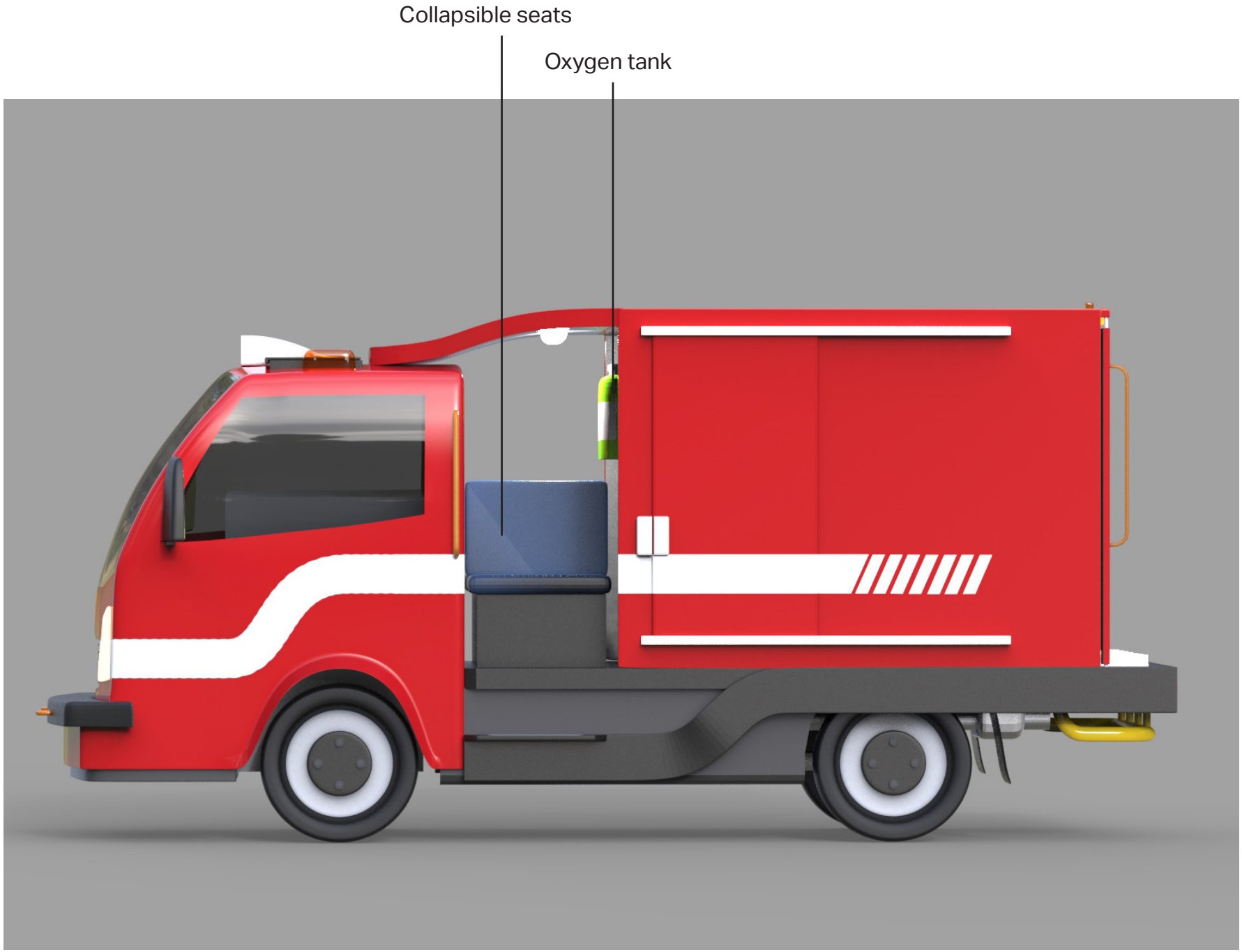
The first concept is based on securing all the equipments inside. Since the vehicles are kept out in the open during stand by, there is a high chance of equipments getting stolen from the vehicle if it is left unattended.

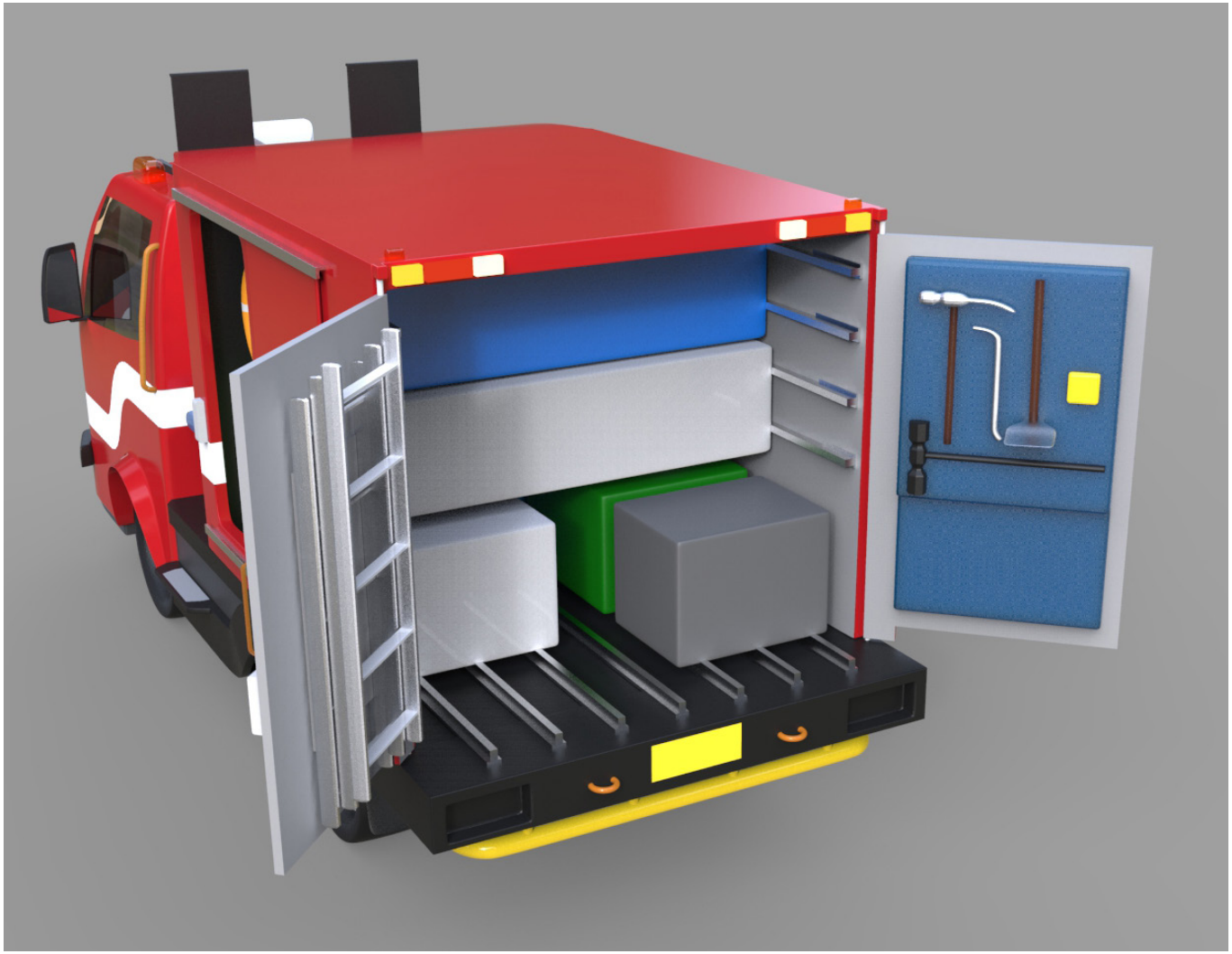
Here, emphasis is given to securing the equipments inside a closed compartment. They can be accessed through sliding doors and the rear door. Seating is provided for two additional firemen in such a way that they can quickly enter and exit the vehicle.

The rear seats can be pulled and extended to function as a bed for carrying and treating an injured person.

In many cases, the fire tends to rapidly spread in dense areas, often knocking down power lines and street lamps as result. It is essential that the vehicle is fitted with it's own illumination system to counter such problems. The roof of the cabin is equipped with LED panels that can be deployed when needed. Another essential feature is the PA system which sits right on the center of the roof.

The sliding doors open to reveal some equipments that might need to be deployed quickly eg., a life buoy.vv


Collapsible seats
Oxygen tank



The rear access door has a foldable ladder and also a tools panels which makes tools easier to access. The entire interior of the rear cabin has rails over which storage slots are placed and can be conveniently slid out or in depending on when it is needed or not.

Heavier equipment like portable generator and mini hydrants are kept on the bottom rails and they can extend beyond the rear frame so that it is easier for the firemen to operate it irrespective of the side of the vehicle they are at.

5.4.2 Concept 2

The second concept is focused towards quick deployment and rapid response. In this, a full size ladder is placed on top so that no time is wasted in having to take the ladder out and then unfold it and deploy. Here, the aim is to keep everything deployable within a few steps. Also, the most essentially used equipment is placed on the rear without any door. The components are locked on a platform and can be deployed instantly.

Other equipments can be accessed from the vertically dropping door. It is made so that instead of a fully swivelling door, it just drops down quickly in a narrow road.

The rear access has a shelf where the hand tools are kept and can be easily taken out and placed into the correct slot. The portable generator and mini hydrant are kept on the bottom and can be extend outwards so that it can be easily used no matter which side the fireman is standing. This makes is hassle free and reduce response time.

5.4.3 Comparison

Concept 1

Pros:

- More secure.
- Less likely for equipment to suffer from corrosion.
- Modular system, setup can be installed on any similar vehicle.

Cons:

- Longer response time.
- Equipment cannot be easily replaced.
- Deploying the ladder is a longer process.
- Ladder height is limited.

Concept 2

Pros:

- Lesser response time.
- Easier to access equipment.
- Ladder has a better reach.
- Larger water storage volume.

Cons:

- Some equipment maybe prone to theft.
- Increased overall weight of the vehicle.

5.5 Refinement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