Interface Design for Condition Monitoring and Predictive Maintenance in Trucks

for small-scale truck owners(<5 trucks)

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ABSTRACT

The aim of this project is to design the interface for a smartphone-based Health and Usage Monitoring System(HUMS) system for predictive maintenance of trucks.

The project aims at supporting users who own small-scale fleets (less than five trucks) . Due to a large number of these small businesses, designing for this sector will enable supporting the digitalization of a sector which is not generally considered as the main focus of digital India campaigns. However, this sector plays an important part in the economy and digitalization will help in getting maintenance done at the right time. Thereby, improving the efficiency of the trucks, reducing cost of maintenance for owners and as a consequence reducing overall pollution in the long run. In order to design for this population, a user study was conducted with truck owners, drivers, repairmen, spare-parts dealers to understand the trucking ecology in Salem, Tamil Nadu.

Based on insights from user studies, various concepts for the interface for a Minimum Viable Product were explored, which were then translated into two prototypes. Due to the situation of the lockdown, actual user testing was not possible. Hence, these prototypes were tested with student peers and a final version was detailed.

CONTENTS

INTRODUCTION

With sensors becoming available at cheap prices [2], the concepts of real-time condition monitoring and predictive maintenance are becoming increasingly popular for the maintenance of machinery, especially in the developed parts of the world [3]. The decreased cost of data storage and network tariffs have made it easier and cheaper to have streams of data coming in from various sensors through wireless networks [4].

With the help of IoT enabled sensors mounted to a particular piece of equipment, it has become possible to predict beforehand as to when that particular equipment will fail. Hence, maximum value can be derived out of the lifetime of that particular equipment. This kind of prediction is made possible by means of monitoring the physical parameters(vibration frequency, rotation frequency, anomalies in power consumption, and others) along with data about the operating conditions(temperature, altitude, and others) and mapping them against data from the previous operation times of the same type of equipment. This kind of information communication technology can go a long way in terms of increasing efficiency in a day and age where mechanical developments in manufacturing and other sectors are moving towards stagnation. [3]

When combined with new-age technology like blockchain, it can open up new possibilities like tracking spare parts throughout their lifetime. This can serve various purposes like inventory management or even knowing how well a particular piece of machinery has been maintained based on knowing the condition of each of the parts at the time of them being replaced [6].

Health and Usage Monitoring Systems (HUMS) that are based on predictive maintenance are already being used in the aviation sector and have demonstrated a fair level of effectiveness [7]. Knowing when parts are going to fail beforehand has also enabled aircraft operators to plan for maintenance activities(ensuring availability of spares, personnel, and others) in advance, thereby reducing maintenance costs and downtime along with enhancing operational safety. It is predicted that HUMS systems will also make their way into the trucking sector in the future [5].

Motivation

With smartphones being available at affordable prices, they are becoming increasingly popular even among people who have not owned any kind of computation device earlier [8]. This combined with the availability of cellular data at cheap prices, it has become possible to provide digital services to people with whom it was not possible before the age of the smartphone.

Looking at the trucking scene in India, smartphone-based speed governors and GPS tracking equipment that are already available in the market [1]. In addition to that, a few start-ups like Rivigo, BlackBuck, and others are working on bringing technology into the scene by providing services like driver relay, fleet management,

among others. However, none of them seem to be working on the areas of predictive maintenance or HUMS.

While in the global scene, OEMs(Volvo, Tata, and others) are predicted to take up the task of providing HUMS solutions in their trucks as part of the standard equipment in their new trucks [5], the same approach might not work in Indian context. Firstly, it would drive up the cost of new trucks. This might not go down well with the owners, a majority of whom prefer to get their trucks serviced at local workshops owing to reduced costs. Secondly, with about 34% of trucks in the country being more than 10 years old [1], the market penetration of such a system would be low.

In India, the number of small-scale fleet owners (owning less than 5 trucks)is quite high. It is estimated that the number of small-scale fleet owners involve about 75% of all the trucks in the country [1]. To help the small-scale owners realize the benefits of a HUMS system, it is important to provide a very low-cost entry point to the ecosystem. Once they begin to realise value in it, they would be willing to invest more on expanding the system. In today's context, one of the best ways to achieve this is by means of providing a smartphone-based modular solution that has sensors to monitor different parts available as separate 'packages'. In such a case, the owner is required to pay only for what he wants to be monitored. Additional sensors can be added at later stages as and when the owner feels the need for them without disturbing the system that is already in place.

Scope

The aim is to design a smartphone interface that enables the small-scale owner to monitor the health of his entire fleet and plan for maintenance accordingly. It is assumed that it is possible to have information from the sensors that are added at later stages to also be detected and be displayed on the interface.

While dedicated interfaces for other stakeholders like the truck driver or the mechanic might provide added benefits, we shall be designing only the interface for the truck owner in this project.

Initial Brief

Design a smartphone interface to enable small-scale truck owners(<5 trucks) derive the benefits of predictive maintenance.

PRIMARY RESEARCH

User studies were conducted in Feb-Mar, 2020 in and around the areas of Salem, Sankagiri, Tiruchengode, and Thungavi in Tamil Nadu. A total of 21 people directly related to the small-scale trucking sector(<5 trucks) were interviewed (5 truck owners, 7 truck drivers, 8 mechanics, 1 spare parts dealer; one of the truck owners was also a broker) by means of face-to-face interviews that lasted for about 30-45 min each.

Fig 1: User study

How the sector works

Most of the trucks in the small-scale sector operate on a day-to-day market system, also known as the ‘mandi’ system. In this system, there is the presence of a broker who provides the trucks with business [9].

For example, let us consider an owner who wants to find business for his truck. He gets his truck parked at the broker’s office and then gives the broker a preference of one location where he would like his truck to be sent. Once the broker gets an order for that particular location, he then sends one of the trucks parked in his office based on a first-come first-served basis. Therefore, all kinds of maintenance activities should be carried out before the truck is sent to the broker’s office.

The preferences the owners give for where they would want their trucks to go is more of a personal preference and there is no method to it. Say, for example, they give preferences based on places their trucks have been to earlier, places the trucks of people they know have been to, and others.

How maintenance is done

Maintenance is usually carried out in local workshops rather than at the dealerships of the OEM, owing to cost benefits. In recent years, OEMs are offering warranty periods at the time of purchase for the initial few years. During this period, the new trucks are being serviced at the dealerships as the warranty becomes invalid if the truck is serviced by anyone apart from an authorized dealership. In addition to that, the parts that are covered under warranty can be replaced free of cost in the event of a fault or manufacturing defect. However, once the warranty period is over, owners switch back to having their trucks serviced by local mechanics.

Looking at the scene of servicing at local workshops, only a few aspects like oil and filters are changed at specific km intervals recommended by the manufacturer. In addition to that, the regular wear parts such as the brake, clutch are checked at the time of the truck getting FC(Fitness Certificate) once a year at the RTO. Every other part is replaced only when there is a fault or it is completely worn out. Though the lifespan of each of the parts is roughly known, there is a fair level of variation for different trucks depending on the driving style of the driver, the amount of load the truck has been

carrying, and others. Hence, replacing all parts beforehand would greatly drive up maintenance costs.

Identification of faults

A part being worn out is generally noticed when the driver complains of any unusual sound or a reduction in pick-up or mileage upon returning from a trip. However, these sounds might be clearly audible only when the truck is moving on level roads. Otherwise, they might just fade into the ambient noises.

When the driver reports of any of the above conditions, then the local mechanic inspects the condition either by removing the part or by taking a short ride with the driver. At this point, it is to be noted that when the faults are not detected at early stages, the truck keeps running with the worn parts causing even more damage to the health of the truck in the long term. Such cases can lead to breakdowns or other safety hazards while the truck is in the middle of a trip.

What if a part wears out while on a trip

Depending on the nature of the part and the operating conditions, it can sometimes lead to a breakdown in which case, nothing much can be done by the driver. In other cases, the truck can still be driven by the driver taking some ‘jugaad’ (ad-hoc) measures that are inherently risky, the details of which we shall discuss when talking about each part individually. While these practices might help bring the truck home, they considerably increase the running costs and bring along the risk of safety hazards. Drivers resort to such measures as there is a shipment that needs to be delivered on time. Even if the truck is returning, the driver cannot choose to get servicing done along the way as it is the owner who is going to pay for it and they would prefer to get it serviced by their trusted mechanic. Therefore, for proper maintenance to be carried out, the truck has to reach home.
The only exception is in the event of a breakdown where the truck is just serviced enough for it to reach home.

Talking about breakdowns, owners of slightly larger fleets tend to own about one or two spare trucks that can be sent to transfer the shipment and continue the trip while the broken down truck can slowly be brought home. Owners of smaller fleets who cannot afford the luxury of a spare truck are left in a bit of a fix as they have to wait for the issue to be fixed if it is a minor one and if not the goods will be transferred to some other truck, causing them to lose earnings. On being asked about how they cope with such a situation, they just say it is bad luck if the truck breaks down on the way.

The People

Driver: They are hired on the basis of recommendations from acquaintances or other drivers and usually tend to drive the same truck over a period of time. The role of the driver in maintenance is usually reporting whether any signs of fault are noticed(sound, reduced pick-up, and others). Along with the helper, they are also

supposed to keep a watch on certain parameters like engine oil level, radiator water level, tyre pressure to ensure proper running conditions.

Owing to the shortage of drivers across the country [10][11][12], there are no helpers in today's trucks. The drivers too prefer it that way so that they can make a bit more money from what would otherwise go to the helper. However, this also means that keeping a tab on ensuring running conditions(fluid levels) now becomes solely the driver's responsibility.

Drivers of the previous generation knew a thing or two about the maintenance aspects that can come in handy when there is an issue midway. This knowledge is, however, it is not expected of today's drivers as they are already hard to find. For instance, while today's drivers can say if some unusual sound is coming from the truck, they would not have any idea on the cause of the sound.

They generally have very low levels of formal education in their regional language and are not familiar with english. Few of them own smartphones and their usage is limited to making phone calls, watching videos, or checking forwards on whatsapp. They, however, are not used to typing/inputting text. For example, they save contacts like A, B1, 1095, which either refer to the first alphabets of people's names or the registration numbers of the trucks. As a result, they tend to rely heavily on visuals and memory to navigate through the phone. They generally approach youngsters in their family or locality to get apps installed or to change something in the settings.

In the event of the truck waiting at the workshop, due non-availability of spares or liquid cash to pay for the spares, the drivers wait for the truck to be serviced and do not go on to drive other vehicles in the meantime.

Owner: The small-scale owners are generally people who are associated with the trucking sector in some way like an ex-driver, broker, mechanic or sometimes a business owner who constantly needs the services of a truck. As a result, they are familiar with the maintenance related aspects to a certain extent, but might not be familiar with the technical terms associated with them.

They are totally dependent on the driver to be informed of any faults as it is the driver who is always with the truck. The owner does not get to see the truck sometimes even for even 2-3 trips at a stretch. Only upon the driver reporting of any fault is the truck sent to the mechanic for inspection.

The owner usually calls all of his drivers once a day to check if everything is alright and to ensure if the driver is keeping a tab on the fluid levels that he is supposed to monitor.

The education level of the owners on average, seems to be higher than that of the drivers and in general they tend to be comfortable

with saving contacts on their phones, albeit with spelling mistakes similar to the likes of using K for a C, E for an I, K for a G, and others. Some of them already own smartphones and apart from using it for watching videos, checking whatsapp, they also use whatsapp to send pictures of bills and other documents that are saved on their phone. In addition to that, some of them owning a smartphone are also familiar with downloading apps from the play store.

Most of them seem to be aware of the existence of smartphone-based GPS tracking solutions in the market and one of the owners who were interviewed was actually using it for his truck.

Mechanic: They are people who have learnt about truck maintenance by virtue of working as apprentices at the workshops, who have later moved on to set up their own workshops. As a result, they are not familiar with the technical terms associated with the work they do. They can, however, identify most faults from the sound or by means of visual inspection if the truck is near them.

With the introduction of BS4 emission norms in 2107 [13], electronics have come into the picture of maintenance. Sensors that monitor the combustion-related aspects present within the engine of new trucks and the drive-by-wire method(that is based on electronics) is being used for elements like the accelerator [14]. While such a system allows for easy diagnosis of the faults that occur in the core of the engine with the help of a scan tool, it is not something the local mechanic is familiar with. As a result, the new trucks can only be serviced by the manufacturer in cases of faults occurring in the core of the engine. This can be primarily attributed to the reason that they either do not have access to a scan tool or they are not able to make sense of the information that comes out of it. However, local mechanics still continue to take up all other maintenance activities that are not related to the core of the engine even in the newer trucks.

Their levels of literacy and smartphone ownership and usage are very similar to that of the drivers that were discussed earlier.

ANALYSIS

Key Insights

- With the absence of the helper, there are certain things like engine oil level, radiator water level, tyre pressure that need to be constantly monitored by the driver.
- Once the truck returns from a trip, the owner gives the broker a preference of where to go next. There is no fixed logic/method to this preference.
- The owner is fully dependent on the driver to be informed of faults for maintenance to be carried out.
- The availability of ready-at-hand cash or spare parts does affect maintenance schedules.
- Not all owners are familiar with inputting text onto the smartphone.

What to represent in MVP

There can be plenty of parts in a truck whose health can be monitored with the help of sensors. However, the interface we intend to make here is for that of a Minimum Viable Product. Hence, we would want to represent only those aspects/parts whose monitoring could prove to be of crucial importance if such a system were to come out in the market.

In a bid to follow that, we have chosen to represent only the aspects/parts that emerged from the user studies as either

a) Difficult to identify or
b) Can cause more serious risks either to the safety or the overall health of the truck if not identified earlier

As an outcome of this exercise, a total of 11 parameters were listed as ‘to be represented on the interface’. The 11 parameters that need to be monitored can be divided into two broad categories - ‘Levels to be monitored by driver’ and ‘To be monitored for predictive maintenance’.

Scenario Mapping

Based on the information from the user studies, scenario maps were made for each of the 11 parts that were listed as ‘to be represented on the interface’. These maps helped understand the maintenance cycles of each part, what measures are taken when the part wears out while on a trip, who can identify these faults, and how they are identified, among others.

Levels to be monitored by driver

While it comes under the responsibility of the driver to take a look at these levels daily, it is very much possible that owing to the workload and the absence of a helper, they might not perform these checks regularly.

Engine oil level: The engine oil provides lubrication to the engine. Without sufficient lubrication, the engine begins to overheat, which in turn reduces the life of the engine. When not noticed beyond a point, it might even cause the engine to cease, leading to a breakdown.

Fig 2: Cap of the engine oil tank to which the measuring stick is attached

The level of the oil remaining can be measured by looking at how much the stick attached to the cap of the engine oil tank is dipped in oil. The engine oil can be filled by purchasing it at any of the fuel outlets.

It is also possible that if the level is checked after the engine has been running for a while, the reading might be higher than the amount of oil that is actually in the tank due to it jumping around in the tank because of the vibrations from the engine.

Radiator water tank level: This water is responsible for cooling the engine. Without sufficient cooling, like in the case of the engine oil, the engine might heat up and result in a breakdown.

Unlike in the case of the engine oil, there is no measure to check the level of water in the tank. The only way to ensure that there is enough water is to fill it to the brim. Hence, it can become really difficult to identify if the water level is low unless the engine temperature starts increasing, which can reduce the life of the engine.

Tyre pressure: When the tyre pressure is either higher or lower than the recommended limits, it can cause the tyres to wear faster and can lead to tyre bursts in extreme scenarios. Given that tyres are the most expensive wear and tear parts in the truck, unwanted wear can prove to be expensive.

While high-end trucks nowadays come with in-built tyre pressure monitoring systems that are connected to the dashboard of the truck, it is still not a standard feature in the average truck. The only ways to detect anomalies in tyre pressure are by manual inspection(kicking the tyre) or from the small differences in the way the truck handles, which might not be obvious to everyone.

In addition to preventing unwanted wear, monitoring tyre pressure can also be helpful in identifying punctures.

To be monitored for predictive maintenance

Clutch plate: The clutch plate is responsible for disengaging the engine from the tyres, to enable the shifting of gears. When the clutch plate wears out, the engine runs like the clutch is always slightly engaged. This causes the engine to race too much that comes along with a reduction in pick-up. Due to the engine racing too much, a significant drop in fuel efficiency can be noticed, leading to an increase in running costs.

In the case of the clutch plate becoming worn out while on a trip, the truck would still be able to make it home with a bit of difficulty in scaling inclines, while consuming significantly more fuel.

Fig 3: New clutch plate

Brake lining: The brake lining is responsible for slowing down the tyres upon braking. It is similar to that of the brake pad in that of a car, except that it is present on the inside of the rims rather than along the side of it. The amount of breaking material left can be visually inspected by looking through a hole that is present on the inner side of the rim of each tyre. Due to the cumbersome nature of the task, it might be difficult for the drivers to perform this inspection regularly.

Even when specifically asked by the driver to inspect it, the mechanic has no other metric apart from visually looking at how much material is left. Hence, he can only give a rough estimate of how long it will last (something like 10 days or 15 days). And if the owner feels that it should be enough for the trip or the spare is not available, the truck is sent on the next trip with the to-fail-soon brake lining itself.

At this point it is important to note that the brake linings on all tyres will not have the same amount of wear. This is due to the fact that since the front tyres are closer to the brake pedal, they tend to get slightly more air pressure(trucks have air brakes) and likewise for the left and right sides as well. When this happens over numerous times, there is bound to be uneven wear.

Inside the housing, there is a spring that pushes the brake lining towards the tyres upon applying the brakes. In the event of the brake lining completely wearing out while on a trip, there is the risk of the spring expanding too much and breaking as there is no braking material left that can come in contact with the brakes. To avoid the breakage of this spring, the driver disconnects that particular brake lining from the braking system by means of ‘jugaad’.

As a result, now one of the tyres does not have a brake connected to it. This causes the vehicle to move towards one side(the side where the brake was disconnected) on braking. This might turn out to be catastrophic under rainy or emergency braking conditions.

Engine oil density: Unlike engine oil level that needs to be monitored constantly by the driver, this is more of an ‘once in x km’ thing. As the engine oil present inside the engine tends to get old, its

density increases. This causes its movement speed to decrease, which in turn decreases the effectiveness with which it can lubricate the engine. Hence, there is the need for an oil service wherein the entire old oil from inside is completely removed and then new oil is filled into the tank.

While oil servicing has to be conducted every ‘x km’, the need for such a monitor came up during the user study and is best illustrated by the following narrative.

For example, the general recommended period for an oil change is around 10,000 km. Now, an owner sees an advertisement of an engine oil from brand X and comes under the impression that X is of superior quality than the one he is currently using. Although it is more expensive than the one he is currently using, he decides to give X a try. He then runs the truck with X for around 12,000 km since it is of superior quality and it holds up too. Now, he wants to do another short trip and opens the oil tank, takes some of the oil present on the measuring stick onto his fingers, and feels the density. He feels it should last the trip and hence sends the truck on the trip.

In this case, feeling the density with fingers is not a concrete measure and it might be possible that the truck might face heating issues while on the trip.

In addition to that, the oil becoming denser is more dependent on how long the engine has been running and how much strain it has been taking than the number of kms covered. Now whether or not he decided to try X, there is always some uncertainty around the exact time when it needs to be serviced. And by the time it is detected in the form of engine heating up, it might have already caused some minor damage to the life of the engine.

Blockage in radiator: The radiator pulls air from outside to cool the engine. As the radiator takes in air, the tiny tubes in the radiator tend to get blocked with dust particles with the passage of time. Hence, there is a need for the radiator to be removed and either cleaned with acid or replaced at regular intervals.

But, just like in the case of the engine oil density, the amount of dust particles clogging the tubes might vary depending on the operating conditions. Hence, there is this uncertainty around the exact time when it needs to be serviced and can cause overheating of the engine if sufficient amounts of air cannot be pulled in.

Gearbox: The gearbox contains the multiple gears required for operation. While it does not have a visible wear pattern, it might happen that over time one of the teeth in the many gears might break off. This leads to a kada-kada sound when that particular gear with the broken tooth is engaged. When the vehicle continues to move in that particular gear, it might cause that particular gear break. When

left unnoticed, it can cause the other gears as well to break one by one, leading to a total breakdown.

If the driver happens to identify in which gear the sound is coming, then further damage can be prevented by not engaging that particular gear. As long as it is something like the 3rd, 4th, or 5th gear, the truck can be brought home. However, for this the driver should be able to identify the exact gear.

In case the damaged gear is the first gear, it becomes very difficult to move the truck from a standstill and if the clutch plate too is worn at that time, it is a guaranteed recipe for breakdown.

Crown pinion: The crown pinion is responsible for transferring the rotation from the transmission to the wheels. The crown also has a tooth-teeth like structure. Just like with the case of the individual gear, a breakage in one of the teeth produces a kada-kada sound. And if left unnoticed, it can lead to breakage of the other teeth in the crown as well, causing a breakdown.

At this point, it is worth noting that a breakage in any of the individual gears or in the crown pinion produces the same kind of sound and even for a trained mechanic, it might take some time to figure out.

Wheel bearing: In the case of wear in the bearing that is connected to each of the wheels, there is slight movement towards a particular direction while the truck is moving in a straight line. This can turn out to be hazardous under emergency braking conditions. In addition, this wavering of the tyre also causes it to wear faster.

Fig 4: New wheel bearing

Wear in the wheel bearing is difficult to figure out upon visual inspection as it is not something that is located on the periphery. Hence, it is important that the driver notices it at early stages.

Brake booster: The brake booster is responsible for sending air pressure to the brakes upon braking. When there are tiny holes in the booster, the air pressure might escape out of these holes, thereby reducing the amount of braking pressure actually being sent to the brakes. This is also something that is difficult to identify upon visual

inspection and in addition to that, it is not the most obvious thing people check for when braking is weak.

PROBLEM DEFINITION

Design a smartphone interface with which the small-scale truck owner(<5 trucks) can:

- See if running conditions are ensured by the driver
- View health of parts and plan for maintenance
- Decide on next trip based on condition of truck

INITIAL CONCEPTS

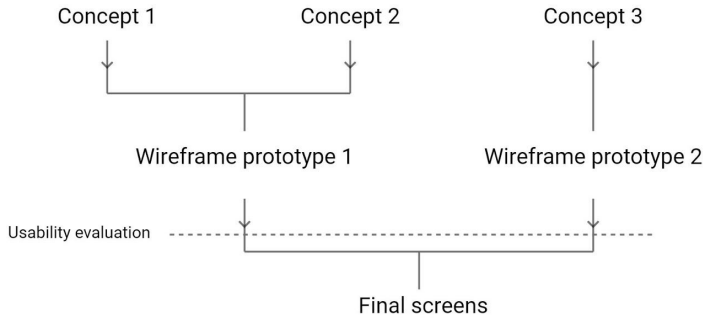


Fig 5: Process followed

For the conception process, 3 individual concepts were first made to see how individual screens can be represented(not as a cohesive app). From those screens, 2 cohesive wireframe prototypes were made.

Due to the reason of not being able to access the target user group during the loakdown, both the wireframe prototypes were subjected to usability evaluation by peers. Feedback was taken and then the final screens were made based on their inputs.

Concept 1

Since most of the trucks in India are from one of the two major OEMs, identification of trucks on the basis of their make would be difficult. Hence, the truck owners, drivers, and mechanics refer to trucks with the last four digits of their registration numbers. The same method is used to distinguish between trucks in the interface. An icon of the truck is added along with the number for better relatability.

Everywhere throughout the interface, all parts are represented with the help of icons. This can help the owners, who might not be aware of the technical terms, to relate to the parts better, while also maintaining simplicity in the interface. This also reduces the confusion that can arise between using technical terms and real-world terms.

Fluid levels on homepage: While the trucks are on trips, the information that would constantly be needed by the owner is knowing whether the parameters that are to be monitored by the

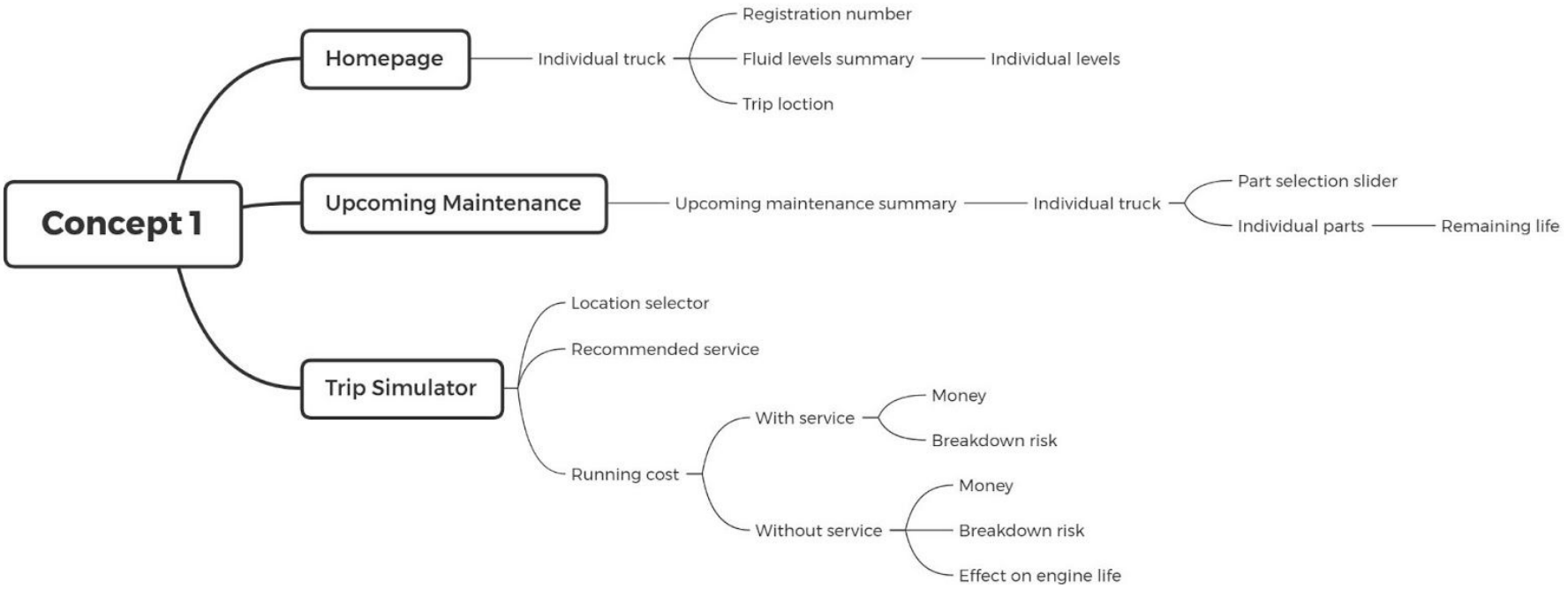


Fig 7: Concept 1 information architecture

driver(fluid levels) are within acceptable limits or not. Hence, this information for all the trucks is provided at the home page itself along with the locations to which each of them is on a trip to.

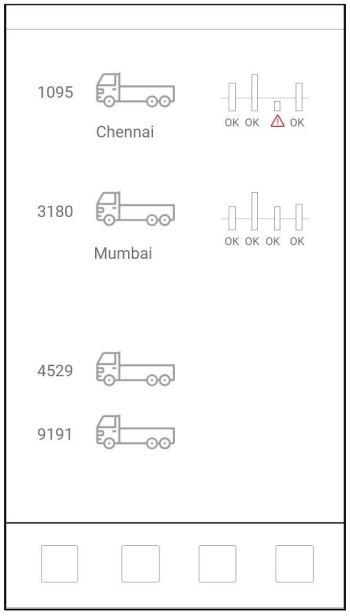


Fig 6: Fluid levels on homepage

In addition to that, an ‘OK’ or ‘!’ is shown along with the data to quickly show a summary of whether the levels are within acceptable limits or not. The fluid levels are not shown for the trucks that are currently not on a trip to keep unwanted information away.

Trip simulator: It was found that not much method exists to the owner giving the preference of the location of the next trip to the broker. We make an attempt to base this preference on the condition of the truck by means of having the feature of a trip simulator.

To select the preferred location, suggestions are shown based on the first one or two alphabets based on the name of the location. Here, we go for the bubble selection instead of a dropdown as it allows for more space allowing the user to browse the maintenance requirements for multiple locations from the same screen.

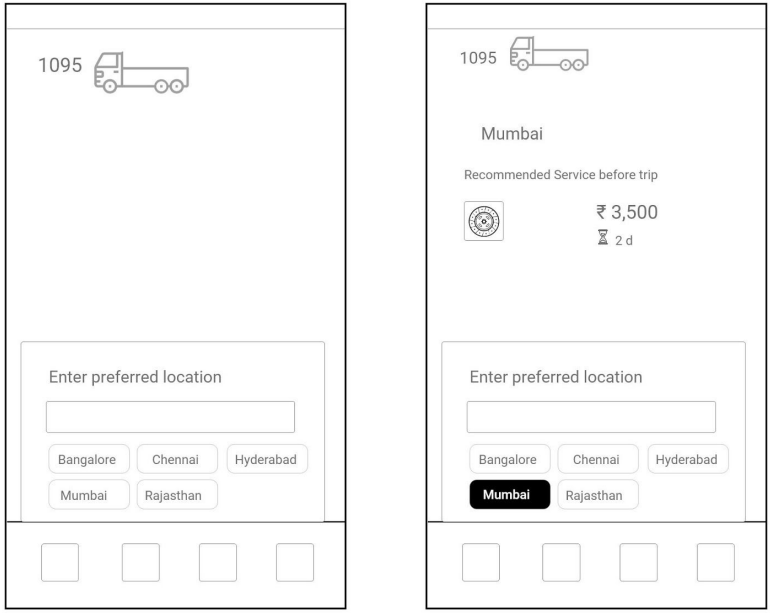


Fig 8 : Trip simulator - nothing selected
Fig 9(R): Trip simulator - Location selected

When a particular location is selected, the part that is recommended to be serviced is denoted by its icon. The estimated cost and time for the repair are also shown along with it to give room to the owner to make a call based on the availability of resources.

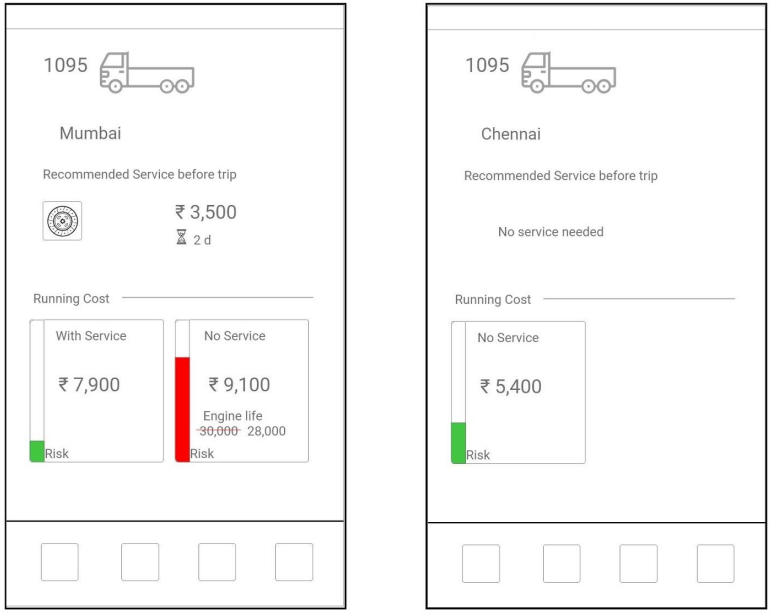


Fig 10: Running costs with and without service
Fig 11(R): Running cost - service not needed

Once the preferred destination is decided on by tapping on the outside of the location selector, the location selector moves away revealing more details about going to the selected location. The running cost associated with the trip, both in the cases of the recommended maintenance being and not being carried out.

Thereby, the owner can be made clearly aware of the losses that might occur if the recommended service isn't carried out.

The running cost has three parameters associated with it - the monetary cost, risk of breakdown(represented by the bar on the left side), and the impact on engine life(represented by the original engine life striked-out and the reduced engine life being shown).

Upcoming maintenance: In the maintenance page, all the trucks are shown together on top. The vertical axis showing the number of kilometers left from right now for each of the parts to be serviced. The position of the icons of the respective parts denote the number of km(from now) around which they are predicted to fail. The greyed out bars present below the last two trucks denote that they are currently on a trip. The length of the bar represents the km they would have covered by the time the current trip ends.

When a particular truck is selected, the owner is taken to the individual maintenance page of that individual truck. The remaining life of each of the parts can be seen on this page in terms of km. The parts are ordered on the basis of their location within the truck, from front to back that can be accessed by means of moving the slider above the icon of the truck in the left-right direction. In addition to that, the presence of a part that is monitored is represented by a dot on the icon of the truck itself. This dot can turn red if there is a fault detected in that particular part, which can help the owner identify faults in the truck.

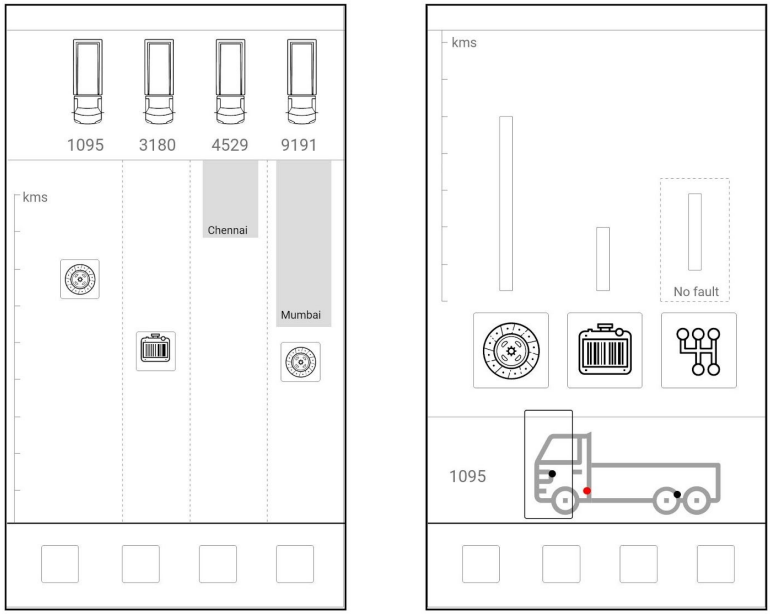


Fig 12: Upcoming maintenance summary
Fig 13(R): Health of individual parts

Later, it was decided, however, to not go forward with this method of left-right sliding selection as it is difficult to depict the location of parts such as the brake lining, which are present on both the left and right sides of the truck.

Concept 2

With this version, the approach was to make things as simple as possible and provide only the information that is absolutely necessary.

Based on the goals defined, there are only three things the owner wants to know from using this interface.

1. Are the drivers ensuring good running conditions?
2. When to be ready for the next service in terms of money, time, and spares?
3. Where to go next?

As a result, there are only three options on the nav bar - Running, Maintenance, and Next trip. This not only helps with easy access to the respective sections, but also makes it clearly understandable as to what all can be done on the interface.

Running: On the homepage, which is also the ‘Running’ page, the running status of each of the trucks is represented visually by the truck moving from left to right as the trip progresses. The magnitude of movement is denoted by the distance covered, causing shorter trips to have shorter lengths. This helps the owner to quickly determine how long it will take for each of the trucks to reach home, looking at how far they are from the right side of the screen.

The destination is placed on the middle of the trip line, as a complete trip includes upward and downward journeys. This provides a quick estimate on how far the truck is from the destination. Along with the visual summary, the distance and time left for the truck to return home are also shown at the end of the trip line.

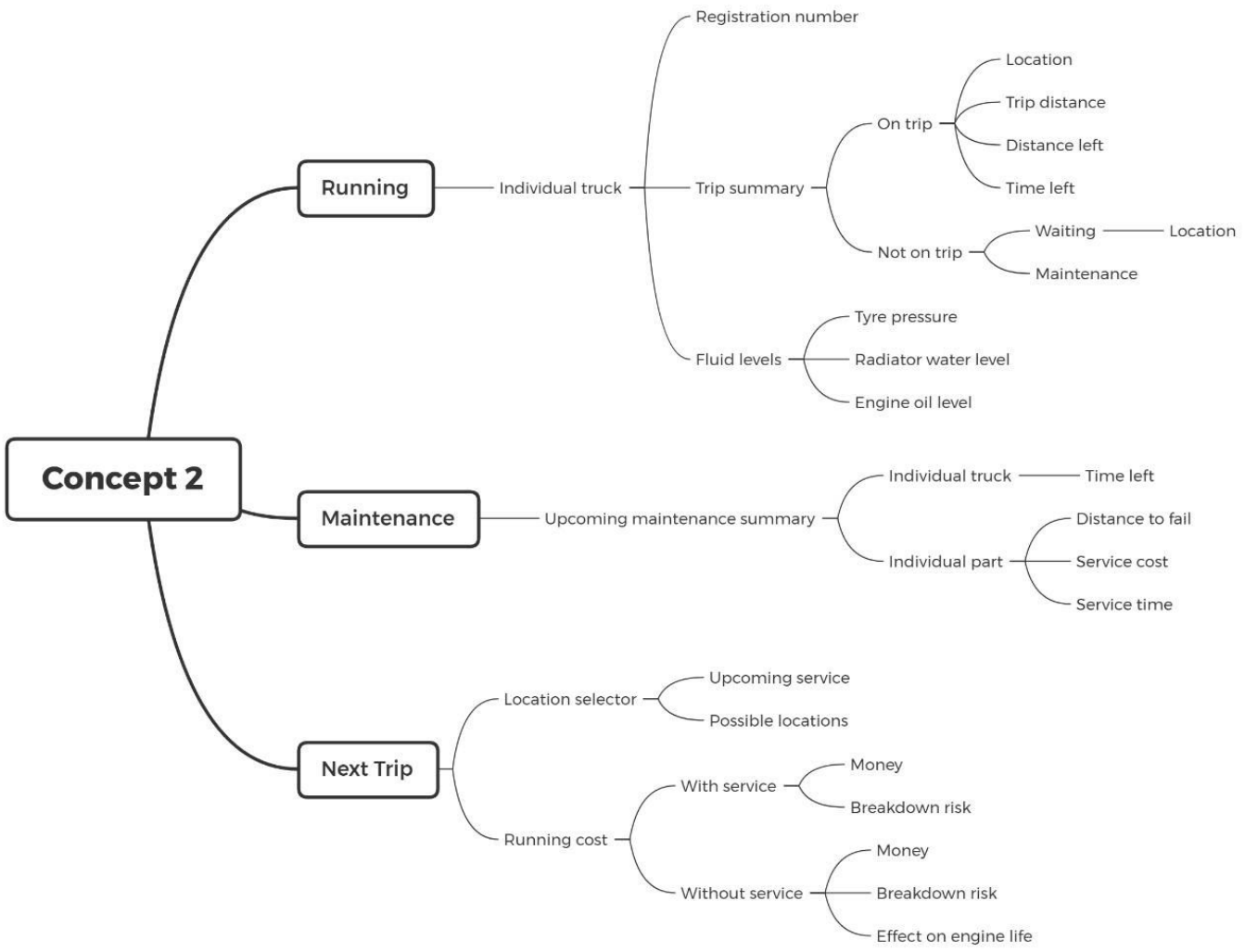


Fig 14: Concept 2 information architecture

The trucks that are currently not on a trip are shown to the left end of the screen along with the registration number. Here, we use the entire registration number(with focus on the last four digits) to identify the trucks so that it is evident that the characters are referring to the registration number by looking at the format itself.

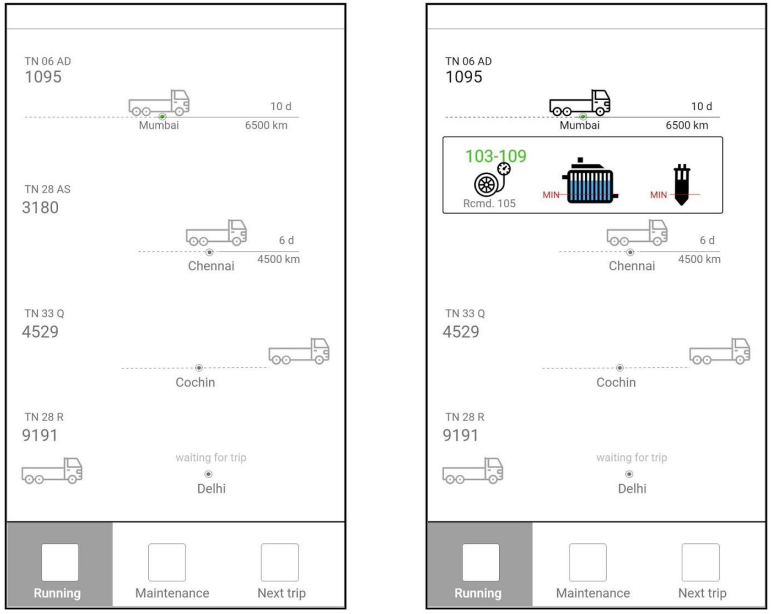


Fig 15: Running status page
Fig 16(R): Fluid levels popup

When the icon of a particular truck is selected, the fluid levels are shown within a popup. Here, the fluid levels are represented visually by using icons so that it is easier to understand. This also maintains consistency throughout the interface as the other parts are already being represented by icons.

Looking at the representation of each of the fluid levels, the first one is that of tyre pressure. Now, tyre pressure is a recommended interval and not exactly a full-to-empty level. It is therefore represented by the range of the lowest and highest values measured from any of the tyres in the truck. The recommended value mentioned below the icon.

The middle one is the radiator water tank level. Here the icon used is that of the tank itself so that the level of water can be shown visually inside the tank. The minimum recommended level is shown with the help of a red line.

The last one is that of the engine oil level. The icon used in this case is that of the measuring stick attached to the cap of the oil tank that is used to measure the level of engine oil. How much of the stick is submerged in oil represents the level of oil in the tank. Just like in the real world, the level of oil is represented showing oil on the measuring stick icon.

Maintenance: On this page, we continue with the same layout as that of the running page. The indication in green on the left of the truck denotes the status of the current trip in terms of the number of days left, to create a link between the running and the maintenance

pages. This is also the reason the maintenance tab is present to the right of the running tab.

Here, the grey line ahead of the truck represents the km it is to cover in the future(from now) and the position of the part icons represents the km around which each of them is predicted to fail. In case a particular part is predicted to fail very close from now or was predicted to fail a few km before and has still not been replaced, it is shown in red to attract attention.

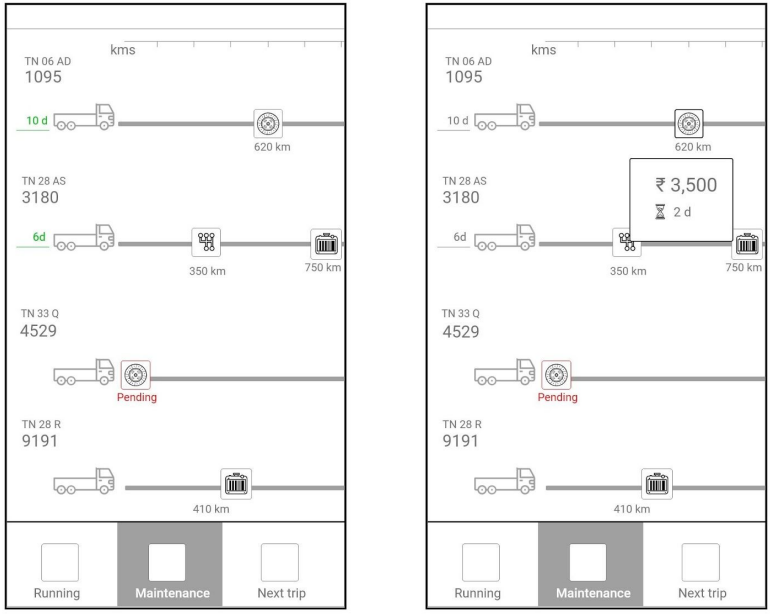


Fig 17: Upcoming maintenance
Fig 18(R): Service info popup

Tapping on a particular part shows the estimated cost and time for the repair within a popup. Here, the green status indicator of how much time is left for the truck to return helps the owner to take that into account while planning for maintenance.

Next trip v1: In this variation, we have adopted the trip simulator from concept 1, except for the fact that the location selector is different. Since not all owners are comfortable with inputting text into a smartphone, we are trying out a method that does not involve any kind of text input at all.

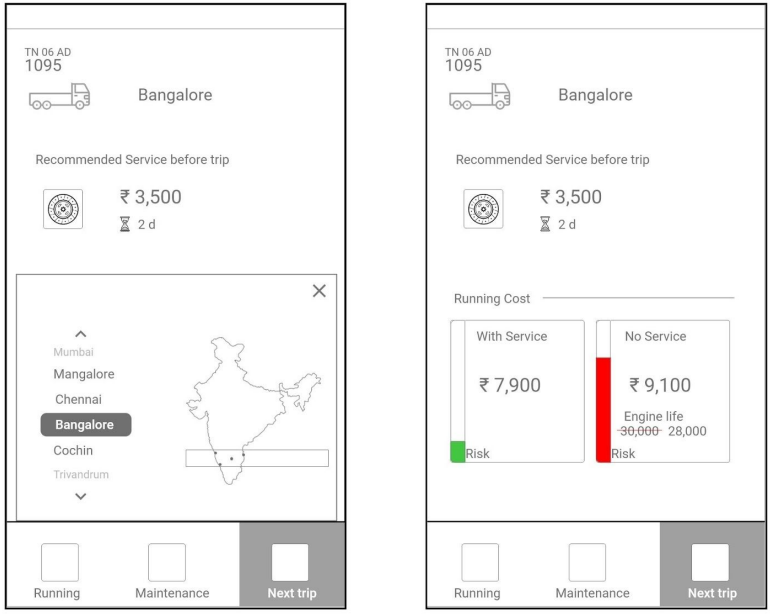


Fig 19: Location selector
Fig 20(R): Running cost estimation

While the owners might not be exactly aware of the location of different places on the map, they generally have a good sense how north or south each location is. We take advantage of this insight and have a rectangular slider on top of an India map on which each possible location is represented by a dot. Moving the slider up and down causes the names of the locations present within the boundary of the slider to be displayed to the side of the map. The desired location can then be selected by tapping on the name of that particular location.

At this point, it is to be noted that while giving preferences to the broker, it is usually given as general locations like Mumbai, Punjab, or Delhi, and not specific areas like Dadar or Kolaba. Hence, the space on the side of the map should be enough to display all the locations within the frame of the slider. And of course, the height of the slider can always be tweaked a bit based on results from testing.

This method to select the location can stand its ground even if the app is to be made in regional languages as the position of the places on the map is fixed.

Next trip v2: In this variation, we bring in an interactive timeline that shows the parts that need to be serviced in the future. It is linked to the location selector. This gives the owner the freedom to look for possible destinations while placing a constraint on what kind of repairs are to be done.

When the owner selects a particular part(s) to be serviced, then the map highlights(in green) all the locations that are possible with the selected part(s) being serviced.

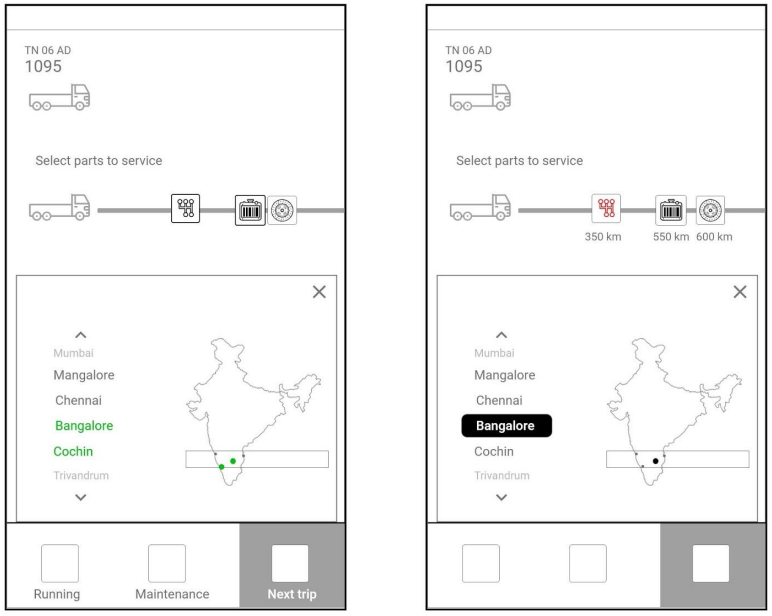


Fig 21: Next trip selector - parts selected first
Fig 22(R): Next trip selector - location selected first

If the owner does not select any part for maintenance, then the locations that are possible without any maintenance are highlighted. The owner can however, also select a location that is not highlighted and doing so will show the part(s) to be serviced for that particular trip to be successful in red.

Concept 3

In this concept we try to do a landscape layout for the interface to explore more possible ways of representation. This was also fuelled by the pretext that since the owners are anyways people who are not experienced with using a smartphone, they might find it easier to adapt to the landscape orientation if it satisfies their requirements better.

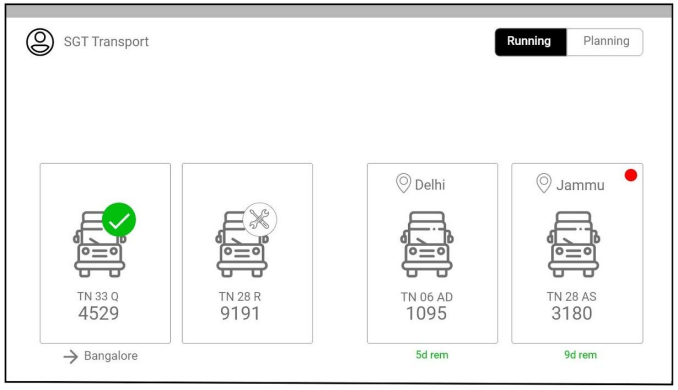


Fig 23: Concept 3 homepage

Since Concept 3 was directly expanded to Wireframe Prototype 2 with only minor changes being made, we shall discuss it in detail under the 'Wireframe Prototype 2' section.

SMS updates

At this stage, it was also evaluated whether something simpler and more accessible like SMS updates could be used to tackle the problem.

It was concluded that while SMS updates can be used to notify the owner when a new fault is detected or any of the fluid levels falls low, it cannot be of much help when the conditions of the parts that do not have a fault is to be monitored.

However, it was decided to have SMS updates as an additional feature in addition to the interface for three scenarios - fault detected, running conditions not ensured, or a truck is about to return from a trip. These updates can be used as a trigger for the owner to then take a look at the interface even when cellular data is turned off or not available.

SMS Format: With these SMSes, we try to be precise and clear by having a consistent format and using only keywords.

TN 06 AD 1095
<Message>
<Additional Info>

Fault Detected: In this case, the name of the fault and the location of the fault are shown.

TN 06 AD 1095
Gear breakage
3rd gear

Unsafe Operating Conditions Detected: There can be two types of this - fluid levels low or unsafe practices adopted upon a part wearing out. Once, they are rectified, the rectification message is also sent.

TN 06 AD 1095
Radiator water level low

TN 06 AD 1095
Brake pad disconnected
Front-Right

TN 06 AD 1095
Radiator water level corrected

Truck about to Return: Here, the aim is to let the owner know of the trips that are possible without any maintenance being required. Since listing all possible locations would create a lot of clutter, we list the states in which trips are possible.

TN 06 AD 1095
Truck returning on 11 Mar, Tue
Without service trips in TN, PY, KL

WIREFRAME PROTOTYPES

Since there are two kinds of orientations(portrait and landscape) among the three concepts that we have, it would be difficult to determine which one is better without actually testing them. Hence, the three concepts were merged into two wireframe prototypes(one portrait and one landscape) so that A/B testing could be carried out on them.

Wireframe Prototype 1

The approach is to take forward the simplicity approach presented in Concept 2 while borrowing some elements from the other concepts and adding a few new elements.

Here too, like in Concept 2, the three things that can be done on the interface are present on the bottom nav bar. In addition to that, the trucks are always shown at the top of the screen across screens so that the selection of the individual truck within the category on the bottom nav bar becomes easier.

Running: Here we continue with the metaphor of the truck moving as seen in Concept 2, but the difference here is that the truck is moving from top to bottom rather than left to right. Due to the increased space along the vertical axis, we can now spatially differentiate the trucks that are on a trip from the ones that aren't. The first two trucks that are above the separation line are not on a trip, while the ones moving along the dotted lines are currently on a trip.

For the trucks on a trip, the length of the dotted line represents the length of the trip(km) and the dot in the middle of the dotted line is the destination. Since the length of the trips will not be the same, they have been aligned to the bottom so that it is easy to identify which truck is going to come home first based on how far it is from the bottom of the screen. The text below the dotted line shows the time and distance remaining for that particular truck to reach home.

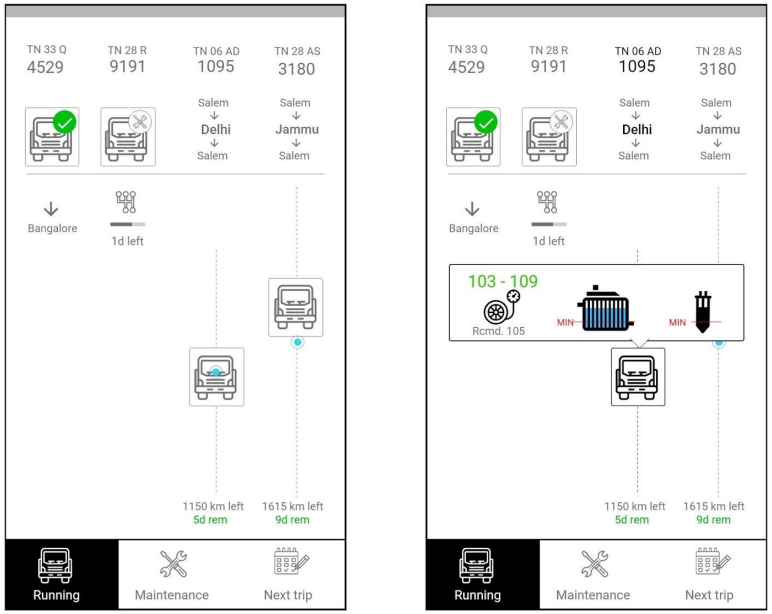


Fig 24: Wireframe prototype 1 homepage
Fig 25(R): Fluid levels popup

Coming to the trucks not on a trip, each of their status is indicated along with the icon of the truck itself - maintenance icon if it is under maintenance and green tick if it is ready for the next trip. Below the separation line, the details of the next trip(truck 4529, the down arrow) and the summary of current maintenance(truck 9191) are shown.

Tapping upon any of the trucks shows the fluid levels of that particular truck within a popup like in Concept 2. This enables the owner to quickly glance through the fluid levels of all trucks in one go without having to move to a different screen.

Maintenance: On this screen, all the trucks are placed above the separation line with their respective registration numbers. The status of the trucks is also represented with the maintenance and ready icons along with the time to reach home. This can help the owner factor in the current status while looking at the upcoming maintenance requirements.

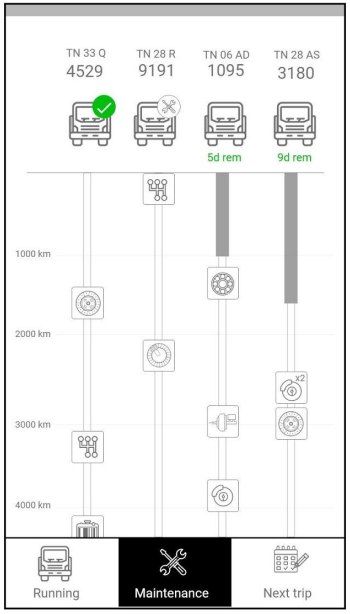


Fig 26: Upcoming maintenance summary

To represent when each of the parts will need maintenance, we adopt the vertical scrolling layout from Concept 1. The position of each part represents how much km from now does that particular part need to be serviced. The grey-filled bars represent the distance that will be covered by the time the current trip ends. The grey-outlined bars represent the distance that will be covered on future trips.

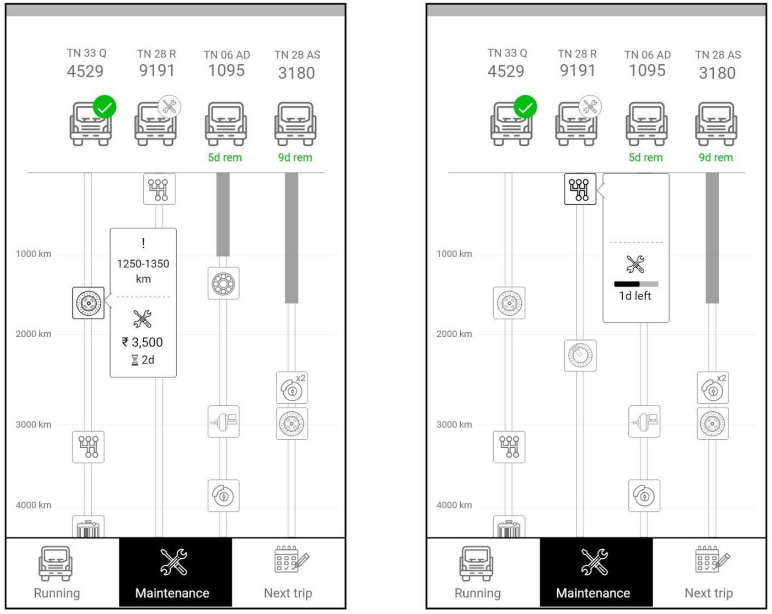


Fig 27: Tapping on a part
Fig 28(R): Tapping on a part already under maintenance

Tapping upon any part shows the predicted interval(km) when it is expected to fail, along with the estimated cost and time required for the repair within a popup. In case the truck is already under maintenance, then the maintenance summary is shown instead. This can help the owner plan the overall maintenance requirements for his entire fleet from the same page.

Next trip: The next trip tab opens with all the trucks(now tappable) at the top and the next trip summary is shown below.

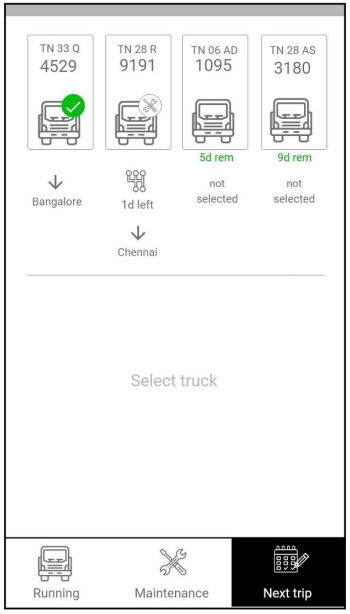


Fig 29: Next trip summary

In case some maintenance is scheduled before the next trip, then that is also shown along with the location. In the event of no trips being scheduled for a particular truck, ‘not selected’ text is shown instead.

On selecting a particular truck(tapping on the truck), the owner is taken to the planning page for that particular truck. Here, the area containing the icon and registration number of the truck acts as a toggle.

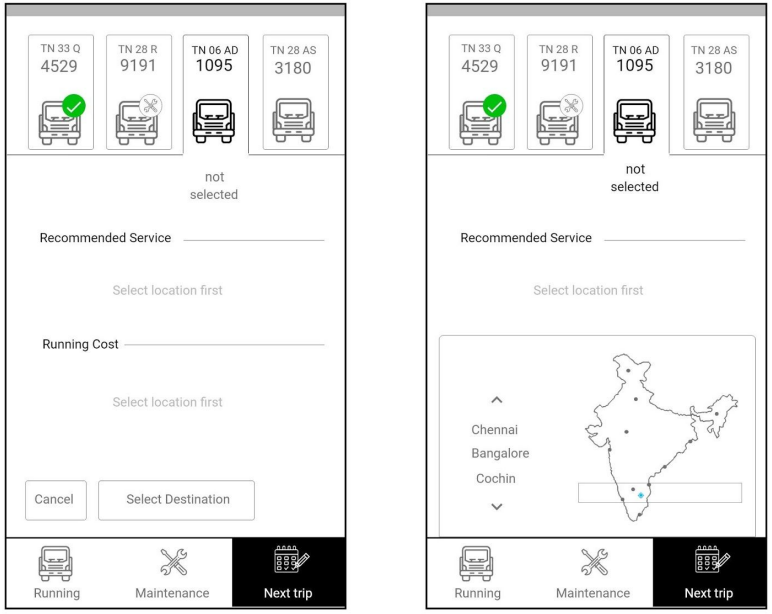


Fig 30: Individual truck next trip selection page
Fig 31(R): Location selector

On reaching an individual truck's planning page, the owner is asked to select a location first. At this stage, we have included the 'Recommended Service' and 'Running Cost' headings even though there is nothing under them right now, to give an expectation to the user of what to expect from this page.

Once the 'Select Destination' button is tapped, the map-based location selector from Concept 2 comes up from the bottom as a popup. Moving the slider up and down changes the location of the names of the locations that are shown on the side of the map. The slider, however, can also be moved up and down by using the up and down arrows present along with the location names. This can come in handy in the case where someone is not able to move the slider with the desired accuracy.

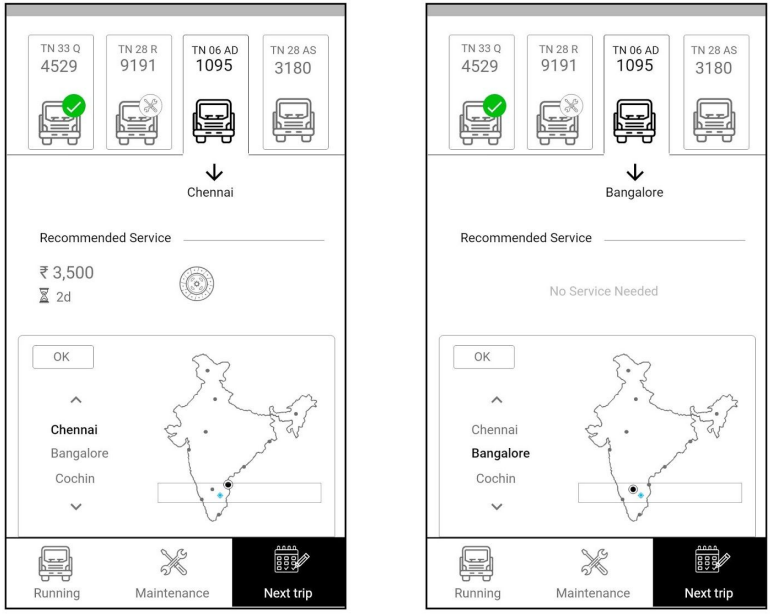


Fig 32: Recommended service
Fig 33(R): No service needed

Tapping on any location name shows the recommended service(part icon, cost, time) for the truck to successfully complete the trip to that particular location in the area above the popup titled ‘Recommended Service’. Selecting different locations shows the recommended service for the different locations respectively. In case there is no service needed to do a trip, then ‘no service needed’ text is shown when that particular location is selected.

In case multiple parts are to be serviced before going to a particular location, then the icons of all the parts to be serviced are shown together. The cost and time shown are that of both the parts combined. Since servicing two parts simultaneously might take less time than servicing the same two parts individually at different points in time, that is also accounted for.

This enables the owner to freely switch and compare between the different locations. Once the owner has decided on a location, then he can tap the ‘OK’ button on the left corner of the popup. This will make the popup disappear and show the content that is below it, which is the running cost estimation.

The running cost estimation shows the running cost that is predicted to be incurred while doing a trip to the selected location in cases of both, with and without servicing done. In addition to that, it also shows the estimated risk of breakdown(as percentage) and other impacts on the health of the truck(engine life here).

This method of representation can nail it into the minds of the owners that performing maintenance on time provides long-term benefits like reduced operation cost or enhanced life of the truck.

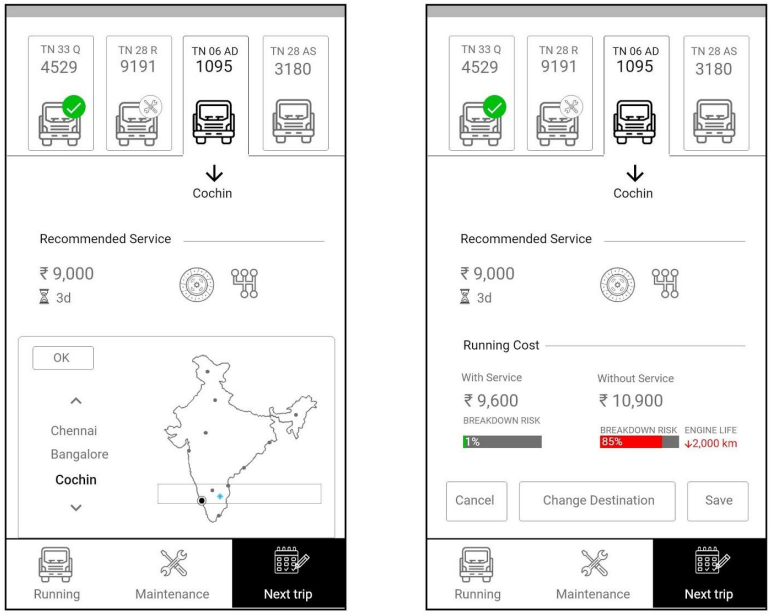


Fig 34: Recommended service - multiple parts
Fig 35(R): Running cost - with and without service

After this, the owner can either change the location(which will bring up the popup again), cancel, or save it. ‘Save’ or ‘Cancel’ buttons will take the owner to the first page of the ‘next trip’ tab(where no trucks are selected) and in case the ‘Save’ button was selected, the newly added trip will get reflected in the next trip summary.

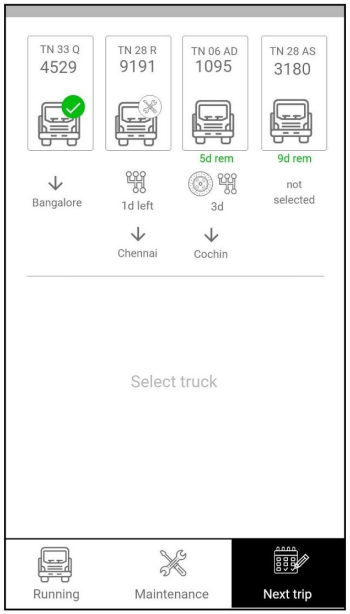


Fig 36: Newly added trip and maintenance reflected in next trip summary page

Once the next trip has been reflected in the next trip summary, selecting the truck again will directly lead to the 'with and without service' page.

Wireframe Prototype 2

This is an extension of concept 3 that was in the landscape orientation. Since the landscape orientation would require holding the phone with both hands, the center portion of the screen might not be reachable by the thumb and hence the positioning of interactable elements in the center region of the screen has been kept to a bare minimum. In addition, the majority of the interactions have been kept to the right-hand side for increased speed and accuracy. [17]

With this version, the approach was to provide flexibility to the owner to access different kinds of information that can aid in his decision making regarding scheduling maintenance.

Instead of the nav bar, here we have toggles to switch between the different features. This is because toggles on the right top corner of the screen would be easy to access in a landscape orientation. There are, however, only two toggles here - Running and Planning. The maintenance is made a subset of 'Running' as we do not have the combined all-truck maintenance summary in this version. Since only the health of the parts of an individual truck can be accessed, it would make more sense to access it by selecting the truck first.

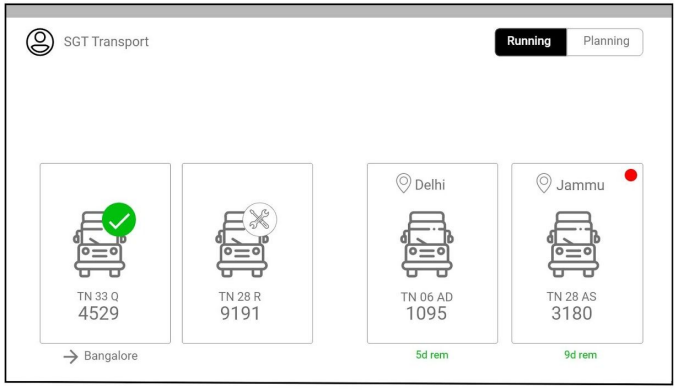


Fig 37: Wireframe prototype 2 homepage(Running Page)

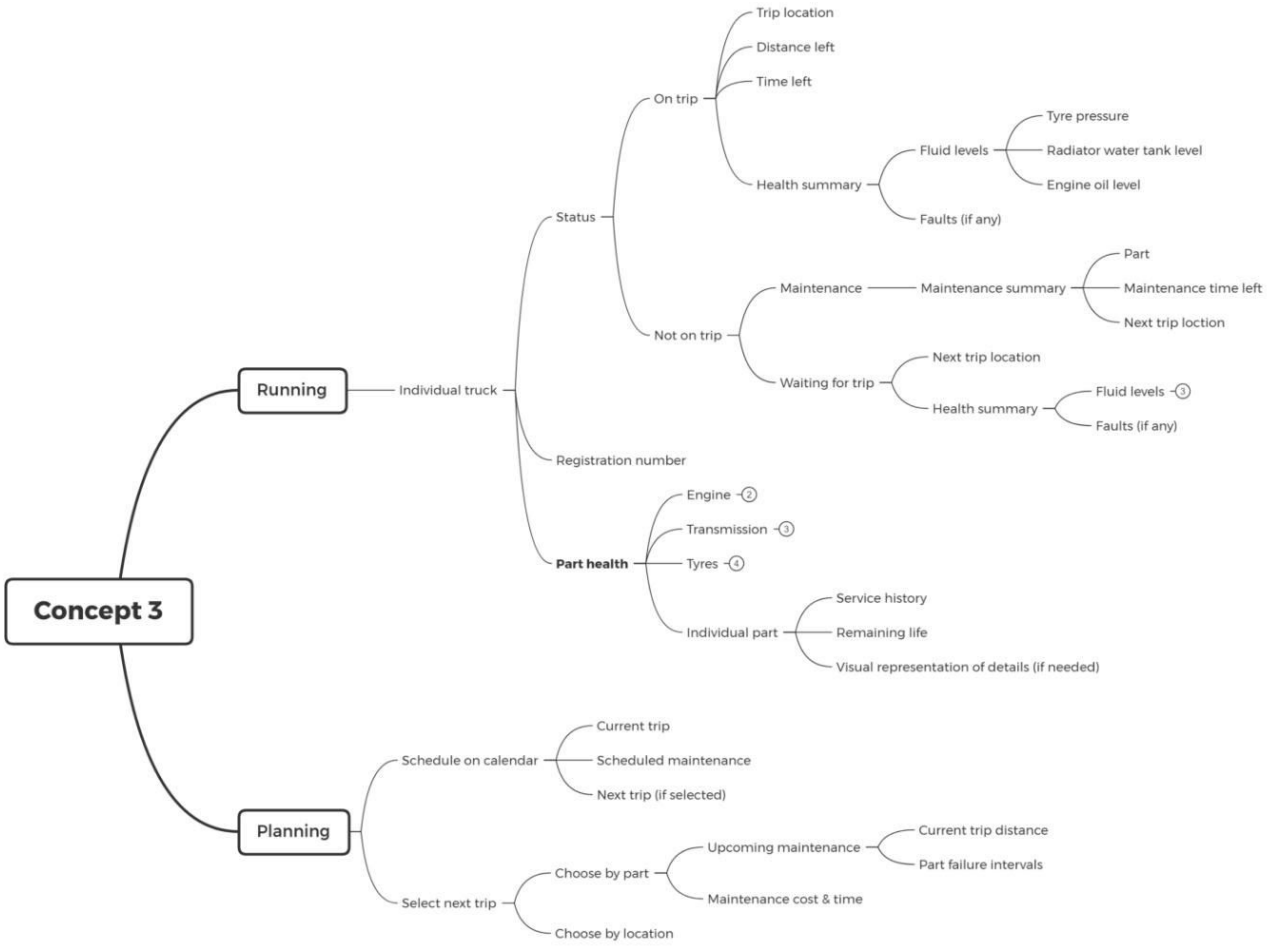


Fig 38: Concept 3 information architecture

Running: On the homepage, we have the trucks in the centre of the screen. The trucks that are ‘on trip’ and ‘not on trip’ are separated with the help of spacing with the ones on a trip placed on the right side. And yes, the position of the trucks is not fixed. Among the ones on a trip, the one that is to reach home earlier is to the left. And among the ones not on a trip, the one that is ready for the next trip is to the left. The mental model with the ordering is that the ‘readier’ the truck is to go on the next trip, the more to the left it is positioned. As a result, it can be easier for the owner to know which truck needs attention earlier in terms of planning for maintenance or for the next trip.

The status indicators(ready icon, maintenance icon, days remaining) are the same as in Wireframe Prototype 1 with the current trip(location icon) shown above the truck and the next trip(right side arrow) shown below the truck.

A red dot appears in the box of the truck(top right) if a fault has been detected in any of its parts as a measure to call for attention.

Tapping on the box of a truck shows the fluid levels(as seen in Concept 2) along with the faults detected within a popup, enabling the owner to quickly browse the running condition of all trucks. A fault is denoted by the icon of that particular part in red colour along with a warning sign. In the case of no faults being detected, ‘no faults’ text is shown.

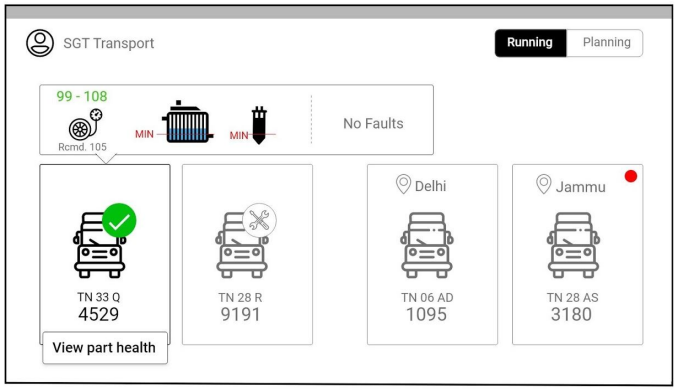


Fig 39: Running condition popup - no faults

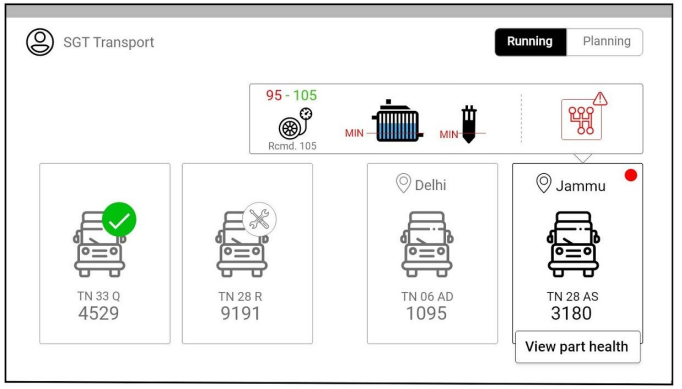


Fig 40: Running condition popup - with faults

Notice the red colour in the lower limit of the tyre pressure indicating that at least one of the tyres has a pressure lower than the recommended limit.

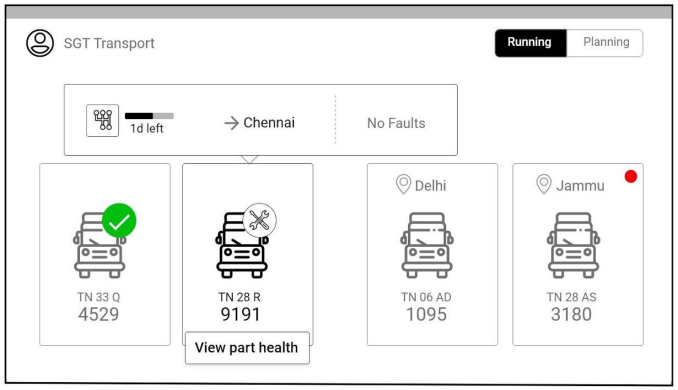


Fig 41: Running condition popup - truck under maintenance

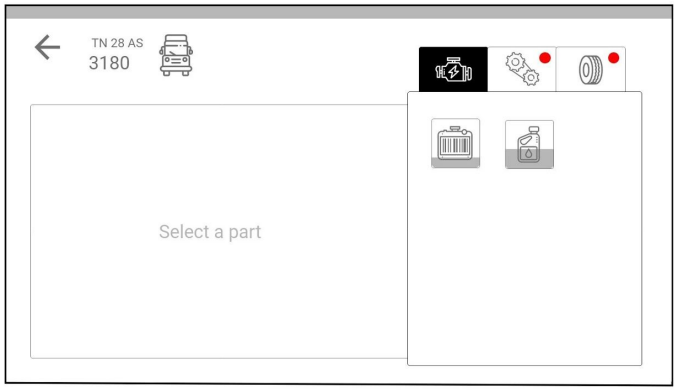


Fig 42: Individual part health page - no part selected

In case the truck is already under maintenance, the maintenance and next trip summary is shown instead.

Part Health: The information on the health of each part of a particular truck can be accessed via the ‘View Part Health’ button that shows up when a truck is selected.

In the part health page, all the parts that are being monitored are put into three category toggles - engine, transmission, and tyres. If there is a fault in any of the parts under a particular category, then a red dot is shown on the toggle of that particular category.

The fill level within the box of each of the parts represents its remaining life and more information about the health of a particular part can be accessed by tapping on it.

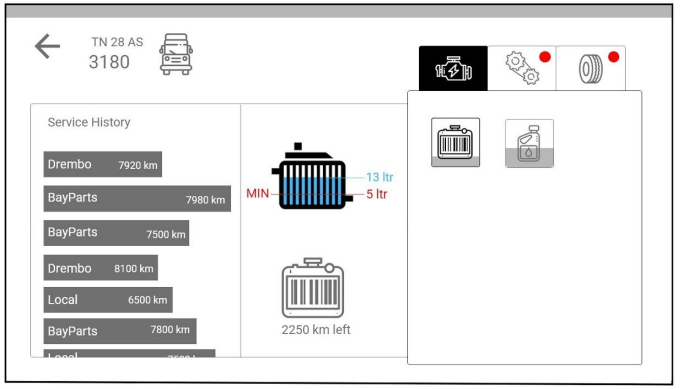


Fig 43: Individual part health page - Radiator

Now, parts like the Radiator, Gearbox or Engine oil, where something within that part needs to be monitored. On tapping on the part icon, the aspect that is monitored within that particular part is

shown visually. In this case [Fig. 43], it is the amount of water left in the radiator water tank that is being represented visually. Below that, along with the icon of that part is the remaining life of the part in km.

To the left is the service history of that particular part. This shows how long each of the previous parts of the same kind lasted, which can help owners in deciding which brand to buy next.

In the case of the gearbox, the individual gears are monitored separately so that the exact gear that has a breakage can be identified. This information can help the driver refrain from using that particular gear until the truck returns home to avoid additional damage.

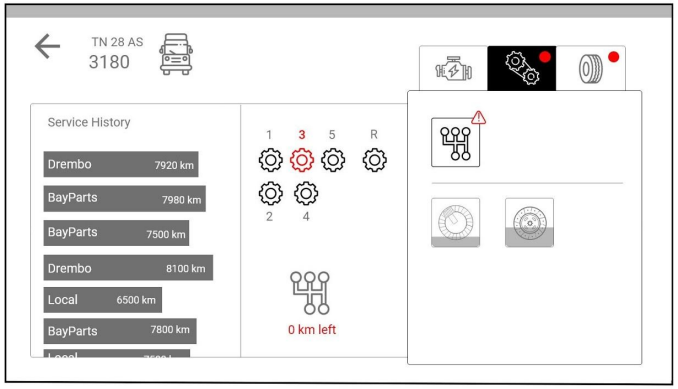


Fig 44: Individual part health page - Gearbox

This method of individually representing faults can also save time the mechanic spends on identifying the fault by removing parts to inspect them or taking a ride in the truck to check for the source of unusual sounds.

In addition to that, if there is a fault detected in any of the parts, then that particular part is shown in with a warning sign and is placed above the others to attract attention.

With the case of parts like the Brake lining, Wheel bearing, Crown pinion and the Tyres that are present more than one in number, a top view of the chassis is used to denote the health of the one of many parts and its health is represented within the location of the part on the diagram of the chassis itself.

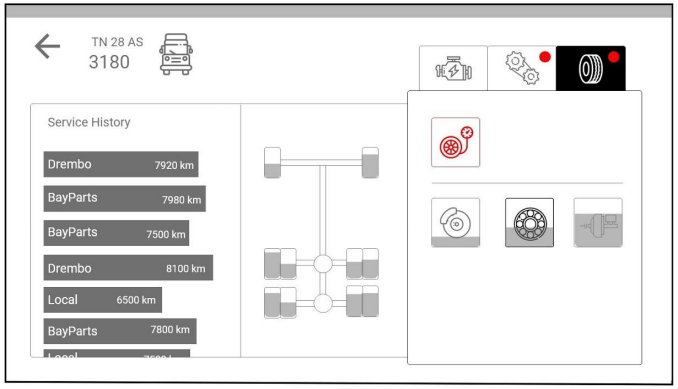


Fig 45: Individual part health page - Wheel Bearing

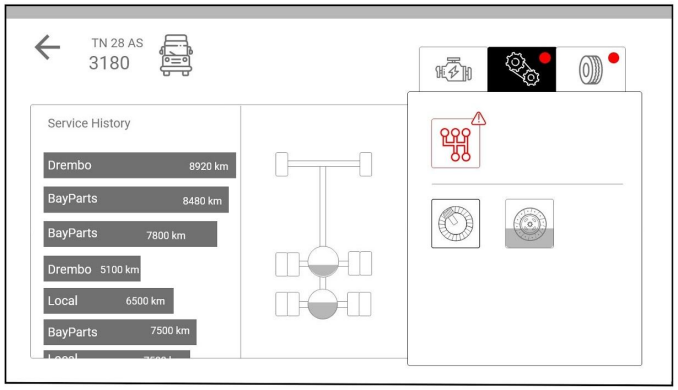


Fig 46: Individual part health page - Crown Pinion

Tapping on the part locations shows the remaining life of the part at that particular location in terms of km within a popup.

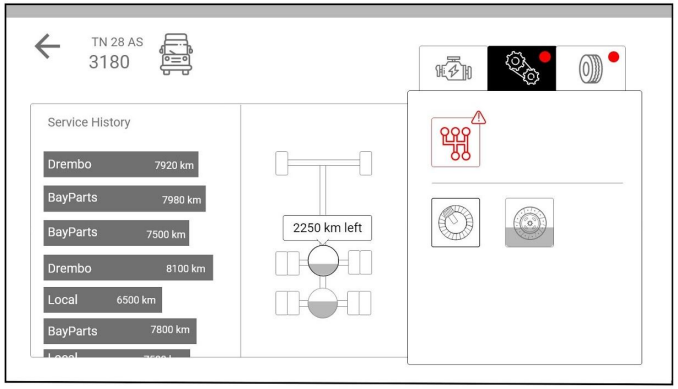


Fig 47: Individual part health page - Crown Pinion with popup

In the case of tyre pressure, it is a recommended range and there is no life associated with it. Hence, the outlines of the wheels are shown in red or green based on whether they are within recommended limits or not. Tapping on the location of a particular tyre will reveal the exact pressure value within the popup.

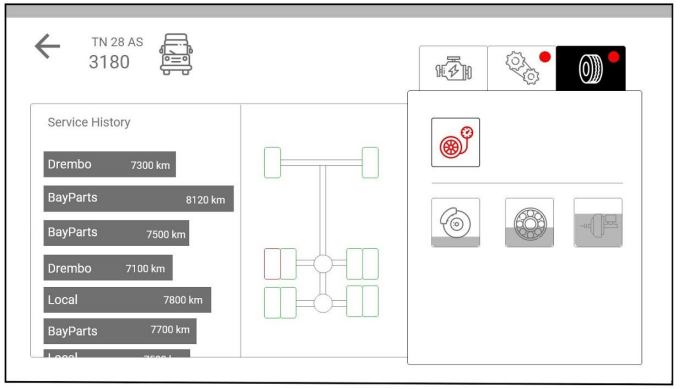


Fig 48: Individual part health page - Tyre Pressure

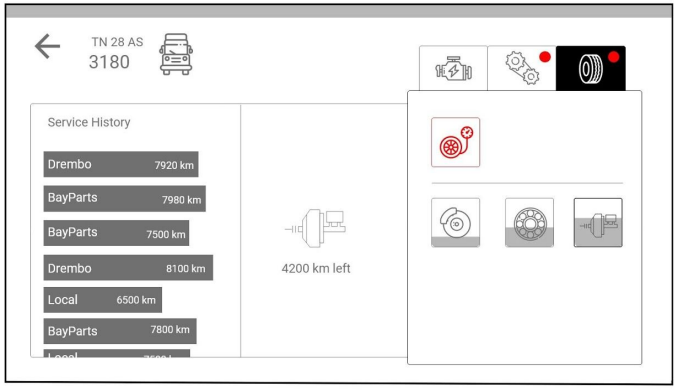


Fig 49: Individual part health page - Brake Booster

With the case of the remaining parts like the Clutch plate and Brake booster that are present only one in number and do not have anything inside them to be monitored, just the remaining life of the part(km) is shown along with the icon.

Planning: Coming to the planning page by switching the toggle on the homepage, there is a calendar onto which the trip and maintenance schedules are mapped. The order of the trucks here is the same as that on the homepage. The grey-filled bar represents the current trip with the details of the trip location present on it. Maintenance is represented by a white-filled dotted outline box with a maintenance icon. By default, the first day on the calendar is today and the calendar can be moved left or right to view the past or the future. The next trip is represented at the end of all fixed events as it is uncertain when as to when the truck will actually get an order.

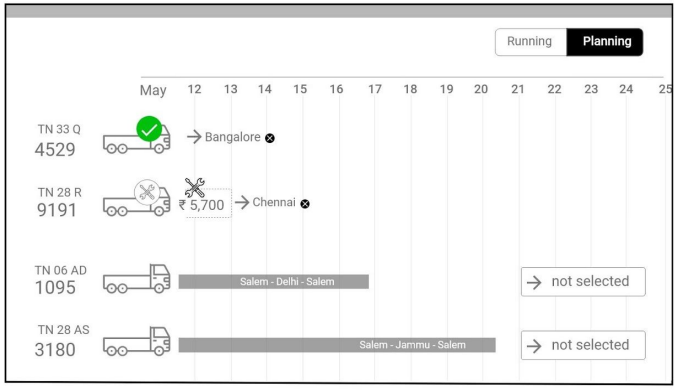


Fig 50: Planning tab landing page

In case the next trip hasn't been selected, then a 'not selected' button with the next trip icon(right-side arrow) is shown floating on the right end of the screen at the height corresponding to that particular truck.

Tapping on the not-selected button, the owner is taken to the trip simulator page. Here, unlike the one in Wireframe Prototype 1, the owner has the freedom to view possible trips either based on location or on the basis of the condition of the truck(if I service this part, where all can I go).

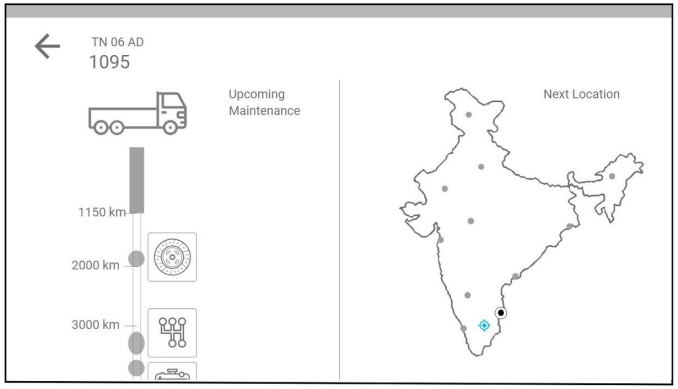


Fig 51: Trip selector - nothing selected yet

Here, the upcoming maintenance is represented along the vertical axis and the parts are shown in the order how soon they are going to fail. The grey patches on the km line next to each of the parts denote the km range in which that particular part is predicted to fail. The

grey-filled bar as usual, represents the distance still left on the current trip.

When nothing is selected, the locations to which the truck can go without any service are highlighted on the map(black). The blue dot refers to the home location of the truck(from where it will leave for the trip or where the broker's office is).

When a particular part is selected(Clutch plate here), the locations that are possible with that particular part being serviced are highlighted on the map(black). Along with that, the cost and time required for the maintenance are shown [Fig. 50].

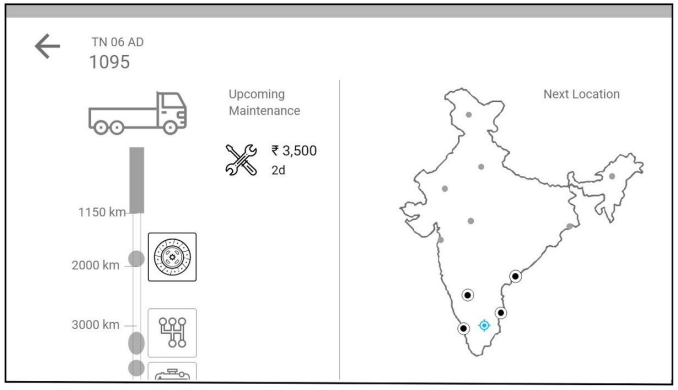


Fig 52: Trip selector - part selected

When the owner selects any of the recommended locations on the map by directly tapping on it, it is shown in green and the name of the location is shown on top of the map. Notice the distance of the trip also being reflected in the km line on the left [Fig. 53].

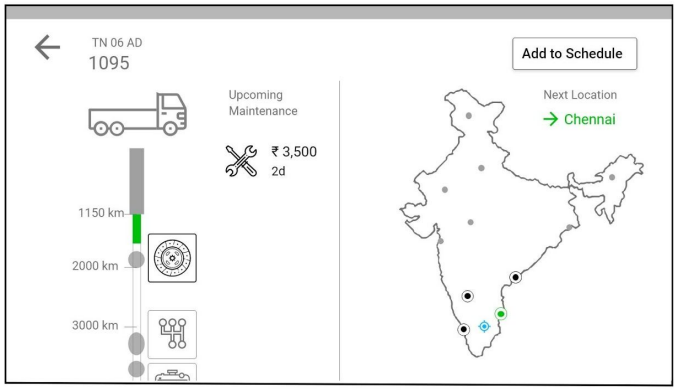


Fig 53: Trip selector - location selected from within recommended locations

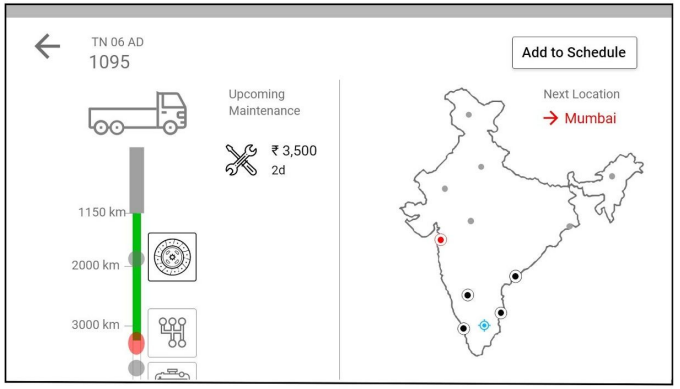


Fig 54: Trip selector - location selected from outside recommended locations

Now, let's say the owner switches his choice to a location that is not recommended[Mumbai in Fig. 53], then it still gets selected but is shown in red. The distance of the trip on the km line on the left highlights the fact that the length of the trip falls into the failure probability zone of the gearbox [Fig. 54].

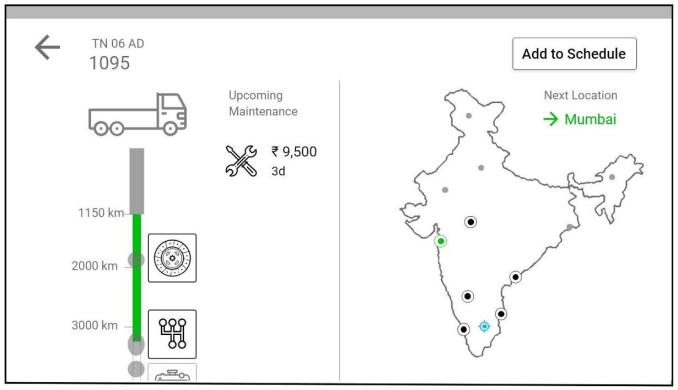


Fig 55: Trip selector - additional part selected to avoid predicted risk

To avoid the risk of the part failing on the trip, the owner can add the gearbox to his service list by tapping on it. This causes the cost and time for maintenance to get updated(as discussed in Wireframe Prototype 1). Now, the selected location becomes green and the map also shows the other trip possibilities opened up by the newly added repair(by servicing the gearbox as well) [Fig. 55].

The owner can however, choose to ignore the recommendations from the interface and still go on to add a location that is not recommended(Mumbai) to his schedule without adding the recommended maintenance.

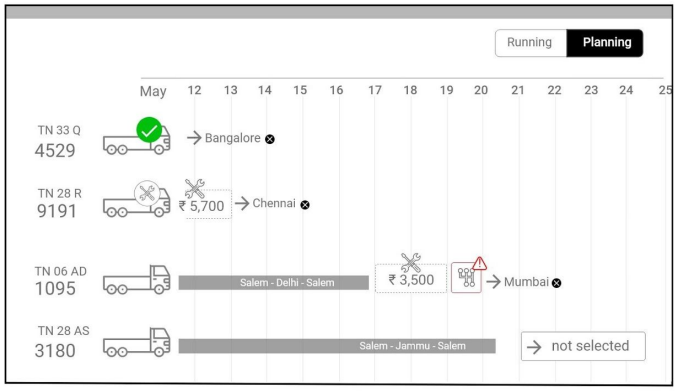


Fig 56: Newly selected trip and maintenance added to calendar (with part failure warning)

In such a case, the location(Mumbai) will still get added to the calendar with the additional cautionary indicator that this part might fail. Therefore, if the part actually fails while on the trip, he can remember that it was already predicted by the interface..

If the owner wants to cancel a scheduled trip, then he can do so by using the 'x' button[Fig. 56] just next to the 'next trip' and it will be removed from the schedule.

USABILITY EVALUATION

In an ideal scenario, A/B testing could have been carried out with both the wireframe prototypes with actual users. But due to the

situation of the lockdown, physical testing is not possible. Moreover, since the target users are people who might not have smartphones, or might not be familiar with using it, getting feedback from them on the screens in a virtual setting is also very difficult.

Hence, feedback was received on both the prototypes from five to my student peers (from the 4th year B.Des and 5th year Dual Degree batches) by walking them through each of the prototypes over video call.

The general feedback was along the lines of ‘the portrait version is simpler to understand while the landscape version is much more capable’.

Students also felt the need for text like the name of the parts, what each status icon means at least the first time they are encountered with. In addition to that, they were also of the opinion that popups were distracting and it would be better to go to a separate screen instead.

Based on the feedback, it was decided to go with the portrait orientation with features from the landscape version like the calendar, individual health of parts and the slider-based location selector incorporated into it.

Now, had the testing been done with actual users, the results could have or could not have been very different. However, given the situation, we go on to make the final screens with the feedback from the students.

FINAL SCREENS

In the final version, the Running, Maintenance and Next trip tabs continue to be on the bottom nav. But the title for the tab is moved to the top bar that is introduced to accommodate the profile icon and the back button. The need for a dedicated space for the back button was highlighted in the usability evaluation. Since the target users are not familiar with using smartphones, a definitive place for a back button would help them come out of unexpected situations.

Bottom and side navigation

With the bottom navigation being fixed to the bottom, the trucks are fixed to the left side and stay there irrespective of whatever happens on the remaining part of the screen, just like in the case of the bottom nav.

When none of the trucks are selected, the page shows a summary of all the trucks related to the title of the tab that is currently active in the bottom nav. Selecting a particular truck shows information only related to that particular truck. Tapping again on a selected truck de-selects it.

Whenever a tab on the bottom nav is selected, the new page that comes up does not have any of the trucks selected by default. It is the same even if a particular truck was ‘selected’ at the time of

switching tabs in the bottom nav. This ensures two things - one, the screen that comes up on selecting a tab on the bottom nav is always predictable. And two, the owner is also provided with a summary before diving into the details.

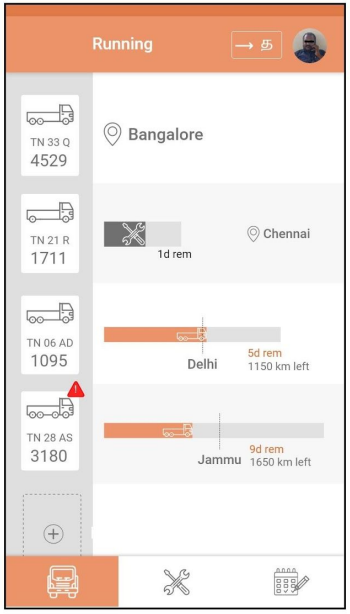


Fig 57: Homepage (Running tab landing page)

Here too, the truck is denoted by its registration number, but the icon of the truck is not the same across all trucks. The icon of each truck denotes its type(the number of wheels), which is the common terminology used by the target user group to explain the type of the truck as opposed to using brand names(since most of the trucks in the country are from either of the two major OEMs and there is not much differentiation on that front).

The position/order of the trucks is fixed and does not change. In the case of adding more trucks to the interface, the side nav containing the trucks becomes scrollable. However, scrolling on the display area of the screen does not cause the side nav to scroll.

Running

On the ‘Running’ page, which is also the homepage, the current status of the trucks is shown. The bottom two trucks are currently on a trip and hence the progress bar. The length of the progress bar denotes the total distance of the trip. The truck icon is added into the progress bar to show that this is the current position of the truck and that the orange color represents the completed distance.

The destination is placed in the middle of the progress bar as the entire trip includes the truck coming home as well. To the right of the distance bar is information on the time and distance left on the trip. They are not placed on the left side as it might interfere with the trip destination text in the case of the trip being very short.

The truck that is second from the top is currently under maintenance and hence the progress of the maintenance is mentioned along with the next trip location(location icon). The maintenance progress bar is differentiated from the trip progress bar with a different height, different colour, and the maintenance icon inside it.

The truck at the top is ready for the next trip and hence only the next trip location is shown(location icon).

When a particular truck is selected, the display area switches to a page showing only details related to that particular truck. Here, additional details like the driver's name and current load are also shown. In case the truck is loaded above the recommended limit, the load indication on the icon of the truck will change to red colour.

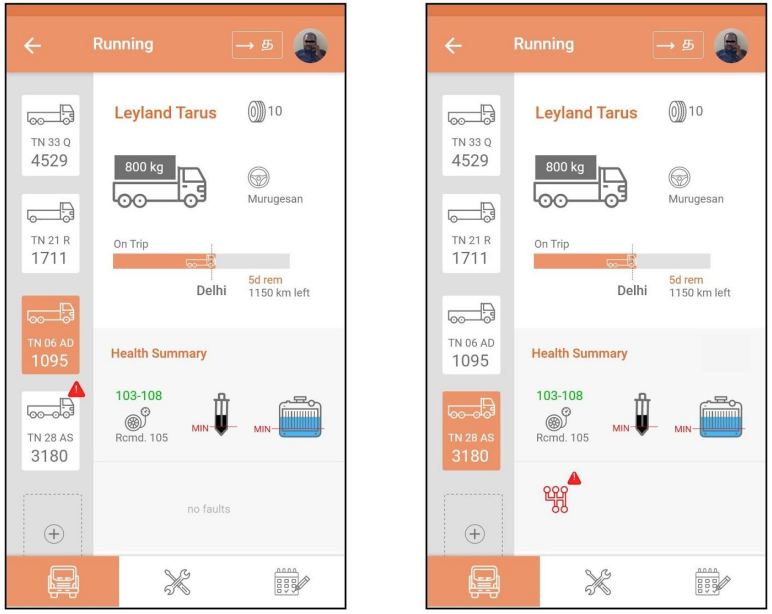


Fig 58: Running tab individual truck - no faults
Fig 59(R): Running tab individual truck - with fault

Below in the grey region is the health summary of the truck that shows the fluid levels - Tyre pressure, Radiator water level, and Engine oil level(as discussed in Concept 2) along with the faults detected(if any).

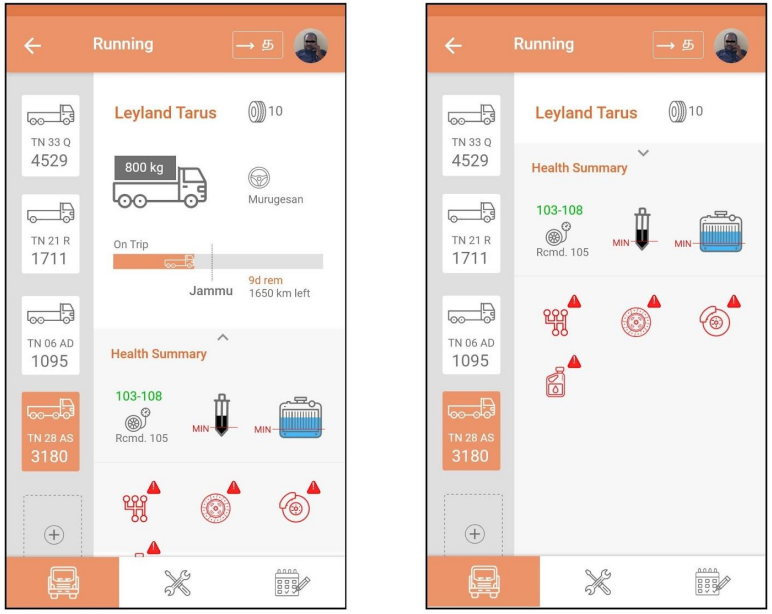


Fig 60: Running tab individual truck - more than 3 faults
Fig 61(R): Running tab individual truck - grey portion scrolling

In the case of more than 3 faults being detected, the grey portion moves up on scrolling, revealing all the faults that were previously not visible. While doing this, the white portion gets condensed to show just the basic information about the truck(name and type). In

the case of even more faults being detected, though highly unlikely, scrolling can take place within the grey region once it has fully moved up.

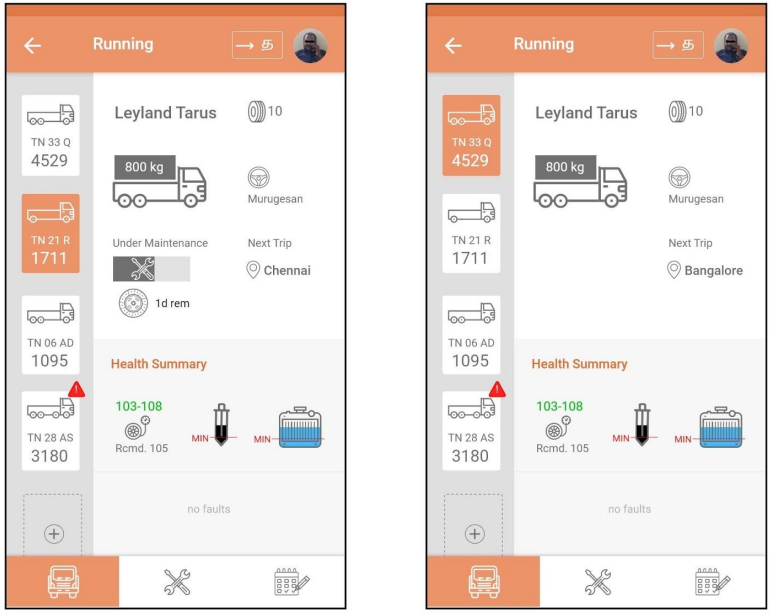


Fig 62: Running tab individual truck - truck under maintenance
Fig 63(R): Running tab individual truck - ready for next trip

If the selected truck is not on a trip, the maintenance progress bar and the next trip details take up the place of the trip progress bar. Here, along with the maintenance progress bar, the icon of the part being serviced is also shown [Fig 62]. If the truck is neither on a trip nor under maintenance, only the next trip location is shown [Fig 63].

Maintenance

On the landing page of the maintenance tab, a summary of the upcoming maintenance for all trucks is shown. Distance is marked on the left-right axis and it refers to the distance to be covered from right now. To depict that the distance bar is made to look like it is coming from behind the side nav with a hint of orange(which denotes the completed distance), unlike the case of the running page where the progress bar is detached from the side nav.

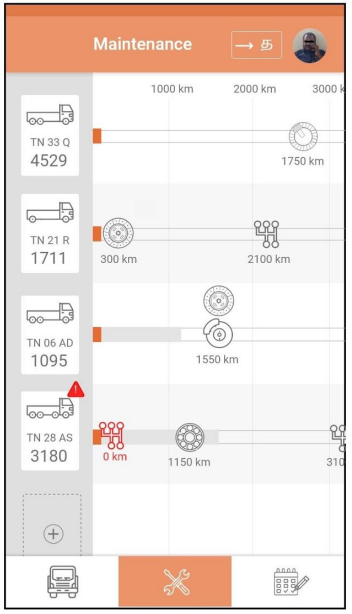


Fig 64: Maintenance tab landing page

The position of the parts along the left-right axis denotes the number of km after which each of them is predicted to fail, the accurate

value of which is shown in text below each of the icons. In the case of two parts expected to fail at the same time, they are placed one above the other and in the case of more than 2, they are placed just to the right of the existing icons without a separate km reading for them.

When a particular truck is selected within the maintenance tab, the owner is taken to the page where the health of individual parts can be monitored as seen on Wireframe Prototype 2, albeit with some modifications to suit the portrait orientation.

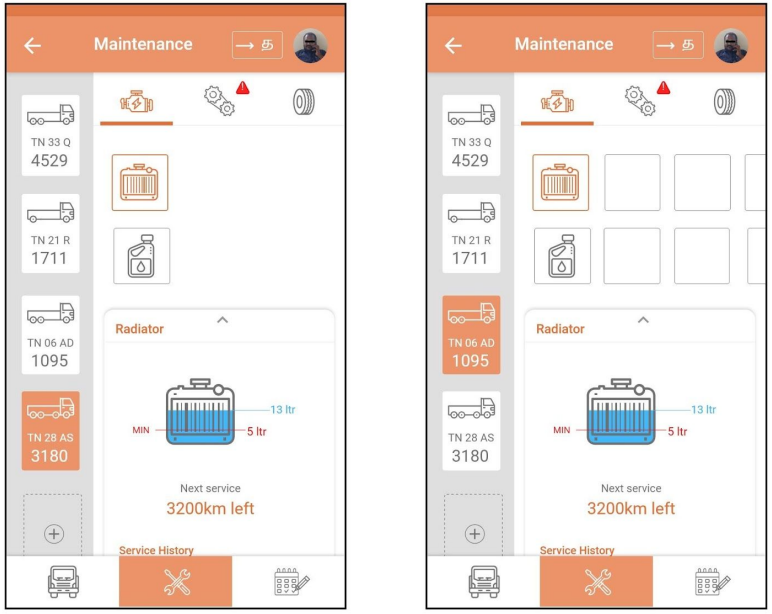


Fig 65: Maintenance tab individual truck landing page(Radiator)
Fig 66(R): Maintenance tab individual truck - more than 6 parts in a category

On this page, the three categories of parts - engine, transmission, and tyres are represented at the top in the form of toggles. Under the hierarchy of the toggles are the parts that come under these respective categories. This means that when a toggle is active, only the parts under that category are shown below. In addition to that, if a fault is detected in a particular part, then the toggle for that particular category carries a warning sign to attract attention.

Among the parts under that particular category, the first part is always pre-selected to give an idea to the user on how to interact with the screen.

In the case of more than 6 parts being present in a particular category, they can be accessed by means of side-scrolling.

Below the parts is an overlay card that contains the details of the particular part that is currently selected. The way in which the health of each part is represented depends on the nature of the part.

What is common to all parts, however, is that scrolling on the overlay brings the overlay upwards, revealing the service history. The service history contains details of how long each specimen of the same part lasted on this particular truck. This can come in handy when deciding which brand to buy next. Once the overlay has reached its upward limit, scrolling can begin to take place within the overlay.

The entire service history is not made visible at first sight as this information is needed only when looking to replace a part as opposed to the health of the part that might be accessed frequently.

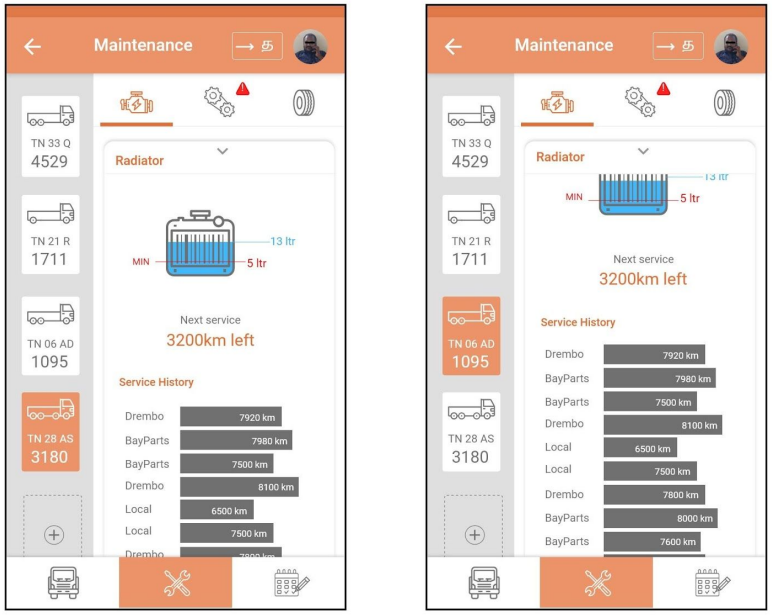


Fig 67: Maintenance tab individual truck - swiping up on overlay
Fig 68(R): Maintenance tab individual truck - scrolling within overlay after upward movement limit reached

Coming back to the topic of representing the health of the part depending on the nature of the part,

Parts that have some elements inside them to be monitored: In the case of such parts like the Radiator, Engine oil and the Gearbox, the elements that are being monitored are represented visually and the km left for the next service is shown at the bottom.

While the fluid levels are shown visually in the cases of the Radiator and Engine oil, the status of the individual gears is represented with the case of the Gearbox. Here, the individual gears are represented in the layout of the gearbox as compared to the size of the gears as the former is more relatable.

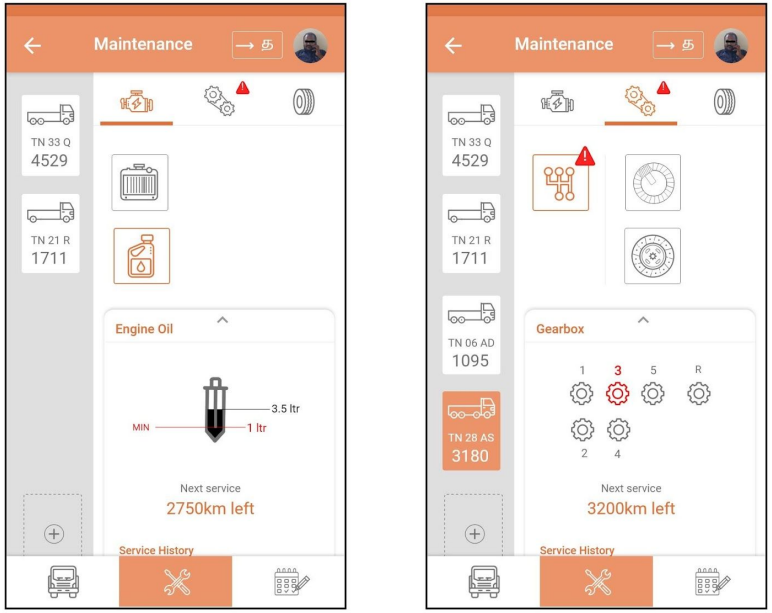


Fig 69: Maintenance tab individual truck - Engine Oil
Fig 70(R): Maintenance tab individual truck - Gearbox

If any signs of breakage are detected in any of the gears, then the colour of that particular gear becomes red. This can help notify the driver to refrain from using that particular gear to avoid further damage. This also saves the time the mechanic spends on taking short rides in the truck or removing components to identify the fault.

At this point, it is worth-noting that the part containing a fault is pushed to the front in terms of the order of the parts within a category to gain attention. This also makes sense since the first part in the category is pre-selected, thereby saving one extra tap to get to the desired screen.

Parts that are present multiple in number: In the case of such parts like the Tyres, Wheel bearing, Brake lining and in some cases, the crown pinion(multi-axle trucks have two of them), the top view of the chassis is used to denote the exact location of that particular part.

The health is denoted by the fill level of that particular location with the remaining life in km shown by the side of it, eliminating the need for a popup.

In the case of the crown pinion, the representation of its location is made bigger and the tyres are made smaller. This kind of abstraction makes it easier to know where the crown pinion is located and avoid distraction that can arise out of the tyres being shown in large sizes. The inverse of the same(tyres are shown bigger) is done in the cases of the parts that are located in the tyres.

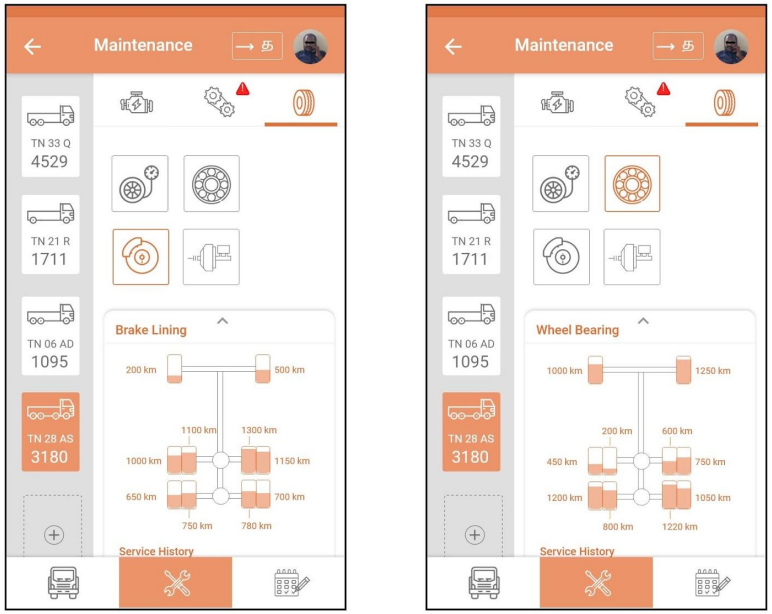
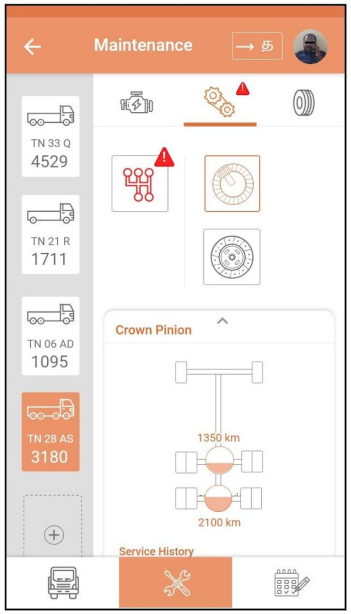


Fig 71: Maintenance tab individual truck - Brake Lining
Fig 72(R): Maintenance tab individual truck - Wheel Bearing

In the case of tyre pressure, it is a recommended range and does not have any life associated with it. Hence, it is represented by the outline of the tyres being green or red, depending on whether the values of each wheel are within the recommended range or not, respectively. Here, the colour green is not used for the text as too much green tends to become jarring. However, in the event of a particular tyre's level falling below the recommended range, the text showing the pressure reading will be in red colour.



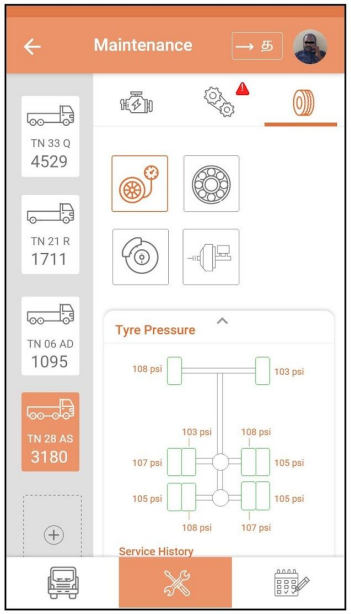


Fig 73: Maintenance tab individual truck - Crown Pinion
Fig 74(R): Maintenance tab individual truck - Tyre Pressure

Parts that neither have something within them to be monitored nor are present more than one in number: With parts like the Clutch plate and the Brake booster, they do not have any smaller elements in them to be monitored and are available in the market only as a whole(no scope to buy the smaller components and fix them in the old housing). In such cases, the remaining life of that particular part is simply shown in the middle.

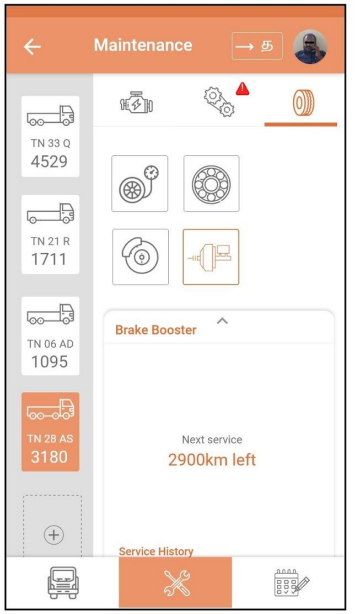


Fig 75: Maintenance tab individual truck - Clutch Plate
Fig 76(R): Maintenance tab individual truck - Brake Booster

Planning

On the landing page of the planning screen, the summary of all current and planned activities is mapped onto a calendar. The calendar, by default, is positioned such that today is always the first day. The calendar can however, be swiped to the left or the right to horizontally scroll to the past or the future. The nature of the scroll here is continuous so that it is easier to understand where the different bars begin and end.

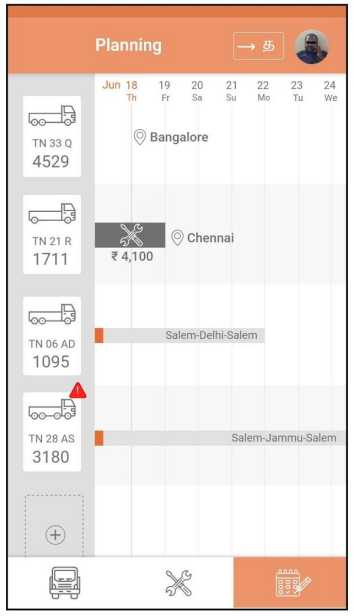


Fig 77: Planning tab landing page

The light-grey filled bar denotes the current trip and the text on it gives details about the current trip. The taller dark-grey bar(in consistency with the 'Running' page) denotes maintenance activity. The price below it refers to the cost of that particular maintenance job. This method of representation enables the owners to quickly gauge how much money is needed during what days with respect to maintaining the entire fleet.

The next trip destination, if selected, is always appended to the end of all the scheduled elements on the timeline. In the case of there being no scheduled activities for that particular truck, then it is appended to the 'today' line.

When a particular truck is selected, the owner is taken to the page from where the destination for the next trip can be selected.

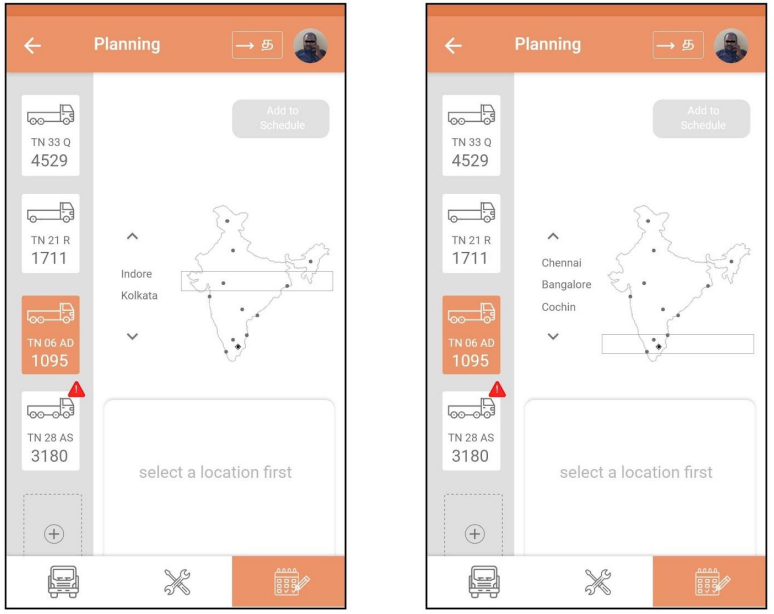


Fig 78 & 79(R): Planning tab individual truck - moving location slider up and down

In the location selector page, moving the slider on the map up and down shows the names of the locations within the frame of the slider to the side of the map. Depending on the number of locations that fall within the frame of the slider, the number of location names displayed to the side of the map also changes. The 'Add to

Schedule' button, though not tappable at the moment, is shown on the top right to give the user an expectation of what to expect.

Once a particular location is selected, the recommended service details - parts(as icons), cost, and time are shown in the overlay card that is present on the lower portion of the screen(similar to the one present in the maintenance section).

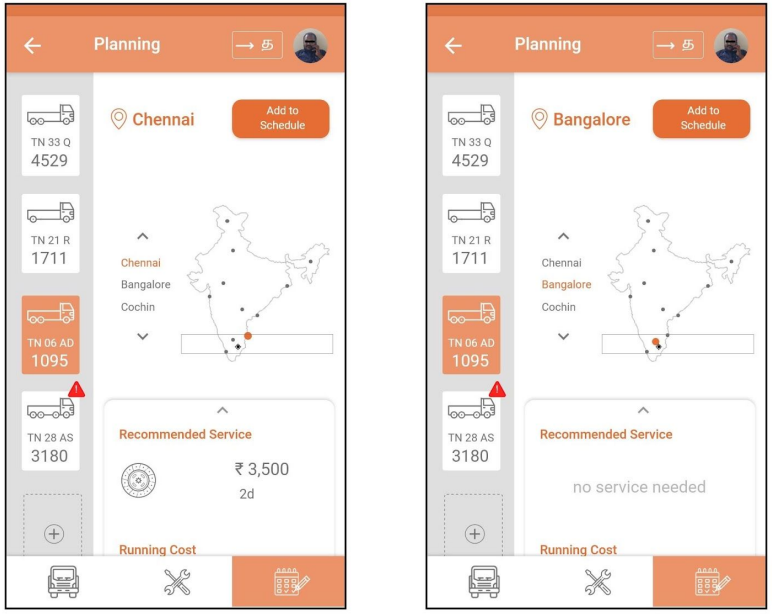


Fig 80 & 81(R): Planning tab individual truck - switching between locations and seeing corresponding service recommendations

This allows the owner to switch between the various possible locations and compare between them before making a decision of where to go next. In the case of a trip being possible without the need for any kind of maintenance, 'no service needed' text is shown in the place of the recommended service.

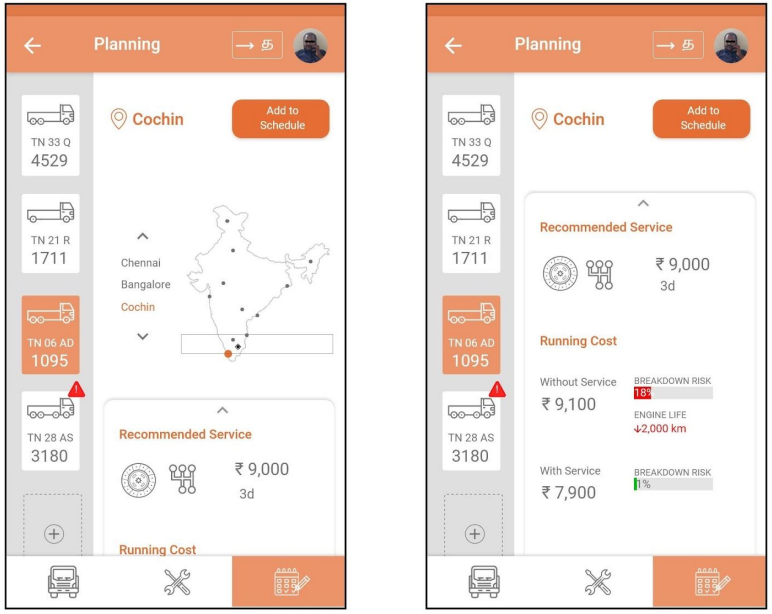


Fig 82 & 83(R): Planning tab individual truck - swiping up on overlay to see running cost

Swiping up on the card overlay moves it upwards, revealing the running cost(money, breakdown risk and any other damage to the health of the truck) in the cases of both - with and without service being done as discussed in Wireframe Prototype 1. Swiping down in the area of the overlay sends the overlay to its original position.

On tapping on the ‘Add to Schedule’ button, a popup appears where the owner can choose the parts that are to be actually serviced out of the ones that are recommended by the interface. It helps bring into account the scenario where the owner might choose to not get a part serviced despite it being recommended so that maintenance cost and time can be shown accordingly.

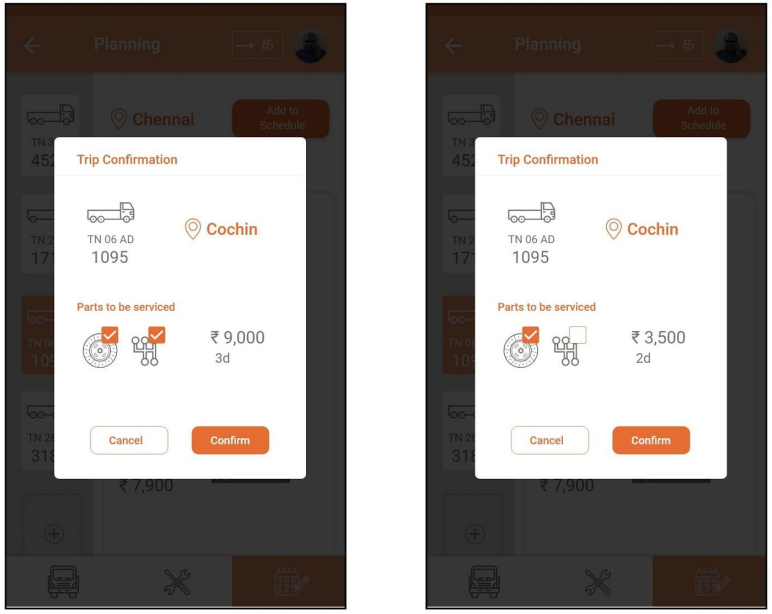


Fig 84 & 85(R): Popup to choose the parts to be serviced out of the ones recommended for the selected trip location

Once the parts that are actually to be serviced are selected and the ‘Confirm’ button is selected, the user is taken back to the calendar in the planning tab landing page. Here, the calendar is seen updated with the details of the maintenance and next trip location that was just selected.

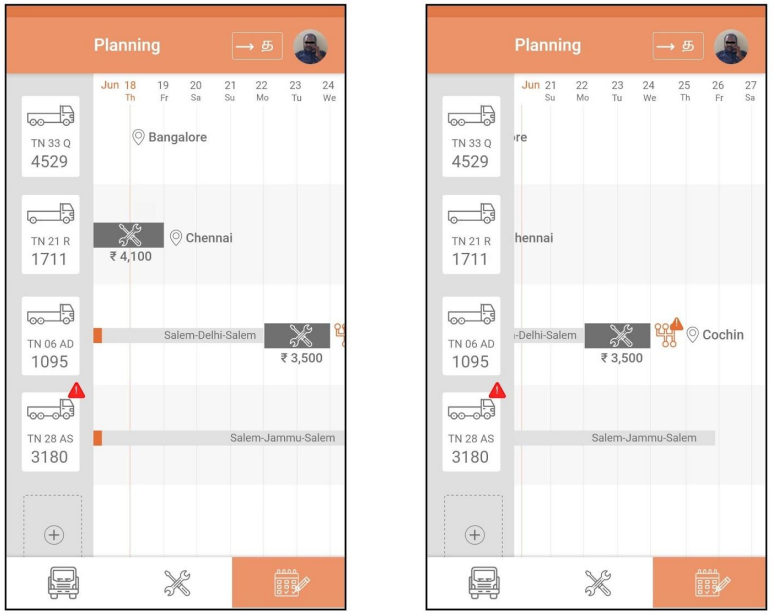


Fig 86: Planning tab - newly added trip and maintenance reflected in calendar
Fig 87(R): Planning tab - scrolling calendar to the left(seeing the future dates)

In case a part that was recommended to be serviced is not being serviced, then the icon of that part along with a warning sign is shown along with the next trip location on the calendar [Fig. 86 & Fig. 87]. This helps in letting the owner know that there is the risk of this part failing during the trip. If it actually fails, then the owner can remember that the interface was accurate with its prediction.

While scrolling through the calendar, whenever today's date goes out of the visible portion of the screen, the back button appears to help the user return to the default position in case they are lost.

Now, when the owner selects a particular truck for which the next trip location is already selected, he is directly taken to the location selector which has the already selected 'next trip location' as a pre-selection. Notice the 'Remove from Schedule' button in the place of the 'Add to Schedule' button in this case [Fig. 88].

Fig 88: Planning tab individual truck - next trip already added to schedule

Visuals

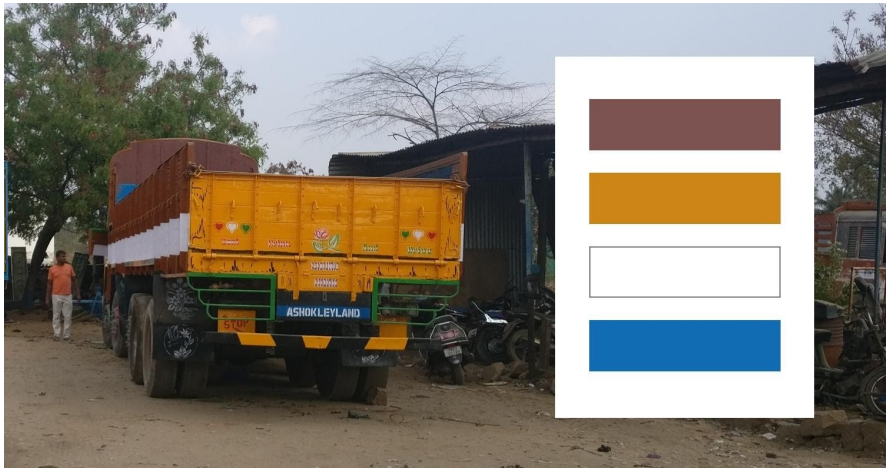


Fig 89: Colours of the truck

Colour v1: Brown is the most prominent colour on the truck and it covers almost the entire body of the truck. Since the accent colour needs to stand out, the next most prominent colour - a shade of orange that is present on the front and back of the truck was tweaked a bit and then chosen as the primary colour.

Upon seeing it in the flesh, the orange felt too bright and couldn't be used as a fill colour. Using a lighter shade made it difficult to relate to the colour on the truck. Hence, this was not taken forward.

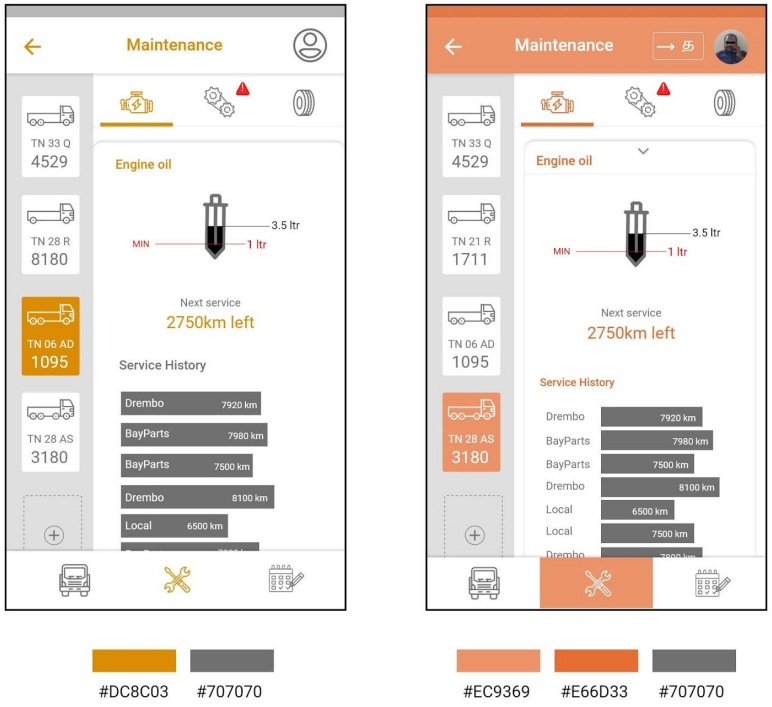


Fig 90: Colour v1(orange) vs Final Colour(brown)

Final Colour: In this version, brown was chosen to be the accent colour. However, since brown is a dull colour, two shades of brown were chosen to counter this problem - a light brown for fill and a bright brown for text. It was, however, ensured that both the shades of brown match the feel of the colour that is found on the truck.

Typography: Roboto was selected for typography as it is readable in lower font sizes, and has a neutral feeling to it. Moreover, it is the default font on android, so every device will have it.

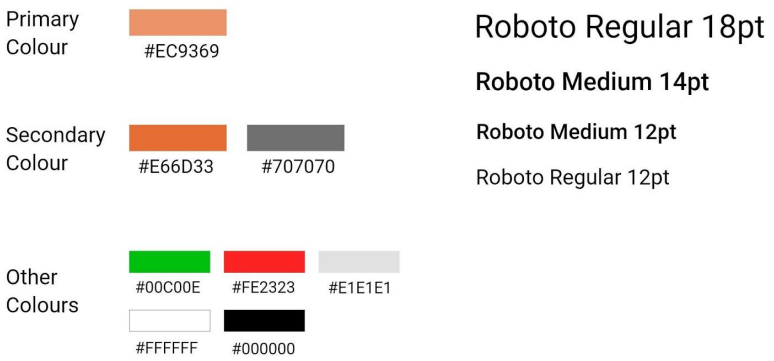


Fig 91: Final colour and typography

Icons: While some of the icons were made from scratch, most of them were derived from a copyright-free source(flaticon.com) and then tweaked upon based on requirements.

Tamil Version

The interface has a tamil version too as some owners might not be familiar with english. It can be accessed by tapping the ‘language switcher button’ that is constantly present on the top bar.

For the translation, we have stayed with words that are commonly used by the target user group rather than going for the literal translation. For instance, kilometers are represented as ‘km’ only as they know what it means from seeing it on signages and other places. Likewise, things like the word ‘clutch plate’ is simply written to read clutch plate in tamil as opposed to using the tamil word for the same. This ensures that the language of the interface is the same as the language of the target user group.

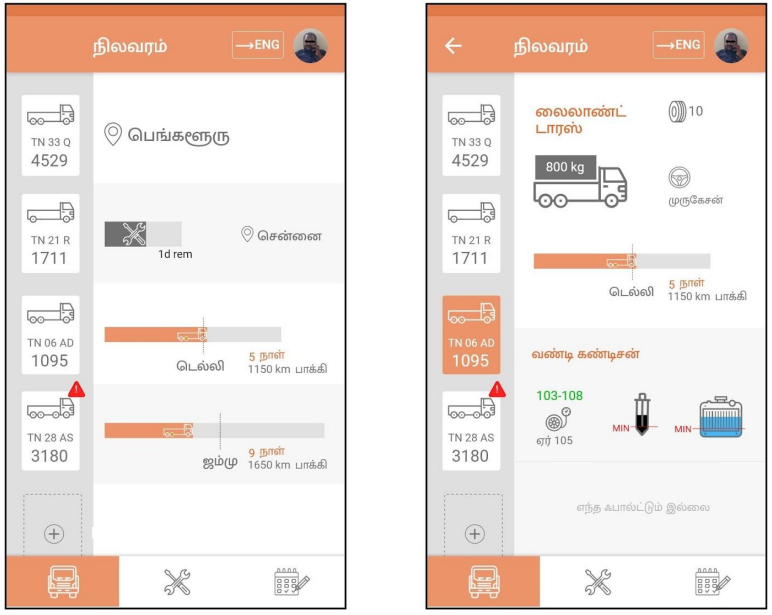


Fig 92: Screens from the tamil version

Muktha Malar was chosen for typography as it has a good variation in weight, is readable in lower font sizes, and has a neutral feeling.

The tamil versions of all the screens used in the report have been added to the appendix.

CONCLUSION AND FUTURE WORK

While the interface has been made, it is to be noted that a final call on which variation to go with was taken based on feedback from fellow students and not the actual users. Had the wireframe prototypes been tested with actual users, the feedback might or might not have been very different.

Hence, future work can be done in terms of testing not only the final screens but also the previous versions to properly understand which suits the target user group better.

Another area for possible future work is thinking about getting trucks added to the interface as the data about the health of the truck cannot be given to anyone who knows its registration number. Some kind of verification system needs to be in place to keep a tab on who gets to access what data. In addition to that, the fact that some of the truck owners might not be comfortable with inputting text should also be taken into consideration while designing such a system.

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17. Florian Lehmann & Michael Kipp. 2018. How to Hold Your Phone When Tapping: A Comparative Study of Performance, Precision, and Errors

RESOURCES

1. Icons from https://www.flaticon.com

2. Engine oil tank image (Fig. 2)
   https://pixabay.com/photos/mechanic-vehicle-car-engine-motor-3581324/

3. Clutch plate image (Fig. 3)
   https://www.freeimages.com/photo/truck-clutch-disk2-1566677

4. Wheel bearing image (Fig. 4)
   https://pixabay.com/photos/wheel-car-bearing-truck-auto-5275131/

APPENDIX

IRCC, Office of the Dean R&D, IIT Bombay

INDIAN INSTITUTE OF TECHNOLOGY BOMBAY
Office of the Dean (R&D)
Institute Ethics Committee

To
Prof. Vivek Kant,
IDC School of Design
IIT Bombay

May 11, 2020

Ref: Proposal No. IITB-IEC/2020/020 titled: "Design of smartphone based app for Health Usage Monitoring System (HUMS) for supporting maintenance among small and medium scale fleet owners, drivers, mechanics and coach builders in the trucking industry"

Sub: Expedited Review of the above mentioned project proposal

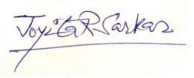
Dear Professor,

The IITB Institute Ethics Committee (IEC) has reviewed (expedited mode) the protocol submitted by you. Based on the discussions & recommendations, and responses given by you, the following documents have been approved.

- Proposal no. IITB-IEC/2020/020 version 06 submitted on Apr 27, 2020
- ICF of Proposal no. IITB-IEC/2020/020 version 06 submitted on Apr 27, 2020
- PI CV submitted on Feb 18, 2020

The study is approved for the entire duration. For studies, which will continue for more than one year, a continuing review report should be submitted annually and a completion report should be submitted within 2 months of study completion. The IEC approval is for the ethical conduct of the study. Please note that any changes to the protocol must be brought to the notice of the IEC prior to the implementation.

It is hereby confirmed that neither you nor any of the study team members have participated in the decision-making procedures of the committee.
With Regards,



Ms. Joyita Roy Sarkar
Member Secretary, IITB-IEC

Proposal No: IITB-IEC/2020/020

Page 1

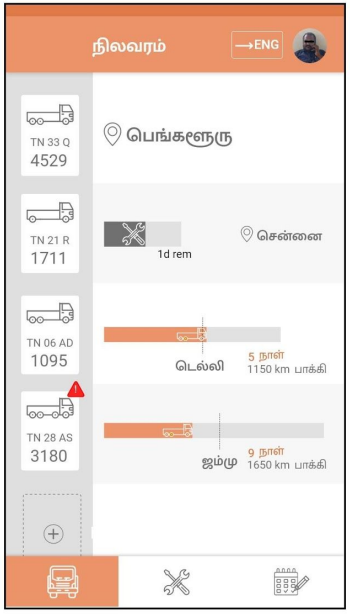
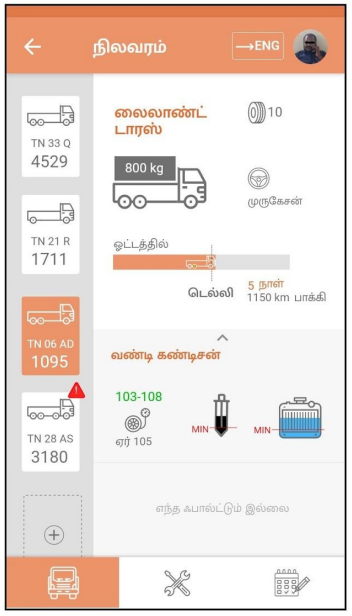


Fig 57-Tamil: Homepage (Running tab landing page)



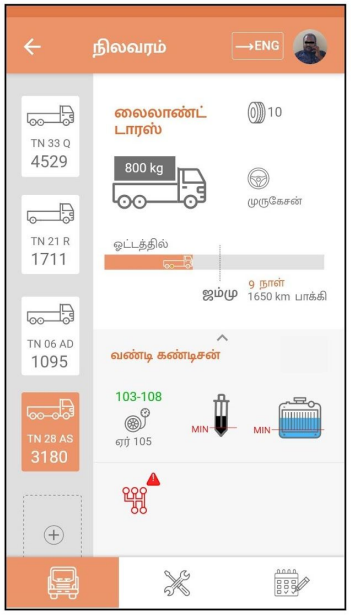


Fig 58-Tamil: Running tab individual truck - no faults
Fig 59(R)-Tamil: Running tab individual truck - with fault

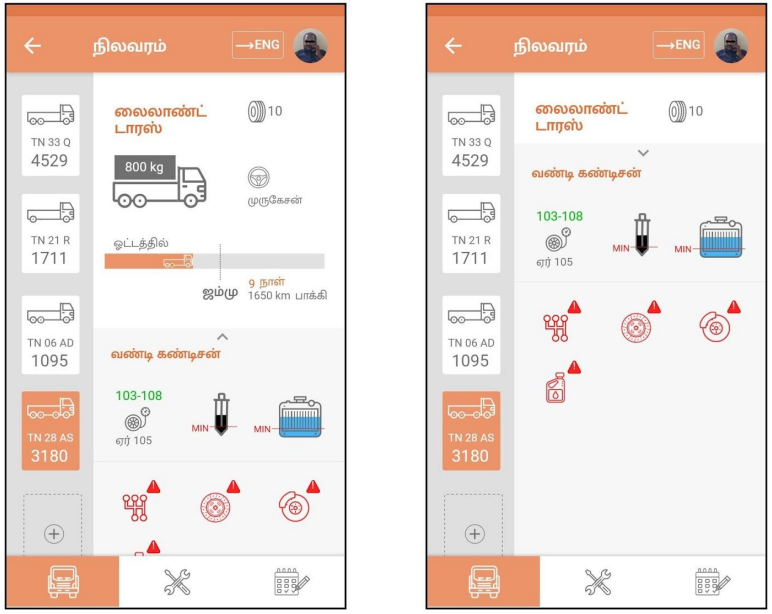


Fig 60-Tamil: Running tab individual truck - more than 3 faults
Fig 61(R)-Tamil: Running tab individual truck - grey portion scrolling

Fig 62-Tamil: Running tab individual truck - truck under maintenance
Fig 63(R)-Tamil: Running tab individual truck - ready for next trip

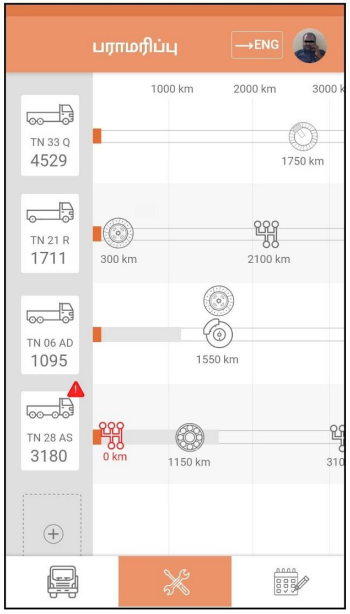


Fig 64-Tamil: Maintenance tab landing page

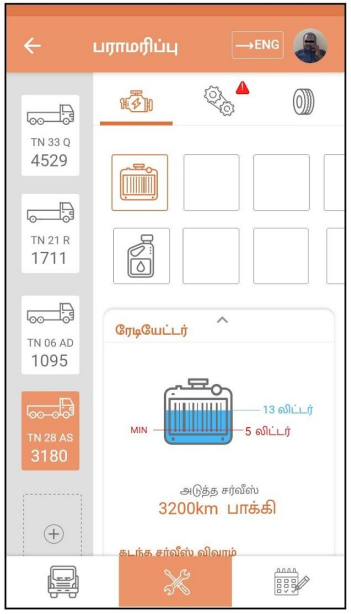
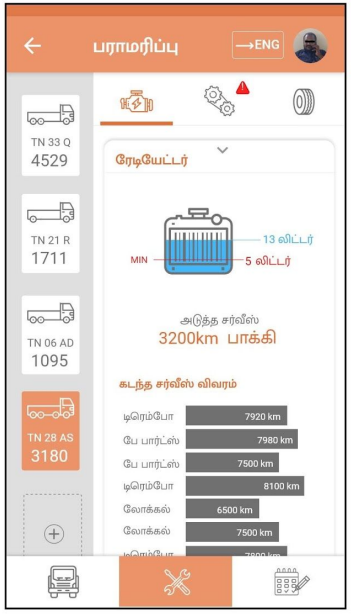


Fig 65-Tamil: Maintenance tab individual truck landing page(Radiator)
Fig 66(R)-Tamil: Maintenance tab individual truck - more than 6 parts in a category



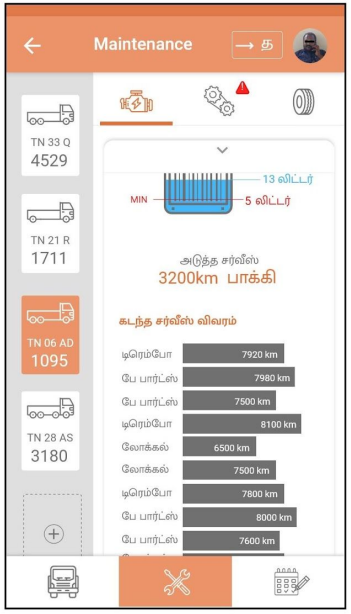
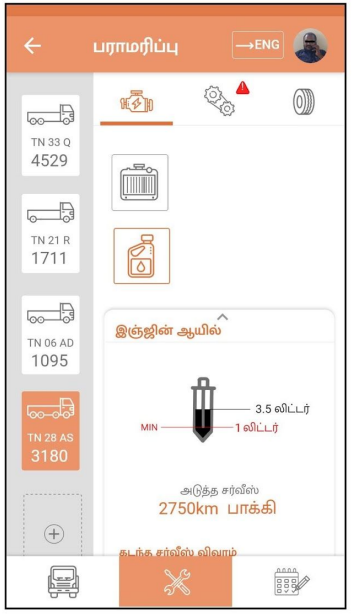


Fig 67-Tamil: Maintenance tab individual truck - swiping up on overlay
Fig 68(R)-Tamil: Maintenance tab individual truck - scrolling within overlay after upward movement limit reached



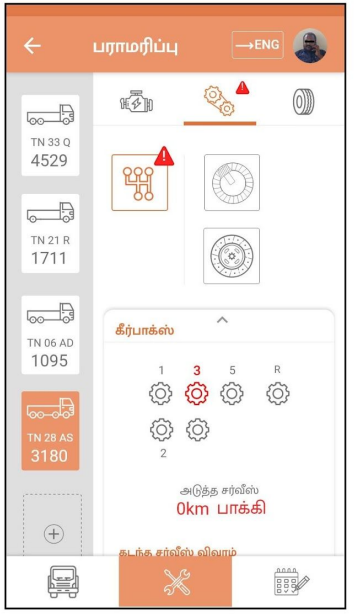
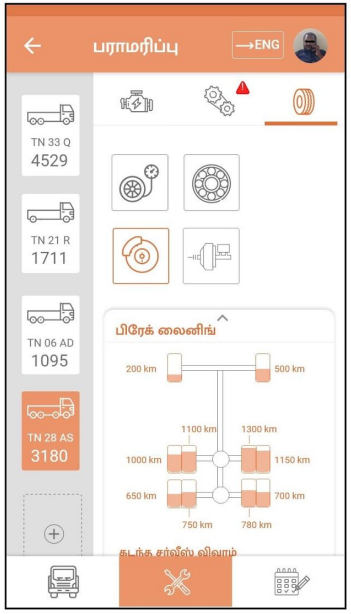


Fig 69-Tamil: Maintenance tab individual truck - Engine Oil
Fig 70(R)-Tamil: Maintenance tab individual truck - Gearbox



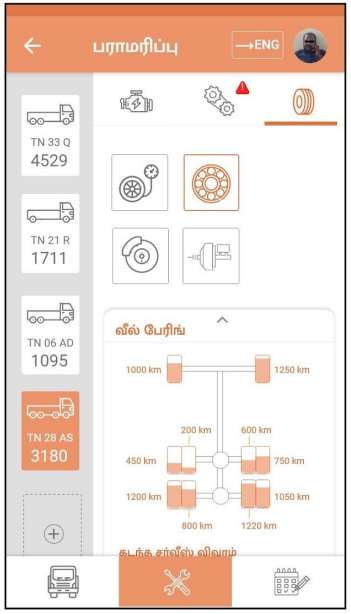
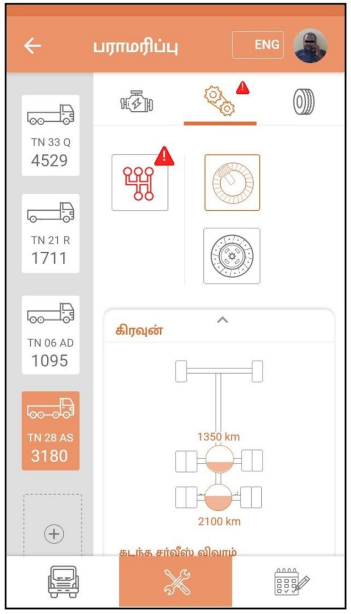


Fig 71-Tamil: Maintenance tab individual truck - Brake Lining
Fig 72(R)-Tamil: Maintenance tab individual truck - Wheel Bearing



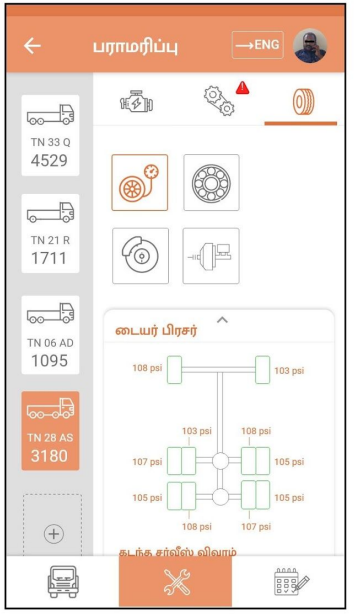


Fig 73-Tamil: Maintenance tab individual truck - Crown Pinion
Fig 74(R)-Tamil: Maintenance tab individual truck - Tyre Pressure

Fig 75-Tamil: Maintenance tab individual truck - Clutch Plate
Fig 76(R)-Tamil: Maintenance tab individual truck - Brake Booster

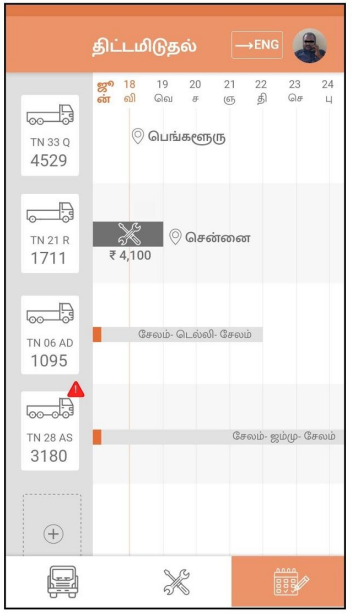


Fig 77-Tamil: Planning tab landing page

Fig 78-Tamil & 79(R)-Tamil: Planning tab individual truck - moving location slider up and down

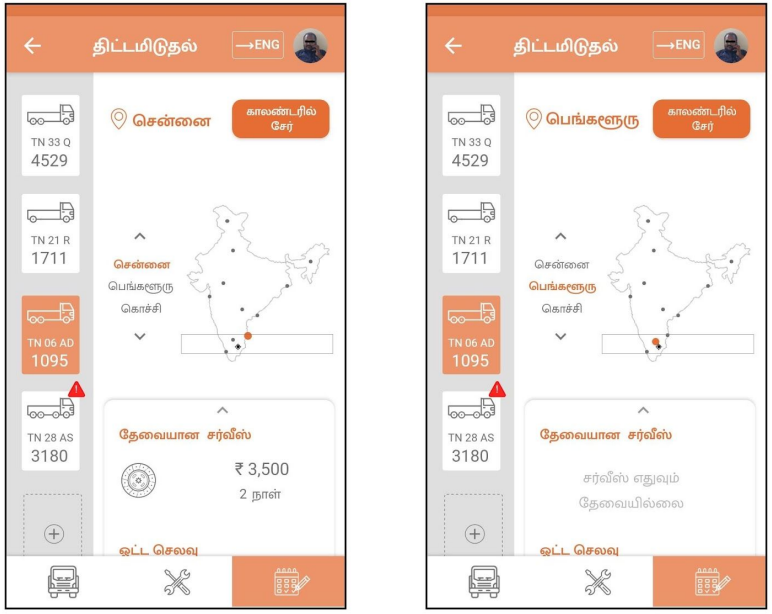


Fig 80-Tamil & 81(R)-Tamil: Planning tab individual truck - switching between locations and seeing corresponding service recommendations

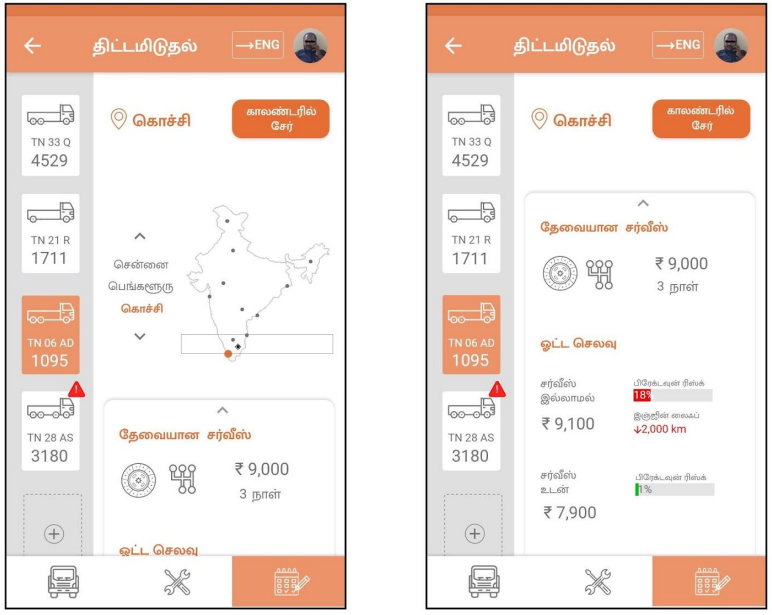


Fig 82-Tamil & 83(R)-Tamil: Planning tab individual truck - swiping up on overlay to see running cost

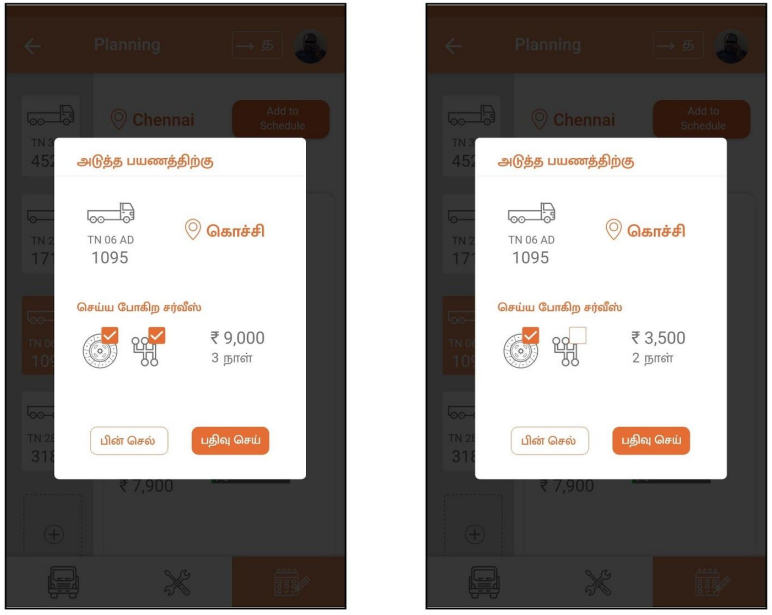
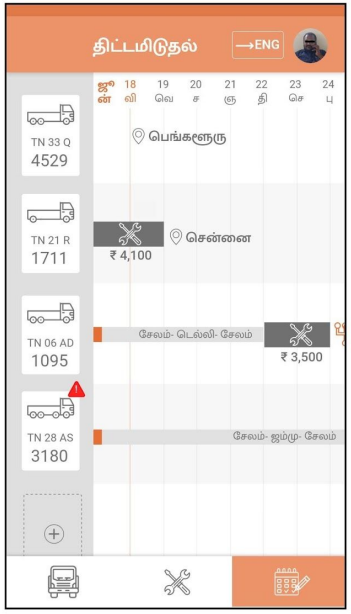


Fig 84-Tamil & 85(R)-Tamil: Popup to choose the parts to be serviced out of the ones recommended for the selected trip location



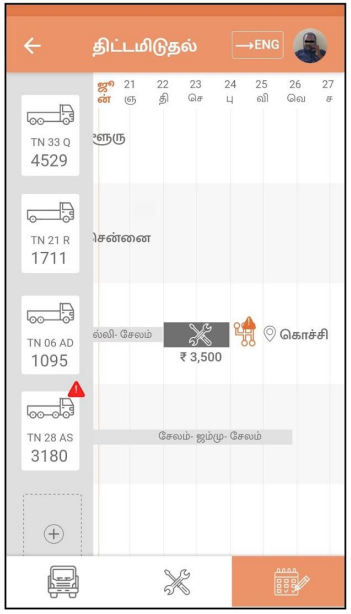


Fig 86-Tamil: Planning tab - newly added trip and maintenance reflected in calendar

Fig 87(R)-Tamil: Planning tab - scrolling calendar to the left(seeing the future dates)

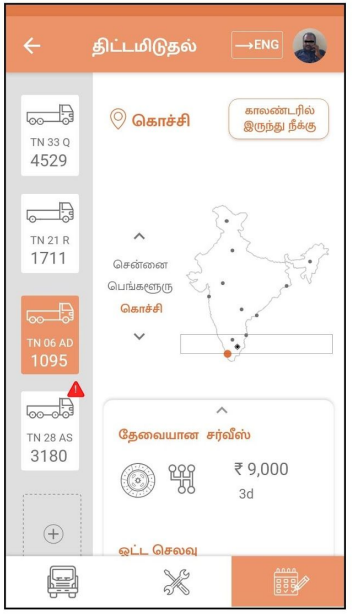


Fig 88-Tamil: Planning tab individual truck - next trip already added to schedule