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Scope for Design in IoT based Predictive Maintenance of trucks in India

Varun Vikash K | 16U130023
Guide: Prof. Vivek Kant

ABSTRACT

In this essay, first, we look at the trends in the growth of predictive maintenance in the industry and its possible future in the trucking sector. Then our focus shifts to the Indian context where we address the plausibility of Information and Communication Technology(ICT) that caters to the small-scale fleet owners, who combinedly own about 75% of the trucks in the country[1] and discuss the challenges in designing for these small-scale owners.

INTRODUCTION

Traditionally, maintenance of machinery is performed by either the preventive maintenance model or the corrective maintenance model. With preventive maintenance, the equipment is replaced before it fails based either on limits recommended by the manufacturer or based on signs of physical wear. This approach can prove to be beneficial for critical equipment, the failure of which can lead to other major failures or simply huge downtimes. However, not all equipment of the same type follows a similar wear pattern. Oftentimes, there is always a portion of the life of the equipment that still remains when the equipment is replaced, leading to an increase in maintenance costs.

In contrast to preventive maintenance, corrective maintenance is carried out only when a piece of equipment completely fails, thereby making full use of its life span. This approach might be suited for non-critical equipment that might not directly impact the ability of the machinery to function. However, having equipment that is not in its best health can lead to higher running costs due to reduced efficiency and might take a toll on the lifespan of the machinery.[2]

While both of these models have their fair share of shortcomings, we see the emergence of a new model called predictive maintenance that relies on continuously monitoring the status of the equipment(such as rotation frequency, vibration frequency among others) with the help of sensors[3]. Analysing the same data from previous runtimes can help predict the failure of an equipment beforehand so that it can be replaced just in time[4].

Knowing when a piece of equipment is going to fail with a fair level of accuracy opens up a lot of other possibilities. These can be of various multitudes ranging from procuring spare parts beforehand to planning maintenance schedules for personnel as per real-time requirements. As a bottomline, predictive maintenance can help reduce maintenance costs, reduce downtime and increase operational safety, all at the same time.[5][6]

PREDICTIVE MAINTENANCE IN TODAY'S AGE

Power of Analytics

Today, with sensors becoming available at cheaper rates[7], the concept of predictive maintenance is entering more and more domains. 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[8]. Along with data about the condition of the equipment, it has now become possible to make sense out of the data pertaining to the operating environment as well. This new trend enables the prediction of failures based on the specific operating conditions of the machinery.

The large scale adoption of predictive maintenance, however, depends on the accuracy of the predictions that are being made. This is where big data analytics and their self-learning algorithms can come in handy. Since the algorithms are self-learning, there is no need to think about the logic behind the analysis or worry about which datasets need to be considered and which ones to be left out. Any additional data, be it internal(machinery) or external(environment) in any form is always going to enhance the accuracy of the predictions. In the end, the key idea is that that having more data is equivalent to having more accuracy.[5]

Place for Blockchain

With so much being possible under the name of analytics, it becomes important that this process is made accessible, efficient and safe. With blockchain, the data is stored on every computer that is part of the system as opposed to having a central database, making it possible to combine the computing power of each of them. Once a particular data is added to the blockchain, it is very difficult to modify it later. Hence, If the data in any one of the computers gets erased or corrupted, there is no effect on the remainder of the system.[9]

With the help of blockchain technology embedded onto the equipment, it would be possible to create concepts such as a 'digital birth certificate' that holds details about when and where it was manufactured, where it is being stored. Once put into use, details pertaining to when, where and at what state the particular equipment was serviced can also be updated to the blockchain. This can be done for possibly any equipment.

Apart from inventory management and locating service stations that have the spare part available at the moment, blockchain will also help in creating a fool-proof maintenance

history logging system. This can play a crucial role in the second-hand market by helping potential buyers in evaluating how well the machinery has been maintained by the previous owner, which is a direct indicator of how long it is going to last in the hands of the new owner. Further, with the amount of data that is being collected, the potential is not limited to just knowing how long an equipment was under operation before being replaced. Details like the exact condition of that particular piece of equipment at the time of it being replaced can also be derived from the blockchain.[10]

In addition to all of these, blockchain can also help monitor the lifespan of the same type of equipment sourced from different suppliers, which can provide the base for a data-driven decision-making process when the particular equipment has to be replaced.

Health and Usage Monitoring System(HUMS)

HUMS is the instantiation of the predictive maintenance model in today's world. It refers to the system of sensors monitoring the condition of the equipment as well as the operating conditions and is wirelessly connected to computing devices that perform the analytics. It usually contains an interface as part of the system through which the user can interact with it.

TRENDS IN THE INDUSTRY

Looking at the current status of the industry, predictive maintenance forms a major component of the connectivity-and-data-driven Industry 4.0, especially in European countries where more and more companies are jumping on the predictive maintenance bandwagon and are reporting positive results as well.

While about 75% of all this implementation might be in production facilities[5], what is of even more interest to us here are the trends that are beginning to emerge in the way things are being done as a result of this implementation. Apart from hiring more data scientists, companies are also using advanced data collection tools, are making use of previously untapped data sources(from the environment) and are becoming more open to the idea of using data from external sources. All of these measures are a step in the right direction to achieve the kind of accuracy that can be possible with the kind of analytics that is possible in today's day and age. Add to that the fact that the culture of data-driven decision making is also becoming more and more commonplace, we might see the widespread adoption of predictive maintenance in the years to come.[5]

Predictive Maintenance in the Transport Sector

HUMS systems are already being used in the aviation sector and have gained a fair level of effectiveness[11] and popularity. It helps keep track of the health of all safety-critical components by monitoring all spinning and vibrating parts by measuring the frequency and other physical parameters and mapping them against historical data to look for when a component can fail before it actually does.

This continuous monitoring ensures that the aircraft always complies with the technical guidelines for safe flying at any point in its lifetime. This greatly enhances the safety of the aircraft which, unlike other forms of transport, cannot be stopped along the way for any kind of maintenance activity. Not only does predicting faults earlier help in ensuring continuing airworthiness, it also helps in inventory management for the spare parts by helping have the right part in the right place and hundreds of such places. An extension of this would be to enable the spare part supplier to engage in just-in-time production. This ensures that the delay caused due to the non-availability of parts is reduced to a minimum without the need to increase the size of the inventory.[12]

In addition to that, the huge amounts of data that is being collected on a day-to-day basis about various flying conditions can be used to simulate virtual testing conditions for the aircraft. This can help in reducing the time, resources, and risk that goes into real-world testing. Add to that the blockchain-based tracking of parts discussed earlier, it would also be possible to create a 'digital twin' for the aircraft that can help simulate a trip to any location. As a result, one can be aware of what the state of wear and tear of the parts would be at the time of the aircraft reaching the destination, even before the trip begins.

Another case of the use of predictive maintenance in the transport sector is in the railways. Though the use of predictive maintenance is not widespread here, some players have already begun using it and are showcasing interesting possibilities.

A prime example of such a case would be that of Infrabel, the state-owned maintenance provider for the Belgian railways. With a 50% increase in the number of passengers since 2000[5], the lines have become a lot busier, thereby reducing the time that is available for visual inspections to be carried out by the personnel. Moreover, performing visual inspections by getting down on the tracks also come with their own safety issues. In an attempt to reduce the need for such inspections to a minimum, Infrabel has focused on converting normal assets into smart assets with the help of sensors and IoT. As an example, sophisticated condition monitoring equipment is integrated onto the train itself to inspect the tracks and overhead lines. In addition, they have also tapped into previously untapped sources of data such as tracking anomalies in power consumption, which is usually noticeable before the mechanical failure of a switch.

PREDICTIVE MAINTENANCE IN THE FUTURE OF TRUCKING

Today, in an age where the boom in software technology is penetrating almost every other domain, trucking is no exception. Due to increasing competition, fleet operators are looking at different methods to increase efficiency and save costs. With the growth in hardware technology sort of moving towards a stagnation point, Telematics(Telecommunication + Informatics) seems to be the way forward in terms of achieving the above goals. The possibilities this opens up in areas like fleet management, route optimization and condition-based maintenance are immense. While some forms of telematic services are

already being used by fleet operators, most of them being retro-fitted after purchase. It is predicted that by 2026 claiming telematic services will become part of the standard equipment in the TRIAD countries(US, EU, Japan and some other highly industrialized countries that account to 50% of world GDP while comprising of only 8% of the global population).[13]

Among the possible telematic services, Fleet & supply chain management, Driver Safety and Vehicle monitoring are the three major areas that have generated the greatest interest for application among fleet operators. Our interest here is the area of vehicle monitoring, within which predictive maintenance is the single most sought after application field by operators.[13]

While optimizing maintenance schedules, reducing cost, and sending the truck to a workshop that already has the spare part are obvious benefits, there can be other not-so-obvious benefits fleet operators can derive out of the data-driven predictive maintenance model. One such benefit could be to send error codes directly to the workshop in the event of a fault even before the truck reaches there. This can ensure that the necessary equipment and personnel are made available to attend to that particular type of fault. Another benefit can come from the fool-proof maintenance logging that eliminates the creeping in of errors associated with maintaining a manual log of service history. The same maintenance log, apart from being of benefit in the second-hand market, can also pave the way for a future where one can get tailor-made insurance quotes depending on how the truck has been maintained.

The possible role of Original Equipment Manufacturers (OEMs)

While the benefits that fleet operators can derive from a HUMS system are undeniable, it wouldn't become a reality unless there being an entity for whom providing such a service makes a strong enough business case.

Looking at the global trends in truck ownership, there is a decrease in the total number of fleet operators and an increase in the number of trucks per operator. It is predicted that this trend will only become stronger. For example in Europe, the percentage of trucks being owned by operators owning more than 100 trucks is predicted to go up to 35% in 2026 from about 25% in 2016 [13]. Now factor in the emergence of predictive maintenance, it becomes that much more easier for OEMs(Original Equipment Manufacturers - Volvo, Eicher, etc) to give more attention to providing specific HUMS solutions to their clients who are now lower in number. And for the OEMs, it is not just about enhancing the quality of maintenance that they were already offering. The data collected from these systems can be directly put into the development and testing of new equipment, which makes a great business case for the OEMs to provide HUMS solutions in the global scene.

TRUCKING SCENE IN INDIA

With a high amount of inland economic activity, trucks and trains are the most popular means of freight transport in the country. Among the two, the modal share of freight transported by road has been constantly increasing from 20% in 1950-51 to 50% in 2007-08 and reaching about 65% in 2011-12 [1]. In terms of tonne-kilometers, the amount of all freight that is transported by trucks in India stands at about 60%, while countries with similar geography such as China and the US report a much lower 40% and 30% respectively[14]. Now, whether or not this indicates an inefficiency in the railway system to transport goods is not of our concern here. Instead, what we aim to infer is that trucking is the single most significant sector for the transportation of goods in India.

Ownership

Truck ownership in India is highly decentralized with about 75% of the trucks being owned by small-scale operators(owning five or less than five trucks) and only around 10% of all trucks being owned by operators owning more than 20 trucks[1]. The proportion of trucks owned by small-scale operators is said to have been even higher at around 95% in the 1980s and has come down over time like in other parts of the world as well. Still 75% is too big a number to not be considered for the adoption of any kind of policy or technology.

While we do not have detailed studies that give insights into the demographics of the small-scale owners, it is known that they are usually people related to the trucking sector - like ex-drivers, brokers, coachbuilders, etc.

Broker

In India, unlike some other developed parts of the world, most of the trucking sector operates on a day-to-day market basis(commonly known as the ‘mandi’ system) rather than trucks being leased out on contracts.

The broker plays an important role here by being a link between businesses and the truck owners and is responsible for bringing orders to the owners. While only about 2-3% of businesses approach the owners directly[15], it is through these brokers that the small-scale owners get their business from. This can possibly be attributed to the fact that businesses do not know how reliable each owner is and hence bank upon the broker to get their goods delivered.

While some startups like BlackBuck are looking to create a digital platform for businesses to get directly in touch with owners, their success is yet to be proven. As of today, the broker continues to be a dominant entity in the trucking space.

Driver

The drivers working for these small-scale owners are either family members or hired people whom the owners consider to be trustworthy as the truck is going to be under the driver’s

custody most of the time[1]. They are usually accompanied by a helper who takes care of cleaning and other smaller tasks to aid the driver. The life of the drivers is pretty harsh in the way that they spend long intervals away from home and are being paid half as much as cab drivers. About 50% of drivers suffer from driving-related health issues and to top it all off, truck drivers comprised 20% of the total 1.4 lakh fatalities in road accidents in 2014[16].

Due to poor working conditions and lack of basic safety, the number of truck drivers has reduced from 900 per 1000 trucks in 2002 to 600 per 1000 trucks in 2017 [17]. The government's recent attempt to fix this demand by lifting the 'minimum education qualification' of having passed class 8 that was established back in 1989[18], shows that there are high levels of illiteracy among truck drivers. Given that a fair proportion of truck owners are also ex-drivers, it wouldn't be a blatant assumption to say that a fair level of illiteracy also exists among the owners.

Maintenance

While some large-scale owners can afford to have their own workshops, a vast majority of small-scale owners have their trucks serviced at local workshops rather than sending them to the OEMs' service centers owing to lower costs. In recent times, OEMs are offering annual maintenance contracts for the initial few years at the time of purchase and during this period, the trucks are serviced with the OEMs. However, once the contract is over, owners switch to having maintenance carried by their local mechanic.

As a result of heavy unregulated competition, trucking prices have become artificially low, which is also one of the reasons for road transport being more viable in India as compared to the rest of the world. To provide services at such low prices, owners look to cut corners in the short term by resorting to practices like overloading and not ensuring proper maintenance, thereby compromising on the safety and long-term reliability of the truck. About one out of every three trucks is overloaded and it is also estimated that overloading reduces the productive life of a truck by about 30% [15]. This becomes even more of an issue when taking into consideration that about 34% of trucks on the roads are more than 10 years old[1]. As a result, poor maintenance combined with overloading can lead to breakdowns or accidents that are definitive losses, both on the monetary and emotional fronts.

The day-to-day market system of operation means that once a shipment is assigned, no maintenance activity can be done while the truck is on the road as the goods need to be delivered on time. In addition to that, the amount of money carried by the drivers might not be enough to pay for the cost of the repair.

Adoption of Technology

Basic monitoring equipment like GPS trackers, speed governors, etc with the potential of displaying the location and speed of the truck via a smartphone app are currently available in the market and are slowly gaining traction even among some small-scale owners.

On the manufacturer front, since the advent of the BS4 emission norms in 2017, sensors that watch for electrical, chemical, and mechanical faults related to the combustion of the engine have become standard across the range. The data from these sensors is processed by a microprocessor called the ECU(Engine Control Unit) that is present in the truck itself. In the event of a fault being detected, the 'check engine' light on the dashboard starts glowing and an error code denoting the type of error is sent to a 16-pin OBD(On-Board Diagnostic) port. The codes from the port can be accessed with the help of a scan tool or a laptop[19].

However, it is to be noted at this point that the above monitoring methods provide information in binary terms, i.e., OK or failed, and hence can be used only for the purpose of fault identification.

Government Policy

With the BS6 emission norms kicking in from April 2020 onwards, trucks are expected to be pricier and truck sales are expected to go down further till 2023 before they pick up pace again[13]. The government is also toying with the idea of implementing a scrappage policy to get old trucks off the roads to control emissions and also give a boost to truck sales during this period[20].

NEED FOR HUMS IN INDIAN TRUCKING

While there are start-ups in India that are working on bringing the benefits of telematics like fleet management, route optimization, and driver relay to the trucking sector, none of them seem to be operating in the area of predictive maintenance or HUMS. A HUMS system based on predictive maintenance can, however, can be of great benefit to the owners especially in the Indian context.

Increase efficiency within the day-to-day market system

Since maintenance activity is difficult while the truck is on a trip, it becomes important to determine if the condition of the truck is good enough to complete the trip before it is actually sent out. It is necessary to avoid breakdowns or accidents that can lead to major downtime or losses. This is where data about the condition of the truck and the data from trips done by other trucks to the same location can be of use. They can be used to simulate if with the given condition, will the truck be able to make the trip to a particular location or not. And if not, what kind of maintenance is needed to make it possible. The same kind of simulation can be used to optimize trip locations based on the availability of money, spares, among other challenges.

Foolproof Maintenance Logging

With a foolproof maintenance log that is maintained digitally, it becomes easier for owners to determine how long a particular part lasted. This can encourage owners to move towards better quality parts that provide higher cost benefits in the long term.

As mentioned earlier, another benefit of the digital maintenance log is while buying or selling trucks in the second-hand market. Since these trucks are not being serviced by the manufacturer, there is no maintenance log available with the OEM too. This might make it very difficult to determine how well a truck was maintained. With the HUMS system, since the condition of every part at the time of its replacement is known, it becomes easier to quote prices for the truck. Along with that, owners who take good care of their trucks can also derive monetary benefits at the time selling their trucks.

Derive value out of good maintenance

In addition to getting good prices while selling the truck, owners can also derive benefits from day-to-day running by ensuring good maintenance. Due to overloading being very much common, it causes the parts to wear well before the limits claimed by the manufacturer. And keeping worn parts in the truck only increases running costs along with posing safety hazards. While the possibility of overloading cannot be entirely eliminated by a single truck owner owing to the nature of the market, good maintenance can definitely ensure lower running costs and enhance the longevity of the vehicle.

Good maintenance means reduced pollution

The increased efficiency that is achieved out of good maintenance would also mean reduced tailpipe emissions, which can be understood on the basis of two aspects. One, the combustion process itself is more efficient, reducing the by-products of incomplete combustion (Carbon-mon-oxide, carbon soot). And two, since the combustion is efficient, a lesser amount of fuel is required, reducing the by-products of complete combustion (Carbon-di-oxide, Nitrogen oxides). In the end, it means less harm from both the resource usage and pollution standpoints.

IMPLEMENTATION OF HUMS IN INDIAN TRUCKING

Leaving it to OEMs won’t work

While OEMs are expected to play an important role in bringing the benefits of a HUMS system to the fleet operators in the global scene, it is unlikely to be the case in India. The market here is extremely price-sensitive and small-scale owners, who own the majority of the trucks choose to not get their trucks serviced by the OEMs owing to cost benefits. In such a scenario, the OEM integrating a HUMS system from the factory itself would make buying a new truck even more expensive and drive the sales even downward. In addition to that, with a large number of the trucks on the roads being fairly old and a good number of them being bought second-hand, the market penetration would be very low if this was left in the hands of the OEMs.

Possibility of a 3rd party Modular Solution

For the HUMS system to become popular, it is important to provide owners a very inexpensive entry point to enter the ecosystem. Once they begin to realize the benefits, they would be willing to spend more on expanding the system. Since making a complete all-in-one system with all kinds of sensors would definitely be expensive, modularity is key here. Hence, it becomes important to have sensors to monitor different parts available as different 'packages' so that the owner can pay only for what he wants to be monitored. More sensors can then be added to the system at later stages as and when the owner feels the need for each of them without disturbing the system already in place. The information from all of these sensors on multiple trucks can be displayed on a common interface, making it easier for the owner to monitor the health of their fleets and plan for maintenance.

Even if the OEMs were to make such a modular solution, they would have their own proprietary software for the interface that would not allow trucks of other manufacturers to be listed on their interface. So, it would be best if it is done by a 3rd party who is not directly associated with any of these manufacturers.

Leveraging upon the smartphone boom

In recent times, with the availability of smartphones and cellular data at affordable prices, smartphones are quickly penetrating through the Indian demographic. While the number of smartphone users stood at 468 million in 2017, the number is expected to double to about 859 million in 2022, bringing the number of people who do not use a smartphone down to 504 million. Among the people who have adopted the smartphone, it is observed that a good number of them have not owned any kind of computing device earlier.[21]

This has opened up immense possibilities in terms of providing digital services to people who did not have access to them earlier. Among these possibilities is that of using the smartphone to let the truck owner monitor the health of his entire fleet irrespective of wherever each of the trucks are. The owner can be notified of parts that might require maintenance in the future so that he can be prepared for it in terms of arranging money or ensuring spares are available. In a time when the adoption of smartphones is increasing and some owners are already making use of the smartphone-based GPS tracking services, such a solution makes it much more easier for the small-scale owner to enter the world of HUMS and derive the benefits of predictive maintenance.

SCOPE FOR DESIGN

Designing the interface for a smartphone-based HUMS system that caters to the context of the small-scale truck owners in India opens up a lot of specific opportunities. For example, it might be possible that the availability of liquid cash could be the determining factor for their maintenance schedules. Hence, letting them know of the cost of upcoming repairs would be of prime importance, which is less likely to be the case with the owners of larger fleets.

In addition to that, these small-scale owners might be people who, despite being aware of the various aspects related to truck maintenance, might not be familiar with technical terms, might not be comfortable with English, and above all, might not be familiar with using a smartphone. Hence, the major challenge here might be that of catering to the emergent user.

It is therefore important for studies to be conducted in the direction of understanding the view that these small-scale owners have on the maintenance of their trucks and the qualitative and quantitative levels of smartphone usage among them for such a system to become a success.

Though the primary user here is the truck owner, dedicated interfaces can also be designed for secondary users like the driver, mechanic, and others who might also fall into the category of emergent users. The driver's interface can help ensure the running condition of the truck by showing the fluid levels and the wear of parts like the brake pad that would otherwise need manual inspection. In the event of a fault, it can also show the nature and location of the fault. With the case of the mechanic's interface, the condition of the truck can be sent to the mechanic even before the truck reaches the workshop, thereby reducing the time spent on identifying the fault or waiting for spare parts to arrive.

CONCLUSION

With sensors becoming available at cheap prices combined with the immense potential of modern data analytics, the concept of predictive maintenance is gaining popularity especially in the developed parts of the world. Health and Usage Monitoring Systems(HUMS) with the potential of monitoring the health of an equipment along with the operating conditions and transferring the data over wireless networks are already being used in the aviation industry. Such systems are capable of predicting when a piece of equipment is going to fail, so that maximum value can be derived out of its lifespan. In addition to that, maintenance schedules can also be planned accordingly to reduce cost, reduce downtime, and enhance safety. With the growth of telematics in the trucking industry globally, it is also predicted that predictive maintenance technologies will soon make their way into trucks.

To bring the benefits of predictive maintenance to the trucking sector in India, it becomes important to make HUMS technology accessible to these small-scale owners, who own a huge majority of the trucks in the country.

The OEMs providing a HUMS system integrated to their trucks might not work owing to the cost barrier and possible issues with cross-manufacturer compatibility. Instead what suits the context better in an age of rapid smartphone penetration is a 3rd party smartphone-based modular solution that has sensors to monitor different equipment available as separate 'packages' with a common smartphone application.

Now, the scope for design lies in designing the smartphone interface for the HUMS system that caters to the needs of these small-scale owners. They are people who, despite being

familiar with the maintenance related aspects of the truck, might not be familiar with using a smartphone and hence might fall into the category of emergent users. In such a scenario, there is also a need for further studies on the small-scale owners that give insights into their perspective on truck maintenance along and their level of smartphone usage. This can go a long way in making benefits of predictive maintenance available to the average truck owner.

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