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An IoT Based Model for a Trucking Transport System Using Predictive Analytics

Renuka Mahajan [1], Preetam Suman [2] and Richa Misra [1]

[1] Jaipuria Institute of Management, Noida, India

[2] Jaipuria Institute of Management, Lucknow, India

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ABSTRACT

The Internet of Things (IoT) has enormous potential to revolutionize the transport industry. IoT can be used to optimize mobility of goods and people, add transparency, update information, and provide convenience at lesser cost. Speed of transportation drives requirements of the trucking industry with sustainability, safety without stress. After reviewing current challenges of supply chain networks, this paper proposes a new solution for booking freight, integrating data from multiple sources using smart cloud-based solutions. This paper provides a solution using two modules. The first module is development of a mobile application for order updates and live monitoring of vehicles. The second module is an IoT device that works as an intelligent device by using sensors and microcontrollers. This results in organizations' transparency on live monitoring of the status of their entire supply chain network, anticipating problems in advance, and providing immediate response to the problem. This paper has implications for organizations driven by enhanced customer expectations pertaining to lead time delivery services, product availability and reliability.

KEYWORDS

Intelligence transportation system, Internet of Things (IoT), trucking, logistics sector, smart city, smart transportation

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1. Introduction

Smart technology implies the integration of software, hardware, cloud and sensor-based technologies. The objective is to utilize live data collected from numerous touchpoints, and applying statistical and analytical operations so that the user is able to make informed decisions about their routine and other tasks (Sharma and Tiwari, 2016). Smart cities would soon be using such smart technologies to provide innovative solutions for problems in urban development, ensuring high standards of sustainability and profitability. Smart Cities form an integral part of any developing country; they bring new reforms and inspire new aspirations in city residents (Ianuale et al., 2015). Smart cities enable residents with information and technology-based infrastructure that is smart, connected and viable (Myeong et al., 2018). Benefits of smart city implementation include efficient infrastructure, e-Governance, power management and traffic management, among several others. Such cities will open up for new job opportunities for all residents, leading to economic growth, which forms the backbone of any country. Smart technology is a self-service application that needs minimal or no human involvement. As an evolving technology, the Internet of Things (IoT) enables innovative solutions to transform industrial systems such as transportation systems and manufacturing systems. IoT is widely used to build intelligent transportation systems. The latest innovative services have started using the Internet of Things (IoT) for smarter traffic management. It enables commuters to be better informed, better coordinated and provides more safety (Prabhu et al., 2017). Such technological progress on IoT can change methods of different business operations (Atzori et al., 2010). Smart transportation is essential for smart cities. Transportation industry is dependent on IT transformation to provide customer satisfaction (Zanella, 2014). Involvement of smart transportation with smart cities will lead to Intelligent Traffic Management, Integrated Multi-Modal Transport, and the Internet of Things to improve overall mobility. All of this can be implemented by encouraging new technology such as IoT, Big data, dashboards and predictive analytics, complemented by a different mode of communication network, global positioning system, camera system, artificial vision, and in-vehicle systems (Ahmed et al., 2014). Tiny sensors embedded in each finished product, generate new patterns that provides new insights. Smart Transportation system has three major components: Smart Infrastructure or Station Subsystem (such as electronic toll collection, automated traffic signals, fare collection and multimodal transport), Data Integration (data monitoring center pertaining to weather, traffic and emergency services) and Smart Services (smart parking vehicle monitoring system). Internet of Things (IoT) includes connecting physical devices to the network. Government of India has ambitious plans to proliferate the IoT industry, touching USD 15 billion by 2020. The objective is to attain reliability, efficacy and security of the transport infrastructure. Moreover, connected vehicles are gaining popularity because they make driving more reliable, enjoyable and efficient.

Automotive sector is a major contributor to Indian GDP. Its growth rate is predicted to be 6.7% to 12% in the future (Huawei Technologies Co. Ltd). Global market size of vehicle tracking devices surpassed 18,984 thousand units in 2018, with an industry value of over USD 600 million. It is forecasted to develop at a CAGR of over 20% from 2019 to 2025 (Bhutani and Wadhwani, 2019). Many telecom operators are focusing on commercialization of next-generation 5G technology. Thus, smart transportation solution is the need of the hour, as citizens have major requirements for transporting goods to other places and cities. According to Business Wire (2017), transportation industry is the second largest segment investing in the Internet of Things (IoT), spending approximately USD 78 billion since 2016. Due to recent advancements in connectivity, this has particularly impacted the trucking industry. This would immensely benefit business the world over, in the sectors of transportation and logistics (Qu et al., 2016), which have been known

Corresponding Author: Renuka Mahajan renuka.mahajan@jaipuria.ac.in, 009873605079

for shying away from innovation and adaptation for a long time. Consumers can expect increased convenience, safety, and commitment to service, by businesses within the industry.

Government of India has the agenda to build 100 smart cities by 2024, and smart transportation system is the key component in transforming smart cities. India has the second-largest road network, fourth-largest rail network (Grant Thornton, 2016), as per the International Journal of Multidisciplinary Research and Development, but India has been ranked as low as 46 among 155 countries in the World Bank International Logistics Performance Index.

This paper aims to develop an intelligent transportation system using a hybrid of technologies such as mobile applications, cloud computing and IoT. The proposed system can plug data gaps such as supplier and customer location, customer forecasts, transportation costs, and realized raw and adjusted service levels, among other key inputs. It will give the organization access to reliable data reporting and the capability to perform the required analytics.

Some problems faced in the absence of Smart Transportation are listed below:

- Retailers and dealers dealing in all sorts of goods and products use heavy vehicles such as trucks and mini trucks to transfer their goods. Usually, while returning, the trucks are empty, which leads to huge loss for the users.
- Usually, while returning, the trucks come back empty, which leads to huge money loss for them.
- It also results in wastage of manpower resources for the dealers, often leading to time delays, corruption in fare negotiations etc.
- There is additional expenditure to maintain the heavy vehicles.
- Different variants of trucks play on roads, leading to complexity of matching available load to available capacity.
- Renting involves brokers' involvement. Confirmations and cost negotiations incur delays, which leads to extra expenditure.
- Proof of delivery of goods arrives late, and hence there are delays in final payment.
- Loss of revenue is common due to breakdown of vehicles on the road.
- Due to delays in transport, or weather conditions and breakdowns, there is loss of goods that are specified as perishable items.
- Tracking position and speed of vehicles on the road in real-time is a challenge.

According to the American Trucking Association, "The revenue of the global Freight Trucking market was estimated at USD 3,844.76 billion in 2016, and it is expected to reach USD 6,252.81 billion by 2025." With the Uber ride-sharing system and similar companies like Lyft, there was a revolution in urban traffic management. This is because now independent drivers can easily connect with commuters, benefiting more than 8 million people who now use app-based ride-sharing services.

Valuation of Uber has risen to over USD 60 billion, and they intend to extend the ride-share model to the shipping freight industry. According to Morgan Stanley analyst Ravi Shanker, Uber Freight, and other similar services, have the potential to act as a true disruptive influence in this sector.

2. Literature Review

In order to address the challenges described in the previous Section, supply chain managers need interconnection of equipment and devices. Hence, organizations started experimenting and involving in detailed literature review of several parameters. Fernando et al., (2020) studied the measurement of attributes of moving vehicles and on how sensors can be used for data retrieval in tracking devices. Qiu et al., (2018) assessed how various data are used in transferring methods for transmission, networks and protocols utilized for communication. Chaniotakis (2020) analyzed different data sources, algorithms, and apps that can be utilized for capture and analysis of raw data.

An in-depth literature review of researches conducted in the last decade, on different architectures related to Smart Transportation/IoT in different settings, is presented in Table 1.

Table 1: Literature Review of papers on Smart Transportation Solutions

Author(s)	Major Direction of Study
Kyriazis et al. (2013)	The paper has devised two IoT based smart city applications. The first application was meant for power management using electricity meter for commercial and residential categories. The second application was meant for the public transport system, utilizing different resources for optimizing travel time (such as environmental and traffic sensing).
Qureshi and Abdullah (2013)	It presents a wide-ranging area of intelligent transportation systems as well as its applications and a range of technologies.
Gayathri (2017)	This study developed a system for intelligent health monitoring of the car using sensor monitors on vehicles to check health of the vehicle.
Hemalatha (2015)	Researcher developed IoT and cloud-based applications to deal with transportation issues in metro cities. This would help in handling heavy traffic, ensuring vehicle security and reducing congestion on busy roads.
Javed et al. (2019)	They proposed the Cooperative Intelligent Transport System (C-ITS), a futuristic application for traffic management. Data analytics has a critical role in C-ITS application.

Redesigning strategies of the company with Transport Management System (TMS) increases upper end of the Return of Investment (ROI) since TMS facilitates end-to-end supply chain visibility (Goshare, 2020). Currently, increasing number of devices are being furnished with bar codes, RFID tags or sensors. With increased density and usage of mobile devices and services, TMS solutions integrate smartphone applications that can be used to create location of specific trucks at any given time. IoT and TMS are definitely set to play a promising role in the transportation industry.

However, for the industry that is modernized by new trucking models, both drivers and freight companies have to deal with issues related to cost and time-saving (Al-Sakran, 2015); (Bandyopadhyay and Sen, 2011). According to Bansal (2015), the transport system in India, particularly involving large trucks, is complicated and unorganized with respect to its functioning model and multiple stakeholders. In India, road transport represents around sixty-five percent of total freight transport, railway comprises thirty-two percent, while water and air present seven and one percent respectively. Globally, India has the second-largest road linkage involving freight of around seven million transport vehicles (Bansal, 2015).

Previous researches done so far have disadvantages such as technology trust (Mengru, 2018), huge cost of the system (Pham, 2015), difficulty in payment (Gandhi et al., 2016), system does not provide guidance (Lotlikar et al., 2016), drivers cannot make reservation for parking (Tsaramirsis et al., 2016) etc. There is no single solution that meets all the needs required for cooperation between devices, infrastructure, and cloud (Van Den Abeele et al., 2015).

3. The Proposed System

Review of literature demonstrated that: (i) IoT based sensors embedded on the location tracking devices in cloud data centres can be used remotely by retrieving real-time data; (ii) The GPS sensors based on the RFID technology can be utilized; (iii) Wi-Fi networks are the most popular networks; (iv) The most used storage method was observed to be cloud for smart vehicle tracking systems.

We propose that the IoT can further make this trucking system more effective by incorporating some additional features. IoT in the warehouse has given clear visibility to the supply chain, right from ordering of materials till the shipment reaches the end customer. This

can reduce inefficiencies in logistics and improve overall efficiency, while reducing costs. By including weather forecast data, data related to government services, road closure advisories, and emergency services, operations can run more smoothly. It could also inform stakeholders about the status of operations in real-time using predictive analytics and feedback mechanism, leading to instant gratification.

By merging IoT with the latest innovations, we can add more value to the business in a systematic manner (Qureshi and Abdullah, 2013). This will help in monitoring supply chain operations right from the stage of new order booking to final delivery of the shipment to the end-user or the customer.

The proposed system consists of two modules.

- The first module is an online order booking system.
- The second module is real-time vehicle monitoring.

3.1. Module 1:

The first module is shown in Figure 1 and consists of storage, application and infrastructure. These components are implemented on cloud infrastructure.

- Storage: It stores all online orders given by customers, and all tracking records of vehicles.
- Application: It is a mobile app that provides an interface to customers for online orders. It also provides an interface to the vehicle driver to get order details.
- Infrastructure: It is a cloud-based service to integrate all the components needed for the mobile app.

Figure 1: Module 1: **Online Order Booking System**

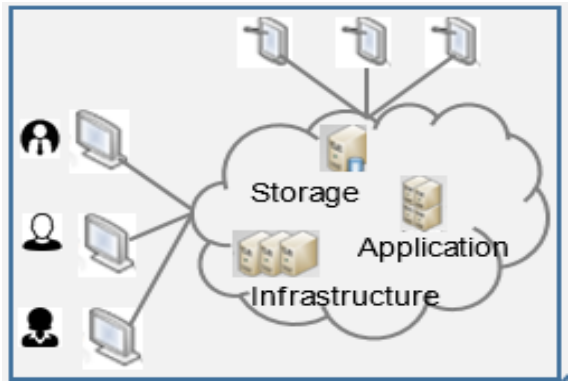

Figure 2: Flow chart of Order Booking Process

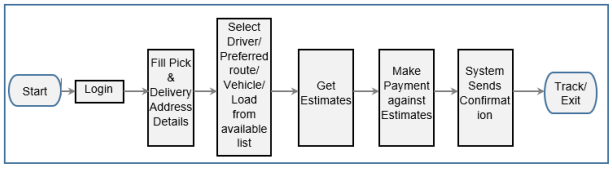

Figure 2 shows an online order booking system. The user can interact with the booking system through the mobile app. Apache Cordova is used to develop the mobile application so that the same source runs on both Android and iOS platforms. Amazon Elastic Compute cloud can be used to connect the application for real-time communication between the mobile app and cloud.

3.2. Module 2:

The second module is real-time truck/ vehicle monitoring. It consists of a device that can be mounted on a vehicle. Figure 3 shows a device that is mounted on a truck, near the steering. There are wireless sensors which can be used to monitor health of the vehicle. In Figure 3, a wireless sensor is plotted, which can measure air pressure and temperature of tires. These sensors will be connected to the device through Bluetooth.

Figure 3: Mounting device on the truck

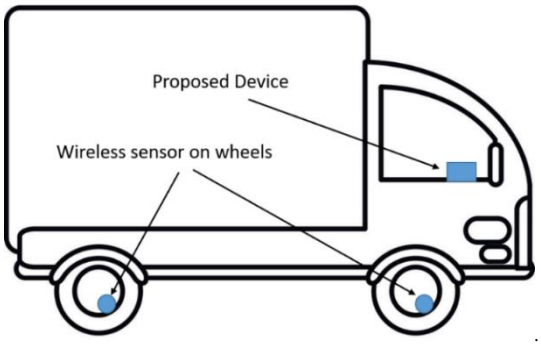

Figure 4: Elements of the proposed device

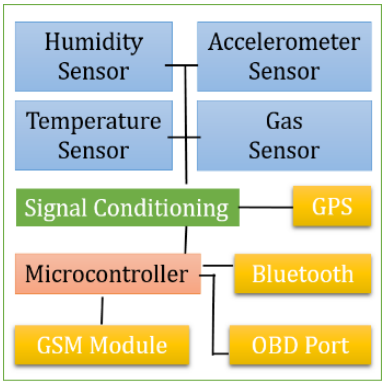

Figure 4 shows components of the proposed device. The components are as follows:

- Humidity sensor: This sensor will collect information about humidity in the air,
- Temperature sensor: This sensor will collect information on temperature from the environment. There will be one more setup of the temperature sensor to measure temperature of the engine.
- Accelerometer: This will record data of movement by the vehicle. In the case of crashes, the microcontroller can predict accidents and report to the owner.
- Gas Sensor: It is also for safety of the vehicle. Gas sensors can sense the presence of methane gas.
- Microcontroller: It collects all data from the sensor and stores all information to cloud storage. In this device, 8-bit ATmega328P has been used.
- GPS: It provides the GPS location to the microcontroller:
- GSM Module: This module will be used to provide connectivity to cloud storage and send messages in emergency situations. It also provides internet connectivity to the app.
- OBD port: It is used to provide connectivity to devices from the vehicle. It includes power supply and other input values from the vehicle.
- Bluetooth: This module will be used to connect the sensor to the device through Bluetooth.

This system has the facility of booking various truck types through different means such as mobile internet, email, or field agents. The user can book by giving the pickup and delivery address, preferences for the type of carrier (emergency vehicles, light commercial vehicles, passenger vehicles etc.), cargo type (perishable items/pharmaceutical products, etc.), preferred driver, favorite route etc. User's preferences

are saved on the cloud so that the same history can be used to understand preferences for the next booking and notification. This information will be matched with professional truck drivers registered with the app, who are vetted by the app and are willing to carry shipment. This way, the dispatcher 'does not have to deal with the challenge of finding, negotiating and booking. Also, truck drivers do not have to negotiate the fare as the price is predetermined in this booking system. One can see the available route and how much will be charged. Pricing also depends upon a number of factors such as the cargo type, location, with distance being the most prominent one. Directly connecting them eliminates price surprises, negotiation delays, and corruption practices. Bookings can be made several weeks in advance or on the same day. This mobile app will be hosted on the cloud to optimize infrastructure cost and on-the-fly scalability as per requirement. This will eliminate data loss because of networked backups and load balancing. Cloud computing will save the shipper/dispatcher the cost of data storage and maintenance.

This module also has the provision of field agents or brokers who can take requests from dispatchers using landline/mobile/web/email. Role of Administrator is crucial in cases where field agents take manual orders and book them on behalf of the dispatchers, they have the provision to handle queries faced by end-users, or generate ad-hoc reports required by them. This results in better customer satisfaction.

Once the load is dispatched, there could be other bottlenecks such as traffic jams, that cause frustration and delay. GPS can be effectively used to address such pain points in transportation. GPS enables smarter route mapping to avoid congestion. Re-routing decisions can be made in case of congestions. The data can be integrated using IoT from multiple sources such as weather forecast, traffic advisory, government services, policies (related to driver hours of service).

Vehicle Health Monitoring- All modern vehicles have a microchip installed which controls working and performance of the engine. This generates much real-time information on vehicle performance that can be used to help manufacturers and mechanics determine a vehicle's health. Drivers have access to this information now through devices such as automatic adapters which plug into a port to monitor engine health, along with an abundance of other capabilities (like tracking the vehicle to its parking spot). This information can be made available directly over the mobile through freely available apps. This makes vehicle maintenance easy and can save both time and costs of vehicle maintenance. The data on vehicle health can be shared with the garage and any issue can be documented, creating a predictive and efficient vehicle maintenance model. Thus, based on these details on vehicle's health, one can predict possible failures. One can use this to book the scheduled maintenance slot at the nearest in-route workshop. Failure codes give a reason and remedy for immediate repairing, and no matter where they are, drivers can catch the issues before they occur. In case of a major breakdown, driver can send details regarding breakdown of the truck, and consequently, a nearest truck can be identified and consignment can be shifted. This facility helps drivers greatly in tackling on-road hassles and vehicle breakdown/maintenance issues.

Invoice generation process – Generally, in the manufacturing industry, an invoice is generated as soon as a customer starts using the goods. However, there is no real-time system available to find the exact time of usage of goods. A physical visit is often carried out by field agents, which is usually done weekly or fortnightly, to check usage of goods and raise invoices accordingly. Looking at the volume involved, there is huge revenue loss to the manufacturer. In such a scenario, containers can be fixed with IoT sensors to send signals as soon as the container is opened and invoice can be raised accordingly. This can significantly help manufacturers in reducing losses. This will also help manufacturers specifically in short shelf life items, to keep track of the batches available in the warehouse and deliver them according to their date of expiry. This is a million-dollar idea, especially for FMCG companies, particularly in the food industry dealing with perishable items (with short shelf lives) or environmentally sensitive products since it minimizes loss by reducing downtime, generating huge value for the business (Verdouw et al., 2016; Verdouw et al., 2014; Ramundo et al., 2016).

Shippers can have real-time information about whereabouts of the truck and how far it has traveled, since the trucks are GPS enabled. This real-time tracking and predictability analytics can be used to find date of delivery, distance covered status, real-time traffic information such as traffic condition on each road, number of vehicles, and average speed, weather forecast, route diversion, over-speeding, stoppage etc. (Sijs et al., 2008).

Thus, this proposed mechanism will provide instant rates, insights into shipment delivery including available real-time tracking, lowering downtime time through the use of IoT. The admin, dispatcher, or end-user can track and access latest information, predict anticipated date of delivery, and other details on-the-go, anywhere, anytime. This will eliminate several bottlenecks while providing real-time location information, live monitoring of goods for shipment to customer's place, resulting in lower cost of investment. The IoT technology can provide benefits in improving visibility, reducing cost and travel, providing convenience, eliminating dependencies on middlemen, identifying and predicting future vehicle breakdown, and providing tactical information all throughout the process. Major advantage of this architecture is reduction in downtime, which is one of the biggest causes of cost and concern for transport organizations. Thus, upcoming freight marketplaces can train their machine learning models to match the right load with the right truck variant and routes.

4. Conclusion

In this paper, a novel IoT based app for smart transportation is proposed, using a hybrid of technologies (cloud computing, IoT and mobile application), to make the online transportation process easy for the modern end-user. This offers numerous advantages and conveniences such as handling traffic congestion, real-time tracking, vehicle health monitoring, emergency resolution and quick payment turnaround time, thus saving cost and time. Truckers can use the app to browse and book available trucks in preferred locations. These truck aggregators are leveraging technology to focus on the entire network consisting of demand-supply scheduling, GPS tracking, safety and maintenance of the vehicle, as well as mobile/web app support and cloud-based documentation. Transporters can gain intelligence on real-time traffic patterns, weather conditions, fuel efficiency while predicting maintenance and repair needs, leading to better speed management, sustainability and elimination of stress.

As per previous studies (Hashem, 2016; Bandyopadhyay and Sen, 2011), smart logistics have played a pivotal role in facilitating communication between customers and organizations, and also assisted them in handling real-time queries, leading to customer satisfaction by providing efficient and quality services. There are many sub-steps to the execution as well as pitfalls to avoid as a company goes through the implementation of a new supply chain network e.g., dependence of internet for vehicle tracking, inaccurate GPS tracking, and privacy and security issues. Appropriate planning is crucial for the success of implementation of a technology-based solution; for that, it is essential to involve all stakeholders in designing a smart transportation system. Working in silos may lead to poor

implementation. Every company has its own problems and complexities; the challenge lies in finding the best fit to appropriately address core objectives of smart transportation in a simple, environment-friendly, secure and connected solution.

5. Future Scope

Further research can focus on the dispatch and unload modules that can be redefined by including IoT sensors in each product. While unloading, alerts will notify both truckers and management when the shipment is opened, for fast invoice payment. This is also important in avoiding damages because conditions of some sensitive products can go awry during shipment,

Bios

Renuka Mahajan

Jaipuria Institute of Management, Noida, India, renuka.mahajan@jaipuria.ac.in, 009873605079

Prof Dr. Renuka Mahajan is working with Jaipuria, Noida in Information Technology (IT). She has completed her Doctorate in Computer Science and Engineering from Amity University. She has published research papers in various Scopus indexed International journals like Springer Education and Information Technologies, Journal of Information and Organizational Sciences, International Journal of Product Development, International Journal of Innovation and Learning, International Journal of Data Analysis Techniques and Strategies, International Journal of Logistics Economics and Globalisation, International Journal of Asian Business and Information Management, e-service Journal and several conference proceedings.

Preetam Suman

Jaipuria Institute of Management, Lucknow, India, preetam.suman@jaipuria.ac.in, 00987376333523

Prof Dr Preetam Suman completed his doctorate from the Indian Institute of Information Technology, Allahabad. His core areas of expertise include medical imaging, real-life applications of artificial, intelligence, and embedded systems. He is involved in a project related to implementing sensor networks in forests to save wildlife. He is nominated by various forums and associations in their committees. He has published more than thirty papers in international journals and conferences and various seminars organized by professional bodies and industry associations worldwide. Dr. Preetam holds professional associations with the IEEE Technical Committee, IEEE Young Professionals, Association of Knowledge Workers of Lucknow.

Richa Misra

Jaipuria Institute of Management, Noida, India, richa.misra@jaipuria.ac.in, 0098683578 92

Prof Dr. Richa Misra is working at Jaipuria Institute of Management, Noida. She has done her Doctorate in Management from Amity University. Her research papers and cases have been published in reputed journals like International Journal of Management Education, Elsevier, On the horizon Emerald, International Journal of Logistics and Economics, Journal of Information and Organizational Sciences, ECCH, Abhigyaan, BHU, IBS Business Review, Smart Journal of Management, Fortune Business Review and International Islamic University Malaysia. She has imparted training in various organizations in the areas of IT Security, Qualitative and Quantitative research methods, Data analysis etc.

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