



Smartphone Application, Blockchain and Data Protection Applied To Cargo Tracking

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ABSTRACT: Hazardous materials are substances with high commercial value and put in risk human health. Hazardous goods transportation must be tracked with privacy to avoid cargo theft. Smartphone application, blockchain, and data protection is a solution without disclosing information to validate the transactions.

Index Terms: BlockChain, hazardous materials transportation, smartphone, tracking control, traffic engineering, workflow, Zero-knowledge proof.

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I. INTRODUCTION.

Possible accidents involving hazardous materials can cause serious consequences for the population [2] and increase problems related to urban mobility [3]. Thus, on one hand, the greater the control and standardization of operating procedures for this type of transport, the better and safer it will be for society, on the other hand, hazardous materials have high value for thefts or terrorists, so their tracking process must be controlled [1].

The surveillance of government entities is not able to track 100% of cargo transport. This fact does not allow government authorities to take preventive measures and increases the time of identification and containment of a possible accident. In case of an accident, firefighters are putting their lives in danger by adopting standard procedures with basic protective equipment which is sometimes incompatible with the hazardous substance and cannot solve the problem. Traffic jams are a growing problem globally [4]. One way to mitigate these problems is the reduction of detection and actuation times.

In the factual workflow, the companies need to ask authorization to road Traffic Company that attributes a time window to execute the transport. There are constraints areas but the municipality doesn't have enough staff to surveillance and many times the drivers do not respect the planned route putting in danger many lives.

This paper proposes an evolution in dangerous goods transportation workflow considering the need for real-time tracking and cargos privacy. Real-time tracking can reduce the accident detection time and makes it easy to control them. Figure 1 illustrates the actual workflow of the dangerous goods transport authorization process.

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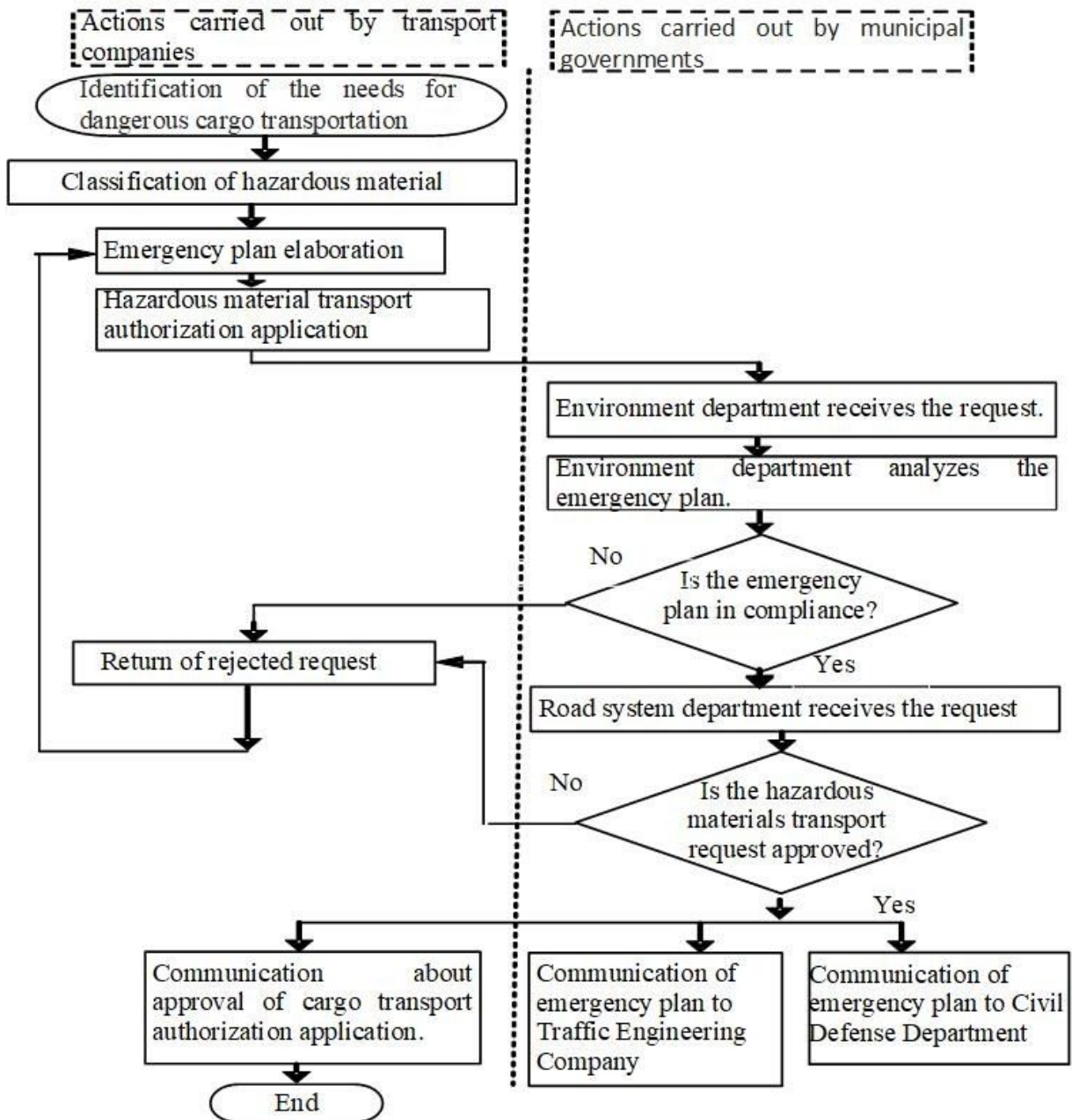


Figure 1 Actual workflow

The proposal considers smartphone applications, a central server to trace and track the truck drivers, and a particular protocol of blockchain, zero-knowledge proof [8], to ensure privacy.

Section II introduces the Integrated Operations Center, vehicle tracking by mobile networks, BlockChain architecture, and zero-knowledge proof protocol.

Section III shows the proposed workflow considering the real-time tracking and the application of zero-knowledge proof protocol in hazardous materials transportation. Section IV shows the results of the simulation. Section V possible future directions. Section VI concludes the paper.

II. RELATED WORK

A. Integrated Operations Center

Cities with high maturity levels have Integrated Operations Centers that are made up of different government departments with their legacy system. Despite several departments working in the same environment, not all information is shared. The lack of integration between different legacy systems thrusts aside the possibility of optimized transport route planning and increases the response time for abnormal conditions. Information and communication technologies are transforming transportation systems [1, 5].

B. Smartphone sensors

Smartphones have many sensors like accelerometer, speed, compass, altitude, latitude, and longitude.

Two location features in smartphones are used to location:

- The *GNSS_Provider* uses Global Navigation Satellite System-GNSS, it is accurate but slow.
- The *Network_Provider* uses the cellular mobile network, it is faster but isn't as accurate as GNSS_Provider.

The feature *FusedLocationApi* optimizes the two smartphone features and avoids excessive battery drain.

Security vulnerabilities for tracking solutions have privacy concerns that analyze United Nations patterns using dangerous goods classification [1,8].

Figure 2 presents the three families of smartphone sensors, GNSS, Radio Frequency, and embedded hardware [25].

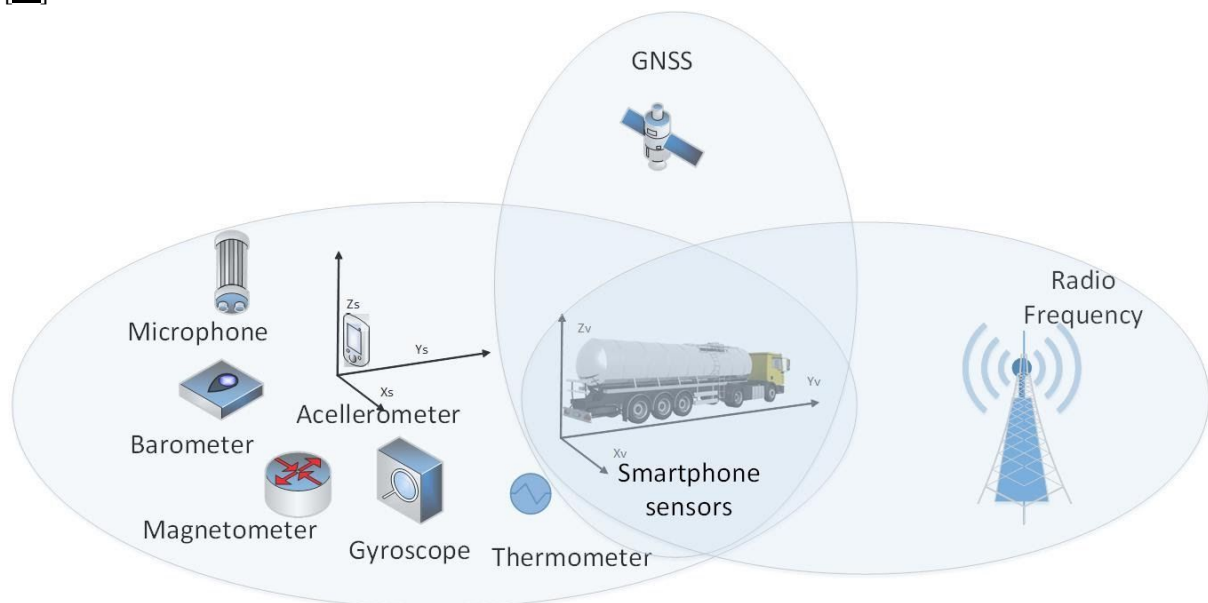


Figure 2. The three families of smartphone sensors, GNSS, Radio Frequency, and embedded hardware [17].

C. Smartphone application interface

There are development platforms used to support applications to collect data from smartphone sensors and handle statistical data [9].

There are four main data acquisition APIs:

- SensorApi* - Read sensor data
- RecordingApi* - Provides data collection and storage on servers.
- SessionsApi*- Provides the application to manage user activity sessions.
- HistoryApi*- Provides access to the database with data insertion, deletion, and reading capabilities.

D. Tracking technologies

Many companies offer their services of tracking systems, which are proprietary systems with high costs of acquisition and maintenance. They often require the installation of an on-board device inside the vehicle, which is difficult to be installed and costs a lot of money. Smartphone applications to track vehicles is a modern and cheaper solution. 5G is considered the IoT generation that can connect virtually any type of device, including smartphones and vehicle-embedded modems. The 5G promises to transfer core-to-edge functions; it will significantly reduce latency in critical mission operations such as collision avoidance functionality [6] and will make feasible the connection between two smartphones, D2D –Device to Device function[7].

The proposal ties smartphone id and vehicle id, so vehicle location, x y z axis acceleration information is collected from the smartphone sensors and transmitted through carrier base stations that provide a coverage

area and forward by packet data networks [1]. The vehicles are tracked in real-time like a flight control room. Any abnormality alert the integrated operations Center and any route change need can be sent from the integrated operations center control room to the truck driver.

Figure 3 illustrates the communication between the smartphone and the central server.

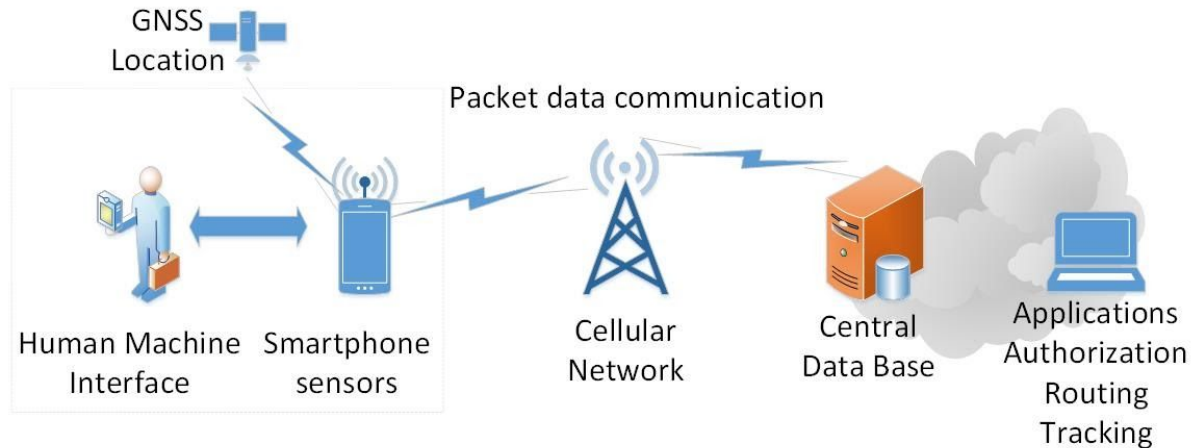


Figure 3. The communication between the smartphone and the central server.

E. Blockchain

Blockchain has been applied as a security technology using electronic signatures, public keys, and hash functions [10,11]. Blockchain works as a ledger in which a new record needs to verify its predecessor generating a chain, the more blocks in the chain the more robust and less susceptible to tampering. Any block of the chain has its owner public key that creates a hash with the block information that makes it cryptographically secure due to complex mathematical algorithms that are very hard to break. Its predecessor block verifies and validates the hash without knowledge of the block information. Every single operation performed by the network modifies simultaneously all full nodes.

Blockchain has been applied to Bitcoin, a cryptocurrency, and Ethereum, a public database that keeps a permanent record of digital transactions. To determine which path is most valid and prevent multiple chains, Ethereum uses a mechanism called the “GHOST protocol.” “GHOST” = “Greedy Heaviest Observed Subtree”, in other words, the path with more blocks of the chain.

For a malicious cracker to falsify the blocks information is necessary to change at least 51% of the blocks to obtain the dominant majority to be a believable chain, something impracticable for large chains.

There are 3 types of Blockchain[11]:

- Public Blockchain: A Blockchain that can be accessed, changed, and verified for any user.
- Consortium Blockchain. Pre-selected users can verify the Blockchain.
- Private Blockchain: The writing permissions are kept centralized in the organization.

The zero-knowledge proof protocol is a technique that can prove a transaction information without disclosing it [10] because the information isn’t inside the blocks, it is stored in a Central Server.

III. PROPOSAL OF WORKFLOW, AUTHENTICATION, AND DATA PROTECTION USING BLOCKCHAIN

IV.

A. Proposed workflow.

Figure 4 presents the proposed workflow, in addition to the transport authorization workflow, there is real-time tracking with the possibility of optimizing and changing routes.

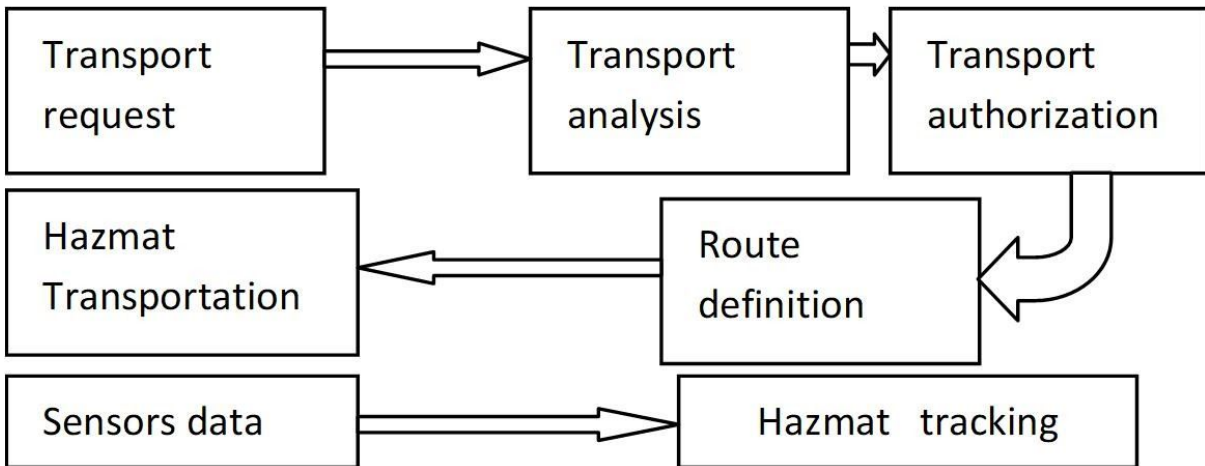
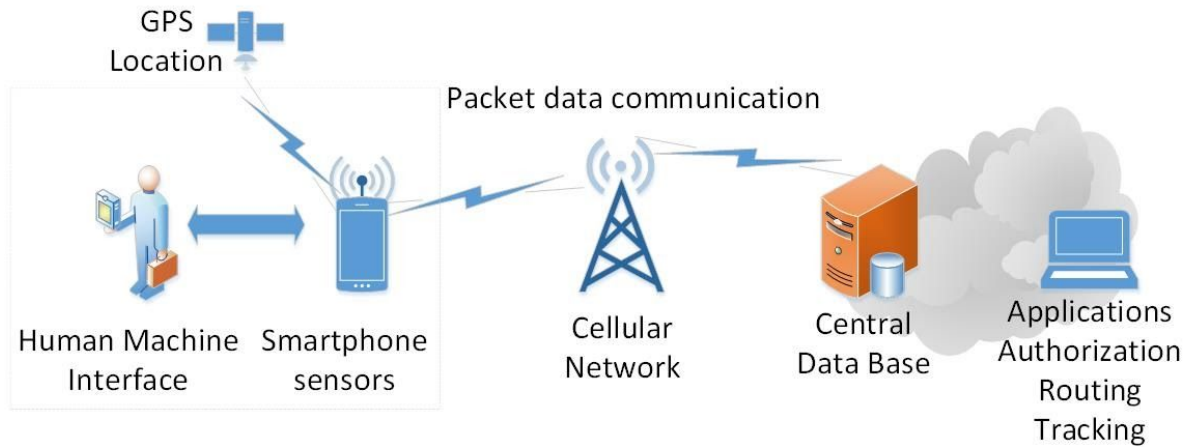


Figure 4. Proposed workflow.

B. BlockChain application

Figure 5 shows the architecture of hazardous materials transportation BlockChain. Considering several drivers from different companies the best way to standardize the communication between the trucks and the Integrated Operations Center is a smartphone application.

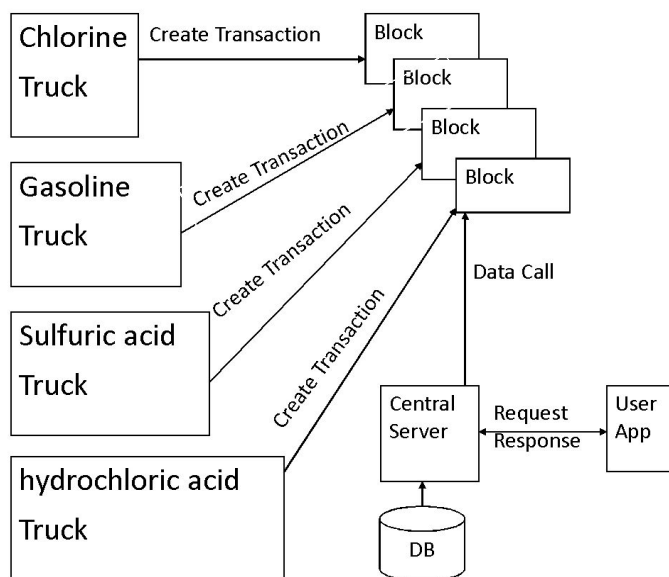


Figure 5. Architecture of hazardous materials transportation BlockChain.

Every truck driver must carry a smartphone with a tracking application defined by the Integrated Operations Center which creates each transaction. Each device has its module for transmitting tracking data that is stored in a BlockChain [11] tracking control. The Central Server is hosted by the Integrated Operations Center and allows access to authorized users only.

C. Signaling diagram

Figure 6 shows the smartphone authentication and data transmission sequence diagram. The user starts the registration with "smartphone ID", "user ID" and "password" to Central Server. The Central Server requests a new account in the blockchain using the typed password. The blockchain responds with address to Central Server, The Central Server stores "Smartphone ID", "user ID" and "address" in Database.

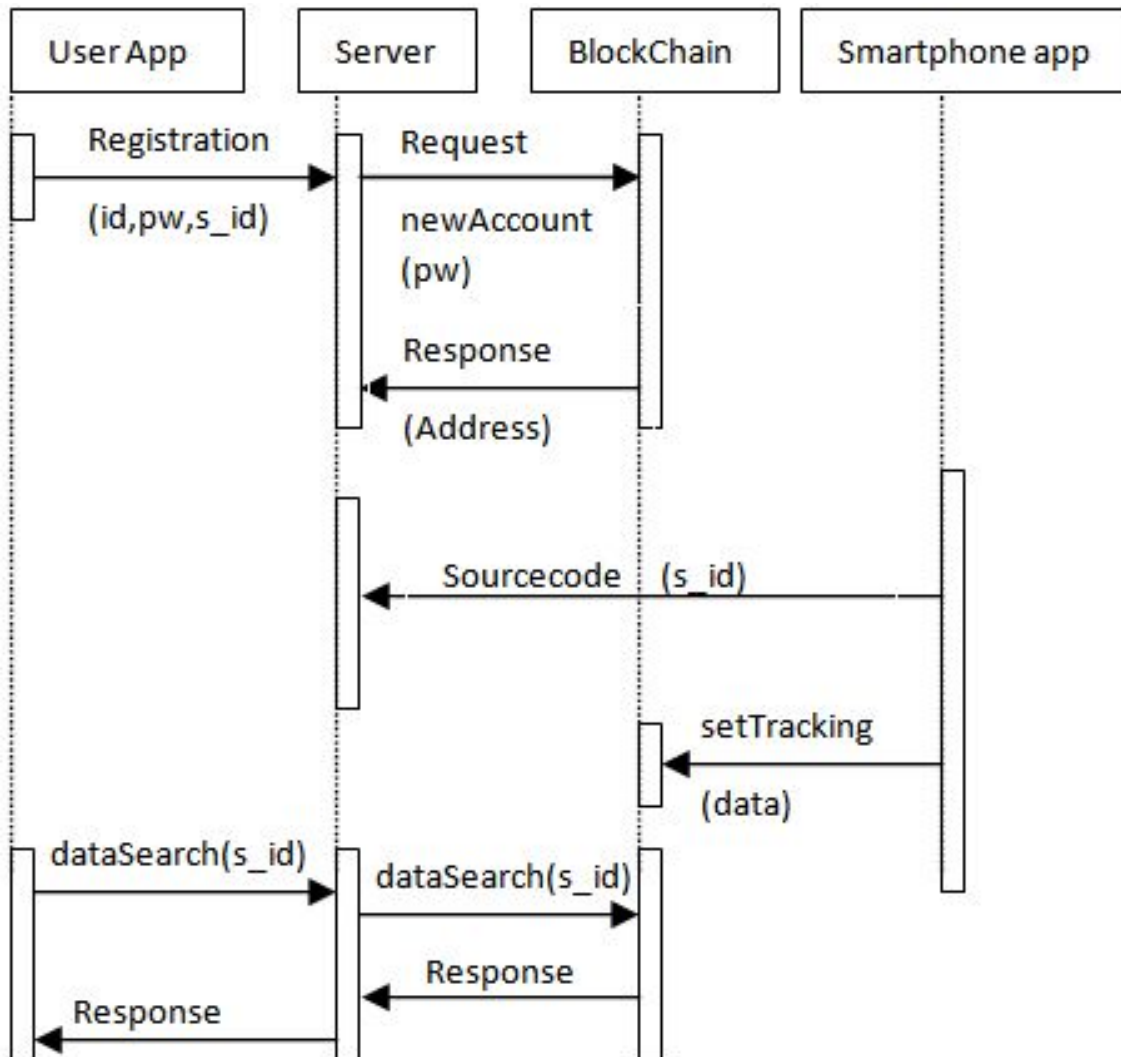


Figure 6. Smartphone authentication and data transmission sequence diagram.

When the hazardous materials transport starts the smartphone app receives the source code stored in the Central Server and sends the tracking information and receives new route constraints. The Integrated Operations Center accumulates the tracking information and stays alert to take emergency action for any abnormalities.

D. Zero-knowledge proof authentication protocol

Figure 7 shows the application of zero-knowledge proof authentication protocol [10] where it builds the hash code without the original information which is stored in the Central server and keeps it protected even if a malicious cracker tries to miner the blocks to get confidential information like the type of hazardous material, quantity, location. The central server will be responsible for mining new blocks, keeping the consensus, and preventing 51% attack.

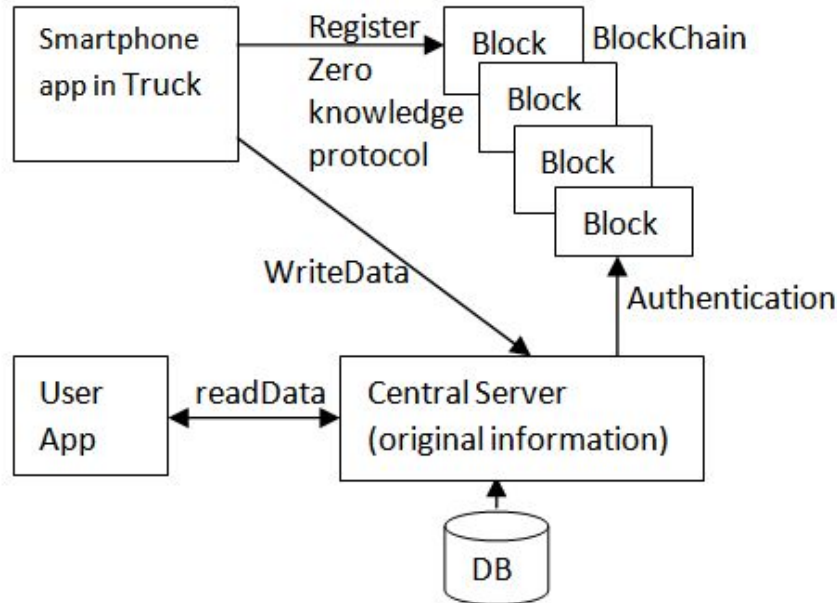


Figure 7 The application of a zero-knowledge proof authentication protocol.

V. SIMULATION

This section uses a simulation of accident obstruction to measure the benefits of better transport control. Considering the capacity of 2000 vehicles/hour/lane as the rhythm of attendance, according to HCM2000 limitation [20], and real-world data collection from an avenue with 6 lanes with an arrival rate of 193 vehicles/minute. Considering an accident blocks one lane, it produces traffic jam as big as the obstruction time: (1) Detection time, 15 minutes is the average time to a patrol detect the accident (2) field teams' displacement time, 45 minutes is the average time to field teams move from headquarter to an affected location (3) removal and release of pathways time, 90 minutes is an average time to remove vehicles without complex leak of hazardous substances.

Based on São Paulo Traffic Engineering Company – CETSP [12], better control can promote a reduction from 150 minutes to 93 minutes of obstruction time per accident. The detection time reduces to 3 minutes, considering the on-line surveillance, tracking vehicles, filtering, and classifying the alerts. The field teams' displacement has no changes, and the removal and release time of pathways reduces to 45 minutes, considering the knowledge of substance characteristics, the field team can control the situation with a better approach.

Figure 8 illustrates a 150-minutes obstruction time after an accident, in the current situation.

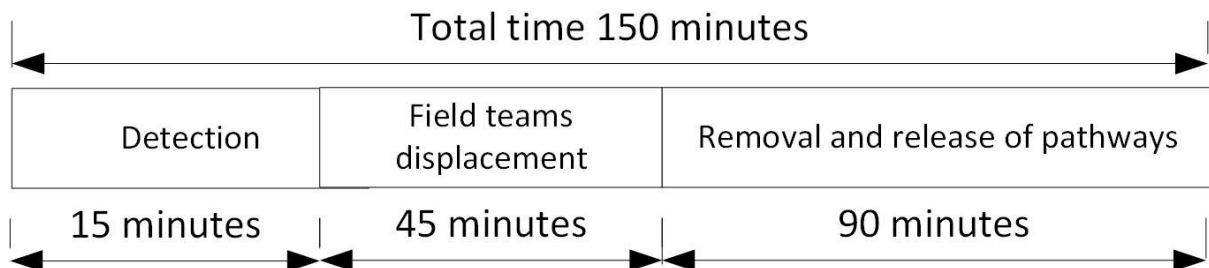


Figure 8. The events of an accident composed of detection, travel, and removal time without improvements.

Figure 9 illustrates a 93-minutes obstruction time after an accident, with improvements, in the proposed situation.

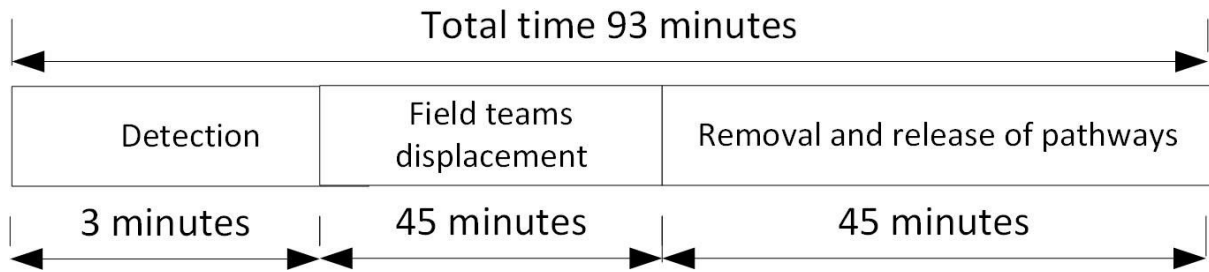


Figure 9. The events of an accident composed of detection, travel, and removal time with the use of improvements.

The simulation considers 6 lanes of 2.8 km of an express avenue with an attendance rate of 2000 vehicles/hour/lane. While one line is obstructed the total attendance rate will be lower than the arrival rate, so the traffic jam queue appears.

In normal conditions, the traffic flow capacity is 12,000 vehicles per hour. One lane obstruction represents a bottleneck of 10,000 vehicles per hour attendance rhythm against an 11,580 vehicles per hour arrival rhythm.

Figure 10. Illustrates the scenario simulated in Rockwell Arena [19].

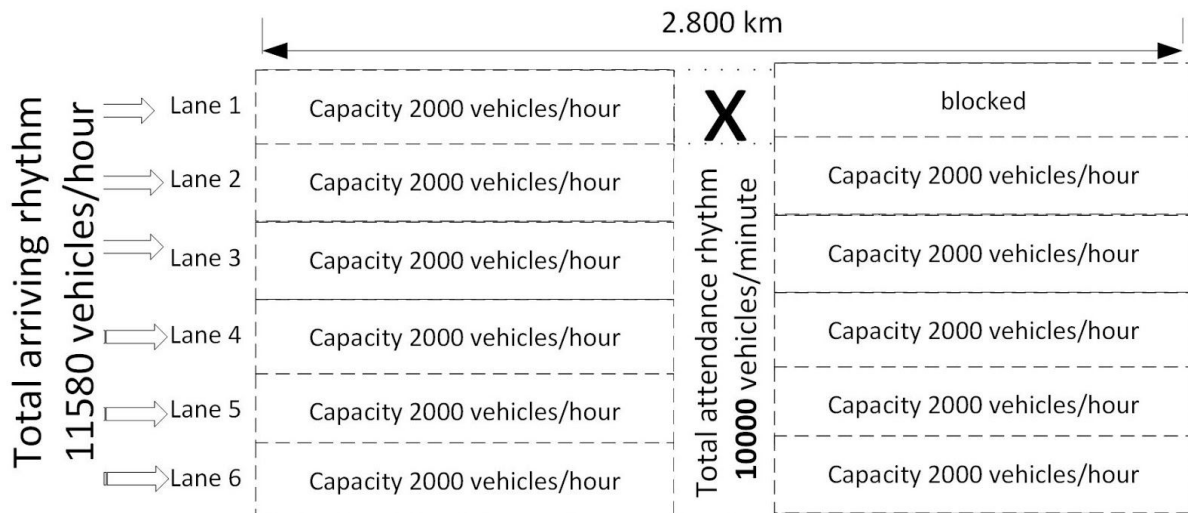
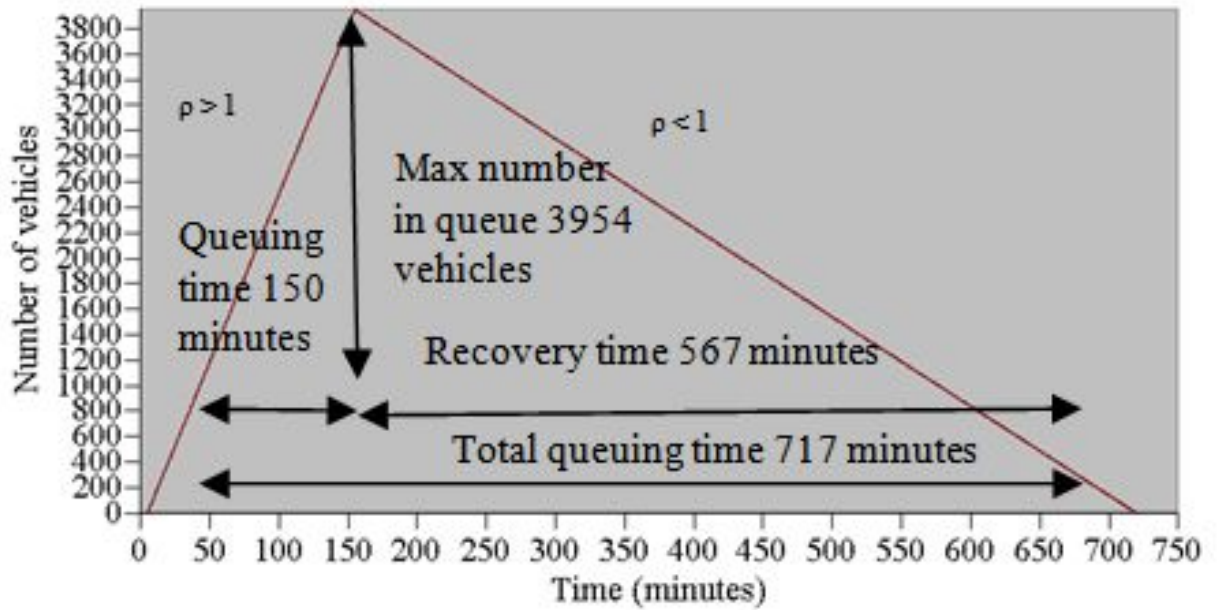


Figure 10. The scenario simulated in Rockwell Arena.

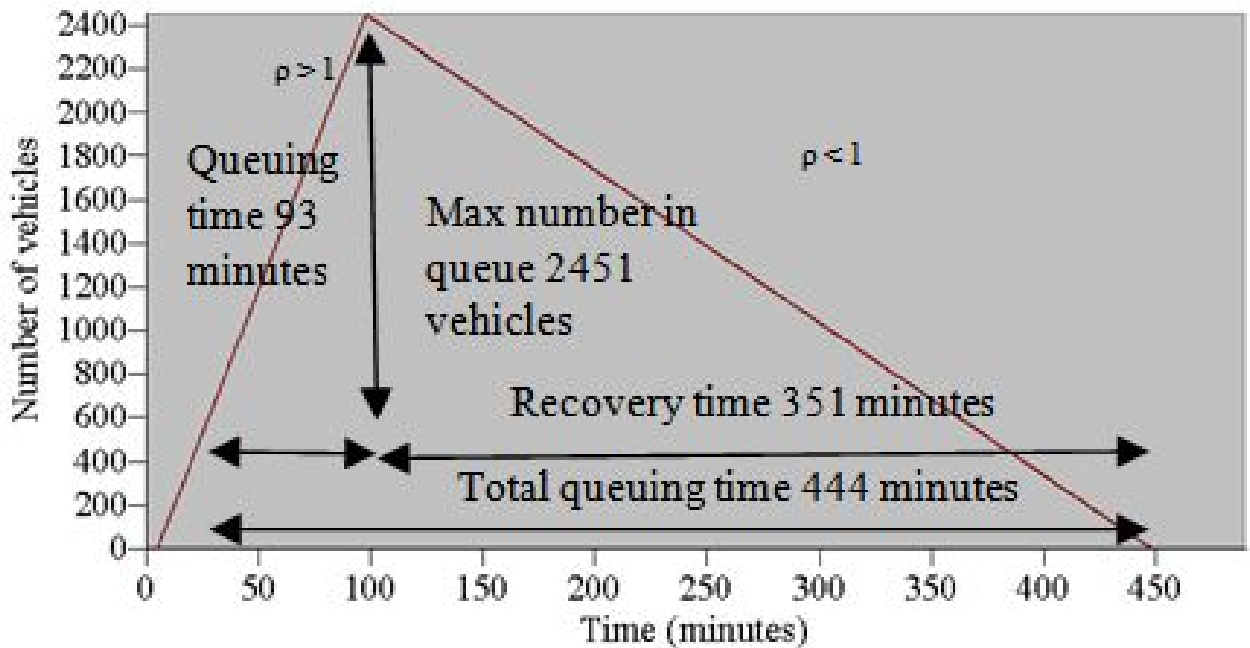
Figure 11 presents the results of the simulation. The impact caused by a congestion, called total delay [18] is the area between the arrival and the departure function, the unit is vehicle.minute. The congestion charge ρ is determined by the relationship between the arrival rhythm and the attendance rhythms. When ρ is less than 1, the system is considered stable, recovery time, when ρ equals to 1, the system is under critical load, and when ρ is bigger than 1, the system is considered supersaturated, queuing time [19].

- Graph of the number of vehicles queued in 150 minutes obstruction and 717 minutes of total queuing time.
- Graph of the number of vehicles queued in 93 minutes obstruction and 444 minutes total queuing time.
- Simulation graphic with the 150 minutes obstruction, the difference between arrival and departures function represents the queue, which has a maximum of 3954 vehicles.
- Simulation graphic with 93 minutes of obstruction, the difference between arrival and departure function represents the queue, which has a maximum of 2451 vehicles.

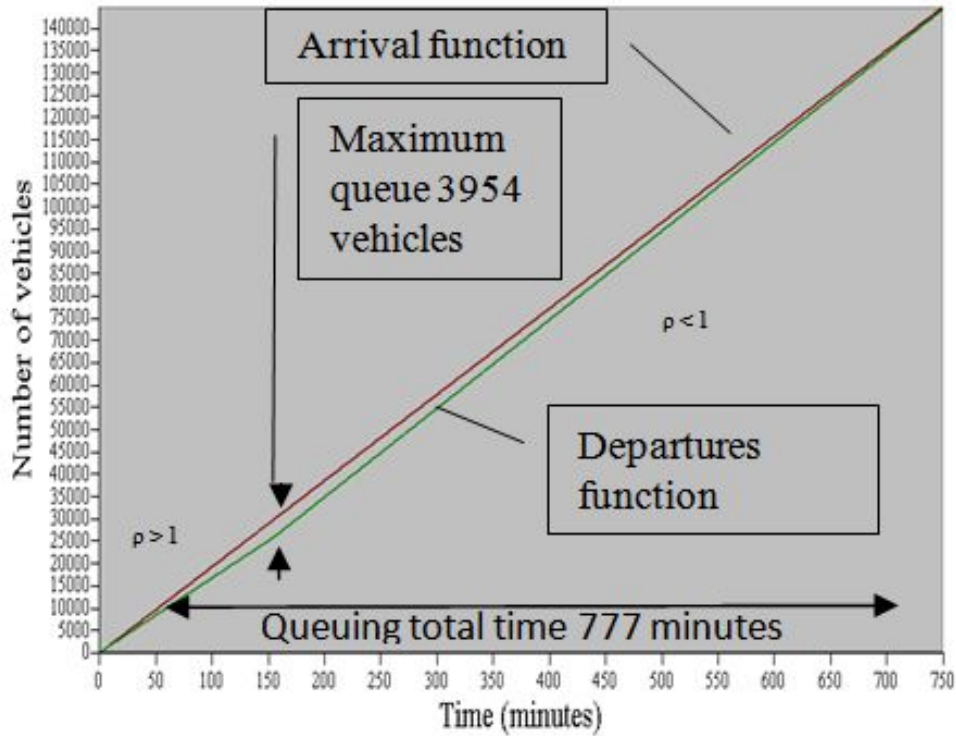


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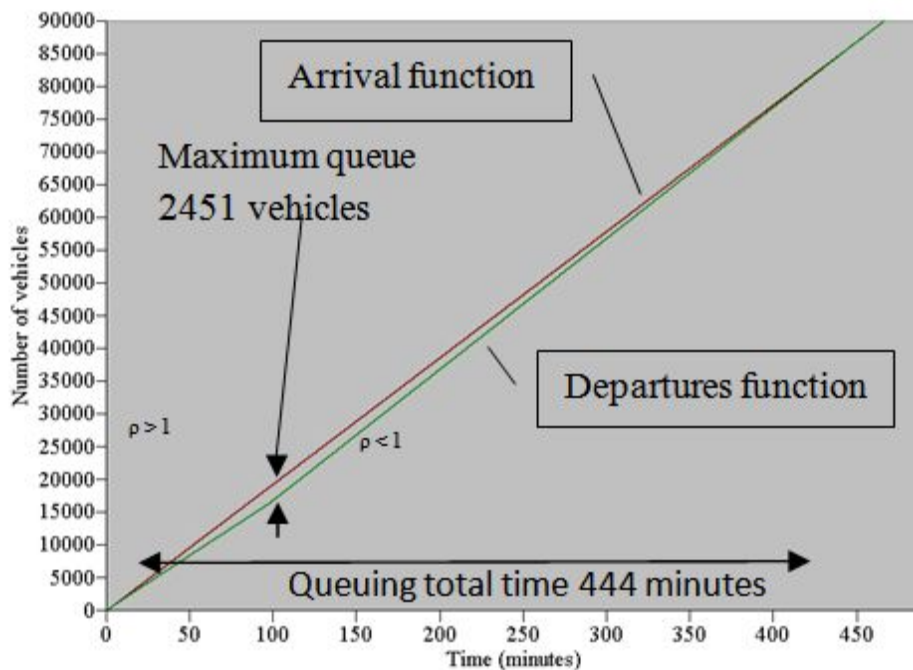
11.a) 717 minutes of total queuing time.



11.b) 444 minutes total queuing time



11.c) maximum queue of 3954 vehicles



11.d) maximum queue of 2451 vehicles Figure 18 Graphs with simulation results.

Table 1 compares the effects of a reduced obstruction time, 150 minutes obstruction without smartphone integration, against 93 minutes obstruction with smartphone integration.

Features\ Simulation	150-minutes obstruction	93-minutes obstruction
Total waiting time	717 minutes	444 minutes
Maximum quantity of the vehicles in a queue	3954 vehicles	2451 vehicles
Congestion impact or total delay	1,418,269 vehicles.minute	545,182 vehicles.minute

Table 1. Simulation results with one lane obstruction.

Figure 12 shows the graph with the reduction in vehicle output per delay in total minutes, considering the time and delays in queues. The arrival rate is the same as 1930 vehicles/hour. Considering 2000 vehicles/lane/hour flow capacity the maximum capacity to a human reaction, to higher flow capacity is necessary high technology to reduce the space between vehicles and improve their speed, this technology isn't available now. According to a simulation of 2000 vehicles/lane/hour capacity, 873,087 vehicles.minute was reduced with smartphones integration. As there is an average of 20 accidents involving dangerous cargos per year in the municipality of São Paulo, it is estimated that in one year a total of 17,461,740 vehicles.minute traffic jams will be reduced; 582,058 liters of gasoline will be saved [15] and 2.000 tons of CO₂ will not be emitted [16].

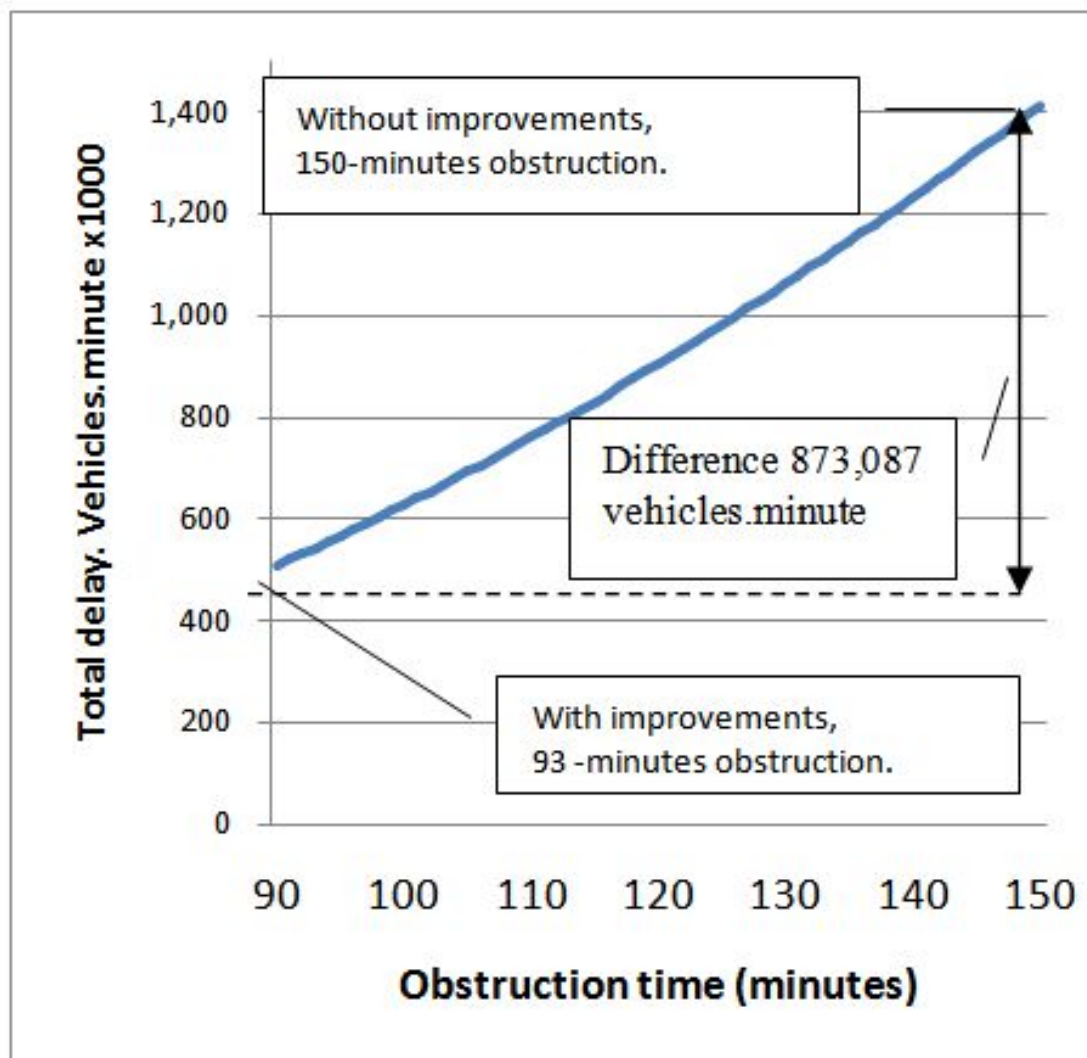


Figure 12. Graph of total vehicle delay as a function of blocking time.

VI. POSSIBLE FUTURE DIRECTIONS

As the continuation of this research work, it is suggested to:

- Development of mobile applications, focusing on security access to traffic data.
- Estimate and analyze the possible theft reductions of dangerous cargo vehicles and extend the study to other cargoes.
- Develop proposals for integration with other studies such as medicine tracking, cattle tracking, blue channel, paperless port, and other forms of integration with revenue tax collection [14].
- Estimate and analyze the possible saving of human lives by avoiding accidents, the cost of social assistance to injured people, and any victims of indirect effects such as exposure to gases and toxic materials spills.
- Incorporate the improvements functionality in the Vehicular Ad Hoc Networks (VANETs).

VII. CONCLUSION

The implementation of improvements in hazardous materials transportation will bring a lot of benefits:

- a) Improvement in surveillance avoiding disclosure of hazardous materials transportation.
- b) The driver trucks must obey a planned route avoiding risks of hazardous materials leak in constrained areas.
- c) Reduction of the lost time: The average origin-destination time in big capitals is also directly related to the duration of traffic jams. Thus the reduction of the roads obstruction times will have a significant impact on the quality of the lives of passers-by and will consequently bring productivity gains in the professional sector as well.
- d) Economic gains: According to INMETRO [15], the average fuel consumption for light vehicles is around two liters of gasoline per hour in a queue. Thus, in the simulated scenario, the fuel-saving generated per year with the eventual implementation of improvements will be around 582,058 liters of gasoline.
- e) Environmental gains: According to the limits determined by CETESB [16], the CO₂ emission per light vehicle is at about of 181g/km and 108,6g/minute when the vehicle is at a standstill. Thus, the implementation of improvements will allow a reduction in annual emissions of carbon dioxide, the main greenhouse effect gas, around 2,000 tons, as well as a reduction in the emission of other pollutants such as carbon monoxide, nitrogen oxides, and hydrocarbons, since average trip times will be much shorter.

In the case of the leak of hazardous materials, in addition to mitigating the detection time, there is a reduction in combat time, with prior knowledge of the field teams which saves the lives of the field team members and the affected population. The leak of hazardous materials can contaminate soil, rivers, groundwater, and air.

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