Agent-based Model for Smart Long Distance Transport System

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***Abstract*—Long distance transport is playing vital role in economic growth of countries. However, there is lack of systems being developed for monitoring and support of long route vehicles (LRV). A sustainable transport system with modern technologies is needed. We propose a model for the long distance vehicle transportation monitoring and support. Our model incorporates the distance vehicle transport mechanism through agent based modeling (ABM). This model constitutes design protocol of ABM called Overview, Design and Details (ODD). This model is proposed with the assumption that every category of agents is offering information as a service. We need federation of services through protocol for the communication between sensors and software components. This integration of services will be used for monitoring and tracking of vehicles on the route. Hence, this model provides an integration of services based on smart objects.**

I. Introduction

The economy is impacting the transport sector and vice versa [10]. Thus, detecting changes and forecasting future freight flows and freight transport demand is a task of great importance. [2] Long distance transport has both negative and positive effects on our economy and society. These effects relate to the economy and social welfare. Long distance freight transfer booms the economy and generate a wide range of employment for common people and business opportunities for the investors. However, in countries like Pakistan where there are not many systems that are developed for the tracking or monitoring of long distance vehicles, this transportation medium is not very productive. Thus, causing negative impact on economy due to long delays in transportation of goods. Some of common problems faced by the long distance vehicles range from small breakdowns to stolen goods or vehicle. While other effects like weather, lack of knowledge about the rest areas, fuel stations, vehicle service areas, road police or ambulance services for any emergency situation is lacking due to minimum or no communication with the vehicle owner company and other help services. The problems also extend to local public authorities causing blockage on roads on local, regional or national level to mega economical issue of not reaching goods from one part to other.

Therefore, a need arises for a sustainable transport system incorporated with modern technologies that is capable of fulfilling the transport needs of society. At the same time, there is need to hinder the negative effects of long distance transportation. By incorporating various types of technologies currently available and other infrastructural measures, it is often possible to influence how these actions are selected and executed.

There has been a lot of research done on the scheduling and routing for the long distance vehicle. We propose a model for the long distance vehicle transportation. Our model incorporates the distance vehicle transport mechanism through agent based modeling. We check our model to basic design protocol of ABM called Overview, Design and Details (ODD). As we assume that every category of agents is offering it information as a service so we need a service oriented protocol for the communication between sensors and software components for monitoring and tracking of vehicles on the route for better transportation. For the service protocol we incorporate concepts of internet of thing. Our proposed model incorporates the different services offered by each entity. This section presented the introduction of our work.

The remainder of this paper is organized as follows: In Section 2, we briefly describe some background study that for the better understanding of used concepts. Section 3 illustrate our ODD agent based model . Section 4 describes a relevant scenario as we have made scenario-based validation. We conclude our paper in section 5.

II. Background

Technology plays an important role for tracking and monitoring things far away. The term used for intelligent and connected devices is called Internet of Things. The Internet of Things (IoT) [10] is a recent phenomenon that have attracted the attention from both academia and industry. The European Commission has already predicted that by 2020, there will be 50 to 100 billion devices connected to the Internet. [8] IoT has the concept of being connected people and things anytime, anyplace, with anything and anyone, ideally using any path/network and any service. [2]

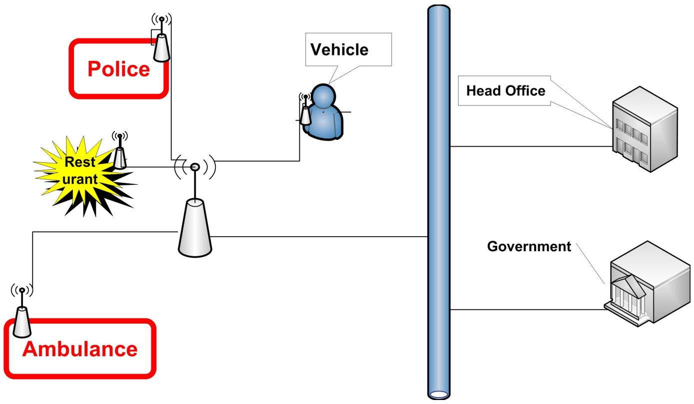

Fig. 1. Conceptual Diagram of LRV Monitoring and Support Model

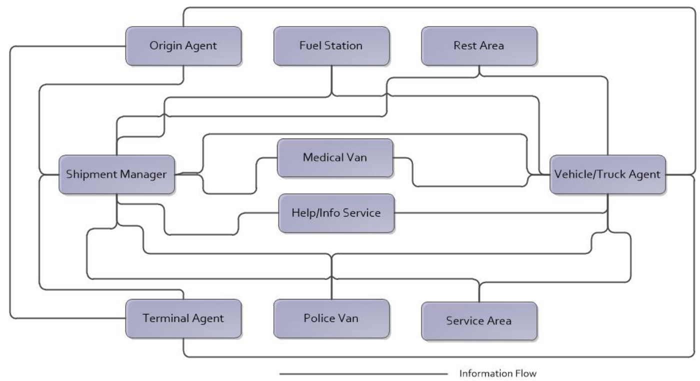

Fig. 2. Conceptual Diagram of Agents Interaction

The concept of offering Everything-as-a-Service (XaaS) [1] is a category of models introduced with cloud computing. Agent-based modeling (ABM) is used to model systems that are comprised of individual, autonomous, interacting “agents”. ABM thus follows a bottom-up approach to understanding real world systems. [5]

A lot of work has been done on the tracking and monitoring of long distance vehicle using real time and passive system. In [7] a low cost vehicle monitoring system is presented. Work states that shipping industry has developed many tracking and monitoring systems first to determine where each vehicle was at any time. While in the modeling perspective there are number of models predicted for the long distance vehicle transport. Recently, also a number of agents-based freight transport analysis models have been suggested, e.g., INTERLOG [4] and TAPAS [3], which belong to the class of micro-level models, where individual entities are represented and the relations between entities are typically studied over time.In [9] a running inter-modal transport service was used as a case study. The performance of the inter-modal transport service was compared against a potential road transport service for a set of mode choice variables, including: price, transit time, reliability and flexibility.

III. LRV Monitoring and Support Model

Agent Based Modeling has been itself grown into vast field so it is difficult to keep all of the model’s characteristics in mind. Many descriptions of Agent Based Modelings presented in literature are not complete, that makes it impossible to replicate and re-implement the model. However, replication is key to science. Scientific models must be reproduced otherwise it is not scientific model. Also the agent based modeling descriptions are lengthy mixture of words of factual description and these include long justifications, discussions and explanations of many kinds. We have to read a lot about the model to understand even if model itself is quite simple. The way to describe ABMs should be easy to understand yet it should describe complete model. A known way to deal with such kind of problems is standardization. It is much easy to know and understand written material if the information is presented in a standardized way and we know the order of textual information. So a consistent protocol that is effective for Agent Based Modeling becomes useful and it makes it easier to understand and write models.

To bring the benefits of standardization to ABMs, a large group of experienced modelers [6] developed the ODD protocol for describing ABMs. “ODD” stands for “Overview, Design concepts, and Details”: the protocol starts with three elements that provide an overview of what the model is about and how it is designed, followed by an element of design concepts that depict the ABM’s essential characteristics, and it ends with three elements that provide the details necessary to make the description complete.

A. Agents

After the analysis of literature and problem domain we identified agents that are involved in the interaction. Several agents were identified to model are shown in Fig. 1 and their interaction is shown in Fig. 2.

- Vehicle (trucks)
- Fuel station
- Rest Area
- Rescue/Medical Van
- Police Van
- Service Area
- Vehicle owner/manager company
- Origin agent (freight sender, shipment agent)
- Terminal agent (freight receiver)

1) Origin Agents : Origin agents are the agent that are the supplier/sender of goods. These are generated at beginning of transport by booking with a transport company.

2) Terminal agents : Terminal agents are the agents that are receiver of the goods. Both origin and terminal agent share information through transport/owner company about the state of delivering vehicle.

3) Owner company/Transport company : Owner/transport company is central agent in the context as it is responsible for monitoring of vehicle. In case of any issue with vehicle the transport company interacts with the police vans present near the vehicle signal or in case of signal loss. These agents store all the information about vehicle movements.

4) Vehicle: Vehicle agents are the actual trucks containing the good. They interact with all other agents which are helpful for making a successful transport. The term we refer connected as "connected smart objects". Smart objects interact with each other throughout the journey and provide better decision making for vehicles and other agents.

All other agents are helping agents in case of emergency or need. Interaction with help service agent is assumed to be generalized for any kind of service at this point of modeling. As we make our model more concrete we will define the specific help service and its interaction with other agents.

B. Behavioral modeling using ODD model

1) Overview :

- **Purpose**

The purpose of model is to design the movement of long distance vehicle transportation, their interactions with the other helping agents and finding out the behaviors of agents over time. Under what circumstances do the vehicle need to contact to police services, rescue services, rest areas, fuel stations or any other agents. By understanding the need of any kind of service needed by vehicle we can predict the time to reach destinations during any trip. We can efficiently provide information to vehicles in need of any kind of emergency situations as well as the road and weather conditions to avoid any breakdowns. By gathering the data after applying the model we can predict why a vehicle takes more time to cover a distance. How often vehicle needs interaction with other agents, and how these interactions will take place.

- **Entities, state variables and scales**

The modal has several kinds of entities including vehicles (trucks), shipper and receiver agents, help and control services, fuel stations and rest areas. Each entity has some basic attributes to model for observing their behavior. To model the entities, we need to model roads and agents. Geographical road forms the patch areas. This can be road on square grid for testing purpose. For real system this is obtained as location of any agent on the ground. With each location has two variables longitude and latitude. Agents are described by which position they are on. Vehicle has variable like speed, fuel capacity, reliability, travel time, load carrying, travel direction, vehicle category etc. Police vans have variable coverage in which those can operate, it may be free or already engaged with some other agent. Same like for the rescue services. Fuel stations may indicate the level of fuel they have, and their locations. Rest areas must be divided category wise as well as the services they offer.

- **Process overview and scheduling**

There are multiple processes in the model, basic process is movement of vehicle (trucks) from one point to another. Interaction to other agents like police, service areas, ambulances or any other service also forms a new process. However, interaction with other vehicles in somewhat nun-important because there is no interaction with other vehicles. So, number of processes are formed during the vehicle transportation while interacting with other agents. Scheduling is also an important aspect for interaction processes in case of unavailability of an agent service. There is need to schedule the vehicle requests to services if an agent instance is not available for temporarily or permanently.

2) Design concept :

- **Emergence**

The concept of emergence has been given connotations being unexplainable in principle, but with ABMs we are focusing on just the opposite: can our model system look and behave like the real one? The concepts which emerge from model are not simply sum of individual characteristics. Whether between any given two points same type of vehicle take different time at same load. The variability in behavior of individuals make some property to emerge from model. The model primary value is trip duration. Trip duration is counted as time taken from starting point to ending point.

$$TotalTime(actual) = \sum_{i=0,j=1}^{n} \Delta Tij \tag{1}$$

Where total time is calculated as sum of time during each checkpoint up to n-number of checkpoint. During the trip number of checkpoints are defined for continuous monitoring of vehicle time. Typical actual/observed time duration between two checkpoints is defined as:

$$\Delta T(actual) = Tcp[j] - Tcp[i] \leftrightarrow i < j \tag{2}$$

$Tcp[j]$ is time observed at current checkpoint, $Tcp[i]$ is time observed at previous checkpoint. This observation is compared to average time between two checkpoints and number of parameters are updated depending upon the total time consumed T and Δt by vehicle. If a vehicle is behind the schedule, route minimization is updated for vehicles such as taking short rest periods and increasing average speed within acceptable limits. Important secondary values are reliability improvement, threats faced and breakdown.

- **Observation**

ABM can produce many kinds of dynamics. What we can learn depend upon what we observer from it. We need to observe each entity; what individual are doing at each time. So in our model we observe each entity to know what they are doing at any time. These observations form a result which predict the outcome of a specific process.

- **Adaptive behavior**

The agents in this model adapt themselves during the trip. For example, if weather forecast is bad for a specific area, the agent may rest early and take longer trip later when situation is better for traveling. Adaptive behavior is most needed in agent based modeling and model entities must adapt to best available solution at any given time.

- **Sensing**

Sensing is most important to this model. Vehicle agents with help of on board unit should sense their current location and time to reach to their next checkpoint. It is assumed that on board unit will calculate the time to reach till next checkpoint. Certain help services offer their services to vehicles during the trip to get better observations. By accessing the location of vehicle, location of next checkpoint and average speed for the current area the time to reach next checkpoint is calculated.

$$Time-to-reach-checkpoint = \frac{Dvj}{ASij} \tag{3}$$

Where Dvj is distance between vehicle's current position v and checkpoint j.

$ASij$ is average speed of vehicle between checkpoint i and checkpoint j.

- **Prediction**

Prediction is fundamental to decision making. Prediction plays an important role for the evolution of our model. This cannot be done by the vehicle itself, rather it can be analyzed over the time by the management company to help in better prediction of tour for a specific route. We can predict why a vehicle extra time in an area? We can predict behavior of breakdowns while observing a vehicle and area's breakdowns. Upon this kind of knowledge, we can make better decision making and prediction.

Let s be a sensor then the super choice will be

$$S_s = Sup(s1, s2, s3, ..., sn) \tag{4}$$

Nearest Criteria choice will be

$$N_s = N_r(s1, s2, s3, ..., sn) \tag{5}$$

whereas, best choice will be

$$B_s = Aggr.(B_s \bigwedge N_s) \tag{6}$$

- **Interaction**

This model include interaction with other agents like police vans, ambulance and service areas in case of emergency. The vehicle must transmit a signal to management company, police station, service area or medical help in case of vehicle damage, some emergency or threat. Vehicle must be contacted by owner company for further investigation. The other agents like police vans, ambulances must also be notified about the nature of incident.

- **Stochasticity**

Variability in the movement of vehicle is too complex to represent. We may not be sure why a vehicle is taking longer time than expected in a certain area. The movement of agents cannot be the same for each trip within a specific area. This variability is represented by reliability of moving vehicle. The higher the reliability the higher chances that vehicle moves as per expectations through that area.

3) Model Details :

- **Initialization**

For initialization of model we need to initialize the landscape upon the vehicle has to travel. Initial population can be set in any range. We can increase or decrease the population. Initial parameters like vehicle reliability and service availability are set in start.

- **Input**

The model does not need any time series data.

- **Sub models**

Models divided into further sub models. A vehicle can use alternative paths during the course of travel. The available services may not be available when needed also makes a sub model which is needed to be address.

Police Service Model

We breakdown the model into set of sub models, the interaction of a vehicle with the police vans forms a sub model. Police vans are the agents that provide help services in case of danger of theft or accident during the trip. Each police van agent can communicate to vehicles within their predefined area and mark their service availability or unavailability.Fig. 3 shows the simple service provision model for the interaction between police van and vehicle agents. Police vans are the agents that are placed on the long-distance roads for the help of vehicles in case of emergency. Police vans are limited to cover a specific area assigned to them to offer services. Vehicles generate request for the help service in an area. If the van does not have a pending request to process, it will mark itself as available agent to offer its services. If the police van is already engaged with another assignment, it will check whether the new request is in way to current request the van is handling van can provide service in way. If new request is not in the current direction of van it is to be marked engaged and request is transferred to other

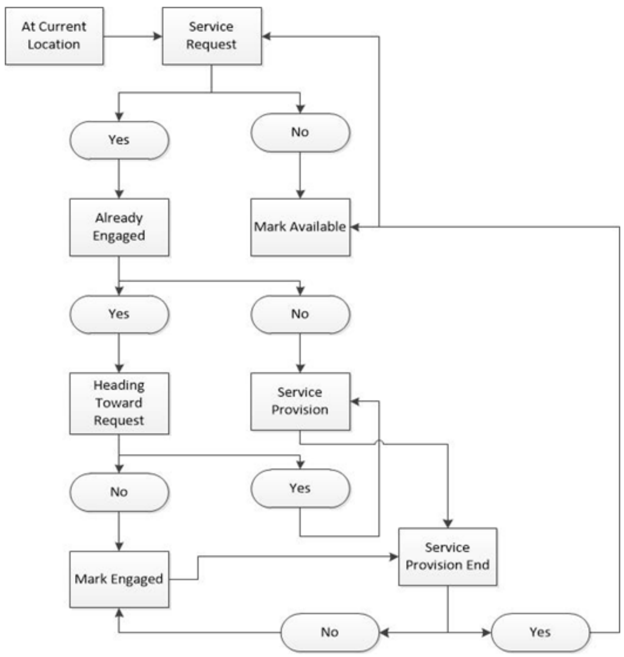

Fig. 3. Police Van Service provision Sub-model

vans. When the provision of service ends, van will mark itself available for service.

Fuel Station

Vehicle agents can interact with the fuel stations on the road during the trip. Fuel stations can mark the availability of fuel to vehicle as well as prices and services available at stations. Vehicles calculate the distance the reach the fuel stations and based on the current fuel level, driver can assess whether to choose a station or travel to next station for some more offered benefits as suits best.

Service Areas/Medical Services

Vehicle agents can interact with the service areas on the road during the trip in case of any fault in the vehicle. Agents may also seek medical help from the provided medical facilities on road during the trip. Service area or medical services agents ask to offer help on-station or off-station depending upon the severity of fault in vehicle or need of medical assistance respectively.

Shipment manager

Interaction with shipment manager is very important in our model. In case of any service needed or unavailability of service, vehicle interact with the shipment manager to seek help. Shipment manager can also interact with the help service agent depending upon the location of vehicle and type of request. Shipment manager can communicate with the help services so that it can better predict the actions needed to be taken by vehicle for on time delivery.

Help Services

Road conditions, weather situations and traffic warnings play important role in the successful completion of trip. Sensing are reading these signals from provided sensors is very important for correct prediction of action to be taken.

Monitoring

For the monitoring purposes we use the on board units that must be installed on the vehicles to gather all the data about vehicle movements.

Use of Internet of Things

This model uses the recent trend of connected things to make an automated model of this process. Internet of Things changing the way how things should be done. So we present a scenario of long distance vehicle transport. In this scenario we say a vehicle has to transport a freight for a longer distance (say 2000 Km). The vehicle starts from origin agent, by starting we means the transport agent has information about vehicle from over a period of time so that he can predict the expected time to reach to destination. The expected arrival time is communicated to vehicle and terminal agent. As the vehicle moves through the expected arrival time is updated upon every checkpoint/stop in central server as travel history for future decisions. The weather and road situations are communicated to vehicle from time to time. In case of signal lost from vehicle an alarm is generated at the transport agent end and also on the police van present near the last signal received, so that the police vans are directed to check the related issue. In case of a medical emergency vehicle can generate alarm to know about medical help available and ambulance services may be directed to vehicle. Vehicle may also get knowledge of next rest points, services areas and fuel stations to get better view of their travel. Vehicle history is maintained during the whole journey; proper analysis of data can report the abnormalities to overcome the bad encounters. We may able to know why a particular vehicle takes more time in an area while other vehicles don't? why a vehicle have more breakdowns than others? What is vehicle average time to reach destinations? Upon this kind of knowledge, we can make better decision making and prediction.

Protocols

While taking everything as a service Interoperability is one of the major challenges in achieving the vision of Internet of Things. The Semantic Gateway as Service provides mechanism to integrate popular IoT application protocols to co-exist in a single gateway system. This protocol allows many of internet of things devices to connect with other web services. Study of different system web services is also needed.

IV. Scenario

Let's consider the scenario of China–Pakistan Economic Corridor of length $2,442 kilometers$. After completion of this corridor China will use it for trading rather than South-China Sea route. If a loaded truck moves from Gawadar to Kashgar at an average speed of $50km/hour$ non-stop then, it will take $48.84hours$ means $2.04days$. It's impossible for a human to remain on a vehicle for such a long time. Normally, a truck driver requires $3-times$ meal a day and also some refreshment after every $3to4hours$. Also, the truck will require refueling after certain distance and we suppose it $5-times$ during this route. Now, we calculate this time to reach the destination. We consider every meal break of at-least $30minutes$ and refreshment break $15minutes$ and fueling time $15minutes$. Now, let's calculate this time

$TotalTime = 2.04(3*0.5) + 2.04(6*0.25) + 5*0.25 + 48.84$

$TotalTime = 56.21hours$

means, $TotalTime = 2.34days$

So, after calculating this time by the model the company owning the fleet and the ultimate customer can expect when the truck will reach.

Secondly, the truck driver can face any problem during this move. In case of any problem he will inform the nearest police van directly, considering all the services interconnected. In case the nearest police van is busy than in this scenario the system decides to convey the message to the other second nearest van or wait for this to continue. So, this whole scenario is depicted in model.

Also, there may happen any accident. In case of accident the ambulance should be informed. And the best suitable ambulance should be assigned the duty.

In case of any mechanical problem, the mobile workshop should be informed. And the same best workshop be selected based on the criteria. Also, the driver should be informed about the next filling station distance. Similarly, the driver should have facility to check the next restaurant. The deals on restaurant and rates of the restaurant should also be visible to driver with the distance from the current position.

V. Conclusion

Long distance transport has both negative and positive effects on our economy and society. Monitoring and modeling long distance transport has been found very interesting field by researcher. We have proposed a model here that uses the agent based modeling approach to model this system as multi-agent system. We have done some background study on how agent based modeling works. Literature review shows that agent based modeling approaches are used to model transport systems lately. We propose our model and map with ABM protocol of Overview, Design concept and Details (ODD). However, proper implementation of model is still needed to be done. We propose the use of everything as service concept, precisely sensing as service where every agent provides services to others and uses services of others. Service interoperability protocols have been studied. For services to connect between internet of things and web services the Sematic Gateway as Service architecture has been found useful. While the study of most suitable protocol has been important work to focus on in future.

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