The transport of hazardous materials (HazMat) is regulated by a legal framework in line with international standards, in particular the European Agreement concerning the international Accord for Dangerous goods by Road (ADR) which entered in Morocco in June 2011- BO 5956 bis, 30.6.2011. In this work, we propose a model for calculating the risk exposure of the transport of hazardous materials (THM) trajectories using the Gaussian stochastic travel time. The THD trajectory meta-model is extended to take into account the risk management dimension. The storage of the TMD trajectories is used for discovering risk patterns on the urban space by means of the mesh of Voronoi. The proposed analytical solution is deployed in an interoperable infrastructure using intelligent transport systems architecture.

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1. Introduction

The European agreement on international transport of dangerous goods by road is applied in Morocco in June 2011. It provides that, with the exception of certain excessively dangerous goods, other dangerous goods may be transported internationally in road vehicles provided that: conditions imposed down in annex A for the goods, including packaging

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and labeling, and others conditions imposed in annex B in particular for construction, equipment and movement of vehicles transporting the goods in question. Materials is considered dangerous according to ADR, when it presents a risk to humans or the environment. The hazardous materials is a multidimensional entity characterized by several dimensions: packaging, storage, handling, transport, and risk management, etc.

In this context, we propose to set up a system for collecting, storing, warehousing and calculating stochastic risks in HazMat transport. The rest of the paper is structured as follows. Section 2 develops the state of the art and related work on THM. Section 3 discusses the modeling of the stochastic risk of transporting hazardous materials. Section 4 declines the warehouse of hazardous materials trajectories. Section 5 presents the cloud-based and analytical ecosystem for HazMats trajectories and finally Section 6 concludes.

2. Related works

Dangerous goods or hazardous materials (hazmats) refer to explosives, toxic gases, flammables liquids and solids, oxidizing substances and hazardous wastes. Events and trajectories of transport of hazardous materials are necessary in different services based on location, for example, the service of support for the decision-making in near real time. Hazardous materials accidents are generally considered as low probability events and high risk.

2.1. Basic concepts of trajectories

A trajectory is a description of the evolution of the physical movement of objects in motion over time. The following are the basic presentations of trajectories:

- Raw trajectory is the recording of geometric positions of an object in a specific area of space and time \((x_i, y_i, t_i)\).
- Structured trajectory\(^1\) is defined as a raw trajectory structured into segments corresponding to significant steps in the trace of the trajectory.
- Semantic trajectory\(^1\) has semantics related to the domain of the applications; it uses the four components (stop, move, start and end). Stop \((S)\), move \((M)\), begin \((B)\) and end \((E)\) are no longer spatio-temporal positions, but rather semantic objects related to general geographic knowledge and geographic data of the application.
- Trajectory based on region\(^2\) describes patterns of movement in spatio-temporal contexts based on notion of regions of interests by defining notion of spatial neighborhood and temporal tolerance.

2.2. Models of presentation of mobile objects trajectories

Meng\(^3\) proposed a system called "DSTTMOD: Discrete Spatio-Temporal Object Trajectory Database" designed to model the trajectory of moving objects by a set of straight lines having a constant velocity. Wolfson\(^4\) presented a data model called "Moving Objects Spatio-Temporal" by representing the database of locations as a function of time and related gap.

Boulmakoul\(^4\) describes a Unified Moving Object Trajectories’ Meta-model. It integrates previous trajectories models described in\(^3,4,5,6\). Using the space-time event ontology, the meta-model models space according to OGC Spatial Data Model, Observation domain of trajectory, according to OGC Sensor Meta Model and OGC Feature Type, physical and virtual activities between the beginning and the end of space time path, sensors used for collecting moving object’s traces, and movement patterns using composites regions of interests.

3. Stochastic risk of hazardous materials transportation

In the field of hazardous materials transportation, two categories of decision makers cohabit, namely network regulators and carriers of hazardous materials, each focusing on distinct issues. The first problem that is mainly studied by hazardous material carriers is a route-planning problem for the shipment of the goods\(^7\). In other words, the determination of the safest route, for a single shipment from its origin to the desired destination. The second problem
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