Digital Twin Road Network as a Part of ITS Rig Move Model: Case Study Oil Industry of Oman

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Abstract—This paper presents a digital twin approach to address a component of the Rig Scheduling Problem (RSP) - rig transport or rig move. The main idea is to apply Intelligent Transport Systems (ITS) technology to solve problems during rig transportation, avoid potential risks, and minimize costs. The ITS concept for the rig moves process is based on a Model of an Intelligent Transport System from a Russian research group, modified to be applied in the current Petrol Development Oman system. The conclusion is that the implemented scenario has been assessed using an open-source tool - SUMO software. This study demonstrates the feasibility of constructing realistic microsimulation scenarios for extensive road networks [1].

Keywords - rig schedule problem, digital twin, intelligent transport systems; oversized cargo, traffic management

I. INTRODUCTION

To extract oil from the surface of the well, it is necessary to use various techniques and equipment. If equipment fails, interventions are needed to restore productivity and fix oil flow losses. These interventions, known as workovers, can involve re-completion, restoration, cleaning, stimulation and other operations that require the use of oil rigs. One such process is moving the rig to another drilling location. Oil rigs are costly and any delay during transportation can result in expenses ranging from US$ 50,000 to US$ 700,000 per day, depending on their type, market and operational characteristics [2].

Intelligent transport systems (ITS) are advanced systems that use innovative techniques to model transportation networks and regulate traffic flow. These systems provide users with more information and safety and improve the level of interaction between road users compared to traditional transportation systems. A key component of ITS is the use of digital twin (DT), which employs mathematical modelling to analyse transportation networks and develop solutions to transportation optimization ensuring smooth data transfer between physical and virtual worlds [3], [4].

In this paper, we aim to utilize Digital Twin models of Intelligent Transport Systems to optimize the transportation of rigs within a specific location as part of the Rig Scheduling Problem (RSP) [5]. Our goal is to minimize unnecessary expenses that may depend on various factors such as motor vehicle incidents involving rig convoys, collisions with stationary objects, traffic congestion on specific road sections, adverse weather conditions, and other accident scenarios [6].

The rest of the paper is organized as follows. Section 2 describes the main theoretical concepts of Rig schedule problem, oversize cargo transport and the digital twins concept. Section 3 describes a suggested modification to the Intelligent Transportation model for use as a Rig Move model ITS. Section 4 presents the concept of a Digital Twin Road network using Simulation of Urban Mobility (SUMO) with a TraCI interface. Section 5 presents concluding remarks and future work.

II. RELATED WORK

The research was initiated based on the identification of the Rig schedule problem, which revealed the existence of the problem and the utilization of operational research methods as potential solutions. The application of ITS can further enhance these solutions [7], [8].

The problem requests determining the optimal schedule for attending to wells using rigs, aiming to minimize rig fleet costs and reducing oil production loss from the well [2].

The research also explored the transportation aspect of the problem, considering the availability of solutions for similar problems. The transportation of oversized, non-standard, or over-metric cargo is classified as over-standard. Specialized transport methods and handling machinery capable of carrying such loads are necessary for transporting this type of cargo [9].

Fig. 1. Problematic elements and structural solutions during the transport of an oversized cargo [2].

In 2020, the group of authors tried to make Czech Republic Backbone routes for transport of oversized and excesive cargoes [3].

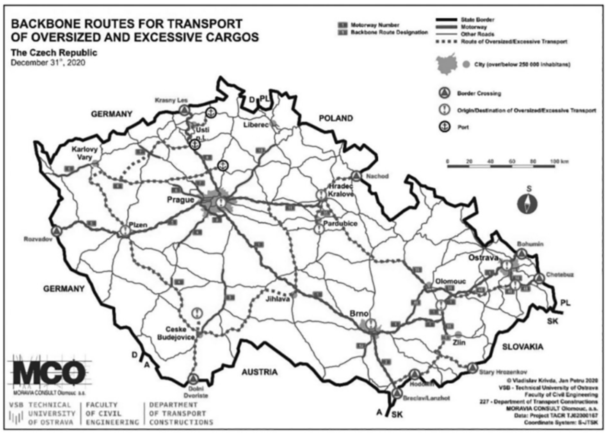

Fig. 2. Backbone routes for transport of oversized and excesive cargoes.

Machine learning and AI can reduce maintenance costs in the oil and gas industry by predicting equipment failures before they occur, optimizing maintenance schedules, and improving the efficiency of maintenance operations. Machine learning algorithms can identify patterns and anomalies that indicate potential equipment failures by analyzing data from sensors and other sources. Additionally, AI can optimize maintenance schedules by considering factors such as equipment usage, environmental conditions, and historical maintenance data. This can help reduce unnecessary maintenance and extend the lifespan of equipment [12].

Road condition monitoring using various AI methodologies, with a focus on deep learning for classification, segmentation, and object detection. Data acquisition systems, which consist of non-intrusive sensors and their platforms, are crucial to the RCM system and can collect 1D data, 2D visual data, or 3D depth data. Different platforms have their own advantages and limitations that complement each other's usability. For simple distress classification tasks, RGB sensors are suitable, while LiDAR, laser, and thermal sensors are better for detailed studies involving various distress characteristics [13].

In the end, research focused on using DT for transportation purposes. Digital Twin technology combines various traditional tools like simulation modelling and sensors to enhance process performance, also DT technology has significant implications for safety management and its development can lead to a competitive and stable industry [14].

The digitization of transportation will require significant improvements in safety, efficiency, and user experience. This will involve incorporating the advantages of cutting-edge technologies and gaining a comprehensive understanding of people, vehicles, roads, environments, and information. To achieve this, we can break it down into several clusters: Cluster A (Blue) focuses on enhancing the efficiency of Intelligent Transportation System Element Management. Cluster B (Red) addresses the flows and goals of managing the entire life cycle. Cluster C (Green) is dedicated to the development and application of digital technologies. Finally, Cluster 4 (Purple) aims to optimize the associated algorithms and models. The growth of digital technologies in transportation is primarily driven by advancements in building information modelling (BIM) and digital twins (DTs) [15].

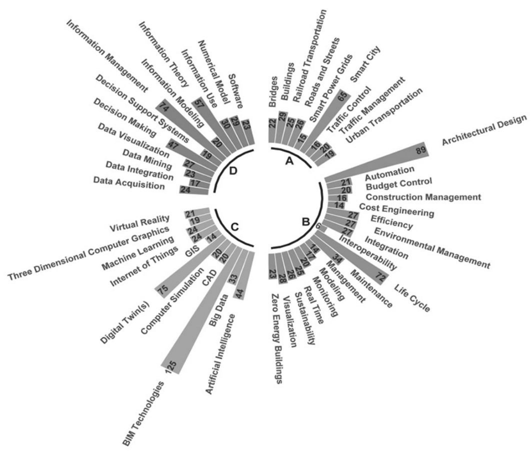

Fig. 3. Directions of digitization of transportation using digital tehnology

III. MODEL

According to conclusions in research that analyze the transportation issues in Oman towards the economic development sustainability of the country, adequate changes in technology are recognized as one of the main problems faced by the transportation system in Oman [16].

Otherwise, according to internal sources, there are several traffic accidents every year during rig transportation, most often collisions with stationary objects and motor vehicle accidents.

As a solution to these problems, we suggest a modified Model of an Intelligent Transport System, which Russian authors develop using the experience of implementation of

ITS in the city of Chelyabinsk, Russia and the case of the Main Roads Western Australia (MRWA), which is developing a digital twin to optimize planning and decision-making on the Australian road network. Also, they researched traffic management systems such as RITM3 (SIMETRA) (which can include modules such as PTV Vision Traffic Suite: PTV VISUM, PTV VISSIM, PTV VISWALK, PTV OPTIMA, LISA+ (Schlothauer & Wauer)), Trafficmap (AssetWise ALIM, Bentley), IRIS open source ATMS, Kimley-Horn Integrated Transport System, SWARCO AG (Traffic Management Software) [3].

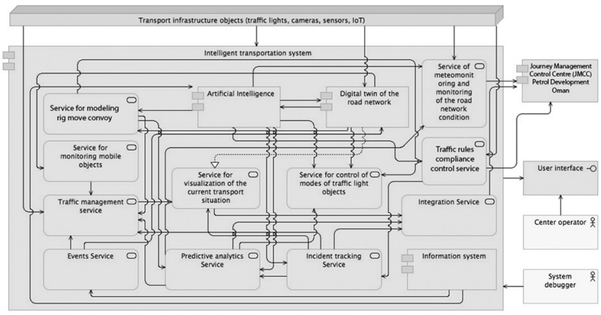

Fig. 4. Rig move Model of Intelligent Transport System.

The main changes of this model are:

- Service for modelling rig move convoys is aimed at the modelling of routes based on artificial intelligence algorithms that analyse current information and also from previous periods stored in the information system (including from sensors installed on the road transport network).
- Service for monitoring mobile objects. This service allows tracking the convoy with all specific dimensions and all parts of the convoy separately. Integrating this service with predictive analytics and a digital twin of the road network allows for displaying information about possible problems during transportation.
- Journey Management Control Centre (JMCC) of Petrol Development Oman is the unit which already exists to follow firstly traffic rules non-compliance and to fast react in case of motor vehicle incidents.

IV. DIGITAL TWIN ROAD NETWORK

Concept of a digital twin of the road network of Oman based on using Simulation of Urban Mobility (SUMO) with TraCI interface to create a map for routing oversized cargo like rig convoy for any dimension of width, length or height of all parts [17].

We will propose the utilization of a new model for the road network in Oman. This model will involve converting data from OpenStreetMap (OSM) format to SUMO XML format using SUMO's "netconvert" program. Additionally, we will manually edit the data using SUMO's "netedit" software. To supplement the data, we will incorporate satellite images and street-level graphical information from Google Maps as a background and conduct on-site inspections. To address connectivity issues, we will match GPS traces to the network, identifying errors in locations where network links are not properly connected. The road network data will consist of a directed graph comprising links and nodes. Each link will include one or more lanes, with important lane attributes such as maximum speed, width, and access rights. These attributes will be determined by analyzing the OSM attributes of the corresponding road segment. SUMO will assign a priority level to each link based on its attributes, ranging from 1 (footpath) to 13 (national motorway). Regarding lane connectivity at intersections, we will derive it from OSM or infer it using heuristics. We will manually verify the connectivity, along with road attributes and geometry. While OSM node attributes indicate traffic lights, we will generate signal information using heuristics. [1].

Fig. 5. Simulation zone from El Jadida city from Open Street Map and XML file edited by SUMO [4].

In combination with Predictive analytics service by selecting the best action among many based on certain objective criteria, we can optimize route performance. If problems are identified early enough, we have a range of control strategies available to mitigate or avoid them.

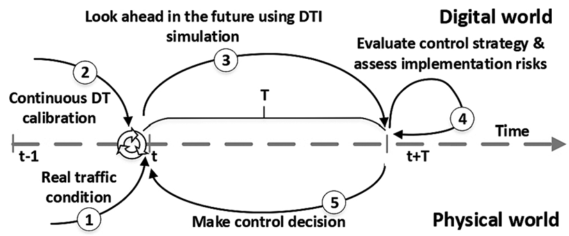

Fig. 6. Predictive analytics service [4].

The Predictive Analytics service of the Digital Twin Road Network will rely on two important options for routing in SUMO software. The first option, DUARouter, calculates the most efficient path between a vehicle's starting point and destination based on trip time or length, with various routing algorithms available. The second option, RandomTrips.py, generates a set of random trips on the road network, ensuring connected routes by automatically utilizing the duarouter tool to eliminate disconnected trips [19].

Furthermore, the utilization of In-Simulation Adaptive Rerouting (iSAR) in conjunction with SUMO empowers vehicles to dynamically update their routes during the simulation, thereby optimizing travel time based on real-time traffic conditions [20].

To assess the effectiveness of the Predictive Analytics service, simulations will be carried out to evaluate the occurrence of traffic congestion within specific segments of our digital road network, but for now, it's limited only by the length of rig movers.

V. FUTURE WORKS AND CONCLUSIONS

The usage of the Kalman filter or its variants for making short-term predictions of the system behavior based on the accumulated data on the previous states contained in the covariance matrix could improve Predictive analytics Service [21].

Moreover, SUMO provides the opportunity to develop Python-based tools that can establish correlations with other dimensions of a vehicle, such as width and height.

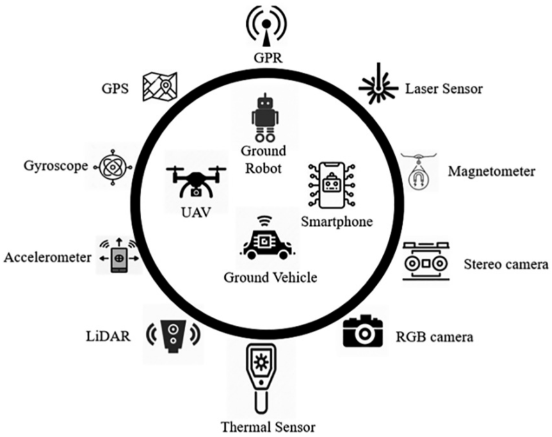

Fig. 7. A schematic representation of next-generation sensors and their platforms [5].

Smart sensing techniques offer highly detailed data on road surfaces, providing high-resolution information while overcoming spatial and environmental limitations. This enables the deployment of non-contact sensors on diverse mobile data acquisition platforms, facilitating convenient pavement inspection methods. Ultimately, this improves the service for monitoring mobile objects and road conditions [5].

The main conclusion of this paper is to propose the Rig Move Model of ITS - a modified model of ITS based on the implementation experiences from Russia. The paper suggests a problem solution utilizing Simulation of Urban Mobility (SUMO) with TraCI interface to create a digital twin of the road network in Oman, specifically designed for efficient routing of oversized cargo such as rig convoys. The Predictive Analytics service of the Digital Twin Road Network relies on dynamically updated routes based on real-time traffic conditions. Simulations will be conducted to evaluate traffic congestion in specific segments of the digital road network, taking into consideration the constraints imposed by the length of the rig mover's route.

The objective of the proposed digital twin for the road network, incorporating a service for modelling rig move convoys and a predictive analytics component, is to optimize the cost of rig moves and prevent motor vehicle incidents. By achieving these goals, significant savings in terms of both cost and time can be realized, which holds great importance in rig moves and overall (RSP).

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