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A Scalable Microservice Framework for Multi-Modal Logistics Route Optimization

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ABSTRACT: In this paper, I am going to present a scalable logistics route planning microservice software that could be implemented to optimize the supply chain and ensure that it is more efficient, flexible, and resilient. The pressure to identify efficient and sustainable logistic operations in fast, cost-effective and environmentally-safe freight transportation, and the need of faster, agile and multi-modal route planning, implies it. The classic centralised route planning lacks the ability to address the dynamical, large, as well as multi-modal transportation system. We decentralise also the logistics (microservices) such as the data collection, prediction, assigning routes and assigning vehicles, monitoring the traffic conditions, cost and analytics. It offers real time connection to any kind of transport network (road, railway, air and sea) that is scalable and resilient to faults. Both the data sources and the intelligent decision-making models utilise data in real-time; the data sources gather and capture real-time data to optimise dynamically and identify the optimal alternative path to identify the cost-efficient paths. The systems are also capable of interconnecting with other systems like the warehouse management systems, fleet management systems and the enterprise resource planning systems. The needed scale and a range of logistics use-cases are provided with the help of containers and API-based communication and distributed model. In the paper, the benefits of the innovations in route planning, computational issues and sustainable logistics based on microservices are outlined. Plainly, it is by the framework that the logistics companies will have a treasure trove and scalable solution to the logistic and supply chain giving the revitalization to the efficiency and precision as well as decision making capacities of the multi-mode transport.

KEYWORDS: Microservices, Multi-modal logistics, Route optimization, Supply chain management, Scalable architecture, Real-time data analytics, Intelligent transportation systems.

I. INTRODUCTION

The ever-expanding global transactions, electronic commerce, urban supply chain and logistics and electronic chain has posed a problem in designing the logistics routes. The logistics industry transport companies are not restricted anymore to a single mode of transport or to a particular route to carry goods. They use multi-mode transport networks that involves application of road system, rail system, air and marine transport system in the transportation of goods in a local, regional, national and international transport system. This has led to the demand of smart and vibrant and scalable route optimization solutions to handle a very large amount of real time data, logistics collaborators, unexpected occurrences such as traffic jam, weather, port stop, fuel expenditure, automobile malfunctions and temporarily different demand [1].

Most of the logistics route optimization systems are traditional, one-dimensional systems. This kind of systems would be more applicable in minor logistics problems and not applicable in huge and highly complicated systems that are decentralized. Monolithic systems consist of solely a single software program that can be utilized and that will consist of the route planning, fleet allocation, demand, schedule, shipment tracking, costs and reporting. Its operation and scaling is also time-consuming and it is also challenging to upgrade it, so that it becomes able to be connected to other systems or be connected to other systems. They can be bottlenecks in the processing rate, scalability, responsiveness, fault-tolerance as well as change attributes of the business requirements, once in case of a monolithic system with its over and under complexity (distribution and time and modes of transport)[2].

A multi-modal logistic route optimisation process has a number of factors. They include distance, time, volume, cost, time of transfers, carbon emission, warehouse capacity, allocated time to the customer and law, time window. The short sector may not be the most favorable as far as being cost effective and even fast. A much cheaper route, not the most reliable perhaps, would be perhaps the one of a relatively low cost, possibly involving obsessive ports, some

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uncertainty in the transfer of the rails or perhaps wasteful transfers. In this context of cost, time, reliability and sustainability, multi-model logistics route optimization problem is a multi objective problem.

The last 10 years have witnessed innovative changes in cloud computing, Internet of Things, GPS, analytics on big data, artificial intelligence and application programming interfaces to transform logistics. Using it, we can track the whereabouts of goods, position of a cargo, the position and closeness to a warehouse in real-time, status of a warehouse, status of a traffic and status of an order. Since these data need to be manipulated it necessitates that software communication and service architecture capable of dealing with the data in real-time, workflow in real-time and decision making in real-time. It is here that can be applied the concept of microservice architecture [3] [4].

Microservice architecture is logic to disaggregate a software system, into a chain of small, autonomous and loosely-coupled services. Microservices do not rely on being able to start and stop, and to communicate with each other, usually (though not always) through lightweight messages or APIs. Different microservices can be tailored to gather data, to logistics optimization, requirement, simulation of the traffic, assign cars, tracking delivery, cost of computation, carbon emission measurement, performance measurement. It is more streamlined and more resistant to stress to sustain with the demands that it needs to be created independently, deployed, scaled and upgraded to fit the demands without relying on the other services.

The multi-modal logistics is also useful in the microservice architecture in a number of ways. The latter is because it enables scaling in a fashion that means that you can scale successfully services that are actively contended against (such as route planning and real time tracking service) and do not cause other services in the system to become contended. Secondly, it is more stable in that a service that is rendered unavailable is reported and will not ruin the operations of the system. Thirdly, it improves interoperability as it can be interlinked with other systems such as warehouse management systems, enterprise resource planning systems, traffic data providers, port logistics systems and applications in which actors will receive the delivery of their customers. Fourth, it can nimble because the added value of the various route algorithm optimizers, transportation modes or data analytics can be introduced without necessarily having to rewrite the system.

Nevertheless, scalability of a system of optimization of logistics paths based on the multi-modal system of microservices is difficult to develop. The logistics systems are associated with different data, constraints, managers and time constraints. It must be able to process dynamic (e.g. traffic, weather, priority of orders and vehicle status) and static information (e.g. transportation network and schedules). Being effective should also be encouraged when sharing, as such it will be processed and decision making. One then assumes that the system architecture, optimisation, data, services orchestrator performance factors will be expressed on the framework.

The planes of the proposed research paper illustrate a suggested scheme of the multi-modal optimisation of logistics routes in a scaled version with the help of microservices. The framework attempts to add value addition aid to the multi modes routing planning through micro services, stream of data and optimisation. The approach based on this strategy will provide the opportunity to split the major logistical processes into the most efficient and beneficial microservices. The architecture will focus on the shortcomings of large monolithic and centralised route planning frameworks when it comes to containers deployments, API communications, data storage and processing and precise scalability of the services.

The general objective of the research is to present the solution to logistics system tracks optimisation that can be scaled. In this paper I would show that I could introduce into practice the concept of microservices of working with multi-modes or data in order to process and make decisions much faster, a hundred time more reliable and real-time. The work also focuses on modularity in order to transform logistic systems to be more active. It gives an insight into how the research will be applicable in the industry of smart logistics, software architecture and digital logistics.

The significance of the given work is that they can be applied to the work of the logistics service operator, supply chain operator, e-commerce operator and transport service provider and to the technological service provider. Along with growing pressure on the services of the information saturated world of logistics the companies will need to come up with even faster, mistake-free and efficient route plans. A decentralized and responsive micro service-based approach can help any logistics company save money, offer faster delivery and avoid the waste of resources, equipments or fuel and plan sustainability logistics. And it has the potential to bring to existence the door of artificial intelligence (AI) and machine learning, blockchain, digital twins and autonomous vehicles.

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To put it in a word, this article shows that the microservice architecture is an appropriate paradigm to consider when developing new logistics route optimisation solutions. The microservice character of the software structure and real time information storage and multi-objective optimisation can remove the bottlenecks of the existing transport networks optimisation systems, and can be used to design intelligent, resilient and diversified transport networks. The literature, system architecture, methodology, optimisation, implementation, benefits and future research are described in the following sections.

II. RELATED WORK

The recent research on the multi-modal logistics and route optimization could explain the high focus on the low-carbon transportation, the lack of clarity in defining the problem of the multi-modal logistics and route optimization and smart logistics, real-time data mining, and scaleable management of logistics. All of these have been taken into account in a multi-modal optimisation of the logistics routes of a scaled-backlogistic system based on a multi-mode based microservice.

Li and Sun [1] suggested to apply unknown optimisation to optimise unknown paths with multimodal low-carbon transportation of containers. This research can be utilized in the proposed paper since it considers the impact of uncertain transport time, cost and network to route planning. It notes that distance and carbon emission can and must be similarly factored in the multimodal transportation routes planning and time and risk must be moved. This confirms the stance of the current article that the route planning should be dynamic and multi-faceted and should take into account a number of scenarios.

Chen et al. [2] studied the multimodal transportation route planning with transportation quality commitment in reference to carbon tax. They found out that route and cost is affected by carbon policy. Our architecture is possible, because the contemporary logistics must consider sustainability and quality and not only price. The carbon tax, and quality commitment are also components of the sustainability and cost-estimation service of the microservice-based logistics system.

However, with the multimodal transportation and uncertain policy of carbon emission policy, Zhu and Zhu might come up with generating multi modal process in route decision making [3]. They arrived at the conclusion that the route decision making process was multi-objective and at the decision they were able to achieve by keeping in mind the cost, time, emissions and reliability. This is in accordance with the multi-objective layer of decision-making of this study. The remaining aspect that they observe is that logistics optimisation must be geared up to assist the decision makers in deciding on their routes in a dynamic manner, in accordance with the changing preferences, and uncertainty.

Wang et al. [4] investigated the development of the multi-modal network hub and spoke structure of congestion and capacity restriction. This applies as it is the changing points of the intermodal transport which is fundamentally the terminals and hubs as its constituents. Hub could be bottlenecked and capacity constrained which could be the cause of delays, costs and losses. With the help of it, they can supplement their study with the need of covering the warehouse, hub and terminal management service process in their framework in order to trace the bottlenecks and plan the process of intermodal transport.

Zhang et al. [5] introduced the practical use of energy and greening of the road freights. The study can be helpful in estimating energy consumption and emission of CO 2 by the road freight. The multimodal transport will typically demand first mile and last mile transport facilitation by road transport and hence the road freight transportation must be efficient. The results of their research reiterate the importance of a proper planning of the route based on emission, calculation of the fuel usage and effective use of mode of transport in our approach.

Serra-Sogas et al. [6] had already tried this new step when they wanted to combine the aerial monitoring process with Automatic Identification System (AIS) vessel traffic data in order to analyze the risk and be able to control the vessels and plan them. The crucial thing in the maritime logistics which makes the work important is that information about AIS may not be as easily available everywhere. This implies that one should combine information to be cognizant. Here we have our system of variable data layer on which we base our planning of routing using data of the GPS distance, AIS distance information, imagery data, port data and traffic information.

Fradus-maritime-adaptive-filtering Lopac et al. [7], in their example of maritime data used was of Shifts fradus-maritime-adaptive-filtering with radial-basis-function enhanced with particle-swarm-optimisation. And to the smart sea

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data processing and optimisation. Metaheuristicity of complex transport information is demanded in the role of the use of particle swarm optimisation test. It can be applied on the intelligence and optimisation level of the proposed model whereby the planning and optimisation can be carried out based on heuristic and machine learning.

To effectively track movements of autonomous ships in separate distance by remotely monitoring through a long range data compression, Jurdana et al. [8] proposed that ship should possess a data compression as an onboard system to accommodate on time communication. This is because during real time management of the logistical process, communication is necessary particularly when the oceans are far apart. This will decrease the bandwidth as well as enhance communication. It has the potential to contribute to real time tracking microservice of the proposed structure especially where a significant number of sensor, location and cargo information is taken into account in the distributed logistics.

The authors of Wu et al. [9] developed a dynamic fuzzy logic based decision of inland traffic separation. The strategy of decision-making, which is founded on the fuzzy logic regarding the uncertainty or uncertainty of the transportation conditions is presented in the paper below. That is a normal occurrence when the determination of logistics paths that define the form of a path is concerned as in most of the situations, the conditions as well as capability of experiencing delays is either suspicious or unpredictable. The authors use a model that makes it possible to run intelligent models to find the dynamical path and address the disturbance.

Bakdi et al. [10] came up with a method grounded on AIS to discover various vessels collision and adaptive safety regions. They give an illustration of how data can be used to identify safety risks in real time in order to facilitate safety. It helps in events based planning and risk evaluation of the proposed system and identification of risk. Maritime transport, and the multimodal road and rail and air transport are founded on safety and risk detection.

Guo et al. [11] have gone ahead to propose autonomous route planning of unmanned boats with the help of deep learning. They also contribute significantly in terms of incorporation of the artificial intelligence in the autonomous planning of routes. Deep reinforcement learning helps the system to be trained to perform the most suitable actions depending on the given environment. It has the potential to be repurposed when AI models can be used in autonomous logistic planning routes in the future of the suggested system.

Zhang et al. [12] observed the multimodal optimization of low carbon capacity in the face of the uncertain demand. They also indicate that they take into account such an aspect in creating routes and selecting modes. The logistics need is uncertain as it can be affected by the environment, season and customers and the system should be dynamic. This is because the system ought to possess demand forecasting and dynamic route planning.

The associated multifixed transport shipment is also stochastic and dynamic which has been developed by Guo et al. [13]. This is very critical to the logistics industry since entertainment of the cargo must take into account any doubt in the demand, carrying capacities and transport medium. Their paper facilitates active matchings in terms of shipments, vehicles, routes as well as matchings in terms of modes. In our system, this is accomplished with microservices of fleet, order and route optimization.

Baykasooglu et al. [14] designed a review of the fleet planning problem as it is with the single and multi-mode transportation system. The work gives the description of the size of the fleet, the distribution of vehicles, timetable, routing of vehicles and capacity of vehicles. This is because fleet planning entails a route planning. The paper provides justification on the need to introduce fleet microservice to the proposed architecture, to control fleet availability, capacity, load and cost.

On the foundations of the AIS data, Yang et al. [15] proposed the issue of big data in the marine research. They have verified that the big data in transport can be used in route scheduling, traffic management, security and logistics. This reminds the notion in this present paper of optimization of big logistics that cross-relates with data collection, data processing; real time and distributed processing. It tests, as well, a microservice solution to address big and heterogeneous dynamic transport data.

On the whole, the literature is able to prove that the current studies have been working towards most of the designations of the low-carbon transport, multimodal transport, marine data gathering and data processing, navigation, fleet planning and decision-making under uncertainty also. Only works do not gaze to the system but rather to the problem or to the models of transport optimisation. The current paper also takes advantage of the given opportunity and proposes a

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microservice architecture that includes a data collection, a route planning, a cost, sustainability, monitoring, orchestration and interaction as an entity to build a logistics decision making system.

III. MICROSERVICE FRAMEWORK FOR MULTI-MODAL LOGISTICS ROUTE OPTIMIZATION

1. Overview of the Proposed Framework
The proposed scalable, multi-modal microservice-based framework for logistics route optimisation is a service-oriented architecture (SOA) system capable of dealing with complex logistics operations involved in both road, rail, air and sea transportation systems. It allows the logistics route optimisation process to be separated into multiple microservices which performs a specific task and interacts with other microservices securely using application programming interfaces (API). This ensures scalability, flexibility, reliability and dynamics of the framework in the logistics environment.

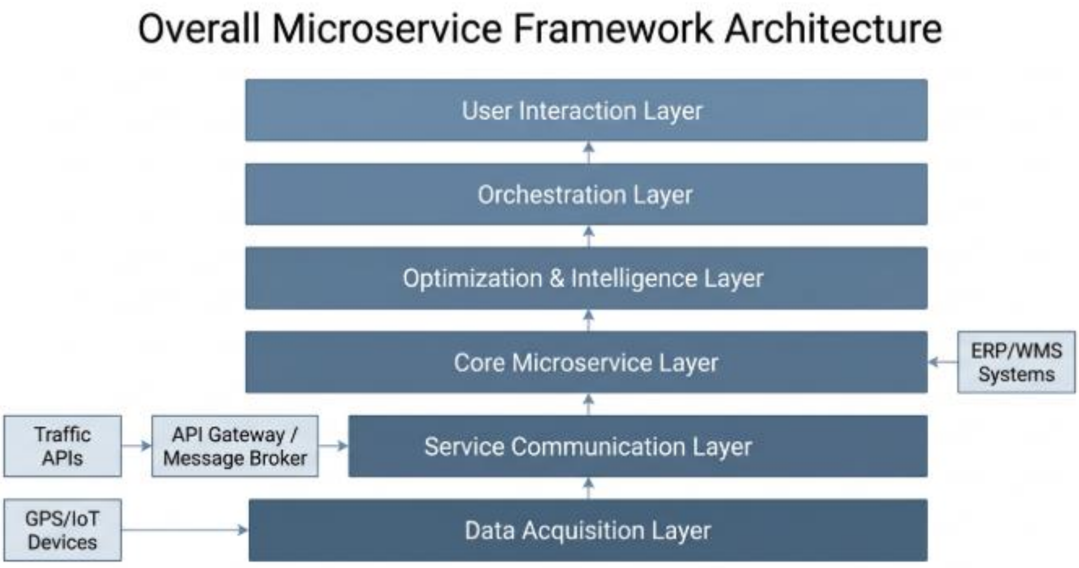

Figure 1: Overall Microservice Framework Architecture

2. Framework Layered Architecture
6 layers exist in the framework that they are designed with a layered architecture: data layer, service communication layer, microservice layer, optimization and intelligence layer, orchestra layer and interaction layer. The layers have a specific role which communicate with other layers. Layers architecture makes it possible to integrate data from external logistics data sources with optimization services and to the dashboard for decision making, fleet management, warehouse management and customer apps.

2.1. Data Acquisition Layer
Data acquisition layer is the core of the system. It will collect data from global positioning system (GPS), fleet management system, warehouse management system, enterprise resource planning (ERP) system, traffic information system, weather information system, cargo port information system, railway timetables, cargo airport system, fuel cost and order management system. Multi-modals need historic and real-time data so this layer will provide maps, schedule, capacity, cargo volume, time of doors, traffic, weather, cargo time and fleet location. This layer will share this data with other services.

2.2 Service Communication Layer
Service communication layer is communication between microservices. To put it simply, it is communication between microservices (via API for synchronous and like message queues for asynchronous communication). For example, after an order is created to transport goods, an order service communicates an event to the route planning, vehicle assignment and cost services. And, if there are congestion headaches, in real-time, the traffic service sends an event to change the route. This way, the services do not rely on each other, but are real-time.

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2.3 Core Microservice Layer

The order management microservice has information on transport orders with origin, destination, product name, weight, volume, time to deliver and priority. Vehicle management microservice has information on vehicle, driver, load, fuel, cost, capacity and location. The warehouse/hub management microservice has information on warehouse, load/unload capacity, transfer capacity at logistics hubs, port, rail and airports.

The transport mode management has information about transport mode and capacities. For road, it considers traffic, toll and road restrictions, vehicle type and time. For train, it looks at train timetable, cargo capacities, time for loading/unloading cargo and rail network. For air, it examines flight schedules, cargo) in terms of amount and type of cargo), terminal handling cost and timetables). For marine, it includes port schedule, port capacity, customs time and transshipment time. Having transport mode rules in a separated service, is helpful for new transport modes coming up and changes in transport mode rules.

The route optimizer microservice is important. It can access other services to receive information about shipments, transport modes, transport network, vehicles and cost. It provides a multimodal optimal set of routes based on distance, time, cost, reliability, emission and quality of service (QOS) criteria levels. Multimodal route planning is a multi objective problem, so it the service provides the shortest route. It takes into consideration of transportation modes (driving, taking a train, flight and ship) to achieve business objective.

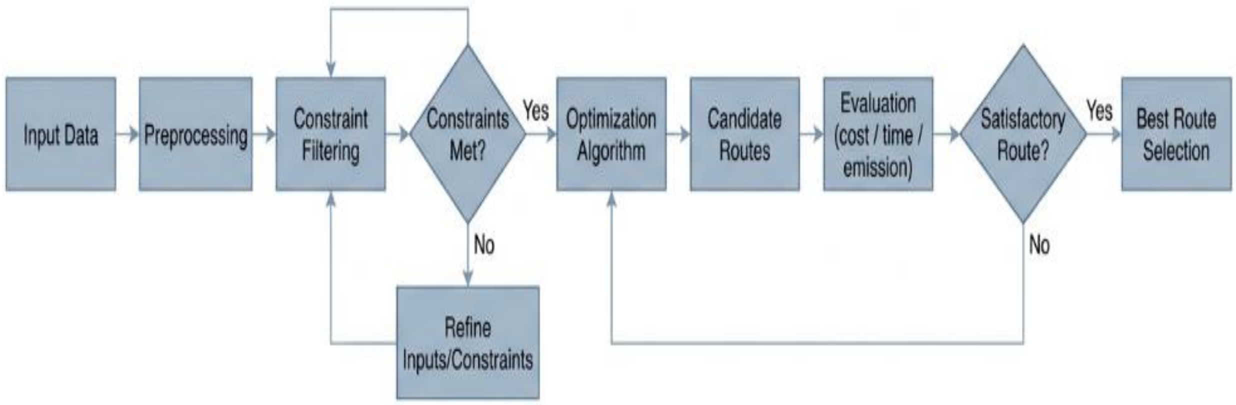

Figure 2 :Route Optimization Workflow

The cost calculator microservice helps calculate the cost of the routes. Consideration is given to the fuel cost, toll cost, driver cost, rail cost, air cargo cost, port handling cost, warehouse cost, loading/unloading cost, customs cost and late delivery penalty cost. The cost of alternative routes, time and distance can be considered by the logistics planner. It allows them to run cost analysis as the fuel cost, transport tariff (price) and congestion cost can change.

Emission or sustainability microservice can be used to calculate the sustainability level. It takes the mode, fuel type, distance travelled, vehicle efficiencies, occupancy of vehicle and fuel consumption to calculate emissions. The microservice can be used to make sustainable transport decisions. By doing so, long haul by train and short haul by road transport is more sustainable than long haul by road transport. With the sustainability indicators, sustainable supply chains can be created.

The monitoring microservice provides information of shipments. It receives real-time information from a GPS/sensors, traffic information service, weather and checkpoints. The monitoring service gives the optimizer the information on a delay, accident, traffic, port congestion and equipment breakdown. The "route optimizer" microservice will provide an alternative route and detour. This allows the intelligent logistical system.

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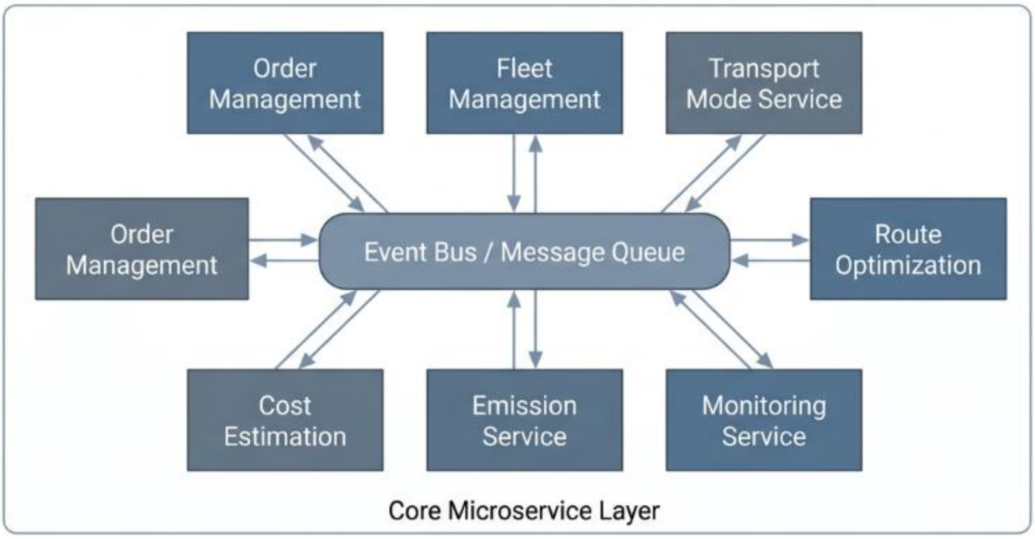

Figure 3: Core Microservices Interaction Diagram

2.4 Optimization and Intelligence Layer
The optimization and intelligence layer is where the route planning and algorithms models are located. This may come in the form of graph algorithms (e.g. the Dijkstra shortest path algorithm), heuristic/metaheuristic algorithms, constraint programming and machine learning. Graph algorithms can be applied to route on transport networks. Heuristic and metaheuristic algorithms can be used for many of the routing problems (which may be complex). Machine learning can be applied to travel and demand forecasts, congestion and delay and cost.

This approach can be for multiple objectives (multi-objective optimisation). It can be cost, time, carbon, vehicle loads (vehicle capacity), reliability and passenger transfer delay. The objectives may not always be satisfied and the method can prioritise the objectives based on business requirements. For example, the critical transport of medicines may consider "reliable and timely" delivery service important and low cost/carbon delivery service less important whereas non-critical transport of industrial goods may consider low cost/carbon delivery service important rather than reliable and timely delivery.

2.5 Orchestration Layer
The orchestration layer orchestrates services. In the microservice architecture, it requires a number of services to be used to decide logistic operations. It will orchestrate the order service, demand service, fleet service, transport mode service, cost service, emission service and optimization service, when an order is placed. It will also coordinate those services and communicate with those services. Other than this, some other responsibilities which can be performed by a container orchestrator is deployment/ scaling, service discovery, health check and fault tolerance.

Scalability is an important characteristic. The services are loosely coupled and the services which are intensive can be scaled up. For instance, in the case of the logistics, during the holiday season, the tracking service, route optimisation service and order service might need to be scaled up. The service framework can achieve it by running more services.

The second design principle is fault tolerance. A typical issue with monolithic designs is that if a part fails, the whole system will fail. However, in our new design we can avoid this by dividing the services. If emission service fails, the route for travel can be calculated taking into account the cost and time. If traffic service cannot be used, traffic information can be obtained from a historical traffic data.

This is a distributed data management. Microservices can have a database. The fleet service can have a database to store fleet information, the order service can have the database to store order information, the cost service can have the database for cost information and so on for the monitoring service monitoring information. The separation helps to make things independent and not reliant on database problems. We can have event driven updates and data store synchronization to address data consistency.

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Access control and security is also important. We have business and customer data (shipment details, routes and customer details) that we need to transfer and secure data between services. Opening access control can be done through authentication and authorisation, encryption, API Gateway and role based access control.

2.6 User Interaction Layer
The user interaction layer can be viewed by logistics managers, route planners, warehouse managers, drivers and customers. The logistics manager can view the optimal route and cost/time alternatives of a shipment, shipment details and KPIs. Drivers can view route compliance, waiting time, load and delivery status. The customer can have tracking and estimated time of arrival. Performance indicators, such as average delivery time, route efficiency, vehicle efficiency, fuel efficiency, total logistics cost and total carbon emission can also be shown.

Our system also has the learning ability. Past shipments and routes, delays, fuel cost and customer service levels can also be recorded. We can also develop learning models based on the information of logistics for travel time prediction, demand prediction and delay analysis. So, our system is flexible.

IV. FRAMEWORK EVALUATION

1. Evaluation Overview
The scalable microservice framework for multi-modal logistics route planning could be assessed based on the framework design, planning module, system fault tolerance and scalability. It includes road and rail, air and sea transport; therefore, scalability, efficiency, cost, fault tolerance, data integration and quality of the assessment are related.

2. Scalability Assessment
Scalability is a crucial aspect. Thousands of requests and change of shipments and vehicles, traffic alerting and route calculation have to be executed in a large-scale logistics system. The microservice approach provides for scale of services like route calculation, order and shipments tracking. This means as the volume of shipments grow, only those services that are significantly used are scaled up. Hence higher efficiency and no bottlenecks than monolithic approach.

3. Route Optimization Performance
The second thing is route optimization. The performance of this framework is tested by the route planning with multiple transport modes. The factors considered include the route length and travel time, transport cost, transfer time, load factor, risk of delay and carbon emissions. Not only the best route is required but also needs some sub optimal routes to meet the business need with an acceptable search range.

4. Response Time and Real Time
The second criteria is response time. In most of the cases, route planning and optimisation activities are conducted in real-time (or close to real-time) particularly in problems. In certain cases, like traffic congestion, bad weather conditions, vehicle malfunction, port delay or rail delay, we have to make new schedule and plan new routes. The sooner the reaction, the better in dynamic environment.

5. Resilience
Fault tolerance and resilience should be considered. In microservice architecture, a microservice shouldn't bring down the system. To begin with, planning can be made in time and cost if core services don't operate. Therefore, service simulation tests, service recovery, data backups and partial service should be tested.

6. Data Integration Capability
Data integration is another aspect. Data sources are GPS, warehouse, fleet schedule, fuel price, traffic, weather, port and customer order management. The framework can be evaluated in terms of the data source collection, normalisation, validation and sharing.

7. Cost-Efficiency Evaluation
The cost-efficiency should be evaluated. It should decrease the additional travel distance and the empty trip distance, waiting time, transfer time, fuel cost and penalty cost. The cost efficiency should be able to compare the routes from the framework with fixed routes.

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8. Sustainability Performance
Sustainability performance is a different perspective. In transport, we consider sustainability due to greenhouse gas emissions. The impacts of mode choice, vehicle operation and deadheading can be considered.

9. Usability and Acceptance
Ultimately, the system needs to be evaluated for acceptability and usability. It should be acceptable and easy to understand to the logistics managers, drivers, warehouse managers and customers. This can be done by analysing the dashboard, value of the recommended routes, interoperability, warnings and decisions.

V. FUTURE ENHANCEMENTS

The proposed scalable and microservice architecture can be enhanced in terms of intelligence, automation, sustainability and deployability. First, we would see the use of the latest artificial intelligence and machine learning techniques to better predict shipping time, demand, traffic, fuel and delay. The models can reflect past logistics operation and activities for real-time planning.

Second, we will see an improvement with the use of digital twins. A logistics digital twin will create a digital copy of the transportation network, the facility, the fleet, the hub and the shipments. This will enable the manager to test multiple routes, the impact of accident and change in real time before any implementation in the real world. Modelling can be used for risk and decision making.

Data sharing and blockchain can be applied for improvement. In multi-modal transport there are various players (carriers, freight forwarders, firms operating warehouse and port, and the customers) and blockchain can be used for transparancy, security and trust in transport. Smart contracts can be used for payments, shipping and delivery.

The software can be further extended for sustainability through carbon sensitive transport. The system can select transport mode and low emission trucks rather than only maximise emission and eliminate empty trips. It can also use electric vehicle recharging stations and renewable energy to complete the recharging.

The other improvement is the edge computing. Location, sensor and traffic data can be used in decision making in real time. It can also be used to pre-process some of the data at the edge (such as vehicles, warehouses or logistic centres) to prevent the communication delay and make decisions quickly in an emergency situation.

We can also use our system for autonomous vehicles, drones and robot warehouses. As automation is increasing on the streets, the system can be used for a fleet of vehicles, end to end delivery of goods via drones or in-built loading and unloading capability.

Finally, further research should be done to explore the system with data and prototypes. This will help to compare with existing monolithic fleet planning systems and traditional planning process, to see if it is cost effective (time, emissions, reliability and scalability). This will make the framework smart, sustainable, secure and support new generation of logistics

VI. CONCLUSION AND FUTURE WORK

We presented a microservice-based multi-modal logistics route planning framework in this paper. The proposed design overcomes the problems of a large monolithic logistics system by service-orienting the logistics functions (data collection, route planning, costing, fleet management, emission analysis, monitoring and interactions). This allows the improved scalability, flexibility, reliability and maintainability of the logistics system for multi-modal logistics (road, rail, air and sea logistics).

The approach allows the integration of real time GPS, traffic control, warehouse, timetables, weather and orders. This leads to a better dynamic route planning with multiple data sources. The multiple objective optimisation enables the logistics manager to optimise route depending on time, cost, load, service and environmental aspects. So, the framework can be applied to a smart logistics with efficient and dynamic route planning in a real-time environment.

The assessment of the framework discusses the benefits of the microservice architecture for route planning; independent scaling of the services, elimination of computational barriers, system fault tolerance as well as fosters

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innovation in the logistics system. The framework should make the services replaceable, scalable and upgradable without impacting the logistics system. So, proposed framework can be applied to a logistics company working with long route and network, e-commerce supply chain, transport operators and companies providing real time transport network.

The suggested system should be researched to test and develop. This system can be verified with transportation data such as route data, traffic data, fuel consumption, delay and transportation cost. This is to be benchmarked against the current route planning systems on delivery time, cost, reliability, CO2 emission and response time.

The proposed system can also be integrated with artificial intelligence, machine learning, digital twins, blockchain and edge computing. Machine learning will enhance the demand and travel-time prediction and disruption detection. Digital twins will be used for risk assessment and optimisation. Blockchain will promote transparency and trust among players in logistics and edge computing will also reduce delays. It may even spawn cars, drones, electric vehicle rechargers and carbon models.

So it's platform for the Internet of the future of route optimisation. It's a scalable, smart and sustainable way of improving the efficiency, reliability and quality of multi-modal transport, operations and decision making in the supply chains

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