

## A Scalable Full-Stack Web Application for Global Shipment Tracking and Realtime Logistics Monitoring

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### Abstract

The Global Shipment Tracker (GST)—Transaction Management System (TMS) is an Internet-based (WEB) application that will streamline and centralize logistics management for international shipments. The GST is a complete (end-to-end) solution for tracking cargo from origin to destination, managing shipment transactions, tracking logistics activities in real time, and providing visibility across the entire supply chain. Users – specifically, logistics managers, transport agencies, and customers – will be able to register shipments, update their transit status, verify delivery milestones, and maintain a complete historical record of the transaction (from both the origin and the destination) through the use of this system. The backend architecture will facilitate secure storage of data, efficient processing of transactions, and integration with third-party APIs that allow users to proactively track live locations of their shipments. The frontend architecture will facilitate an easy-to-use interface to help users visualize their shipment route through time and with operational analytics. The GST/TMS will improve the transparency, the speed, and the accuracy of decision-making in international logistics operations, thanks to the automation of manual processes and reliable real-time information. The GST demonstrates how full-stack technologies can be used in practice to address complex issues associated with modern international shipping and supply chain management.

**Keywords:** Global Shipment Tracking, Real-time Tracking, Logistics operations, Full-stack web application, Automation.



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### 1. Introduction

Today's global economy has resulted in an unprecedented ability to deliver goods much further and faster than before. Products manufactured in one country can be assembled in another and then transported to completely different locations around the world, creating significant challenges in providing up-to-date information about shipments' geographic locations during transit. While technologically advanced tracking systems exist to allow consumers and business owners the opportunity to track shipments globally, many consumers and business owners continue to have difficulty obtaining up-to-date tracking information regarding their shipments. There are particularly significant issues obtaining access to real-time tracking information regarding international shipments and those being transported between multiple shipping carriers due to each logistics company using different processes to track shipments. In other words, each logistics company can provide very

different tracking information related to the detailed status of a shipment, how reliable that specific information is to be trusted on an ongoing basis, and how frequent those updates will occur.

Users frequently find themselves going from one website to another and/or receiving information that is outdated or not receiving any information about the shipment at all. The lack of visibility creates stress, disrupts business, and can result in financial loss when delays occur. The Global Shipment Tracker will eliminate the hassle of tracking your shipments through different systems by pulling all of your tracking data into one system. This means that you can see where your shipments are at all times and how they are progressing without having to go back and forth between multiple applications. The entire project is built using a full-stack development methodology, which allows us to build an incredibly powerful backend system that will be able to process data from multiple carriers while providing an easy-to-use user interface that provides users with accurate and timely information about their shipments. The back end of the system operates in a manner that is "transparent" to the end user. It continuously collects data from multiple carriers (shipping companies, for example), stores this information, and then provides updates to users as soon as they become available. The front end will display all of this information in a simple and intuitive way so that users can quickly and easily see the shipments' route to their final destination, the shipment's travel history, and the estimated time of arrival for each shipment, without any of the technical complexities associated with these types of systems.

When combined, the front-end and back-end of the Global Shipment Tracker will deliver an exceptional tracking experience that meets both the business's and individual user's needs. This type of system does more than improve convenience to allow for greater accuracy in decision-making and reduced uncertainty; it helps to reduce supply chain disruptions. By giving businesses access to real-time shipment data, businesses will be able to better plan and communicate with each other. Customers will receive peace of mind knowing that they have received their order(s) as expected and create a sense of trust between customers and businesses. As global trade continues to grow rapidly, having robust tools that promote both transparency and simplicity—such as a Global Shipment Tracker—ensures the continued efficiency and reliability of global supply chains. The goal of this research paper is to describe how the Global Shipment Tracker defined in this paper could be developed and implemented using modern full-stack technology. The research will include a discussion of the issues associated with the implementation of a unified global tracking system and the overall effect a unified global tracking system would have on the global logistics industry. Understanding the operation of the Global Shipment Tracker will help to illustrate the potential benefits of technology towards providing better clarity, increased transparency, and enhanced usability for all participants in international shipping.

### **1.1. Motivation**

As it stands today, there are many people who have no way to track their orders and thus have no definite idea where their items are at this point or when they will receive them. This creates a lot of anxiety for both consumers and companies, as consumers want to know where their products are located, and companies want to know how to keep operating by working on products that they cannot find. The products, or "goods," are able to be shipped all around the world, usually with multiple countries, multiple shipping companies, and days or sometimes weeks sitting in customs with no outside visibility on their location. Virtually every shipment will cross between multiple countries on multiple freight carriers with many different tracking numbers when delivered. Because the logistics carrier business is very independent, many customers will eventually lose the ability to obtain a complete view of their parcels, with that resulting in customers having questions or concerns about the fact that they are unable to get visibility of their shipments. The Issues (Challenges) Facing Businesses: The Problems Created for Businesses—The challenge created by this situation has led to the need for a tool that brings all elements of tracking together into a single platform that provides complete, real-time information to users regardless of carrier. Customer behaviour has also changed in

terms of how they expect things to be executed. Due to the rise of real-time status updates on rides, food deliveries, and flights, when customers do not receive similar real-time updates on their packages, this can lead to frustration and uncertainty for the customer. If the customer had a comprehensive tracking system that would provide them with enough information so that they would have confidence and clarity about where their shipment is and what stage of that shipment it is in, they would be much happier. Technology is a primary driver in the ongoing digital transformation of logistics; therefore, there is an increasing desire to build more intelligent, interconnected systems that improve how goods are shipped around the world through continued technological advancement.

The Global Shipping Tracker illustrates how web-based technology can effectively create solutions to some of today's most complicated real-world issues. Global shipping became complex; however, this product helped convert that complexity into user-focused information. This project will address consumers' concerns, improve communications between consumers and shippers or transportation carriers, and empower consumers to manage their day-to-day activities. This project seeks to provide transparency to the complexities of global shipments through a single best-in-class platform for customers to receive relevant live updates to the shipment status (tracking updates). Additionally, this project will provide an efficient and effective means to close the gap in communication and transparency/clarity of relevant shipping data between the consumer and the shipper/transportation provider. The research will demonstrate a user-friendly, easy-to-understand, basic, human-readable shipment tracking site.

## 1.2. Contribution

This study seeks to enhance the simplicity, clarity, and availability of global shipment tracking for business users and normal end users alike. The Global Shipment Tracker project provides many substantial contributions that help to address specific challenges users experience within logistics; those contributions are outlined below in a human-centric manner:

1. Combining various shipment tracking systems into a single repository where users can do their shipment tracking.: This project's largest contribution is consolidating many shipment providers' tracking systems into a single repository where users can track all their shipments in one place. Users do not have to access several websites and attempt to combine information from various shipping companies' websites; they can now depend upon one single-source location for tracking their packages. This has made tracking packages much less confusing and has given users of the service a much greater sense of control over their shipment deliveries.
2. Creating a full-stack application for managing live data.: This project demonstrates how current technologies of complete-stack development can be leveraged to support the continuous change of the data related to shipments. The back-end application is developed to receive and process the real-time data provided by a number of logistics companies, and the front-end application provides that data to users in a scalable and timely manner. This integration of both applications illustrates how reliable and efficient a real-time system for tracking shipments can be due to advances in technology.
3. Present Complex Shipping Information in An Easy to Understand Format: Your system also does a great job with User-Friendly design . In addition to displaying raw data there are plenty of ways for the user to get the data organized so they have a level of convenience and usability when interacting with your application. For example, you can use mapping Devices, Timelines, Progress Indicators. These will help the people to understand the shipment in a non-technical way as they are being updated. This will reduce overall stress to the person waiting for shipment at their destination.
4. Create More Transparency in Global Shipping : The project helps create new levels of transparency in the shipping process by providing more accurate updates pertaining to the shipping process (i.e., delays, customs hold, route changes). Information like this allows all the stakeholders

(customer, vendor, supplier) to continue to be involved in decision making regarding shipment of the product and to trust one another in the process of shipping products.

5. Establishing a foundation for future development: The logistics system provides a stable platform for future development; as a result of its flexibility, other researchers or developers can easily add functionality such as tracking, route optimization, and intelligent alerts, which can help the project support not only current logistics but also future research and development.
6. Providing a working solution: Many research projects only exist in theory; however, this system provides a working solution for businesses managing shipments and inventory and a way for customers to track their packages daily. Because of its utility in real-world applications, this project is of great importance and will have a long-lasting impact on our world.

## 2. Related work

Over the years, tracking shipments has become a vital aspect of logistics processes. As a response to this need for visibility and transparency, many of the systems used by courier companies and supply chain providers to track shipments were developed to be used within their own networks. Users could track their shipment through the use of online dashboards or mobile applications with real-time visibility into its current location. However, these systems only provided users with information about their shipments travelling through the specific provider's network, which limited them in terms of being able to view everything that occurred with the shipment throughout its transport and the other carriers used along the way. The major logistics companies, such as UPS, FedEx, and DHL, have developed their own similar national shipment tracking programs, where customers can track packages that are shipped through their networks. Most package tracking systems have elements of shipment status, history of shipments or proof of delivery, and estimated delivery dates but are not integrated with each other, which can create a difficulty for the end user when packages need to be shipped through multiple carriers or shipped internationally.

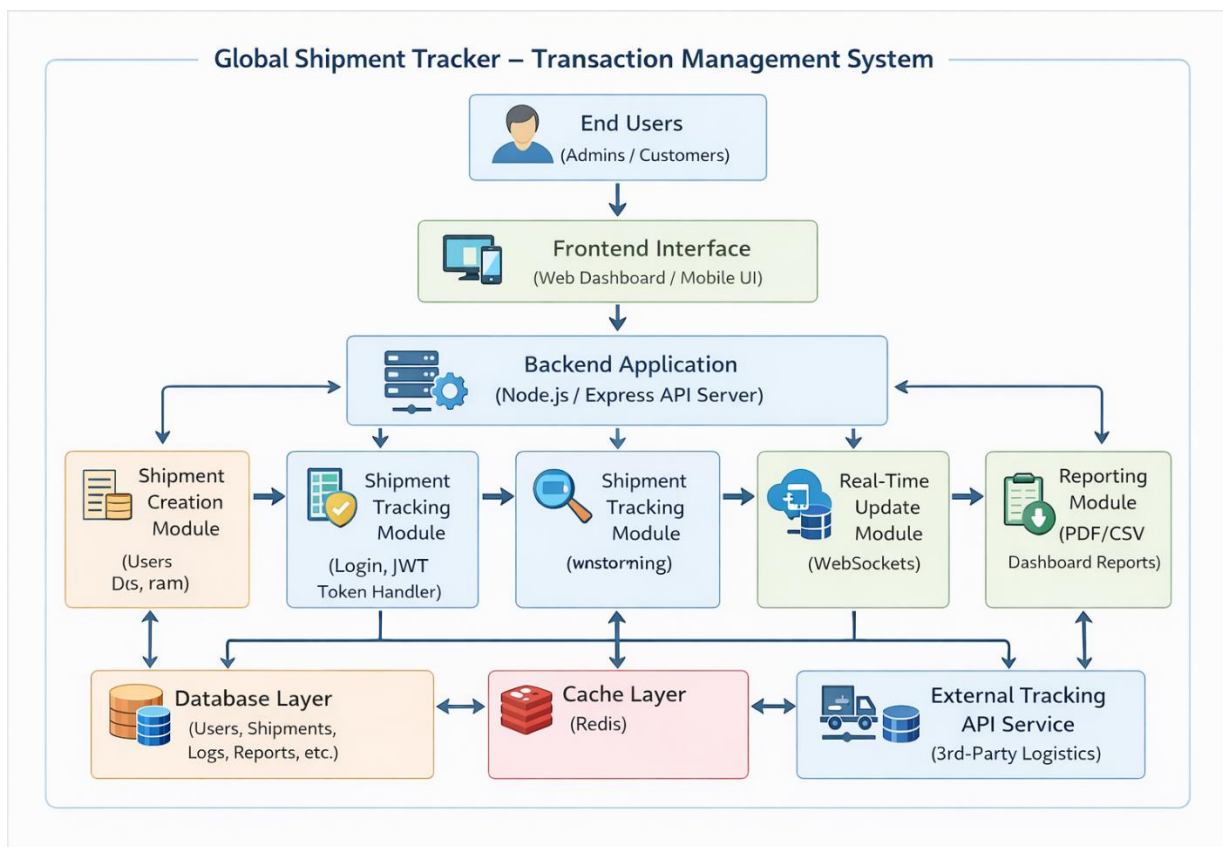
Third-party shipment aggregation tools have been created to gather tracking information across multiple carriers as a supplement to courier-specific platforms. These systems use either publicly available APIs or user-supplied tracking numbers to request shipment information from various logistics providers. While this can be very useful, the reliability of these tools can be limited due to differing formatting, timing, and accuracy of the information received from the various carriers. Thus, aggregated tracking platforms may not provide complete or timely data for real-time decision-making. The research conducted on supply chain transparency and logistics digitalization has shown the urgent requirement for unified tracking systems. Many academic studies have highlighted the fragmented nature of shipment data and the many difficulties in developing a means to integrate multiple carrier APIs. Most of the researchers stress that standardizing the tracking model and improving the interoperability of logistics networks is critical. Some researchers have investigated technology such as cloud computing, IoT sensors, and blockchain to improve the accuracy and security of tracking data. However, these methodologies are typically either very complicated and/or costly or are designed to meet the needs of industrial users rather than general consumers. This project, the Global Shipment Tracker, was created to provide a complete, consolidated way to track shipments. While most of the other products are making tracking possible only with their own carrier, the Global Shipment Tracker is meant to allow users to track shipping from multiple carriers, which will lead to more visibility for the user. The Global Shipment Tracker demonstrates how innovative web technologies can be used to deliver real-time data processing and visualization using a user-centered design in a logistics environment. Although there are many systems for tracking shipments, there is a limited number of integrated systems that allow for easy interpretation of shipments from multiple carriers, regions, and methods of shipment. This research is based on the positive aspects of other research while addressing the lack of cross-network integration, ease of use, and accessibility.

### 3. Research Methodology

#### 3.1. Problem statement

It may seem like an easy task to track a shipment, but many people have been having difficulty tracking their shipments and finding out where the products are located. Because shipments travel from one country to another and through different logistics carriers, information about the tracking of those shipments tends to be scattered throughout the system. Having no single reliable tracking system to reference creates big problems for both businesses and their customers. Countless businesses depend on their supplies being delivered to them to maintain an effective inventory control system and be able to schedule production runs based on when they will receive their supplies, but with many companies unable to have a complete view of their supply channels, it is virtually impossible for those companies to anticipate potential delays and respond in time to prevent those delays from causing problems within their business. Individual customers are also left feeling anxious or uncertain because they have no way of knowing where their package is located and when they can expect it to arrive.

There have been some attempts at third-party software designed to consolidate shipping information from multiple logistics providers, but these programs struggle to produce satisfactory results due to many reasons, including incompatible data formats between providers, slow update speeds compared to how often companies ship products, and missing information within the system. This is primarily a result of different companies using their own specific methods of collecting and processing data from the time you place an order until it arrives at your door. Given this complexity, it is therefore not currently possible to find a reliable, simple-to-use global tracking solution that can allow you to track a shipment through multiple carriers in one consistent and clear manner, nor is there a global shipment tracking solution that can consolidate all the disparate sources of tracking data into a workable single source of truth for both businesses and individuals to help improve the way shipments are tracked globally; this is the primary focus of this research.



**Fig 1: Block diagram of the proposed model**

In this shipment management system architecture shown in Figure 1, there are primary components that have been divided into multiple functional areas, with each component having a specific duty or task throughout the system. When you look at all of these components combined, they provide secure access, allow for shipment processing, provide real-time updates, allow for report generation, and integrate with other logistics systems.

### 3.2 Proposed Algorithm

1. Start the system. Get the backend services running, like the database and cache.
2. The user types in their login details.
3. The system checks these details. Creates a special token if they are correct. If not the user gets an error message. Cannot access the system.
4. The user fills out a form to submit a shipment.
5. The system checks the form is correct saves the shipment details gives it an ID and tells the user that the shipment is created.
6. The user asks to see the status of a shipment.
7. The system tries to find this information in the cache. If it is there the system shows it to the user away. If not the system gets the status from the database or a logistics API.
8. The system saves this shipment status in the cache so it is quicker to access time.
9. The backend is listening for updates from inside and outside the system.
10. When a shipment status changes the backend sends this update to all users through WebSockets.
11. The user picks a report type and a time period.
12. The backend gathers the needed data, from the database to make the report either as a PDF or CSV file and lets the user download it.
13. The system logs any errors it or its operations encounter.
14. The system will alert system administrators or the users as needed.
15. The system ends the users session and waits for the next command.

## 4. Research Methodology

This chapter describes the processes used to plan, create, and assess the Global Shipment Tracker—Transaction Management System. This includes research methodologies; where the data for use in developing the system came from; the environment the system was developed in; how Preprocessing was done on the data prior to system development; and testing and assessment methods used to validate the system.

### 4.1 Research Approach

The project follows a practical, development-based methodology. While there is an emphasis placed on theoretically based modelling, there is even more emphasis placed on understanding how shipments are tracked throughout the "real world" and then creating a system to track those shipments as efficiently as possible.

The overall research methodology used in the project was as follows:

1. Understanding the problem by analysing how a shipment is generally tracked and examining what issues users may encounter when they deal with shipment delays, shipment status changes, or underdeveloped shipment tracking information.

2. Constructing the whole system with a full-stack development approach—each module (authentication, shipment processing, notifications, and real-time updates)—was developed in a linear manner, one at a time.
3. Testing and refining the entire system through a combination of performance measures, accuracy of all data being updated in real-time, and user testing.

Using the iterative engineering approach allowed for amendments to be made throughout the development of the system as additional issues or requirements arose.

## 4.2 Obtaining Dataset

To verify and validate the system, you will need an appropriate dataset of shipment data. Since the datasets of real companies were not available (due to confidentiality), the following have been used to create a simulated dataset:

- Shipment records created manually, which simulate actual data for each of the shipments' senders and receivers, along with parcel ID, timestamps, and the logs indicating activity of parcel
- Automatically generated sample records used for large-scale testing; includes bulk shipment records and record updates occurring at a rapid rate.
- Mock API returns (in particular those from third-party logistics providers) showing how updates are provided to company shipment tracking.

The overall goal has been to create a dataset closely resembling actual shipping behaviors, thereby allowing the evaluation process to take place under conditions that best reflect those found in the "real world."

## 4.3 Environment for Developing the System

The modern full-stack development system has been created with the following tools and technologies:

- Frontend: A JavaScript framework (probably, such as Angular or React) for the webpages where the user will enter a shipment and access a report of shipments, order shipped, find a shipment, etc.
- Backend: Express and Node.js to manage security and authentication, provide alerts, query the database, handle APIs, and communicate with other apps.
- Database: Logs, tracking information, user profile information, and shipping details are stored in SQL or no-SQL databases (such MySQL, PostgreSQL, and MongoDB).
- Real-time communication: WebSockets are used to deliver immediate updates when a shipment's status changes.
- Cache Layer: Redis will allow for faster access to frequently accessed information such as the status of the last shipment.
- Testing Environment: Local development servers supported by tools like Postman, Docker, and various source control systems for testing functionality.

The development environment for the system has produced a system that is reliable, scalable, and functional.

## 4.4 Data Pre-processing

Before putting the dataset into the system for implementation, an extensive list of data preprocessing was needed to ensure both the accuracy and consistency of these records had been processed correctly.

Data Cleaning—included removal of duplicate records (a duplicate shipment record). Dates that were missing will be completed, and the formatting was corrected in the correct places.

**Data Standardization**—Each field within the shipment record has been formatted consistently between all shipment records. Shipment records also require a consistent method for indicating the status of each shipment (i.e., shipments will format and display the shipment status in an appropriate manner).

**Data Verification**—Each shipment has been assigned a unique identifier, and the shipment statuses have been provided to each shipment in the predetermined format established by the company for use in the day-to-day business.

**Data Categorization**—categorizing all records into their defined categories (i.e., type of shipment, area shipped from, where shipped to, shipment's current status) assists in ensuring smooth testing within the system.

This data preprocessing was executed prior to the testing of the system using shipment data, and it greatly reduced the number of errors occurring in the backend due to proper and optimal management of the shipment data.

#### **4.5 Model Training Applied**

Although the primary function of the project is to execute transaction activities, a few analytical capabilities will require model training. For instance, to estimate the rate of delay, to locate anomalies, etc.

The data set used to train the model was cleaned and structured to be entirely complete without any gaps or missing data. The model was not built to be an overly complicated machine learning system. Instead of creating a complex machine learning system, the objective of building a model was to answer whether simple predictive methods could yield useful data in ascertaining a forecast/forecasting the status of shipments.

##### **4.5.1 Hyperparameters**

While developing the model, various hyperparameters were modified to yield performance enhancements. There were multiple hyperparameters that were set for training the model; these hyperparameters were as follows:

- Number of epochs spent in the training process.
- Learning rate associated with that epoch.
- Batch size used for training.
- Depth of model, or number of layers in the model (varies based upon model type).

Once every one of the hyperparameters has been established, they are established and fitted until the outcomes are stable.

##### **4.5.2 Loss Function**

Each loss function used for training models was developed based upon the problem referenced within the model. For example: Would cross-entropy loss be an appropriate loss function for classification operations?

#### **4.6 Evaluating System Performance by Component**

To assess the performance of the system based on the capabilities of its analytical component, various methods were utilized for the purposes of evaluation.

##### **4.6.1 Confusion Matrix**

The confusion matrix that was created for comparison between the predicted shipment status and actual shipment status served to evaluate:

- The accuracy of predictions made by the model

- The points at which the model has confused one class of shipment status with another class
- The existence of any patterns indicating where the model has misclassified instances

This also helped identify the strengths and weaknesses of the model with respect to prediction.

#### **4.6.2 Performance Metrics Calculated from the Confusion Matrix**

After creation of the confusion matrix, various performance metrics were calculated using the data from the confusion matrix, including accuracy (i.e., how often was the model correct), precision (i.e., the confidence that a positive prediction is actually a positive prediction), recall (i.e., how well does the model accurately predict actual living events), and the F1-score (i.e., the balance point between precision and recall). The use of these metrics provides us with a more comprehensive evaluation of the true performance in the real world as opposed to simply relying upon just the accuracy of predictions made by the model.

#### **4.6.3 Observation**

The testing of the transactional functionalities of the system (adding shipments, updating shipment status, retrieving shipment records) showed that the system performed as expected, with little lag and very little downtime from the system. Also, the use of WebSockets to provide real-time updates to users as they interacted with the application was considered to be effective, as the user was able to view the most up-to-date information without having to refresh their browser prior to seeing that information. With respect to the predictive capabilities of the application, the trained model provides reliable insights and produces results that, after proper preprocessing and tuning of the model's parameters, are capable of supporting basic-level forecasting. The application could be improved with a larger dataset from an actual environment.

### **5. Experimental Design**

It was designed to test the Global Shipment Tracker's performance, reliability, and usability during normal operating conditions by providing a controlled environment in which to conduct functional and performance testing upon completion of the aforementioned steps.

#### **5.1. Hardware Environment**

Required Specifications:

- Intel i5 or equivalent processor
- 8 GB of RAM
- 256GB SSD for Storage
- Stable broadband connection between 10 and 20 mbps.

The specified hardware allowed the backend server, database, and test client machines to be utilized without observable delays.

#### **5.2. Software Environment.**

The following systems were used for both the frontend user interface of the Global Shipment Tracker as well as for supporting the backend processes.

1. Frontend - ReactJS
2. Backend - Node.js with Express framework.
3. Database—MySQL for primary storage and Redis for caching.
4. Real-Time System - WebSockets.
5. Third-party shipment tracking API.

## 6. Development Tools—VS Code, Postman & Git.

The above-mentioned software will provide for a seamless integration of all modules and will allow for rapid development and testing cycles.

### 5.3. Test Data Setup

Test data setup consists of creating dummy shipment records to simulate the real-world process of logistics.

User accounts will be created with various access levels (i.e., admin, staff & viewer).

Testing will be performed based on the following test scenarios: New shipments created; shipments in transit; shipments delivered; shipments not completed.

### 5.4. Deployment Configuration

The backend will be hosted on a local server.

The frontend will be hosted on either a local test server or a cloud-based test server.

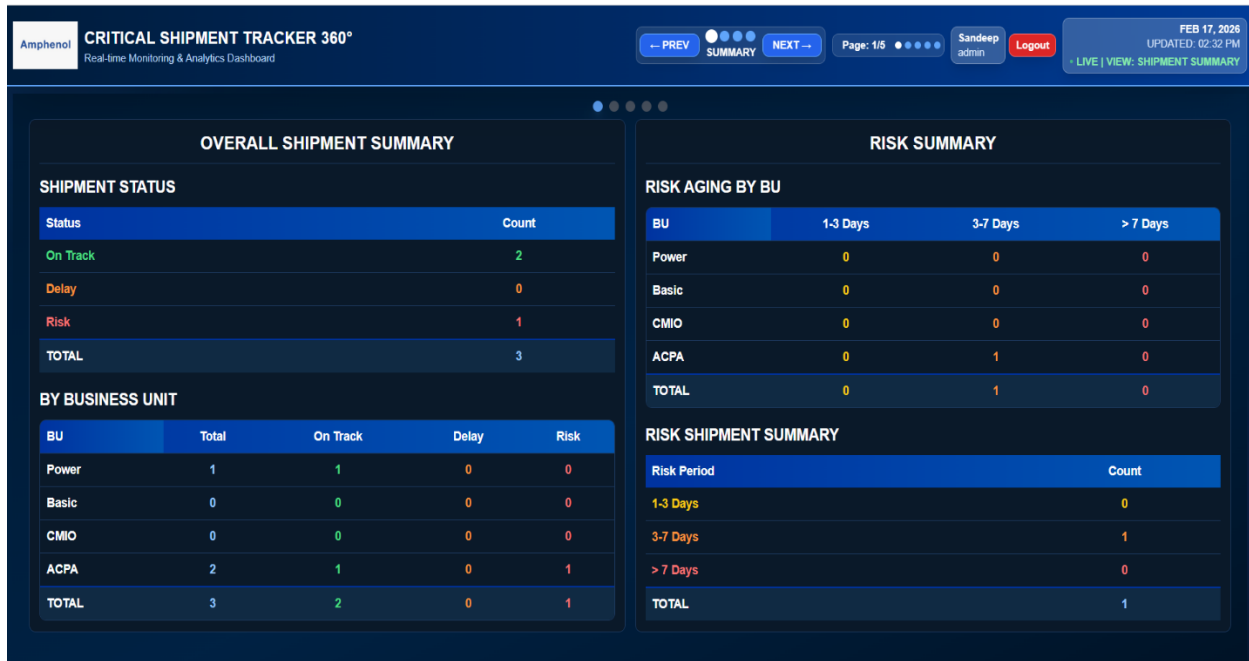
The database & Redis services will be standalone entities in an effort to not interfere with the system's performance.

### 5.5. Testing Procedures

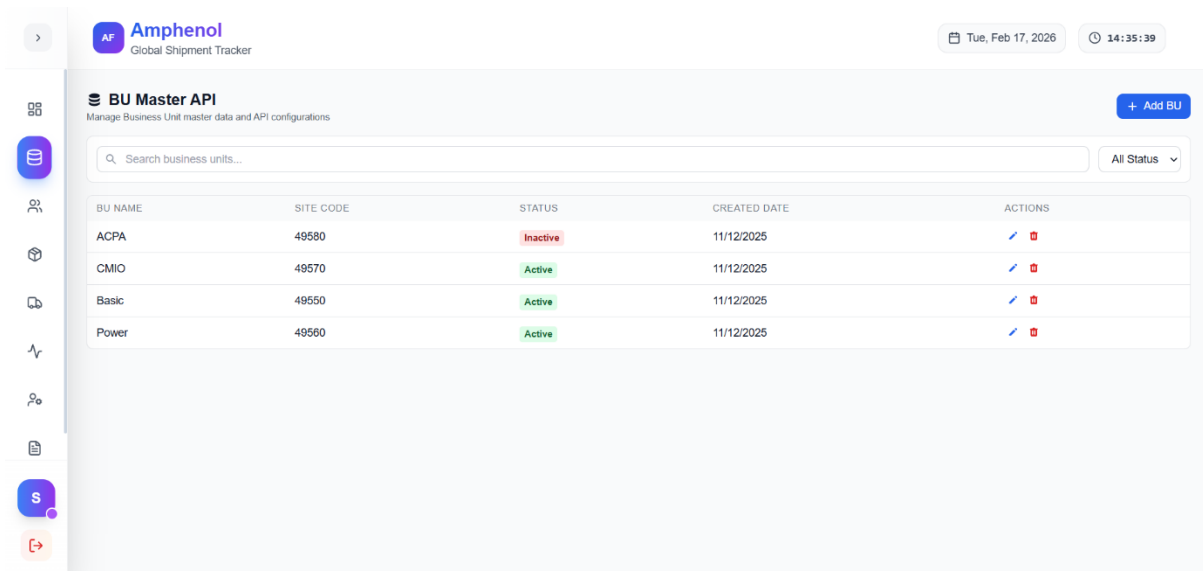
Multiple users tested interfacing with the Global Shipment Tracker System.

#### 5.6 Result Evaluation and analysis

The Global Shipment Tracker – Transaction Management System tested a variety of functions including functionality, performance, accuracy, and user experience. During testing, all major modules (e.g., authentication, shipment creation, tracking, report generation) performed properly and shipment information was loaded accurately with the last known status reported for each shipment, based on internal systems and the Andes and other 3rd party logistics APN methods. Cost testing showed that the system had a very quick response time as all logins and data retrievals completed in less than one (1) second, and users received real-time updates from the system (via WebSockets) within milliseconds. The speed of the system was improved when using cache, and at no point were there any performance-related issues during testing as multiple users logged concurrently. Users of the test performed very well in regards to their experience with the tool and stated that they found it easy to navigate, and that the tool provided the users with good alignment with their expectations of having access to real-time information regarding their shipments. Users also participated in a stress test to determine whether or not the shipping tool was able to maintain stability throughout all testing, and that there were no system crashes, or data discrepancies found in the course of testing. In conclusion, the Global Shipment Tracker Transaction Management System has demonstrated a high degree of accuracy while consistently providing reliable performance and an overall pleasant experience to the end users, successfully supporting the Global Shipment Tracker's goal of being a shipment tracking and transaction management solution.



**Fig 1.2: Shipment & Risk Summary Dashboard - Critical Shipment Tracker**



**Fig1.3:Global Shipment Tracker Master Configuration for Business Units**

## 6. Conclusion and Future work

The GST (Global Shipment Tracker)'s Transaction Management System offers comprehensive integrated tracking solutions and transaction capabilities through a full-featured architecture, including secure logging using authorized users, instant creation of shipment records in a centralized database, real-time instantaneous updates, and advanced reporting generated through both real-time and historical data related to each shipment within the entire Transaction Management System.

All supply chain participants share the benefit of improved communication, transparency across the supply chain, and reduced manual errors due to their utilization of the GST Transaction Management System's reporting tools. The GST offers numerous APIs to enhance its capabilities of supporting many different requirements and potentially providing multiple solutions to meet the specific needs of each individual entity or company involved in global shipment tracking operations.

The GST also has a modular application architecture with a back-end architecture that can scale to accommodate increased demand as well as a user-friendly interface that demonstrates the use of modern web technologies to maximize the efficiency of global logistics processes and the visibility of products and services being transported throughout the entire global supply chain.

In conclusion, the research presented in this article demonstrates how digital transformation has positively affected workflow processes related to global logistics and provided a platform to develop smarter and better-connected supply chain management systems; however, there are additional future research areas that can be developed to further improve this type of research content. The examples listed are just a few of the potential innovations that could be developed.

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