Presentation by: EcoLogix_LT

AI-Driven Route Optimization Software: Reducing Carbon Emissions in Logistics

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South Africa's logistics sector significantly contributes to the country's high carbon emissions, exacerbating climate change and environmental degradation. This presentation introduces an innovative solution that leverages AI-driven route optimization, real-time traffic management, and predictive analytics to reduce inefficiencies in logistics operations. This is done by applying Industrial and Systems Engineering (ISE) principles to improve operational efficiency and reduce costs. This approach not only addresses the immediate environmental challenges but also provides a scalable, sustainable framework for the future of logistics in South Africa.

Global Climate Change Challenge

- Carbon emissions are a major contributor to climate change, with the **transport sector** playing a significant role worldwide.
- Countries, including South Africa, are under increasing pressure to **reduce emissions** to meet global environmental goals.

South Africa's Climate Crisis

- South Africa's carbon emissions are the **highest in Africa**, with rapid urbanization and industrialization contributing to increased greenhouse gases.
- The country's **mean annual temperatures** have increased at twice the global average, leading to greater climate volatility (extreme weather, unpredictable rainfall).

Logistic sector Contribution:

- The logistics sector**, crucial to South Africa's economy**, relies heavily on road transport, which is fuel-intensive.
- This sector contributes significantly to the country's emissions due to poor route optimization, vehicle inefficiencies, and outdated logistics practices

PROBLEM STATEMENT

- **High Carbon Emissions**: South Africa's logistics sector heavily relies on inefficient road transport, contributing significantly to emissions.
- **Impact**: Affects the environment, logistics companies, agriculture, and society due to worsening climate change.
- **Previous Efforts**: Route optimization and vehicle efficiency improvements have not yielded substantial results.
- **Consequences if Unsolved**: Increased environmental degradation, disrupted food supplies, and higher business costs.
- **Global Relevance**: Solutions in South Africa can provide insights for other developing economies working to reduce transport-related emissions.

Root cause analysis: 5 WHYs Analysis

Why are carbon emissions high in South Africa's logistics sector?

❖ Reliance on fuel-intensive road transport

Why does the sector rely on road transport?

❖ Limited use of more efficient alternatives like rail and waterways.

Why are alternative transport modes not widely used?

❖ Underdeveloped infrastructure and lack of investment.

Why is there a lack of investment in alternative transport?

❖ Focus on short-term cost savings and convenience of road transport.

Why is road transport considered more convenient?

❖ Insufficient use of technology for optimizing routes and improving efficiency.

1 Transport mode

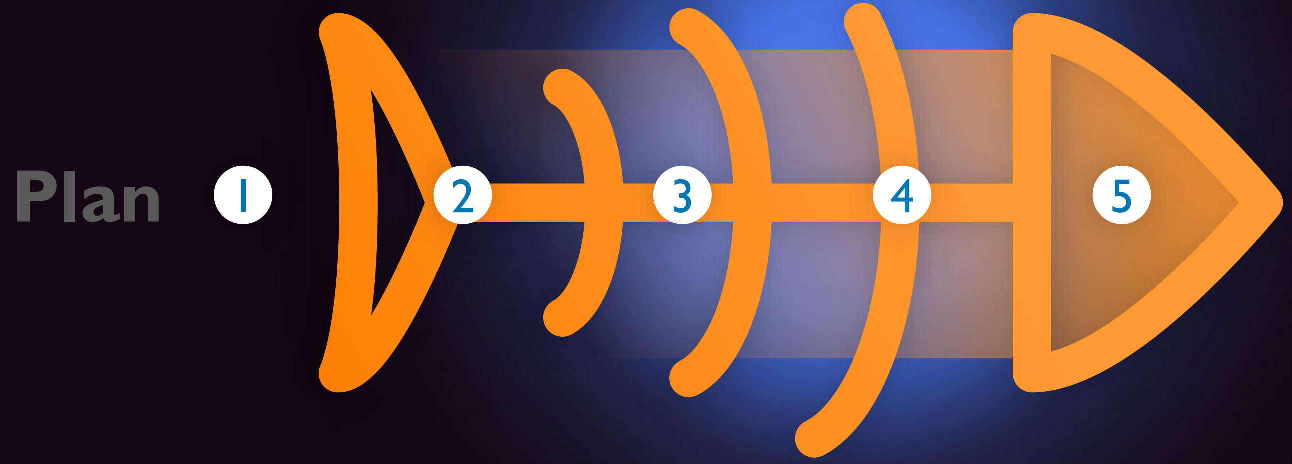
- Reliance on road transport
- Lack of rail and waterway infrastructure
- Inflexibility in switching transport modes

2 Route Optimization:

- Inefficient route planning
- Lack of real-time traffic management
- Absence of predictive analytics

3 Vehicle Efficiency:

- vehicle technology
- Poor maintenance practices
- Lack of fuel-efficient vehicles



6 Contributing Factors to Carbon Emissions in Logistics

4 Load Management:

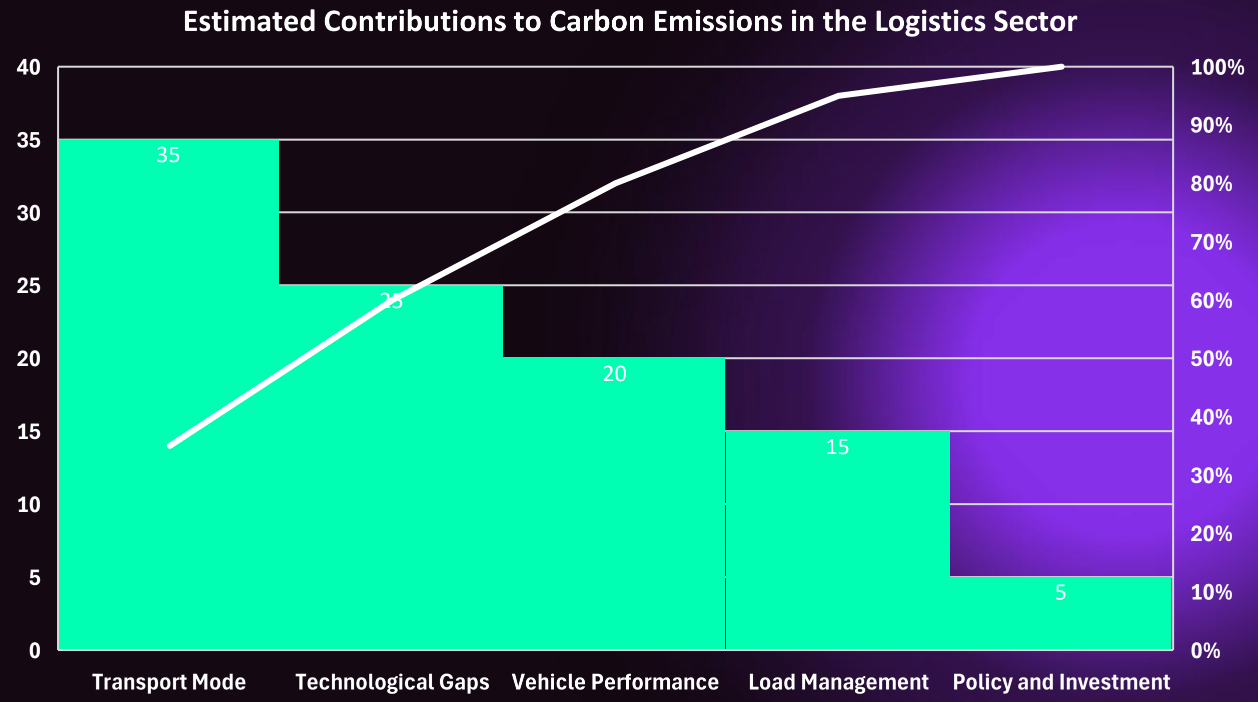
- Underutilized vehicle capacity
- cargo planning
- Inefficient load balancing

5 Policy and Investment:

- Limited government incentives for greener transport
- Lack of investment in sustainable infrastructure
- Weak enforcement of emissions regulations

6 Technologic[redacted]

- Slow integratio[redacted] technologies
- Low usage of da[redacted] making
- High cost of impleme[redacted] technologies



Data Collection:

- Gathered real-world data from logistics companies.
- Key metrics: fuel consumption, route efficiency, vehicle performance.
- Utilized telematics systems and GPS to track vehicle movements and emissions

Emissions Estimation:

- Used emissions calculators (e.g., Greenhouse Gas Protocol) to estimate CO_2 output.
- Data analysed using Excel and Python for accuracy

Results & Insights:

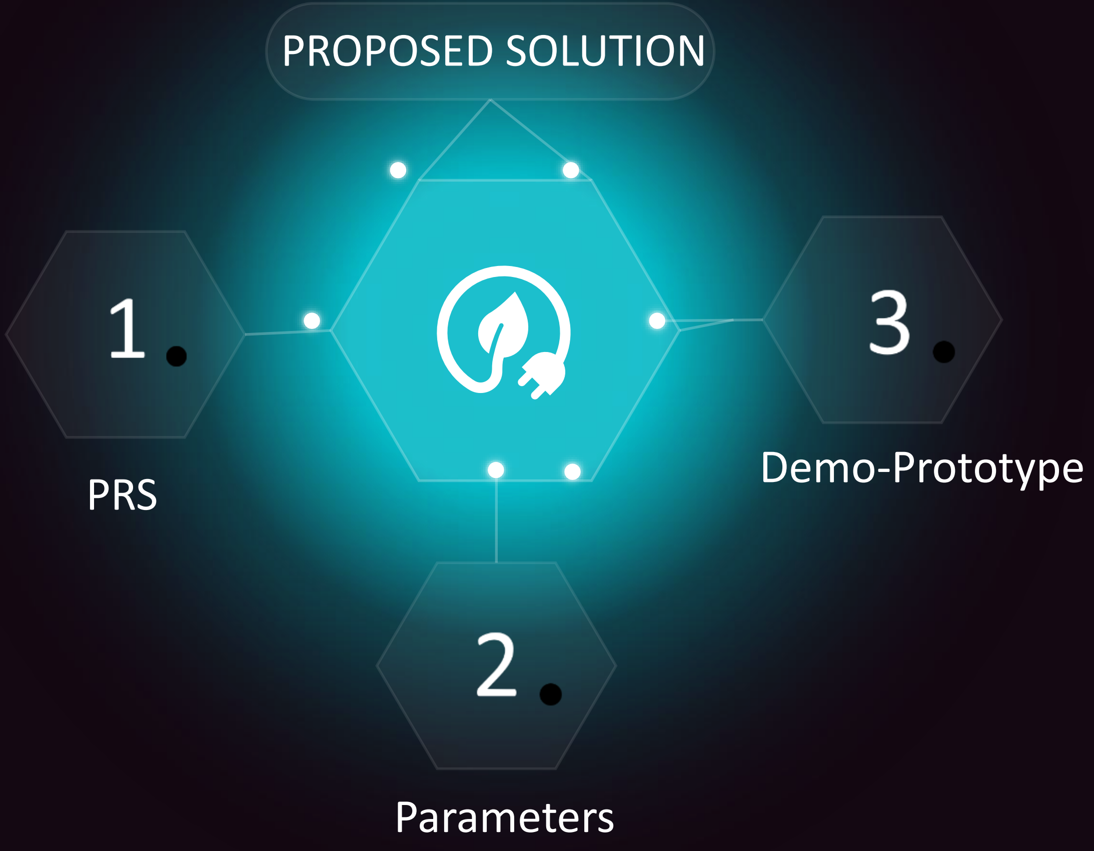
- Pareto chart highlights top three emission contributors.
- Addressing these categories could resolve 80% of inefficienci
- Strategic focus on these areas yields the highest return for pe improvements

Key Capabilities of the Software:

Route Optimization:
- Uses real-time data and machine learning algorithms to find the most efficient routes, reducing fuel consumption and emissions.

Traffic Management:
- Manages traffic flow at warehouses and harbours, reducing delays caused by truck congestion through machine learning-based solutions.

Inventory Management:
- Ensures optimized scheduling and movement of goods, minimizing unnecessary trips and fuel usage



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1 Product Specification and Requirements

Requirements:

- Reduce carbon emissions.
- Improve route efficiency and vehicle loading.
- Scalable and adaptable solution.
- Integrate AI and real-time data technologies.

Constraints:

- Limited alternative transport infrastructure.
- Budget constraints for new technologies.
- Compliance with environmental regulations.
- Industry resistance to new technology adoption

Criteria:

- Cost-effective with high [redacted]
- Significant environm[redacted]
- Practical and feasi[redacted] systems.
- Effective use of tech[redacted]

2.

2 Parameters and Variables

Parameter and Variables:

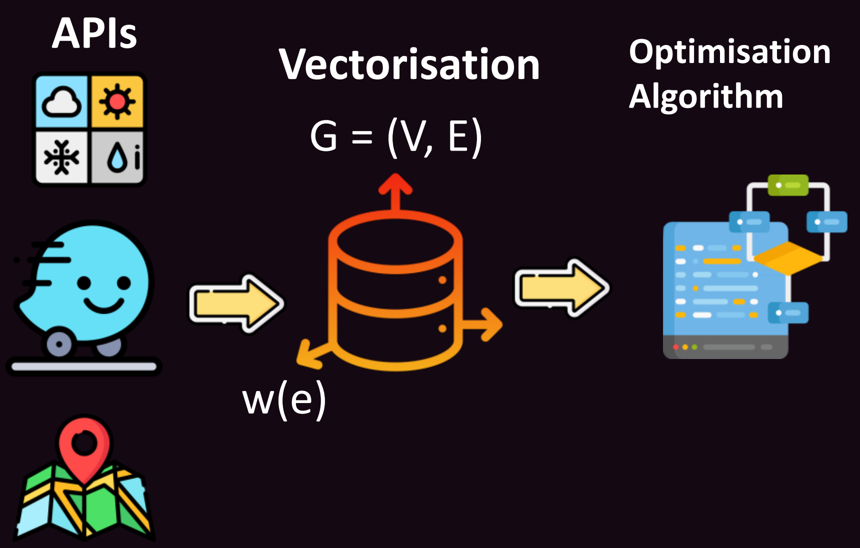
The following variables are critical in defining how the AI-powered solution selects optimal routes. It leverages real-time data from the OpenWeatherMap, Google, and Waze APIs, where the road network is represented by a graph, where **G = (V, E)** represents the road network:

G = (V, E): A graph where V represents intersections or locations (nodes) and E represents roads (edges).

To compute the weight of each road segment for route optimization, the formula below is used:

$$\mathbf{w(e) = d \times t \times r \times w \times g}$$

- **d**: Distance multiplier
- **t**: Traffic condition multiplier
- **r**: Road quality multiplier
- **w**: Weather condition multiplier
- **g**: Topographical multiplier
- dist(v): Tentative distance of node v from the source node, used in route calculations



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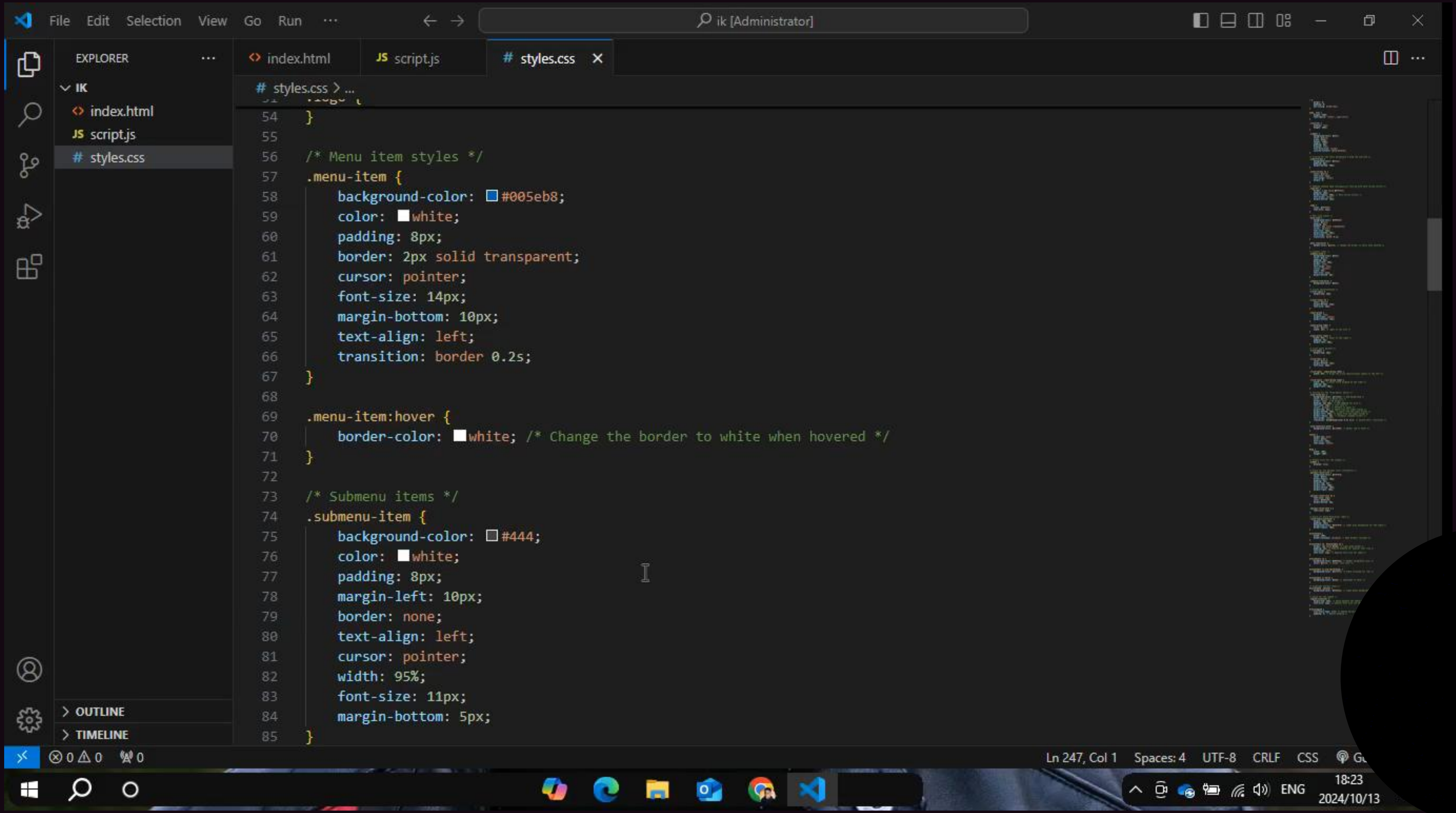
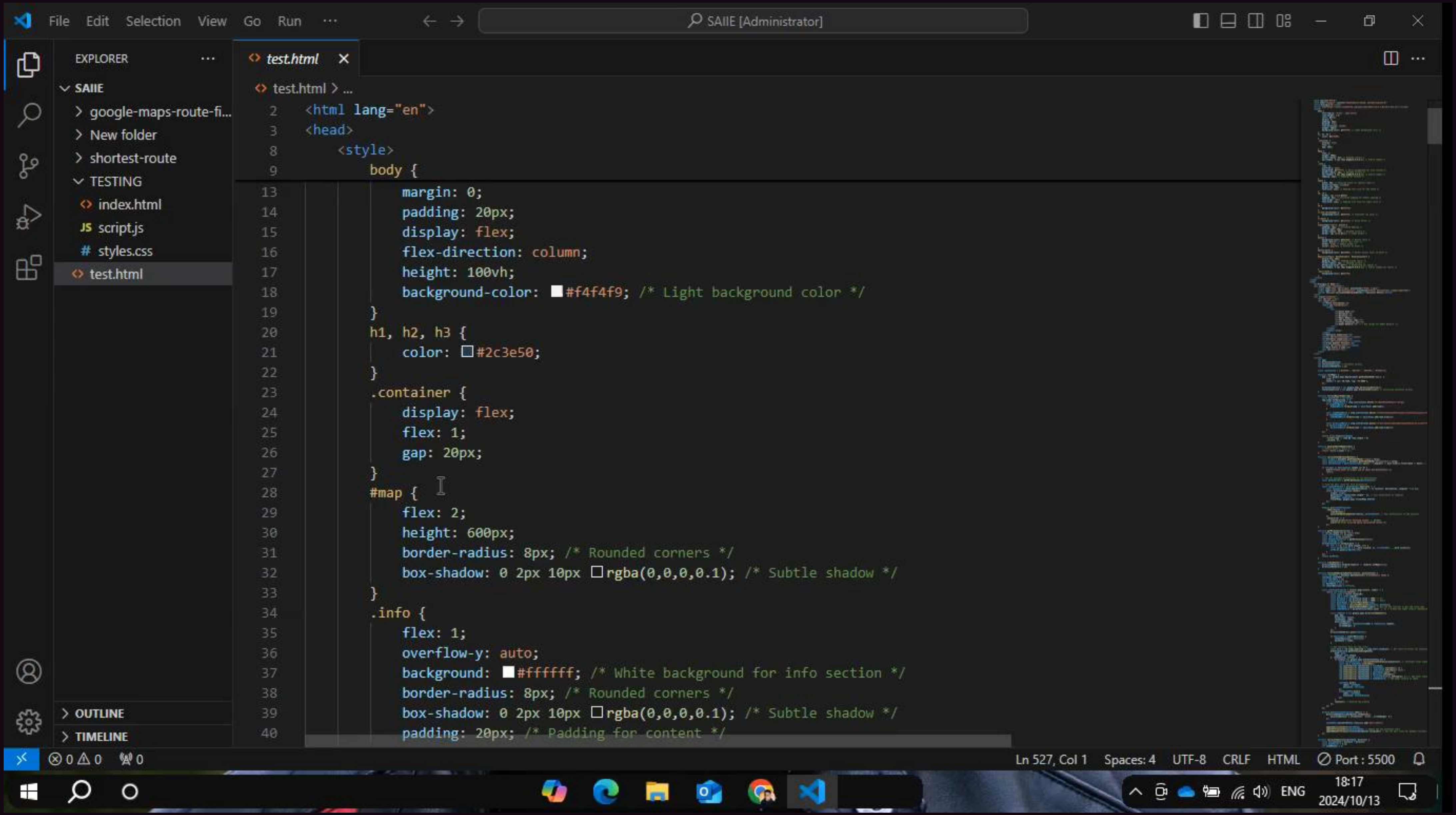
3 Demo-Prototype

One Destination Demo:



Demo-Prototype(continued)

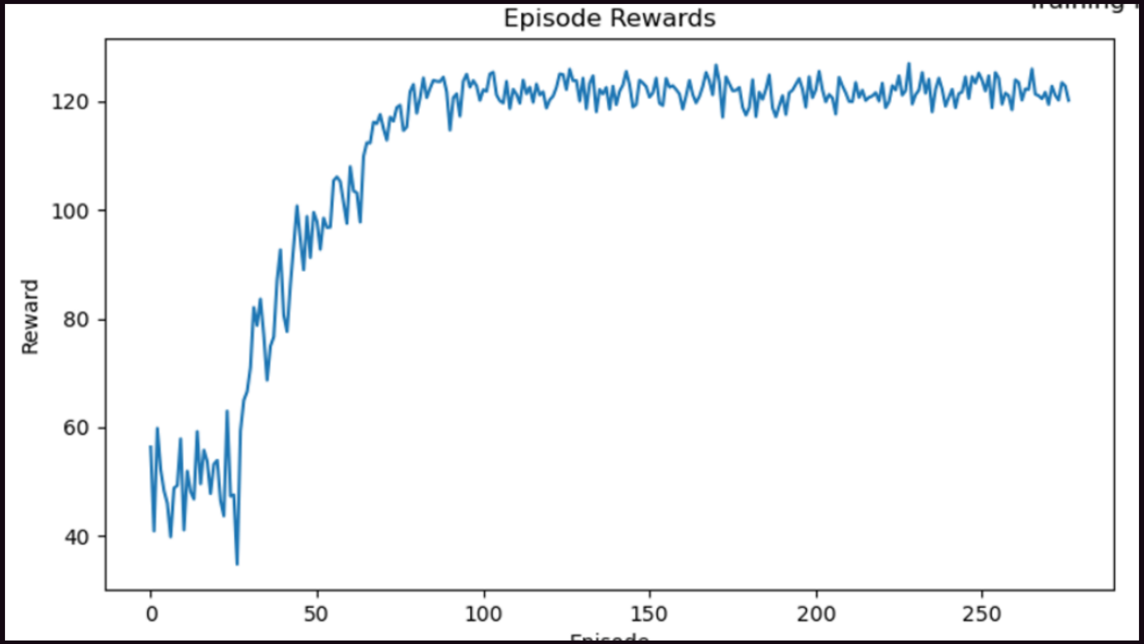
Multiple Destination Demo:

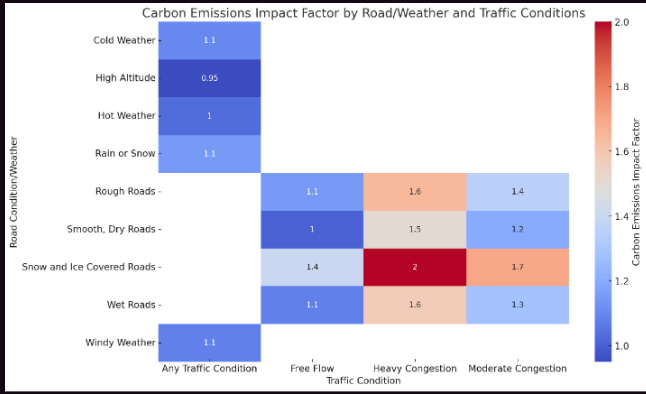


Testing

Methodology:

- Applied reinforcement learning (RL) DQN algorithm in Python by building a delivery custom Environment.
- Used historic trip data available online.
- Simulated small to medium-sized logistics company deliveries
- And plugged in available routes from Waze APIs



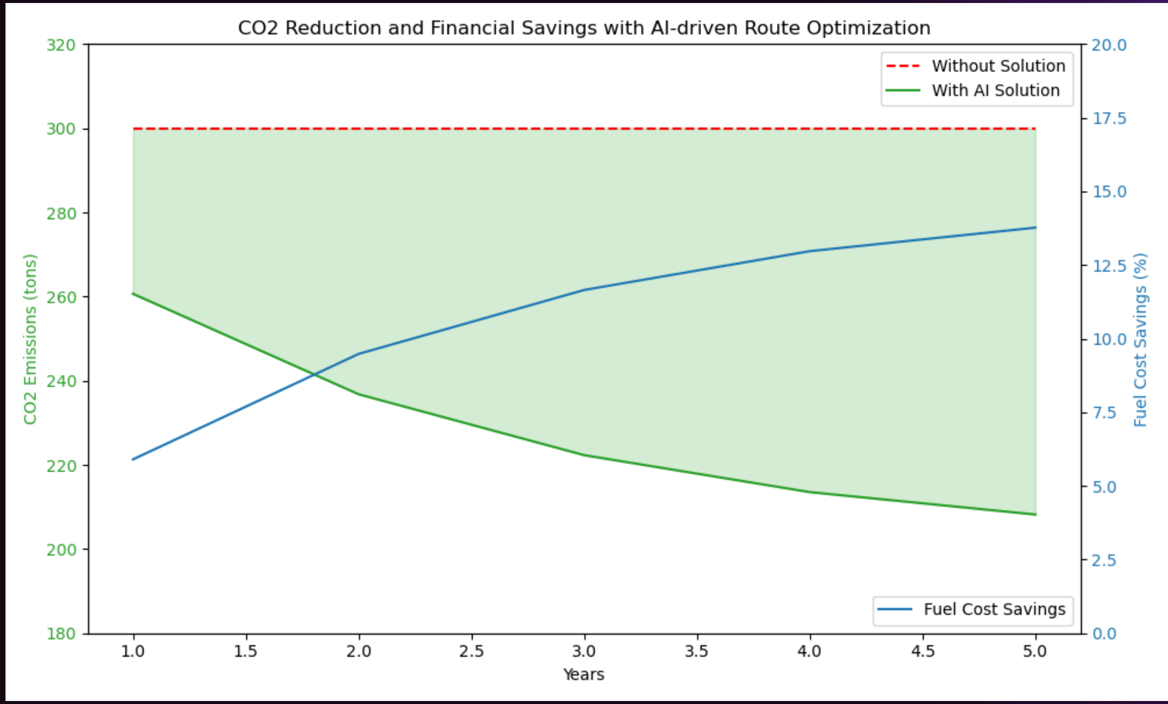


Custom reinforcement learning

```python
def _calculate_reward(self, route):
        # Normalize all factors to be between 0 and 1
        distance_factor = 1 - (route.distance / 100)  # Shorter distance is better
        time_factor = 1 - (route.estimated_time / 5)  # Shorter time is better
        traffic_factor = 1 - route.traffic_level  # Less traffic is better
        road_quality_factor = route.road_quality  # Higher road quality is better
        steepness_factor = 1 - (route.steepness / 0.2)  # Less steep is better
        emission_factor = 1 - (route.emissions / 50)  # Lower emissions are better

        # Weather factor (average temperature deviation from 20°C, normalized)
        weather_factor = 1 - np.mean([abs(temp['temperature'] - 20) / 30 for temp in route.weather_forecast[:

        # Elevation variability factor (standard deviation of elevation, normalized)
        elevation_factor = 1 - (np.std(route.elevation_profile) / 1000)

        # Combine all factors with equal weights
        total_reward = (
            distance_factor +
            time_factor +
            traffic_factor +
            road_quality_factor +
            steepness_factor +
            emission_factor +
            weather_factor +
            elevation_factor
        ) / 8  # Divide by 8 to keep the reward between 0 and 1

        return total_reward * 100  # Scale to 0-100 range
```

Factors that went in the RL Custom environment

Solution Impact for a small to medium Logistic company



CO2 Reduction (With AI Solution):

- There is a reduction in emissions, showcasing optimized routes and reduced travel.

Fuel Cost Savings:

- Up to 15% savings in fuel costs over 5 years, as the solution adapts to real-time conditions.

- Simulate emission reduction for 4 trucks traveling from Durban to Lagos, Harare, and Cairo(AT RANDOM), 3 times a week.
- 5 years of simulated trips.
- Current Emissions: 260 tons of CO_2 per year.
- Measure the impact of optimized routes on emissions

Trucks properties:

- Heavy diesel trucks
- Produce 0,2kg-0,9kg CO2/Km

Advanced Route Optimization:
Technologies: Implemented using JavaScript and Python.

- **Functionality:**
  - Utilizes real-time data for dynamic route adjustments.
  - Factors in distance, traffic, road quality, weather, and topography using custom multipliers.
  - Ensures minimal fuel consumption and reduced carbon emissions

Inventory Management:

Technologies: Developed using Simio, Python, and JavaScript.

- **Functionality:**
  - Manages scheduling and movement of goods efficiently.
  - Ensures optimal inventory levels and minimizes unnecessary trips.
  - Integrates with route optimization for seamless logistics operations.

Traffic Management:

Technologies: Powered by Machine Learning (Unsupervised Learning).

- **Functionality:**
  - Designed for retrieving traffic data from the APIs, including weather and road parameters.
  - Uses unsupervised learning to identify patterns and recommend routes to take for deliveries.
  - Reduces delays and improves truck flow, minimizing emissions caused by idle times

Financial benefits

Cost Reduction

- Lower fuel costs by optimizing delivery routes.
- Reduced vehicle maintenance due to the system’s ability to avoid bad roads and traffic jams.

Increased Efficiency

- Faster deliveries resulting in higher customer satisfaction.
- Better fleet utilization reduces the need for excess vehicles on the road

Regulatory Compliance

- EcoLogix-LT helps logistics companies meet growing carbon emission regulations, avoiding fines and benefiting from green tax incentives.
- Return on Investment (ROI)
- Significant ROI through a combination of operational efficiency, fuel savings, and reduced carbon footprint

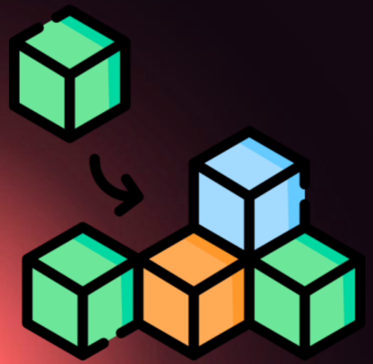
Environmental Benefits

- **Reduced Carbon Emissions**
  - EcoLogix-LT’s AI-driven route optimization minimizes unnecessary mileage, cutting fuel consumption by up to 15%.
- **Sustainable Logistics**
  - Encourages greener logistics by reducing the environmental impact of transportation and decreasing reliance on fossil fuels.
- **Alignment with Global Sustainability Goals**
  - By lowering emissions, The solutions has potential contributes to corporate sustainability targe[redacted] supports South Africa’s commitment to [redacted] carbon footprint under the Paris Agre[redacted]

Scalability

Modular Design

- The software is modular, allowing easy integration with existing logistics platforms.
- New features like multi-transport mode selection and alternative fuel considerations can be added as logistics operations evolve.



Global Expansion Potential

- While initially focused on the South African market, EcoLogix-LT’s framework is adaptable to logistics challenges worldwide, including regions with complex infrastructures.

Conclusion

- EcoLogix-LT solution is poised to revolutionize the South African logistics sector by offering a comprehensive, AI-driven solution for route optimization and emissions reduction.

- With Inventory management in later stages.

- With clear financial and environmental benefits, and a system designed for scalability, this solution provides logistics companies with the tools to enhance their operations while also contributing to global sustainability efforts.