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Reduce Waiting Times at Electric Truck Charging and Battery Swapping Stations Through Optimized Facility Layout Design: Case Study ABC Company

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Abstract

Sustainability and climate change mitigation have become critical factors in modern business. Many countries have introduced trade barriers for carbon-intensive products, such as the Carbon Border Adjustment Mechanism (CBAM) in the European Union. As a result, manufacturers must comply with these regulations to maintain their customer base, leading to rapid growth in carbon-reduction–related businesses. Electric trucks are one of the fastest-growing sectors. They can be used to claim carbon-reduction benefits. In Thailand, electric truck adoption has increased rapidly. By April 2025, 963 electric trucks were registered, representing a 125.96% increase compared to the same period in 2024 (Department of Land Transport). A truck with a 280 kWh battery typically requires 30–50 minutes per charging session, depending on the remaining battery level. Reducing other sources of delay to ensure smooth operations is therefore a significant challenge. ABC Company currently faces waiting times exceeding its KPIs at the main operations hub. The site operates 14 chargers (10 charging points) and two battery-swap stations with an average swap time of 7 minutes. The main issue is an inefficient layout. Studying and applying world-class layout designs can significantly reduce waiting time (Figure 1).

Figure 1. Battery Swap Station in Logistics Terminal ABC Company

Keywords
Electric Vehicle, Logistics Terminal Layout, Waiting Time, Swap Battery Station and Charging Station.

1. Introduction
Sustainability and the global warming mitigation trend are crucial in contemporary business operations. Many countries have established tax barriers for high-carbon-emission products, such as the Carbon Border Adjustment Mechanism (CBAM) in the European Union. Consequently, manufacturers are compelled to comply with these regulations to maintain their customer bases. As a result, businesses related to carbon footprint reduction have gained significant traction today.

Electric trucks represent one of the rapidly growing sectors. In addition to high operational efficiency, they can be utilized to claim carbon emission reductions. This has led to the rapid growth of electric trucks in Thailand. According to data from the Department of Land Transport, in April 2025, there were 963 registered electric trucks, reflecting a growth of 125.96% compared to the same period in 2024.

The primary waiting time at electric truck charging stations is a major obstacle for executives managing logistics operations that utilize electric trucks. A truck with a battery capacity of 280 kWh requires approximately 30 to 50 minutes per charging session, depending on the remaining battery level. Therefore, reducing other associated waiting times to ensure the smoothest possible truck operations is a significant challenge in the current landscape.

ABC Company is a comprehensive EV Logistics service provider, offering both land and water transportation. Its service coverage encompasses the Eastern, Lower Northeastern, and Central regions of Thailand. These are strategic areas supporting the growth of the Eastern Economic Corridor (EEC) and its vicinity. Companies within industrial estates that export goods to the United States and Europe have a high demand for electric trucks to reduce their carbon footprint during production. Consequently, the volume of electric truck operations is substantial in these regions.

The problem encountered by ABC Company is a waiting time that exceeds the established Key Performance Indicators (KPIs). At the origin station, which serves as the operational hub, there are 14 electric truck charging cabinets with 28 charging dispensers, requiring an average charging time of 40 minutes per vehicle. Additionally, there are 2 electric truck battery swapping stations, with an average swapping time of 7 minutes per vehicle. The main operational activities commence with the driver reporting for duty, receiving the keys, and driving the truck with a trailer to the destination. Upon retrieving the goods, the driver returns to the origin station and detaches the trailer. Subsequently, the charging personnel take control of the vehicle to either swap the battery or recharge it, while the driver transitions to another truck to collect goods for the next trip.

Studying world-class layouts in logistics terminal design is essential for Thai logistics operators. World-class logistics terminals employ layout principles specifically designed to minimize waiting times and reduce the probability of accidents. The author has studied three such terminals:

1. CFL Intermodal (Luxembourg)
2. CPKC Voughan Intermodal Terminal (Canada)
3. Los Angeles Intermodal Terminal (United States of America)

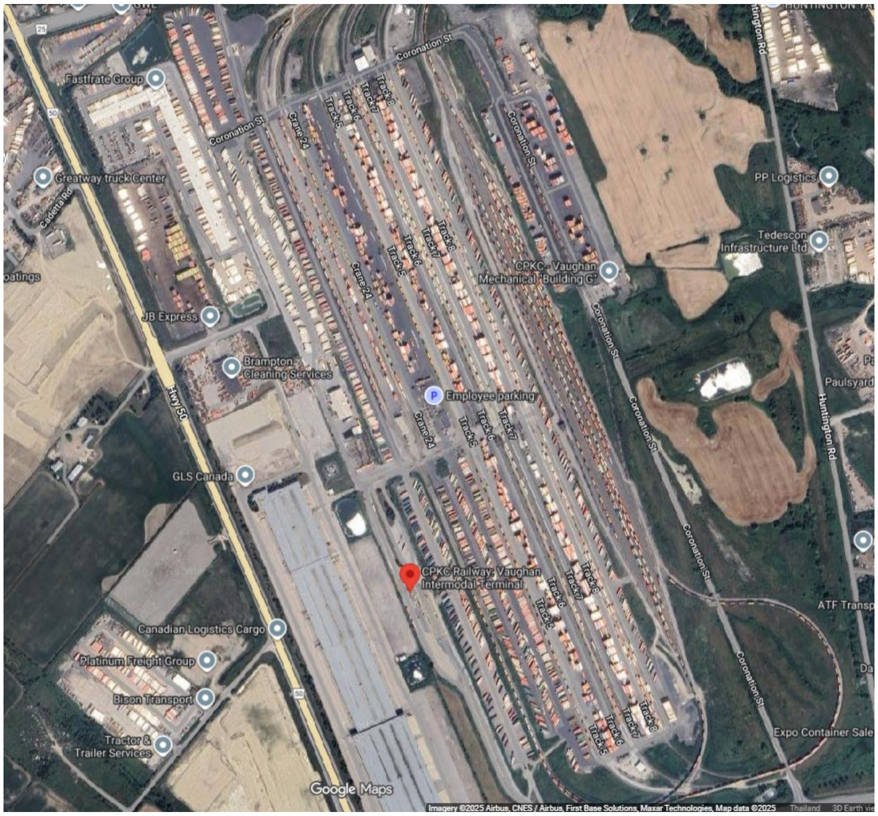

Figure 2. CPKC Vaughan Intermodal Terminal , Canada

Based on the aforementioned information, the researcher is interested in studying the reduction of waiting times within the logistics processes at the origin station, which comprises the charging station and the battery swapping station of ABC Company. The findings of this research will serve as operational guidelines and standard operating procedures to enhance ABC Company's capability in building a green logistics infrastructure in Thailand. Ultimately, this will empower Thailand to compete effectively in the global market (Figure 2- Figure 5).

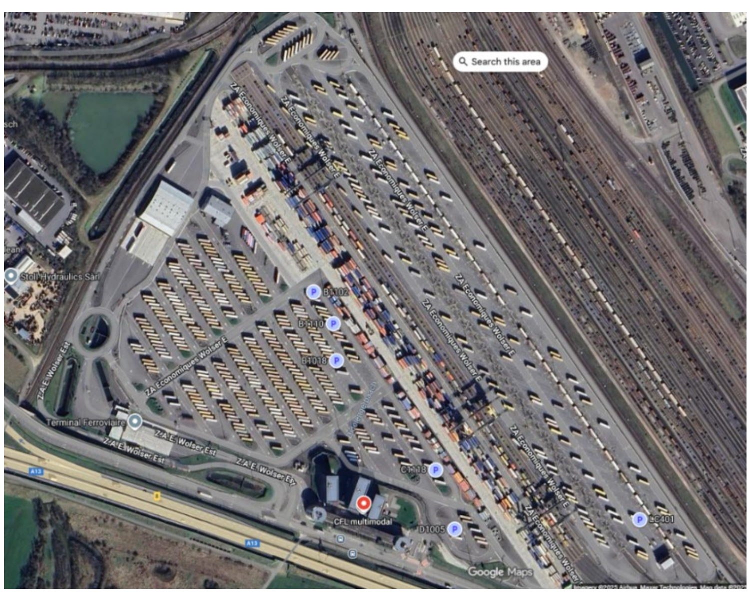

Figure 3. CFL Intermodal, Luxembourg

Scope of the Study
Time Scope The duration for document data collection, stakeholder interviews, and data processing spans a total of 3 months, from September 2025 to November 2025.

Geographical Scope For this research, the study specifically focuses on ABC Company, an electric truck logistics service provider in Prachinburi Province, with service coverage across the Eastern, Lower Northeastern, and Central regions.
Population Scope The population consists of the electric truck drivers operating 215 electric trucks for ABC Company in Prachinburi Province.

1.1 Objectives

- To apply layout design guidelines from world-class logistics terminals to design a layout aimed at reducing the waiting time of the transportation process at the origin station, which comprises 6 electric truck charging cabinets and 2 battery swapping stations.
- To investigate the problems and obstacles in applying logistics layout design to reduce the waiting time of the transportation process at the origin station of ABC Company.

2. Literature Review

Theories and Related Research
Addressing logistics terminal problems is a complex undertaking due to the multitude of interconnected activities within the terminal. If any single activity encounters an issue, it subsequently causes a cascading effect on waiting times. Resolving these problems necessitates a thorough understanding of relevant theories and tools, along with an examination of international expert research. This information is integrated into a comprehensive body of knowledge to serve as a fundamental guideline for conducting this research. The literature review of this study is divided into three main sections:

- World-class logistics terminal layout theories
- Battery swapping station efficiency enhancement
- Related research

2.1 Logistics Terminal Layout Theories

The layout planning of a logistics terminal is highly critical. A flawed layout makes rectifying, relocating equipment, and modifying structures extremely difficult and incurs additional costs. Therefore, an accurate layout design from the beginning helps reduce accidents and minimizes waiting times in each area within the terminal. Based on the study of world-class logistics terminal layouts, the guiding theories are as follows:

2.1.1 Traffic Flow Principle: Minimizing Route Intersections The design necessitates a one-way traffic system to mitigate accidents and reduce delays caused by waiting. This is achieved by establishing a perimeter road network around the terminal, with specific branch routes leading into designated zones.

2.1.2 Functional Zoning Principle
Areas must be divided according to their specific operations to prevent the intermingling of personnel, vehicles, and equipment. This zoning can be broadly categorized as follows:

- Loading Zone
- Battery Charging and Swapping Zone
- Maintenance Zone
- Driver Rest Zone

2.1.3 Minimizing In-Terminal Vehicle Travel Time
Reducing vehicle travel time within the terminal equates to reducing waiting time. Therefore, the positioning of the entrance and exit gates must be well-coordinated to prevent bottleneck issues.
Regarding the structural facilities within the terminal, constructions are typically categorized into three configurations: I-Shape, T-Shape, and X-Shape. Each configuration serves a distinct purpose as follows:

- I-Shape and T-Shape**:** Suitable for terminals with 60 to 150 doors.

- X-Shape: Suitable for large-scale terminals with high throughput.

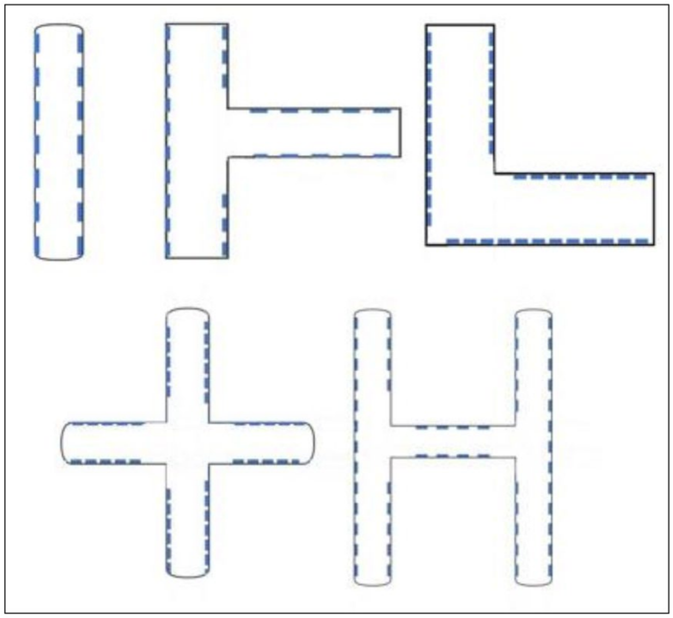

Figure 4. Building Shape in Logistics Terminal

2.1.4 Sizing the Waiting Area to Accommodate Vehicle Volume

A waiting area (parking area) is an unavoidable component of a logistics terminal. It is essential for vehicles waiting to load goods or to recharge or swap batteries. Allocating excessive space for the waiting area leads to inefficient land utilization, whereas insufficient space inevitably creates bottleneck problems.

A widely adopted theoretical approach to resolving waiting area issues is the implementation of a "truck appointment time window" to control the volume of arriving vehicles during specific time periods.

Figure 5. Truck Appointment Time Window

2.1.5 Safety-Oriented Layout to Minimize Accidents
Reducing the probability of accidents requires the strict separation of pedestrian walkways from vehicular traffic routes. Furthermore, blind spots must be minimized, clear directional signage must be installed, and angled parking layouts should be implemented to eliminate the need for reversing during entry and exit, thereby further decreasing the risk of accidents (Figure 6).

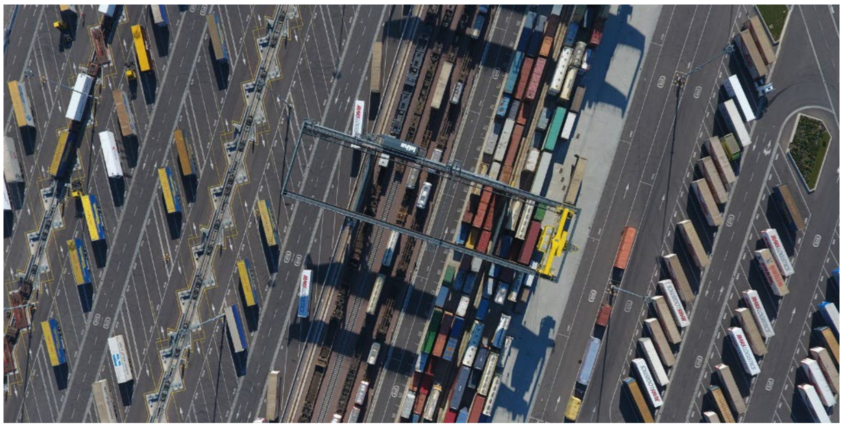

Figure 6. Herringbone Parking in CFL Intermodal ,Luxembourg

2.1.6 Clear Separation of Inbound and Outbound Operations Strictly separating inbound and outbound operations helps mitigate cross-flow interference, which is a primary cause of congestion. Implementing an I-shape or U-shape configuration can effectively alleviate congestion in terminals with spatial constraints.

2.1.7 Accommodating Future Expansion An optimal terminal design should facilitate future expansion without requiring the demolition of existing structures.

3. Methods
This research aims to investigate logistics terminal layout planning and apply the findings to the design of an Electric Vehicle (EV) logistics terminal in Thailand. In the Thai context, layout planning has not always been given sufficient emphasis, which has led to operational inefficiencies such as excessive waiting time caused by bottlenecks within terminal configurations. Furthermore, inadequate layout design may increase the risk of accidents due to improper traffic flow, spatial constraints, and poor allocation of operational zones.

Accordingly, this study seeks to develop a systematic and evidence-based framework for EV logistics terminal layout design that enhances operational efficiency, reduces congestion, and improves safety performance.

This study adopts a qualitative research approach consisting of the following methods:

1. Collection and analysis of logistics terminal layout designs from multiple countries.
2. Comprehensive literature review on logistics terminal planning, layout optimization, EV infrastructure, and related design principles.
3. Analysis of logistics terminal activities, equipment utilization, and operational stations.
4. Examination of design tools and simulation techniques applicable to terminal layout planning.

The research will be conducted in the following stages:

1. Data collection on travel time within the existing terminal layout, measured from vehicle entry to exit (or completion of operations).
2. Development of a new terminal layout based on the findings from literature review and international best practices.
3. Development of a simulation application using Google Maps to model real geographic locations and ensure realistic and accurate simulation outcomes.
4. Analysis and synthesis of results, followed by research conclusions and recommendations.

4. Data Collection

Company ABC's logistics terminal is designed in an inverted U-shape layout with a single, centralized access point to facilitate access control and security. The charging station is located on the right side, while the battery swapping station is situated on the left. The remaining area is allocated for driver facilities and parking spaces for tractors and trailers. A perpendicular parking configuration is utilized, necessitating reversing maneuvers for all parking operations (Figure 7 - Figure 10).

Figure **7**. ABC Company EV Logistics Terminal

Figure **8**. ABC Company EV Logistics Terminal (AS IS Layout)

The primary pain point of the aforementioned operation concerns vehicle changeover times. Although management established a Key Performance Indicator (KPI) target of 10 minutes per vehicle, data collected in September 2025 indicated actual waiting times ranging from 53 minutes to 1 hour and 48 minutes. These delays stem from various factors, which were analyzed using a Fishbone diagram (as illustrated below), with problem-solving efforts specifically focusing on the "Method" category (Table 1).

Table 1. Waiting Time in Logistics Terminal

วันที่ (Date)	Waiting Time in Terminal (hrs.)
W1-Sep	00:53
W2-Sep	01:07
W3-Sep	01:43
W4-Sep	01:48
Avg-Sep	01:23

The application of the Fishbone diagram identified key logistics terminal issues originating from the "Method" category: complex traffic flow, frequent accidents caused by intersecting paths, a lack of clear zoning, and charging bottlenecks. Addressing these four specific problems constitutes the primary objective of this project, with the aim of reducing waiting times within the logistics terminal.

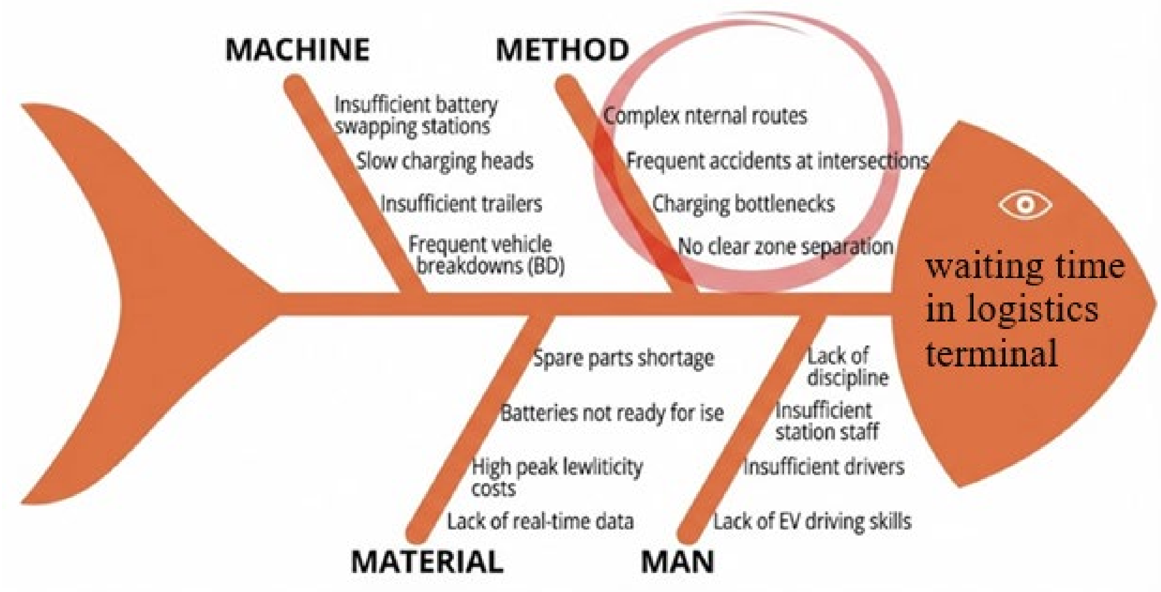

Figure **9**. Fishbone Diagram for root cause analysis

The layout planning of a logistics terminal is critically important, as rectifying errors or relocating equipment and infrastructure later is highly challenging and incurs significant additional costs. Therefore, implementing an optimal layout from the outset helps mitigate accidents and reduce waiting times across all terminal areas. Based on an analysis of world-class logistics terminal layouts and theoretical frameworks, the following principles were adopted as guidelines for the new layout design:

1. Traffic Flow Optimization (Minimizing Intersections): Implementing a one-way traffic system with a right-side entrance and a left-side exit to reduce intersecting routes.
2. Functional Zoning: Separating the terminal into two distinct zones. The right side is designated for tractor and trailer parking, while the left side is allocated for charging and battery swapping stations.
3. Strategic Infrastructure Placement (Minimizing Internal Travel Time): Selecting an I-shaped layout to optimize spatial efficiency and accommodate the herringbone parking configuration.
4. Parking Area Allocation (Matching Vehicle Capacity): Designating two specific waiting areas. The left side is for vehicles awaiting charging or battery swapping, and the right side is for fully charged vehicles ready for their next assignment.
5. Separation of Inbound and Outbound Flows: Dividing the right section into two wings. The lower-right wing handles inbound operations (staging loaded trailers for factory delivery), while the upper-right wing manages outbound operations (staging empty trailers for supplier material pickups).
6. Herringbone Parking (Enhancing Safety and Reducing Accidents): Designing an angled, herringbone parking layout instead of perpendicular parking. This eliminates the need for reversing, thereby reducing maneuver-related waiting times and minimizing the risk of backing accidents.

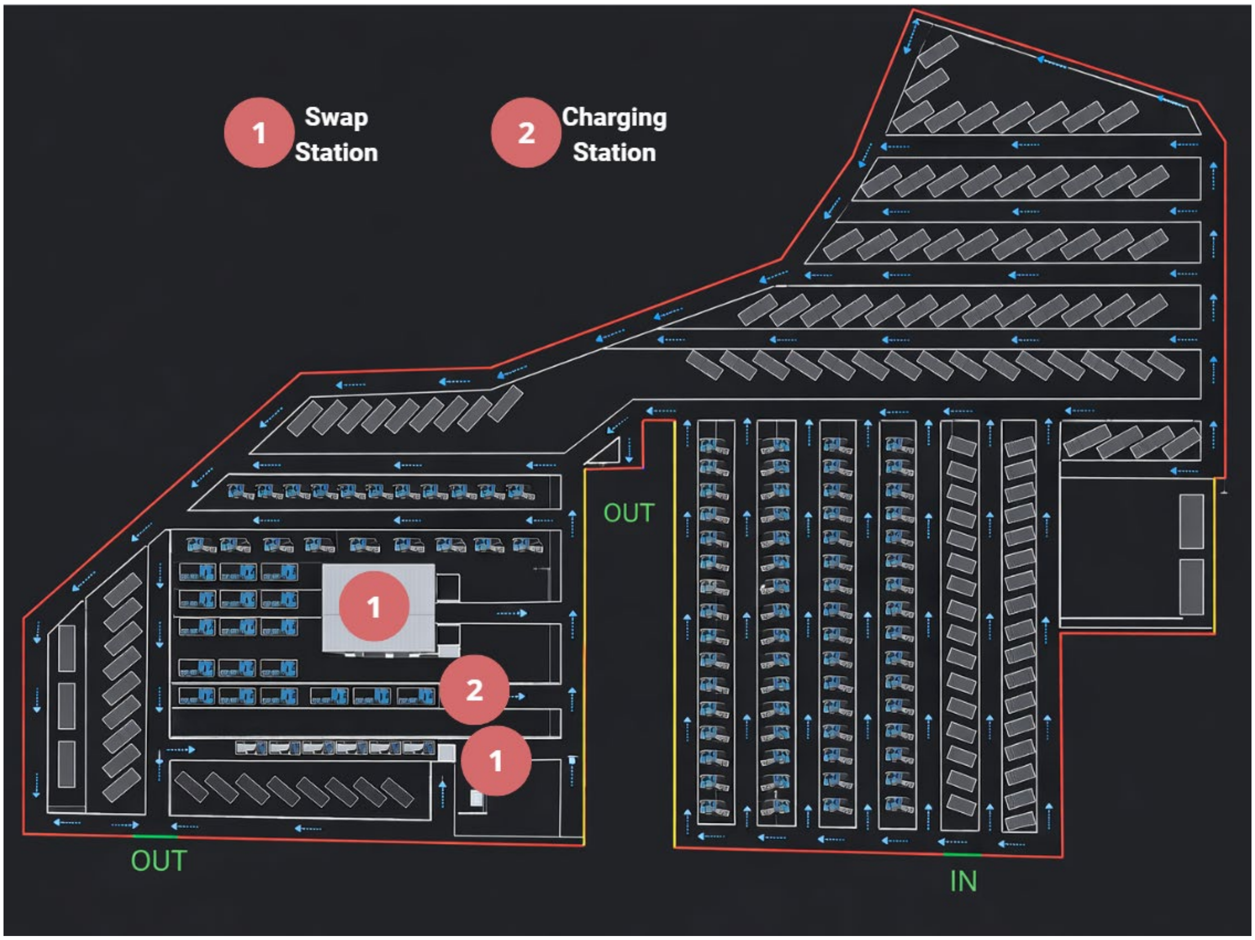

Figure 10. ABC Company EV Logistics Terminal (To Be Layout)

5. Results and Discussion

To ensure the design and simulation closely reflect actual operations, a custom application was developed utilizing real-world data and Google Maps integration. This tool facilitates a direct comparison between the existing and proposed layouts to quantify the reductions in both waiting times and travel distances (Figure 11- Figure 17).

5.1 Numerical Results

1. Trailer Drop-off and Battery Swapping Route
    - Current Layout
        - Distance: 1,147 meters
        - Time: 3.4 minutes (204 seconds)

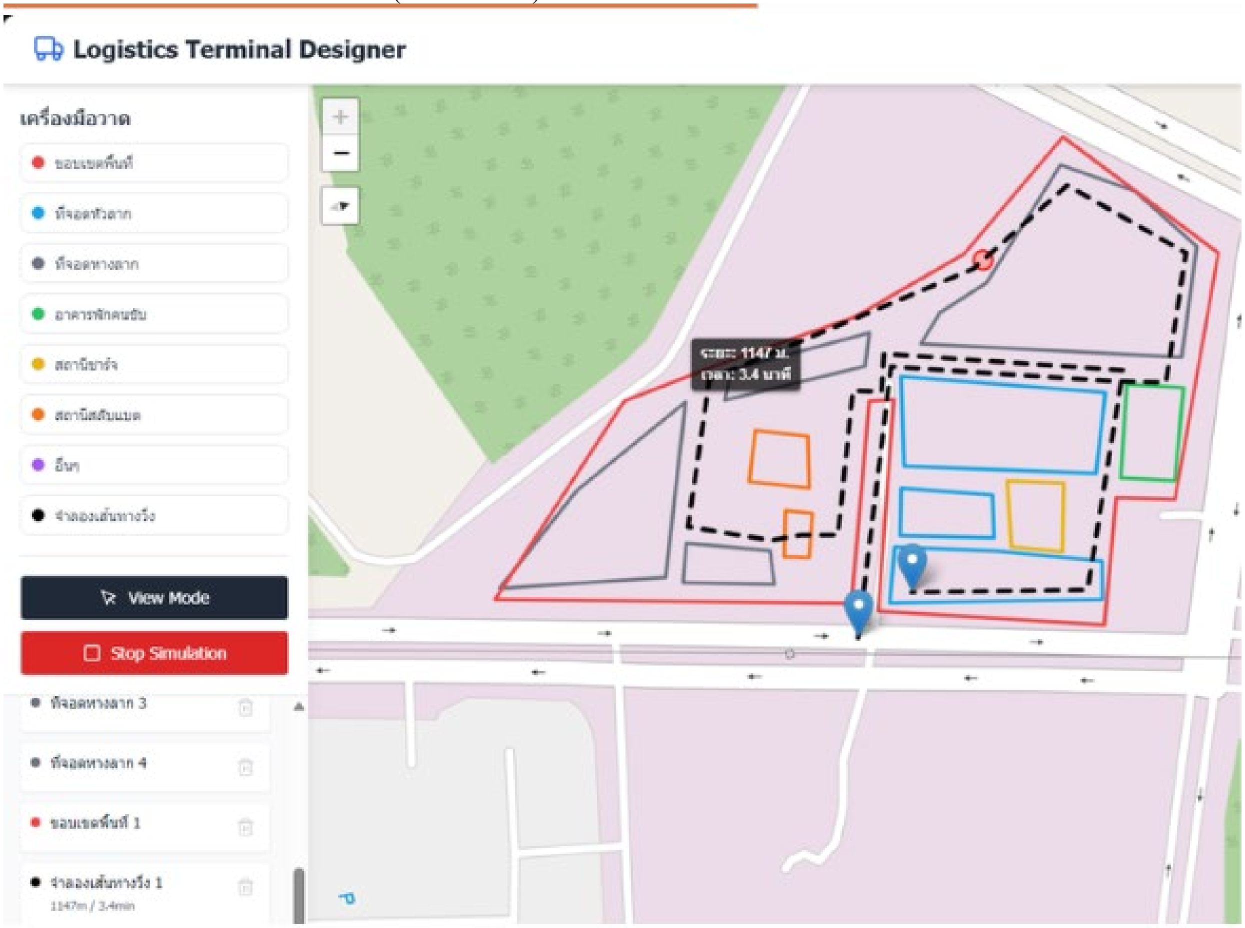

Figure 11. Simulation result for the current layout in Trailer Drop-off and Battery Swapping Route

- Proposed Layout
    - Distance: 852 meters (Reduced by 295 meters, or 25.7%)
    - Time: 2.6 minutes (156 seconds, which is 48 seconds faster)

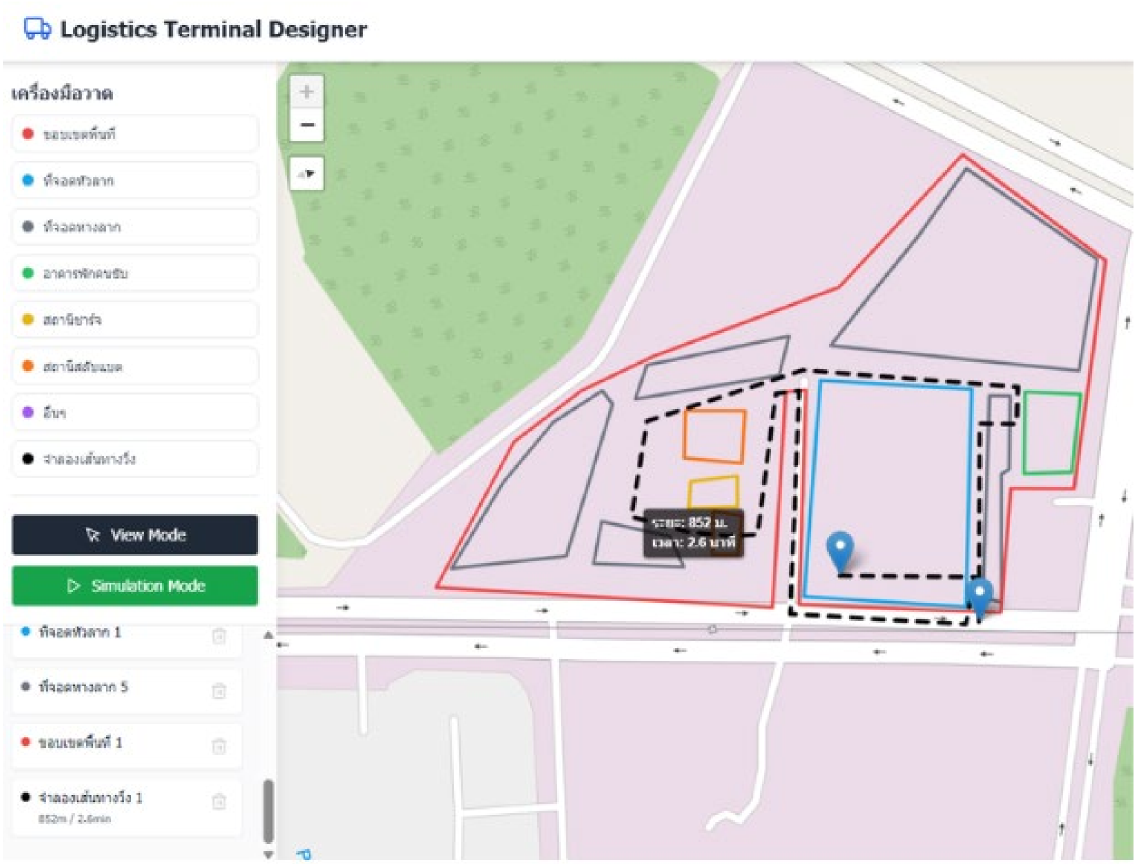

Figure 12. Simulation result for the proposed layout in Trailer Drop-off and Battery Swapping Route

2.Trailer Drop-Off Route and Supplier Materials

- Current Layout
  - Distance: 962 meters
  - Time: 2.9 minutes (174 seconds)

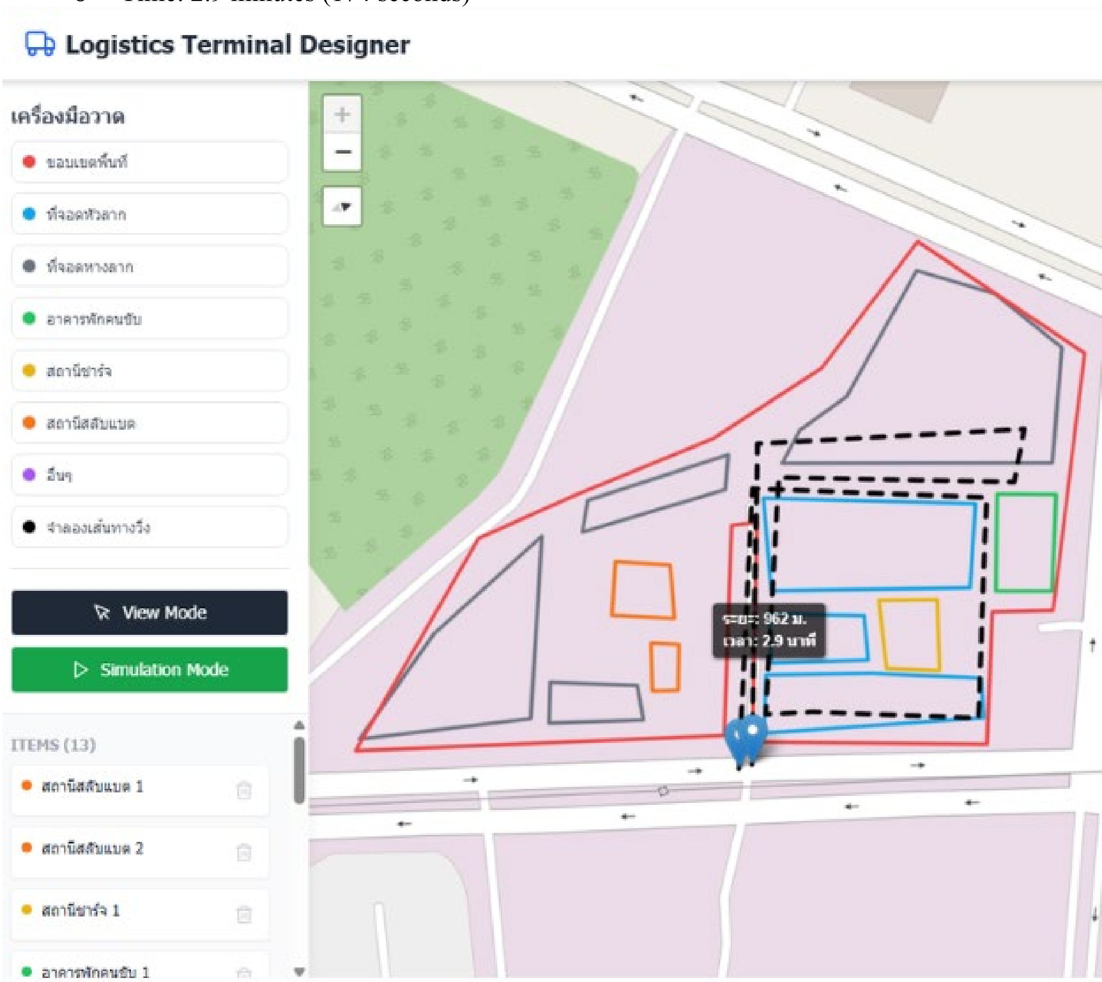

Figure 13. Simulation result for the current layout in Trailer Drop-Off Route and Supplier Materials

- Proposed Layout
  - Distance: 623 meters (Reduced by 339 meters, or 35.2%)
  - Time: 1.9 minutes (114 seconds, which is 60 seconds faster)

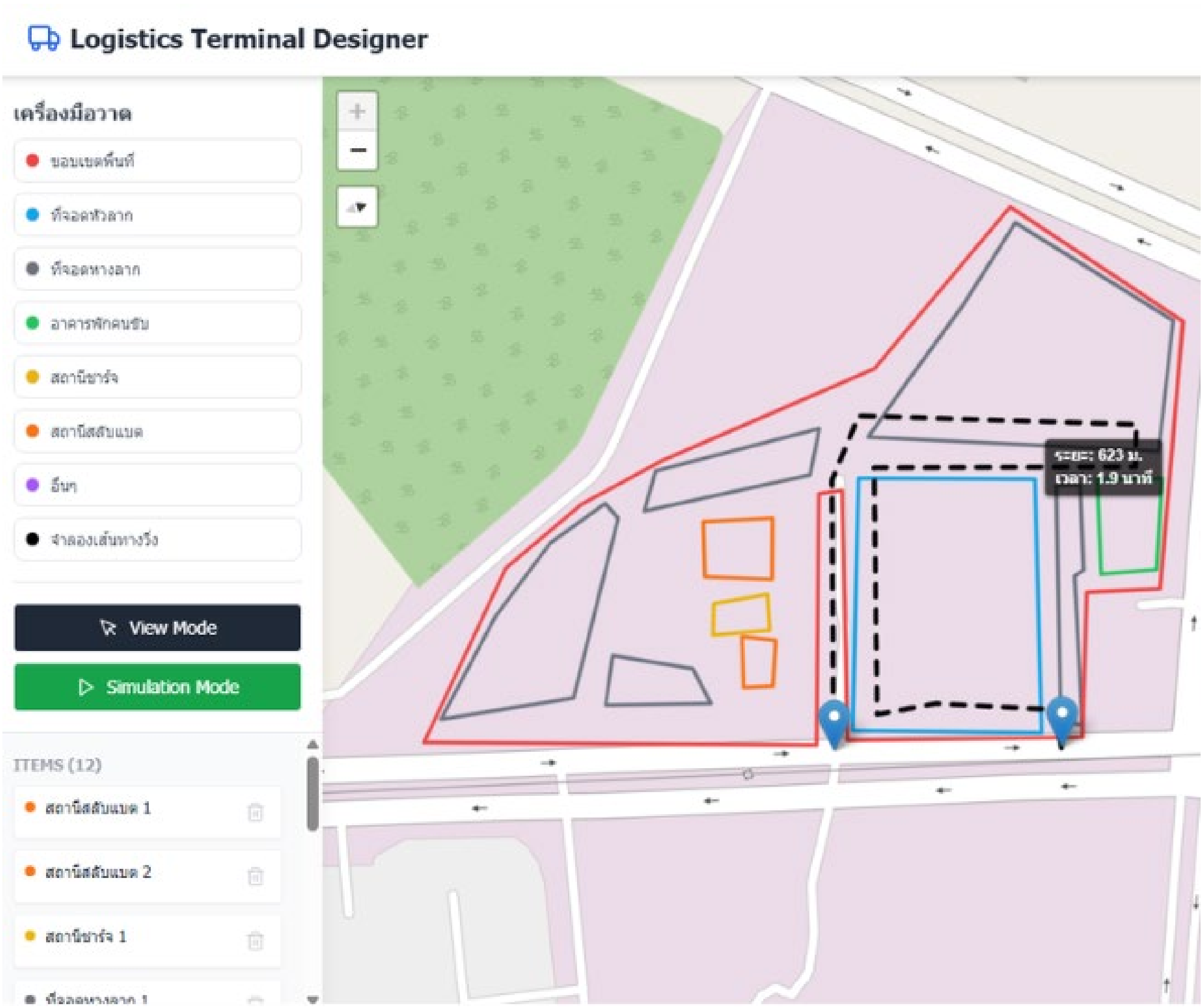

Figure 14. Simulation result for the proposed layout in Trailer Drop-Off Route and Supplier Materials

3. Trailer Drop-off and Factory Delivery Route
  - Current Layout
    - Distance: 1,029 meters
    - Time: 3.1 minutes (186 seconds)

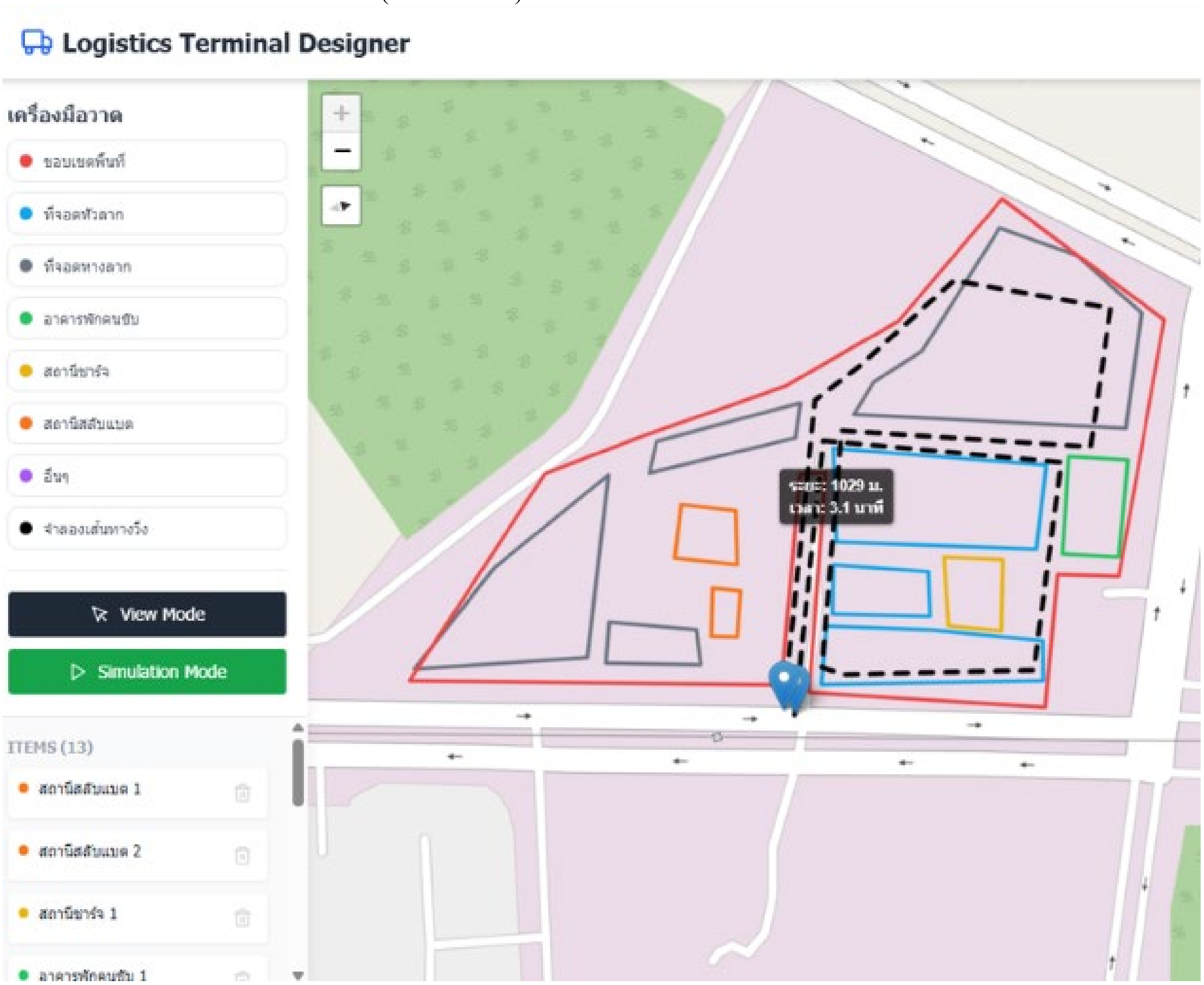

Figure 15. Simulation result for the current layout in Trailer Drop-off and Factory Delivery Route

- Proposed Layout
    - Distance: 694 meters (Reduced by 335 meters, or 32.5%)
    - Time: 2.1 minutes (126 seconds, which is 60 seconds faster)

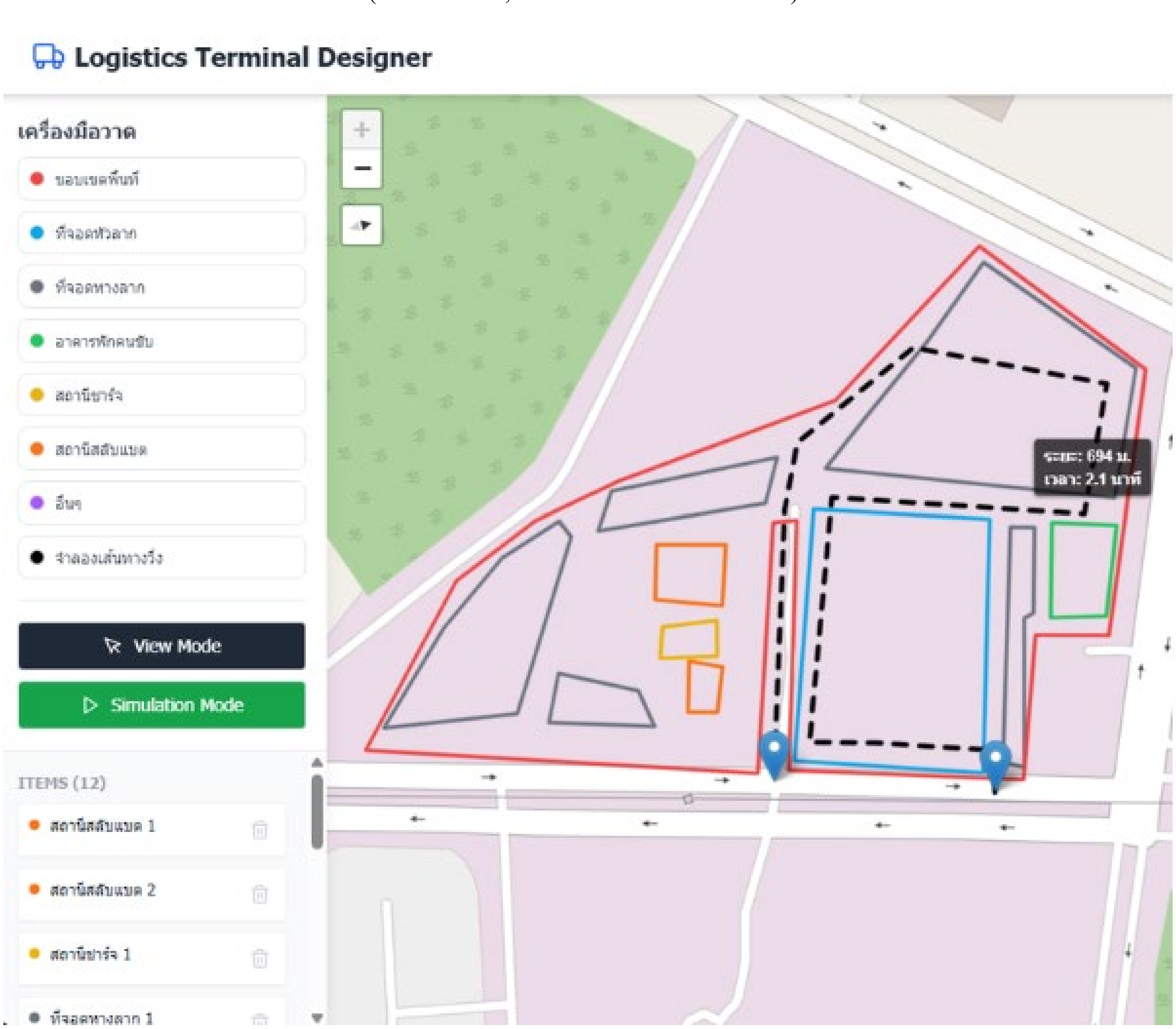

Figure 16. Simulation result for the proposed layout in Trailer Drop-off and Factory Delivery Route

4. Time studies indicate that the current perpendicular parking method requires a total of 68 seconds, consisting of 30 seconds for initial positioning and 38 seconds for reversing. In contrast, herringbone parking requires only 5 seconds per vehicle (referenced from CFL Intermodal). Consequently, adopting the herringbone layout reduces parking time by 63 seconds per vehicle.

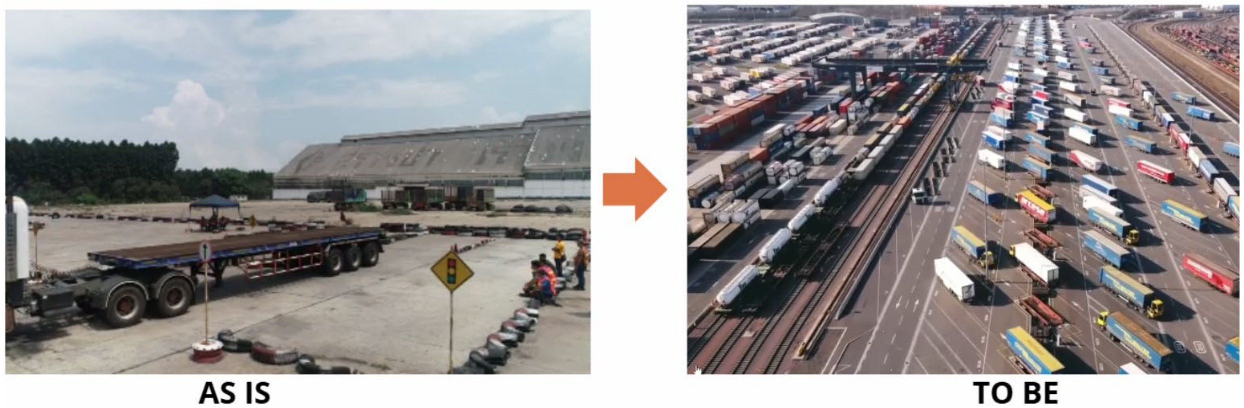

Figure 17. Simulation result for the current parking and herringbone parking

6. Conclusion

Based on the design and simulation of the proposed layout, structural issues within the logistics terminal—including complex traffic flows, frequent accidents at intersecting paths, lack of clear zoning, and charging bottlenecks—were successfully resolved. These improvements resulted in the following reductions in travel distances and times:

- Loaded Trailer and Battery Swapping Route: Distance decreased by 295 meters and time by 48 seconds (25.7% improvement).
- Empty Trailer Pick-up for Supplier Materials Route: Distance decreased by 339 meters and time by 60 seconds (35.2% improvement).
- Loaded Trailer Drop-off and Factory Delivery Route: Distance decreased by 335 meters and time by 60 seconds (32.5% improvement).
- Herringbone Parking: Reduced parking duration from 68 seconds (perpendicular parking) to 5 seconds per vehicle (93.6% improvement).

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Biographies

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