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APPLICATION POSSIBILITIES OF LOGISTICS SIMULATION AND AI IN THE CASE OF INTERMODAL TERMINALS

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***Abstract**: The paper addresses the fundamental operations and services of intermodal logistics terminals from the ground up. The information collection was primarily based on site visits to several companies, one of which was East-West Intermodal Logistics Service Ltd., and the other was ZÁHONY-PORT Ltd. (Záhony-Logistics and Load Handling Servicing Company). The process continued with data collection, where local leaders and managers provided information through PowerPoint documents and site tours. The entire information gathering process started with the understanding of the main details of the companies, followed by the site visits, and finally, the acquisition of the requested information. The next step was the processing of the collected information, of which the article only describes the analysed results. The application possibilities of AI are closely related to digitization and data collection. Without data, AI cannot be trained for the given task. To increase the available information, we can also use simulation methods (for generating so-called synthetic data), allowing us to introduce artificial intelligence in a relatively new field in a short time.*

***Keywords:** AI application, intermodal terminals, transportation simulation*

1. INTRODUCTION

Intermodal logistics terminals are facilities primarily focused on moving goods between different transportation sectors. In addition to transshipment, they handle warehousing, customs clearance, repackaging, and the documentation of these processes. The transfer of goods generally takes place with the use of road, rail, or water vehicles, but it can also involve air transport. The terminal plays an essential role in transportation, as it allows products to be transported in the most favourable and cost-effective manner. The role of intermodal logistics centres is increasingly important due to the growing demand for freight transportation and tightening environmental regulations. In addition to transshipment, several logistics services are provided to enhance efficiency and offer proper service to customers. Temporary warehousing and customs warehouses provide cost security for customers and allow for faster customs clearance [1, 2, 3]. The research examines two intermodal logistics centres: the Záhony intermodal logistics terminal operated by Záhony-Port Ltd., and the Fényeslitke intermodal logistics terminal operated by East-West Intermodal Logistics Service Ltd. Both terminals primarily focus on rail-to-road transshipment, meaning that goods are exchanged between rail and road, as well as between road vehicles. The broad- and narrow-gauge system plays a significant role in transshipment between railways at both terminals [4, 5].

The types of intermodal logistics terminals can be classified based on the number of transport modes available, with the most common types being:

- Unimodal: One main transportation sector, typically road.

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- Bimodal: Two transportation sectors, usually road and rail.
- Multimodal: Three or more transportation sectors.

Beyond these types, terminal evaluation can also consider the following main characteristics:

- Ownership type: Public, private, or mixed.
- Size: Facility area (e.g., in hectares).
- Cargo handling capacity: Capacity of transloading equipment and storage areas.
- Traffic: The volume of handled goods (in tons or combined transport units), customer numbers, routes, and product composition [3,6].

2. EWG INTERMODAL LOGISTICS TERMINAL OVERVIEW

The East-West Gate (EWG) aims to serve as a versatile gateway for the new Silk Road, suitable for gauge change, and expanding rail container traffic between the East and West. Located in Fényeslitke, it is Hungary's largest such facility, covering 85 hectares, with a potential capacity of up to 1 million TEU (twenty-foot equivalent unit) after the development of rail infrastructure. The most modern control software enables online communication with customers, as well as real-time tracking of containers on the road. The terminal's storage area features an independent crane track that starts with one crane but can be expanded with more. The railway crane track is 850 meters long, capable of handling 740-meter trains. The cranes have a load capacity of 45 tons, and they can handle 45" containers, cranes, and special semi-trailers. Additionally, the terminal is equipped with 4 mobile container handlers, 5 terminal tractors, and 10 terminal semi-trailers.

An X-ray gate and OCR (Optical Character Recognition) system ensure the recording of container conditions on the broad-gauge railway track. Furthermore, a rolling digital scale is installed at the wide and standard railway entry points. The terminal can handle up to 4 full-length trains simultaneously. Broad gauge service is provided on the Csop-Záhony-Komoró route, while standard service is provided directly from Fényeslitke Railway Station.

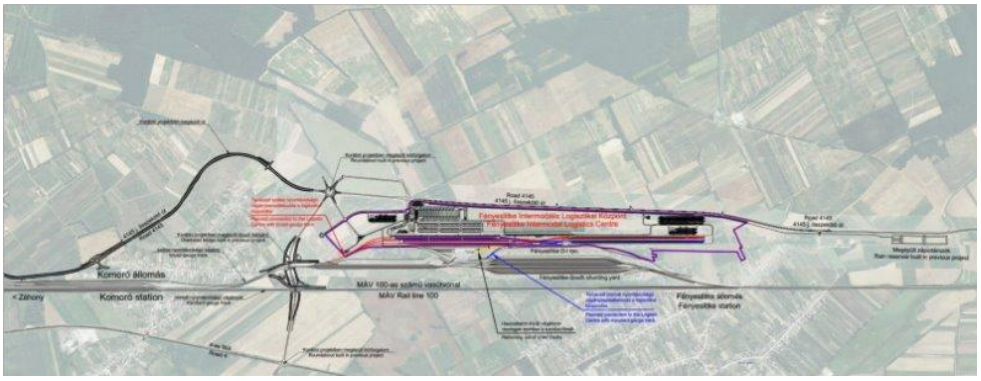

Figure 1. *EWG Site Plan Fényeslitke [7]*

The storage capacity allows for the accommodation of 15,000 TEU of loaded or empty containers, and it also offers suitable conditions for storing 500 TEU of refrigerated containers. The terminal complies with SEVESO regulations, enabling the handling of

hazardous goods and tank containers. There is 15,000 m² of rentable warehouse space with an internal clearance height of 12.5 meters.

Upon request, they can build warehouses, assembly, or manufacturing plants on up to 500,000 m² of land, with internal clear heights of up to 30 meters. In the case of long-term leases, the necessary buildings can be constructed.

2.1. Services Provided

Container transshipment between broad or standard gauge railway wagons or trucks. The terminal is capable of transhipping containers between different gauge railway cars and road transport vehicles, ensuring efficient cargo forwarding. Containers can also arrive by road. The terminal organizes road transport for the containers it handles, ensuring fast and safe delivery to the destination. The terminal is equipped with railway and road digital scales. Modern digital scales accurately measure the weight of transported goods, whether they arrive by rail or road.

OCR Identification: Using OCR technology, the containers and goods are identified through photographs, speeding up and improving the accuracy of documentation.

5G Access: The terminal has the world's first 5G coverage across its entire area, enabling communication between crane systems. This ensures fast and reliable data communication.

Transshipment of Semi-Trailers: The transshipment of semi-trailers is carried out by modern remote-controlled crane systems, ensuring the process is both safe and efficient.

Storage of Loaded and Empty Containers: The terminal is organized for the storage of both loaded and empty containers.

Refrigerated Container Handling: The terminal offers handling, storage, and refueling of refrigerated containers to preserve the freshness of goods. They also handle Flexi tank installations for safe storage and transportation of liquid goods.

Container Inspection, Repair, and Cleaning: The condition of the containers is regularly checked, and repairs and cleaning are carried out as needed.

Warehousing and Warehouse Leasing: The terminal has extensive warehousing capacity, including warehouses located in customs-free zones, available for lease. The terminal offers 85 hectares of enclosed and strictly controlled space for safe cargo handling.

Fulfilment Services and Commissioning Tasks: They offer goods assembly and fulfilment management, including commissioning processes. Office spaces are available for lease on the terminal grounds, providing a modern and well-equipped work environment.

24/7 Customs Clearance: The terminal offers 24/7 customs clearance and customs administration services, ensuring efficient management of related paperwork.

Handling Hazardous Goods: With ADR and ATEX certified cranes, the terminal ensures the safe handling and storage of hazardous goods. In addition to hazardous goods and containers, they also handle bulk materials, such as loose goods, ensuring safe transport.

Clients can access the terminal services via the TOS (Terminal Operating System) software. Separate parking and well-equipped resting areas are available for drivers, as well as dining and hygiene facilities. Tenants working on the terminal grounds also have access to dining facilities and parking [4].

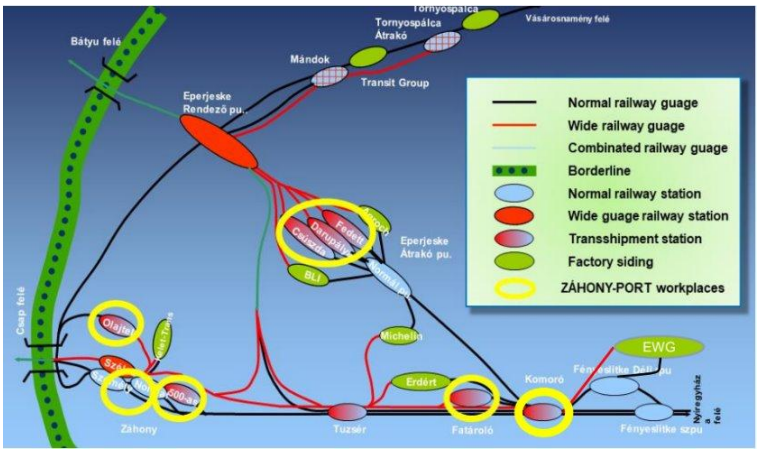

Figure 2. *ZáhonyPort Ltd. Facilities [5]*

3. ZÁHONY-PORT LOGISTICS CENTRE OVERVIEW

The Bátyu-Eperjeske and Csop-Záhony border crossings play a significant role in freight transport passing through the UZ-MÁV railway network. These two crossings have different capacities and infrastructures.

Bátyu-Eperjeske and Csop-Záhony Crossings Operations. At the Bátyu-Eperjeske crossing, 7 daily wide-gauge train pairs run, with trains up to 950 meters long, carrying a maximum load of 6,000 tons, powered by UZ locomotives. The axle load is 23.5 tons on a 1520mm track.

The Csop-Záhony crossing operates 5 daily wide-gauge trains, although traffic is currently suspended but can resume with coordination with UZ. The trains here are 880 meters long, with a 5,000-ton maximum load.

3.1. Services Offered

The terminal provides a wide range of services, including transshipment, storage, railway services, freight forwarding, customs processing, and various industrial and maintenance solutions.

The network handles up to 2.1 million tons of cargo annually, with a total capacity of 4 million tons. The terminal operates one of the largest chemical breakdown facilities in Eastern Europe, with 19 crane tracks and mobile loading equipment, managed by 300 skilled workers.

The terminal has substantial warehousing capacity, with 177,000 m² of open space and 17,000 m² of covered storage. It also includes customs warehouses and Hungary's first free-trade zone, covering 17,400 m².

Transshipment Solutions:

- Forklift transshipment: Handling palletized goods with daily capacity of 2,900 tons.
- Bulk cargo transshipment: Handling up to 10,000 tons of granular or powdery goods per day (iron ore, coal, etc.).
- Grain transshipment: With a daily capacity of 1,800 tons.

- Crane operations: With 4 crane tracks and 19 frame cranes for up to 120 tons per load, capable of handling 7,000 tons daily.

Container terminal: Equipped with 3 frame cranes (60- and 35-ton capacities) and one mobile loader, with a daily transshipment capacity of 150 containers.

Chemical transshipment: For products like oil, gasoline, diesel, alcohol, and others, with specific capacities for materials like methanol and ethanol (10 wagons/day) and gasoline/diesel (20-30 wagons/day).

Maintenance and Services: The terminal also provides maintenance services for forklifts, loaders, and other machinery, including container refurbishment, welding, and cutting services. Intermodal services include railway tank containers.

Future Developments: In 2022, a successful CEF grant application was submitted for upgrading railway infrastructure, building new tracks, and improving digital solutions (OCR systems, terminal software, paperless operations).

4. AI AND SIMULATION IN LOGISTICS

The operation of both terminals has been thoroughly examined. Information gathering was based on the products and services. The process covered everything from the request for quotation to the completion of services and finalizing the paperwork. Alongside these tasks, the research also focused on where and how artificial intelligence (AI) or simulation methods can be utilized.

By using simulation programs, we can gain important insights into facilities, machines, transport vehicles, and traffic situations that have not yet been commissioned or are still in the planning phase. These tools can assist in planning, scheduling, and possibly cost calculations. The most critical factors are costs and efficiency, which can significantly influence the operation, objectives, sustainability, and return on investment of logistical systems and projects.

One of the key applications of artificial intelligence is in optimization tasks, particularly in areas where a large amount of information is available about the starting and ending points of transport. Essentially, the more usable information is available about the initial state and the resulting outcome, the more accurately AI can be taught to operate effectively, requiring data volumes in the tens of thousands at present [8, 9].

AI can assist in optimizing escape routes, scheduling railway trains, trucks, and tractor-trailers, as well as determining optimal transportation routes. In addition to the routes for vehicles and operators, it can also optimize the placement of products, the loading times, loading sequence, and appropriate storage duration, thus enhancing overall efficiency.

A potential issue is the lack of sufficient information on which to train the AI for a specific task. Here, we can make use of one of the best features of simulations—obtaining substantial amounts of data in a relatively short time through appropriate simulation experiments. Based on the data generated in this way, AI can be trained to a usable level in a short period.

A simulation program that can be used for such transportation tasks is Eclipse SUMO, which offers a free license and is highly versatile due to its programmability.

SUMO (Simulation of Urban MObility) allows modelling of intermodal traffic systems, including cars, public transport, and pedestrian traffic. In addition to urban transportation, it is also suitable for simulating trucks, tractor-trailers, railway vehicles, and waterborne transport vehicles. SUMO comes with various supporting tools for route planning,

visualization, network import, and emissions calculation. It can be customized with individual models and offers various APIs for remote control of simulations [10].

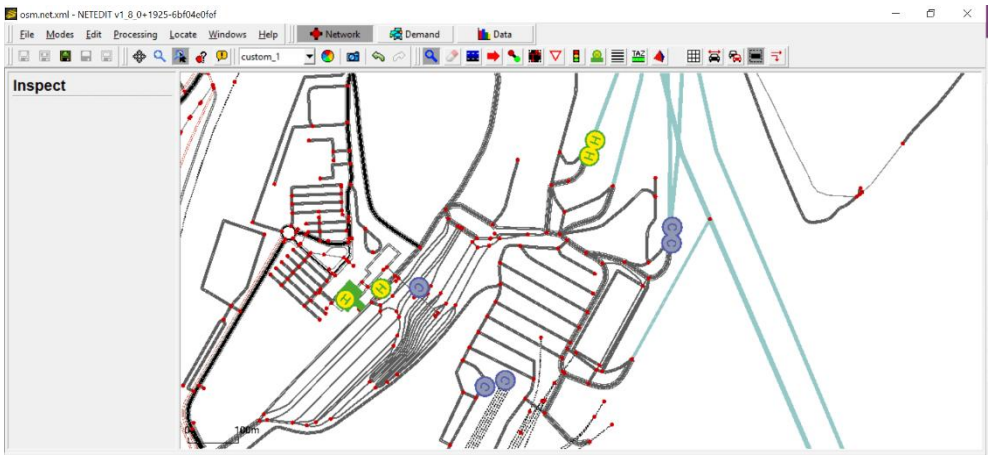

Figure 3. *Eclipse SUMO Port Simulation [11]*

Simulation programs like SUMO can be used in intermodal logistics terminals even to eliminate daily disruptions, as these programs can speed up time, allowing scheduling issues to be anticipated in advance and delays to be calculated ahead of time. Much more accurate estimates can be made, and such programs can also be used to avoid similar issues and minimize losses.

5. SUMMARY

In conclusion, intermodal terminals play a key role in modern freight transportation, and the integration of AI and simulation technologies can significantly improve their operations.

Intermodal logistics terminals specialize in transferring goods from one mode of transport to another. They also provide warehousing, customs handling, and documentation services. They play a vital role in cost-effective shipping. The importance of terminals continues to grow due to increasing freight demand and stricter environmental regulations. This research focused on the terminals of Záhony-Port Zrt. and East-West Intermodal Logistics Service Ltd., both primarily dealing with railway transshipment but also handling road transport.

The detailed examination of terminal operations has provided opportunities to explore the application possibilities of artificial intelligence and simulation methods. Traffic simulation programs like SUMO can help model the traffic situations at terminals, optimize logistical processes, and contribute to cost-effective operations. Artificial intelligence can assist in optimizing transportation routes, schedules, placement of unit loads, and products. ZÁHONY-PORT Zrt. plays a key role in freight transportation, handling various types of goods daily, though its capacity is not fully utilized, and there is currently no demand in the region for further expansion. The terminal deals with bulk goods, with appropriate machinery available for this purpose.

East-West Gate aims to support rail container traffic between the east and west. Located on an 85-hectare area, the terminal has a capacity of 1 million TEUs per year. Its modern

software enables online communication and real-time tracking of containers. The services offered by EWG include container transshipment, warehousing, repackaging, customs handling, and order fulfilment. The terminal also provides rest and shower facilities for workers using its services.

In summary, we successfully gained an understanding of the two terminals' operations, and the goal of determining where artificial intelligence and simulation programs can be applied has been achieved. After completing the task, more opportunities have arisen for integrating these two important tools in various areas.

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