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Assessment System for the Optimization of Logistical, Operational and Administrative Processes at Multimodal Hubs

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Abstract. Based on a case study at the Port of Vienna a standardized simulation system with new algorithms is developed that combines and optimizes significant (administrative, operational and logistic) processes as well as location based conditions. The medium- to long-term strategy concept for an efficient supply chain at multimodal hubs takes into account all detailed considerations and implementation requirements. With the help of layout planning and logistical process optimization, waiting times are to be reduced and the internal hub supply chain will be optimized with regard to the use of resources (energy, space, time). On the basis of standardized procedures and the presentation of an ideal target process chain, the development of an optimized solution for multimodal hubs is implemented, which not only integrates business-related components but also overall economic aspects.

1. Introduction

1.1. Initial position and problem

Freight transport is faced with ever-increasing challenges due to increasing transport volume. Macroeconomic developments in the global context, such as reindustrialization, regionalization of the production of certain products, and more, push for a shift in freight transport. In other words, a transition from the two conventional modes of road and rail to the water transport mode, which promotes sustainability in freight transport.

In an international comparison, the Austrian hubs are well positioned, but lack of transnational and European political strategies or investments hinder the expansion of the waterway. Budget constraints and the not consistent draft of 2.5 m on the Trans-European Network corridor VII (Danube corridor) also make it more difficult to shift the freight transport to the alternative modes of transport.

Furthermore, delays in the transport process may result from infrastructural limited circumstances (e.g. bridges, locks, power stations) as well as technical, legal and organizational barriers. Inadequate capacities in the hinterland or a low capacity utilization of the rail connections especially in eastern European countries make it difficult to increase the traffic volumes and coordinate the arrival and processing of cargoes, which in turn leads to a delay in transshipment processes at multimodal hubs.



In the case of existing multimodal hubs, there are limiting factors such as surrounding residential areas due to the location of the site. Rail connections for delivering goods, which pass directly through or by residential areas, also pose great potential for conflict.

A spatial, traffic engineered and organizationally coordinated location development is a sensitive and complex task for multimodal hubs, due to the multitude and diversity of logistical processes as well as site-specific conditions (e.g. traffic connections, settlements and economic structures). Innovative solutions are required.

1.2. Approach

Seamless transportation is a strategic objective and key factor in state of the art cargo transport and multimodal hubs. It aims at achieving an improvement of effectivity and efficiency of the overall traffic system on a macroscopic level including system parameters, business models, involved actors, actor-specific claims and objectives towards the multimodal hubs. [1]

Within this approach, the resource-orientated use of existing and planned cargo handling areas as well as the resilience of the traffic system is considered. Therefore, an innovative and standardized assessment and model-system for process optimization at the level of individual loading units and vehicles is developed. This model-system is able to simulate and analyse process sequences of logistical, operational and administrative types at any multimodal hub.

The development and test application of the optimization system is carried out by means of a case study at the Port of Vienna. Based on the status quo it focuses on various kind of effects (e.g. infrastructure congestions and mutual obstructions) resulting from the overlapping of formerly isolated processes including their spatial and temporal context within a simulation model. Special consideration is given to operational and overall economic aspects (e.g. environmental protection and welfare goals) as well as the embedding of processes of waterway affine types of goods in terms of space, traffic and organization. Consequently, new potentials for the use of the Danube waterway capacity can be identified

1.3. Objectives

The goal is to improve logistic, operational and administrative processes at a multimodal hub with the aid of a specially developed simulation model. Developed and tested at the location of the Port of Vienna and its container terminal WienCont, the results and recommendations will be generalized and made applicable for other multimodal hubs.

Added value in view of environmentally-friendly transport is generated by the shifting of goods from road to rail onto the waterway by identifying (new) potential turnover waterway affine freight groups. Efficiency increases and the economic prosperity or strategic reorientation of multimodal hubs are the focus of the developed standardized optimization process.

2. Assessment system

Within the assessment system a blueprint for analysing and optimizing multimodal hubs is developed. The key element of process optimization is a simulation model.

There is a need for research regarding the development of systematized processes for increasing freight traffic on the Danube and optimization procedures for multimodal hub processes. In addition to the simulation of process flows, (business- and macroeconomic) objectives, visions, strategies and concepts should be taken into account.

A theoretical strategy concept has been developed that provides the most comprehensive possible framework for carrying out the necessary investigations. The contents of the strategy concept range from the description of the existing situation, the problems, the basic conditions, and the variant analysis, to the elaboration and assessment of the operation or rather measures. Thus, the theoretical concept provides guidance for the optimization of a multimodal hub, which illustrates the sum of the optimization steps that have to be adapted at individual terminal locations. They will have to be adapted depending on the site-specific data situation and information availability. Ergo, in order to be able to

develop recommendations for action, the theoretical concept is adapted, tested and subsequently used as a basis for the development of recommendations.

Based on the results from the tests of the Vienna Port, the so-called blue print can be used for multiple and different types of multimodal hubs. Its strategy concept is elaborated as a standard scheme. The blue print combines both the theoretical considerations as well as the practical insights. Seeing that the strategy concept is tested by the Port of Vienna and lessons can be learned from this research, it prevails as a base concept. [2]

The main goal of the blue print is to provide an easy-to-use check list for analyzing and optimizing multimodal hubs. Following the action steps of the blue print, the process of analyzing and improving multimodal hubs, which was used for the Port of Vienna, can be subsumed in a 3-step-flow chart diagram (figure 1). The points 1-3 (Analyzing, Optimizing, and Evaluating) describe the main process steps.

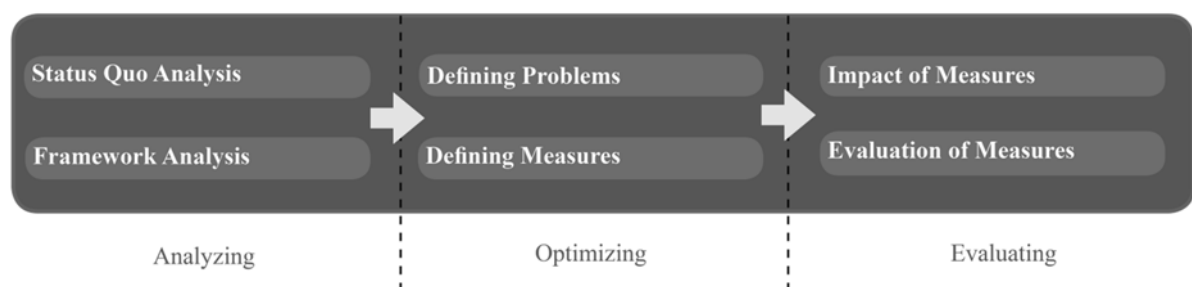


Figure 1. Blueprint

2.1. Analysis of the multimodal hub

Due to the increasing relocation of production from Europe to Asia, the transport of bulk goods will tend to decrease across all modes of transport. In order to increase the traffic volume on the Danube, it is necessary to identify alternative navigable goods and to promote the transport by inland waterways. An assessment system based on major criteria e.g. increasing of reliability, time gains and minimized transportation costs is developed and can be used to analyze systematically and site-specific the potential of new goods for inland waterway transport. International bottlenecks along the waterway are specifically taken into account for the estimation of the future potential.

Particularly waterway affine commodity groups are non-time-critical goods, such as agricultural and forestry products, stones, soils and building materials along with petroleum and mineral oil products. The less affine product groups include vehicles, machines and other semi-finished and finished products.

The comparability of locations with respect to their equipment and their competitiveness is achieved by means of benchmarking. Benchmarks enable the use of quantifiable or measurable indicators on the micro- and macroeconomic level to compare infrastructural, superstructural, operational, organizational, economic and environmental conditions of sites.

- Infrastructural indicators describe physical properties and capacities along with – due to their fundamental importance – underlining the performance of the basic design of a location.
- Superstructural indicators provide information on the capacity and performance of a site.
- Operational and organizational indicators provide information on key figures for the operational and organizational processing of services at the location. They are very dynamic and are directly related to the available infrastructure, superstructure, administration, management and the operational practice.
 - Economic indicators describe the economic activity taking place at a location. They are of great relevance to governments and authorities to justify public investments or financing of site projects.
- Environmental indicators contribute significantly to sustainable development and to the monitoring of "green" logistics. [3]

Based on the study INWAPO and researched international experience, a benchmark system with different indicators is developed [4]. In order to the effective optimization of multimodal hubs 22 indicators out of 56 indicators were selected (figure 2). The following criteria were relevant for the selection of indicators:

- Significance (In which quality is the performance of multimodal hub measured?)
- Existence (How is the benefit/cost ratio of the data collection?)
- Availability of data (Is the data accessible or public? Are the port authorities required to collect any data at all?)
- Comparability (Can data be collected at any multimodal hub?)

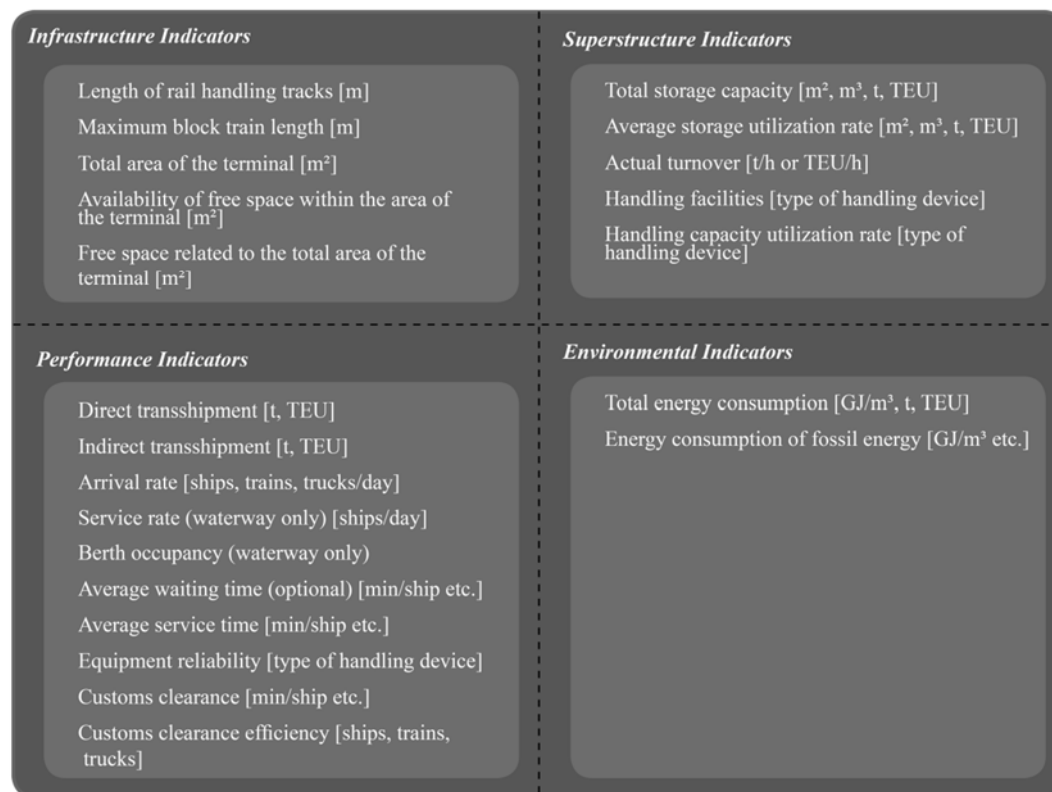


Figure 2. Infrastructure Indicators, Superstructure Indicators, Performance Indicators, Environmental Indicators

Once the potential areas for improvements are identified, the multimodal hub can be analyzed in more detail. Processes, like transshipment or special services, such as value-added services and refinements etc., enhance the complexity of the simulation of processes at the multimodal hub. This way the analysis needs to take all of these aspects into account. In addition, it is recommended to separate the transfer of goods and information, since information transfer requires different resources (e.g. work force, computers, and time).

For each process part (e.g. entry, transshipment, storage, repair, refinement, commissioning, and exit) the following aspects (sub-processes) need to be described:

- Goods/information/description/unit type
- Location
- Time and length
- Stakeholders involved
- Mode of transport (street, water, rail etc.)

- Means of transport (truck, ship etc.)
- Form of documentation (paper, digital etc.)

In addition to analysing the process parts, it is necessary to define their location at the multimodal hub as well, in order to present the spatial-temporal connection between infrastructure, superstructure or other resources (e.g. human resources, energy demand, and spatial resources). When different processes overlap, analysing this connection of resources is important in order to learn more about resource utilization and the capacity constraints of infra- and superstructure.

The main challenge of spatial organization is the multimodal hub model, which determines the competence of involved actors (e.g. hub authority and tenants) to change the spatial organization. Therefore, it is important to assess goals, requirements and priorities of multimodal hub stakeholders, in order to consider these aspects in terms of their relevance for spatial organization.

Based on the identified problems, suitable optimization measures can be defined by the specific stakeholders for spatial management aspects (e.g. use of space, size of reserved area, arrangement and configuration), traffic management (e.g. street categories, access and routes for vehicles, traffic rules) and organizational aspects (e.g. information, communication, documentation, administration). For each measures and variants (package of measures) problem indicators (e.g. transit time, waiting period, number of hubs, and length of traffic tailbacks) are developed.

2.2. Optimizing the multimodal hub within a simulation model

An overall efficient and effective transport system requires well timed transports and the optimal integration of different modes of transport – in favour of reducing misalignments between arrival and processing of cargoes or rather different logistical processes. Optimizing a process sequence, in order to match process sequences and avoid waiting times, can be achieved by means of a technical adaptation of the multimodal hub, as well as the provision of sufficient traffic areas and buffer locations.

Generally, there are two ways for traffic simulation: traffic flow on the macroscopic level and the car-following on the microscopic level [5]. On a large scale level road traffic can be modelled within different models considering spatial-related aspects (e.g. neighbourhood, region), time-related aspects, congestions evaluation (e.g. vehicles impacted, duration) and (transport) demand on short/medium/long term horizons [6]. On the microscopic level traffic simulation (e.g. for toll stations) can be used to implement different scenarios and potential problems or bottlenecks. By doing so possible traffic volumes and total capacity as well as the optimal configuration of areas are analysed [7]. Microscopic traffic simulation model should be calibrated in order to align simulation results (e.g. traffic volumes, speed and travel time) with the reality/field traffic data (Yu and Fan 2017).

The key element of (process) optimization of multimodal hubs is the developed simulation model. The simulation model was selected based on reviews and assessments in line with the simulation concept and it is focused on future potential requirements regarding demanded goods eligible for inland waterway transport. For this purpose, standardized procedures for mapping local terminal conditions (such as traffic organization, land use etc.) and process flows are defined. Based on the input data (e.g. vehicle permits from the in- and out-gate of a terminal, work schedules of a terminal management system, information regarding delays of incoming/outgoing trains, container depot information) a simulation model for intermodal hubs (especially for port areas) is developed, which attempts to optimize processes on multimodal hubs. The required parameters are identified and standardized algorithms for mapping processes are programmed. In order to record the existing processes and local conditions in the system. Different processes (e.g. logistical and administrative) are being visualized. The approach for the system is developed in a way that a conversion to other national and international locations with appropriate data availability is generally possible. Based on the input data, the current situation of the Port of Vienna is mapped and validates the model through various performance indicators.

For this purpose, spatial and traffic related conditions as well as logistical and organizational requirements are examined. By means of quantified benchmark indicators, including the market

situation and stakeholder-specific objectives and interests, capacities (e.g. incoming orders, loading units, and priorities for order processing) can be assessed and imported into the simulation model. Whereby, different process operations (e.g. traffic movements, disturbances in access roads) are simulated under existing spatial circumstances.

Different scenarios are implemented in the model for the Port of Vienna. System recordings are for example, new transshipment technologies, IT applications, the increased use of border areas, the relocation and rationalization of locations, infirmity scenarios, and flood situations.

The simulation tool can be used for the assessment of the following scenarios, amongst others:

- Traffic queuing caused by heavy vehicles in conjunction with existing traffic signals at existing and planned in- and out-gates of multimodal hubs
- Impact of heavy load cargo handling in combination with parallel running “normal” processes
- Effects of different in-gate configurations regarding traffic flow, dwell times, processing times, traffic queuing and checking procedures

Due to the ongoing localization of the vehicles, loading units and the determination of the temporal activities the simulation model calculates pre-defined performance indicators (e.g. movement times, waiting times, number of strokes). These indicators enable deducible performance statements, bottlenecks and other problems. On the basis of the problems (e.g. insufficient flexibility in cargo handling) identified by the initial simulation, customized solutions (e.g. use of mobile crane) are developed. Furthermore, proposed solutions are considered individually or can be bundled by means of additional simulations and visualizations in terms of variants (figure 3).

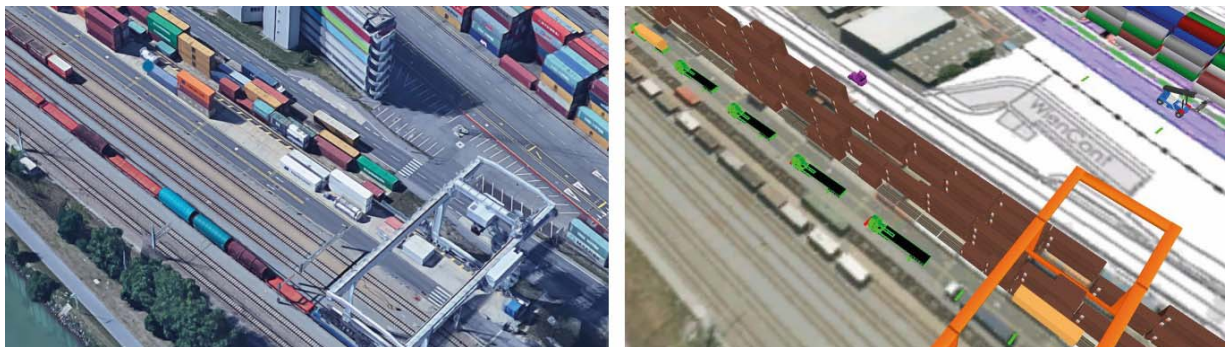


Figure 3. Comparison of a simulated detailed situation with the real situation

Transit times and waiting times are minimized. The environmental situation is improved and negative impacts on the surrounding residential areas are reduced. The economics and the attractiveness of the multimodal hub are to be increased for all stakeholders in the best possible way.

The quantified indicators are calculated by the simulation model as well as the comparison of the status quo and variant simulation. The suitability of one or several measures for problem solutions can be assessed and the occurrence of potential consequences (positive as well as negative) can be investigated. At last, the proposed solutions can be evaluated from a business and an overall economic perspective.

2.3. Evaluating the optimization

For the qualitative evaluation, the measures are assessed in terms of (1) business-related objectives of private companies, (2) micro-economic objectives, (3) macroeconomic objectives and (4) welfare-related objectives. The costs of a measure are also considered.

On a macroeconomic level, these exemplary factors would be relevant:

- Assessment of negative effects [EUR] caused by noise [dB] or pollutant emissions [g/m³]

- Assessment of increased resilience [++/+/ -]
- Assessment of increased waterside transshipment [% or EUR]
- Generation of regional effects in terms of spill over [EUR]

Exemplary factors that can be used for the assessment from a business-related point of view:

- Evaluation within the framework of the strategic focus of the multimodal hub [++/+/ -]
- Evaluation of resource demand ([m²] or [h] or [kW/h] or [pers.h])
- Transportation and transshipment efficiency ([strokes/h] or [t/day])
- Improved competitiveness due to increased regional value added [%]

Apart from this, it is to be identified whether the interdependencies of different measures or the competence of a single measure or a bundle of measures can solve a problem appropriately.

These evaluations are based on the problem indicators generated from the simulation model through individual assessment as well as by experts. Efficiency (degree of problem-solving), feasibility, urgency, and importance are taken into account for each measure.

3. Added value and application potential

An efficient handling of the hub-internal and the hub-related inward and outward accesses can take place with the aid of problem indicators generated by the simulation model (e.g. the number of unloaded vehicles per time unit, waiting time, and driving time). Through the modelling and planning function of the developed approach, resources and capacities can be planned or coordinated in a timely manner. Thus, congestion and waiting times can be reduced or prevented. Due to the improved performance, the flow of goods can be maintained even under unfavourable conditions. Not least, this makes a major contribution to the reduction of energy and resource consumption as well as negative environmental impacts.

The simulation model is suitable for the assessment of planning alternatives whose effects on terminal processes can be rated for selection of suitable optimization measures. The following applications can be indicated exemplarily:

- Effects of the use of different/specialized handling equipment to ensure flexibility and capacity increase (e.g. reduction of handling and waiting times)
- Estimation of the potential for a change in use of different areas and its corresponding advantages and disadvantages
- Standardized process integration of waterside handlings including assessment of the process-oriented effects of increased use of waterside handlings
- Identification of suitable areas for terminal expansion
- Impact of various land reclamation measures
- Spatial rearrangements and/or measures for the interlocking of process operations

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