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Investigating into the challenges of European inland ports: A multifaceted approach

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Abstract

Despite their outstanding importance, challenges of inland ports are hardly focused upon in research. Therefore, many major challenges that European inland ports face are neither systematically identified nor addressed. In times of increasing integration of transport chains and modes, inland ports can serve as pivotal enablers in their natural role as intermodal logistics nodes. Hence, addressing the challenges of inland ports supports the efficiency and resilience of entire transport corridors and even logistics networks. With the findings of this research article, the major challenges of European inland ports are identified, systematically collected, empirically validated through semi-structured interviews, and validated with supporting geospatial analyses. On the basis of the findings of this research article, subsequent research can be motivated, initiated, and perpetuated, respectively.

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1. Introduction

In view of the disproportionate growth in freight traffic in Europe, greater use is to be made of the capacity reserves of inland waterway transportation (IWT) and the logistics competence of European inland ports. While seaports and their logistics aspects are regularly the subjects of extensive research, this is not the case with inland ports. Yet, inland ports are an important complement to seaports for business and logistics as regional transport, industrial, and commercial enterprises are linked to them through traditional port functions. The services offered by inland ports range from the provision of high-quality land and real estate to the operation of handling facilities and the organization of efficient logistics chains. In the hinterland of the European seaports, they are already part of such chains in segments like bulk and liquid cargo and increasingly even containerized cargo (Witte et al., 2019). Increasingly, modern inland

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ports are also freight traffic centers, linking the transport modes road, rail, and inland waterway while numerous businesses and facilities are located in their vicinity. As intermodal logistics hubs, inland ports are, thus, fundamental to a successful modal shift and the achievement of climate targets. Therefore, securing and preserving the inland ports is a challenge whose urgency is steadily growing due to the ongoing freight structure effect and the continuous erosion of bulk transport by IWT. The threat is further exacerbated by the shortage of young and skilled personnel and particularly the imminent disappearance of smaller inland vessels, which operate on smaller waterways and canals.

As a consequence, the challenges faced by European inland ports are manifold. This holds true due to the geographical and economic disparities across the continent but also due to the different management concepts applied and technical requirements prevailing in the various locations. Ongoing research, however, has hardly focused on such challenges of inland ports. In order to close the gap, the present research article presents the results of a tripartite approach. Thus, the major challenges of European inland ports need to be identified systematically and proven with the help of supporting data before the terms of reference of improved inland port operations can be determined.

2. Methodology

The conducted research documented in this article is subdivided into three levels of examination, consisting of thorough desk research of relevant scientific literature and further publicly available publications, semi-structured expert interviews in order to validate the consolidated findings, and geospatial analysis of the movement of the inland vessels in order to underpin the above-mentioned challenges with (quantitative) data.

On the first level of examination, a desk study of relevant scientific literature and further publicly available publications is used to gather an overview of the major challenges of European inland ports. The findings resulting from the desk research have been scanned for relevance, processed, and interpreted in terms of containing challenges of inland ports. In the second stage, the findings have been filtered, grouped, and consolidated into challenge categories. These findings are validated by means of a series of semi-structured interviews with experts from inland ports, seaports, or inland port associations. Based on a qualitative content analysis of the interview results, geospatial analysis of time series data sets of positions of inland vessels in defined geographical areas and a defined time interval represents the third stage. It was used to determine where bottlenecks on the inland network occur. Parallely, various inland ports in the considered area have been scrutinized for quantitative evidence supporting the earlier findings.

Ultimately, a thoroughly and carefully compiled list of challenges is presented and serves as an orientation for future research and development – both concerning organizational management and technical development.

3. Challenges of inland ports – derived from literature

In order to get an overview of the typical challenges faced by inland ports, relevant scientific literature has been analyzed and interpreted with respect to the pressing challenges of inland ports. According to Rowley and Slack (2004), literature reviews are to extract the existing literature and state of the art in a research field and develop an understanding of it. Due to the scarcity of scientific sources, non-academic articles have been included in the search and collection process as well. The articles have been grouped by the thematic affinity of the contents and eventually consolidated into ten categories of challenges which are discussed in more detail in the subsequent sections.

3.1. *Expand the efficacy of the port industry as an overall logistical system of various actors*

Ports are of great importance for the entire national economy in their function as freight centers and job creators with their direct, indirect, and induced employment effects by creating jobs in the port sector, related industries, along the entire value chain, and in their nearer geographic vicinity (BMVI, 2015, pp. 85–87, 2019, pp. 91–92; Islam, 2016; van der Enden, 2012). Similarly, changing work requirements require increasing specialization and, thus, up to 50 50 different professions based in ports (BMVI, 2015, pp. 32–33). Highlighting their pivotal role in the logistics industry and communicating this outstanding role within the national economy to the general public in the form of orchestrated marketing and communication campaigns is another pending task for the inland ports (Flämig & Schulte, 2011b, pp. 13–14; MBWSV.NRW, 2016, p. 19). Likewise, inland ports need to increase their competitiveness – not only by improving classical economic performance indicators, such as volume, cost, turnover, and profit, but also through a

sufficient digitalization level, an attractive service portfolio, adequate multimodal connectivity, and state-of-the-art facilities and equipment in the port (BMVI, 2015, pp. 88–90).

3.2. Promote modal shift

Inland ports are assigned an important role in the promotion of modal shift, which can be achieved by the ports shifting both incoming and outgoing traffic away from the road towards more sustainable transport modes and subsequently reducing the road-borne traffic load around the port (MBWSV.NRW, 2016, pp. 20–21). As to IWT, the transport mode needs to gain increased importance in the transport industry so that the expected growth in traffic can be handled (BMVBS, 2013, pp. 167–169; BÖB, 2021, pp. 6–7). Furthermore, inland ports should improve the conditions for project and heavy cargo transport by creating rail- and waterborne transport corridors for this cargo type and informing potential customers about the reliable and comfortable alternative to road transportation (BMVI, 2020, pp. 36–39).

3.3. Improve hinterland connectivity (esp. rail connections)

Maintaining a close link between seaports and inland ports via all three major transport modes is of major significance to the smooth operation of seaports. For inland ports, in turn, it is important to create a network of inland port hubs, distribution centers, and shunting yards to provide improved service to their own hinterland (BÖB, 2021, pp. 3–4; Caris et al., 2014; Witte et al., 2016). However, many inland ports face concerns regarding road accessibility, rail connectivity, and inland waterway access (BMVI, 2015, pp. 61–64). While rail connectivity is limited by the train length, shunting areas, and inadequate rail connection to the seaports, IWT requires optimized clearing clearance profiles, including bridge heights, lock dimensions, and unloading depths (BÖB, 2021, pp. 5–7; PLANCO, 2013, pp. 161–167).

3.4. Provide space

Many inland ports represent the last inner-city land reserves for commercial use. Hence, their expansion plans oftentimes require additional operational space but conflict with competing interests regarding such well-developed plots and waterfront properties (Bey, 2018; VVW, 2019, pp. 5–6). For environmentally friendly and urban-friendly logistics concepts, inland ports need to pursue a fitting land use policy and consider securing locations for potential use a strategic task as areas with good transport connections will be of outstanding importance and great scarcity. (EFIP, 2011; Flämig & Hesse, 2010; Flämig & Schulte, 2011a, pp. 197–198).

3.5. Expand inland port infrastructures and superstructures

Closely linked to the need for space is the expansion of port infra- and superstructure to accommodate the expected growth and to realize the role shift towards a trimodal freight distribution center. Being important central industrial locations, inland ports oftentimes need to provide a direct connection to the customers and sufficient handling infrastructure as prerequisites of the engagement of the local industry (BÖB, 2021, pp. 3–4; VVW, 2019, pp. 10–12).

3.6. Improve on-site logistics and further develop innovative port technologies

In the sense of process optimization, inland ports need to improve on-site terminal logistics and develop new solutions for organizing the port traffic and cargo transshipment by better managing the available resources, especially with even stricter requirements coming from consignors, forwarders and the seaports. Such process improvement encompasses physical and digital upgrades and implies technology deployment (BMVI, 2015, pp. 86–87).

3.7. Improve the inter-terminal transfer of cargo

Whereas seaports traditionally face the need for a well-organized inter-terminal transfer scheme, the challenge also becomes relevant for larger inland ports with multiple terminals as the vast majority of these transfers take place on the road today and lead to further congestion in and around the ports.

Thereby, new rail and waterborne solutions on the planning and operational levels need to be developed to the delight of the stakeholders and residents (Duinkerken et al., 2007; Heilig & Voß, 2017; Hu et al., 2018; Hu et al., 2019).

3.8. Reinforce digitalization

In order to exploit the economic success potential resulting from digitization, digitalization, digital networking, and digital business models, inland ports need to transform themselves into data hubs, next to transshipment hubs, and connect themselves with fellow inland ports on a digital level. Therefore, investment in the appropriate digital infrastructure, the facilitation of the digital connection of all stakeholders in and around the port, the standardization of communication and data exchange formats, and the design, set-up, and configuration of new digital business models based on innovative, data-centered services belong to the prerequisites that the inland ports need to ensure (EFIP, 2016, pp. 10–11, 2017; VVW, 2019, pp. 20–21).

3.9. Reduce emissions in and around inland ports

Emission reduction is a pivotal challenge to inland ports as these locations are under increasing pressure from the administration and the public. This refers to its activities on the waterside, the land side, the terminal itself, and the wider vicinity of the port. The challenge unfolds into several individual activity fields, including retrofitting existing infra- and superstructures to meet modern standards, providing onshore power supply to inland vessels, introducing emission-based port fees and charges, and developing infrastructure for alternative energy sources like hydrogen or electric batteries for a transformation to energy hubs (BAG, 2021, pp. 25–29; BMVI, 2015, pp. 105–106; BÖB, 2021, pp. 7–8; VVW, 2019, pp. 14–15). Further, the port authorities are well-advised to prevent pollution through particle, noise, and light emissions actively and, thus, invest in adequate protection measures in order to maintain and extend acceptance of port operations (BAG, 2021, pp. 19–25; Flämig & Hesse, 2010).

3.10. Exploit accompanying funding programs

Oftentimes financially weak, inland ports should exploit the existing multitude of funding programs on municipal, regional, national, and European levels more effectively for a consistent and sustainable progress in economic, technical, and ecological terms. Furthermore, inland ports should consider engaging in public research and innovation projects that aim to tackle specific challenges a port faces and develop the required solutions by themselves. By this, the port authority shows its proactive role in shaping the future in a sustainable manner (BMVI, 2019, pp. 13–19).

4. Challenges of inland ports – validated by sector experts

Expert interviews are very popular in empirical research works. They can serve different purposes, e. g., to acquire deeper knowledge in an exploratory phase, to sort and systematize a comprehensive and complete collection of relevant knowledge, and to generate a theory through the communicative development and analytical reconstruction of the subjective dimension of expert knowledge (Bogner & Menz, 2005b, pp. 36–39, 2005a, p. 7). In the present case, the expert interviews are partly systemizing and partly explorative since the experts are to explain the multitude of challenges of inland ports and reveal their very own views, on the one hand, and provide the involved researchers with guidance in their further research work and to add new facets formerly unknown. The selected experts are representatives of major European inland ports along the Rhine-Alpine Corridor and from other geographical areas, national, and European port industry associations, and major European seaports.

4.1. Overview of the interview results

The semi-structured expert interviews were conducted with the help of the findings from the literature review presented earlier. The experts were asked to comment and elaborate on those challenges' relevance and rate their respective significance. A total of fifteen expert interviews have been conducted, each of a duration of approx. 90 to 150 minutes, and most of them were held online (due to restrictions related to the COVID-19-pandemic). At the end of each interview, the interviewees were asked to score each challenge with one (low prio) to ten (top prio) points.

While some challenges were perceived by the interviewees in a heterogeneous manner, others found universal acceptance as a top or low priority, respectively, and none of them has been rejected. Fig. 1 presents the average and median scores across all fifteen conducted interviews as well as the upper and lower bounds for the scores of each challenge. While digitalization and hinterland connectivity are understood as significant fields of activity, inter-terminal transfers and relevant funding schemes are considered marginally relevant only. The biggest differences in perception refer to the challenges of scarce space, the need for additional infrastructure, and process optimization.

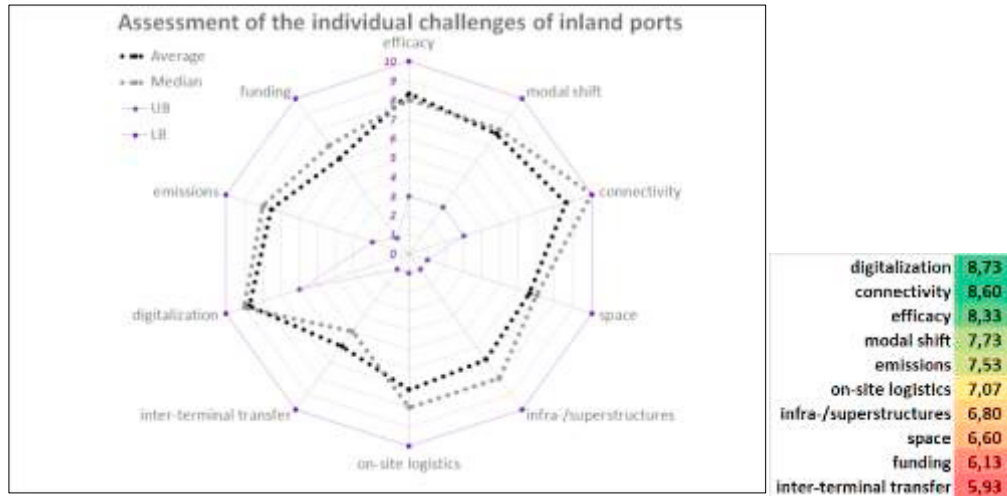


Fig. 1. Overview of the consolidated results of the semi-structured interviews about challenges of European inland ports.

The highest-rated challenge, *'reinforce digitalization'*, has achieved a score of 8.73 points on average. With no expert ranking the challenge lower than a 6, they confirm its general importance and strategic value.

With an average score of 8.60, the challenge *'improve hinterland connectivity'* is the second highest-rated challenge which only two experts ranked the challenge with less than 7 points due to the favorable situation in their own ports.

On the third rank, the challenge *'expand the efficacy of the port industry as an overall logistical system of various actors'* has reached an average score of 8.33 points. Only one expert regarded the challenge less important than an 8, awarding only 3 points.

The next challenge, *'promote modal shift'*, has also been voted relatively high with an average of 7.73 points and only three experts assessing it below 7 points. Corresponding to the societal mega-trend, the challenge *'reduce emissions in and around inland ports'* is rated reasonably important with 7.53 points on average. A topic often discussed was the provision of on-shore power supply. The lower half of the list of challenges begins with the challenge *'improve on-site logistics and further develop innovative port technologies'* with a mean value of 7.07 points, followed by *'expand inland port infrastructures and superstructures'* which has achieved an average score of 6.80 points. While one port claims to be well-equipped already, many experts agree that maintaining and investing in existing facilities is a necessity.

The third least important (and principally nevertheless significant) challenge from the list is *'provide space for future operational growth'* with 6.60 points on average. This challenge is followed by *'exploit accompanying funding programs'* (6.13 points on average). A major issue with funding programs pointed out during the interviews is the time-consuming nature of the application formalities and processes, posing a problem particularly for smaller ports without the capacity or budgetary overhead to employ someone to work dedicatedly on these applications.

Lastly, *'improve inter-terminal transfer of cargo'* is ranked lowest on the list with only 5.93 points on average. It is not a surprise as this is not a topic at all in many inland ports. Those ports that are large enough to accommodate more than one terminal of the same cargo type, have ranked the challenge very high with 8 or even 10 points.

In addition, the preparation for climate resilience of inland ports, the maintenance of a proactive and good port-city relationship, and personnel shortage are considered major additional challenges brought up by the experts themselves.

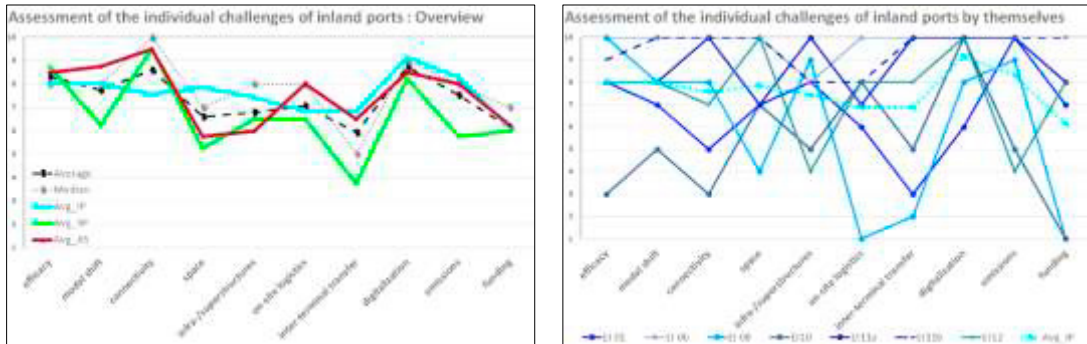


Fig. 2. Overview of (a) the average interviews results per subgroup (left) and (b) the individual results from inland ports (right).

Fig. 2a shows the average results of the semi-structured interviews about challenges of European inland ports per subgroup, i. e., inland ports, seaports, and inland port associations, i. e., associations responsible for inland ports of a region, a country, an international waterway, or even internationally.

4.2. The viewpoint of the inland port themselves

Being the main focus of this research, the majority of expert interviews were conducted with experts from inland ports themselves (7 out of 15). They rated the challenge *'reinforce digitalization'* the most pressing one with an average score of 9.14, followed by the challenge *'reduce emissions in and around inland ports'* with a score of 8.29. These two challenges are ranked ahead of *'expand the efficacy of the port industry'* and *'promote modal shift'*, both of which come in third place (with 8.00 points each). At the bottom stands *'exploit funding programs'* with 6.14 points. Fig. 2b shows the all the individual ratings assigned by the experts as well as the mean and median rating.

4.3. The viewpoint of the inland port associations

Four interviewees from inland port associations ranked the challenge *'improve hinterland connectivity'* as the most important one to inland ports with 9.50 points on average. The challenge *'promote modal shift'* was ranked second highest with 8.75 points on average, ahead of the challenges *'expand the efficacy of the port industry'* and *'reinforce digitalization'* tied in the third place with 8.50 points each. From the associations' point of view, the challenge *'provide space'* is regarded as the least important, with merely 5.75 points on average (see Fig. 3a).

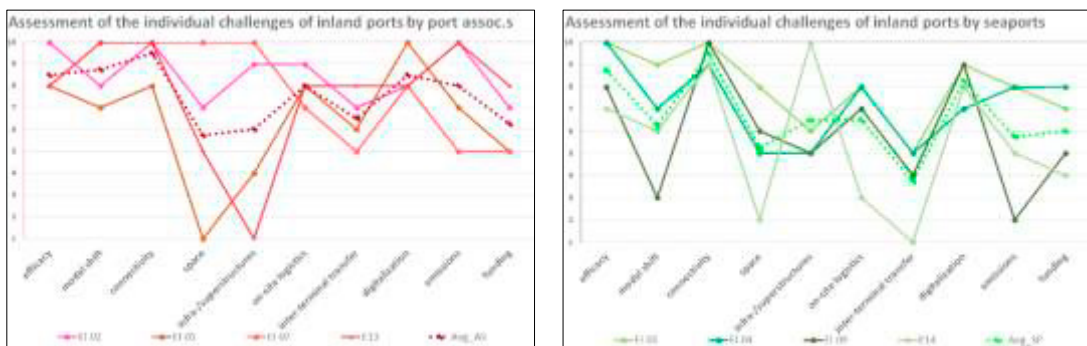


Fig. 3. Overview of the individual results from (a) inland port associations (left) and (b) seaports (right).

4.4. The viewpoint of the seaports

From the four seaport experts' viewpoint, the biggest challenge of an inland port is to *'improve hinterland connectivity'* (9.50 points on average), followed by *'expand the efficacy of the port industry'* (8.75 points) and

‘reinforce digitalization’ with an average 8.25 points. With a score of 3.75, the challenge ‘improve inter-terminal transfer’ is ranked lowest by the seaport experts which represents the lowest score of all sub-group average ratings. Interestingly, the seaports have had only a few disparities in their perception of challenges (as can be seen in Fig. 3b).

5. Challenges of inland ports – represented in inland vessel movements

In order to underpin the above-mentioned challenges with quantitative data, geospatial analysis of the inland vessel movement along the Rhine-Alpine Corridor is conducted, and various geographic regions of interest are focused upon. The related AIS data has been retrieved from a German vendor of data on global (historical and real-time) vessel position tracking information. The results of the geospatial analysis can be shown both in tabular presentation and heat maps in order to illustrate the travel intensity on certain waterway stretches, waiting times in certain areas, and, possibly, striking movement trajectories. With increasing traffic volume registered in a particular area, the green marking in a heat map intensifies until full coverage before turning yellow and eventually red. After defining the geofences for all ports and locks along the Rhine river and the connecting waterways towards the seaports of Antwerp and Rotterdam, geospatial analysis of the vessel traffic of thirteen inland ports, two seaports, and two locks along the Rhine-Alpine Corridor has been conducted.

With respect to the above-mentioned challenges of inland ports, some of the issues can be translated from the geospatial analysis. To these issues belong the efficacy of the port industry in the respective port city, the existing hinterland connectivity of an inland port, the need for additional space and transfer services between various terminals, and the need to reduce emissions caused by port and transport operations. The efficacy of the industry is obvious in Duisburg due to the numerous terminals scattered throughout the city, all of which are frequented by inland vessels regularly (see Fig. 4a). For the same reason, inter-terminal transfers are required in port cities like Duisburg, Cologne, and Strasbourg (see Fig. 4a, d). The multimodal connectivity is evident in Liège, Mannheim, and Duisburg due to the several highways and rail links to the port areas (see Fig. 4a-c). The space problems in Liège led to the opening of the Trilogiport terminal approx. fifteen kilometers north of the existing terminals (see Fig. 4b). Moreover, Mannheim port and the Upper Rhine stretch north of it show high traffic intensity indicating emission problems existing or arising soon (see Fig. 4d).

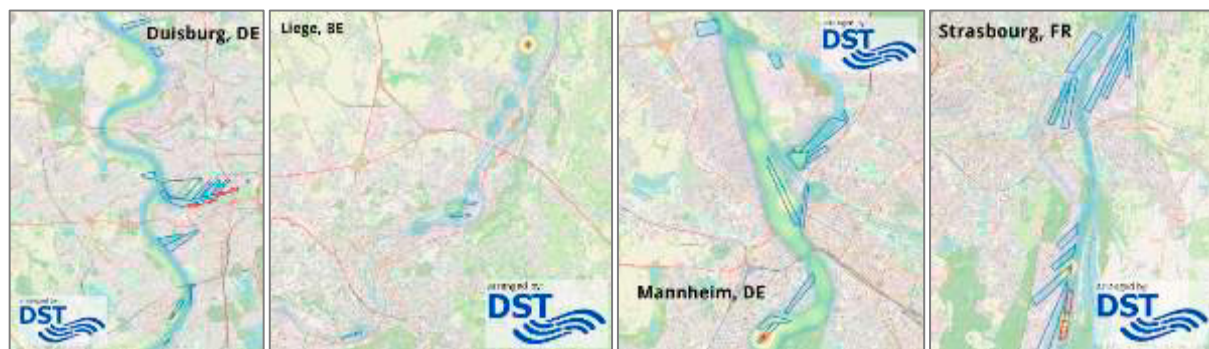


Fig. 4. Geospatial analysis of the inland vessel movement in (a) Duisburg (DE), (b) Liège (BE), (c) Mannheim (DE), and (d) Strasbourg (FR).

6. Conclusion & Outlook

The research article defines the challenges of European inland ports and validates them by analyzing the painpoints on a qualitative and quantitative level. A list of descriptions of the challenges of inland ports including their respective scope represents the main result from the first level of examination. This list is an aggregation of multiple individual statements and remarks in a variety of publications. The qualitative assessment of the significance and urgency of each identified challenge by multiple experts, a list of additional challenges highlighted in the expert interviews, and the differentiation of the expert opinions between the views of individual inland ports, seaports, and port associations, respectively, belong to the results of the second layer. Thereby, the viewpoints of the interviewee sub-categories can

be compared with each other as they have varying and possibly even conflicting goals and priorities. The results of geospatial analysis of multiple inland ports verify the significance of the respective challenges on a quantitative level. Thereby, the qualitative statements from the preceding levels of examination are corroborated.

The findings of this research article will also serve as a guide for political and commercial planning of a sustainable and successful inland port development. It includes the viewpoints of the actors engaged in the operational side of the identified challenges of inland ports.

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