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# Applicability of pre-gate concepts in RoPax terminals and ports

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## Abstract

**Purpose** – RoPax ports are confronted with approaching urban development. Therefore, planning for port expansion is increasingly restricted, while the challenges of more traffic due to increased handling volumes in the form of congestion and handling times are growing. Hence, access to RoPax ports is an increasingly challenging task requiring due attention from port authorities, city planners, and logistics service providers.

**Design/methodology/approach** – An in-depth literature review of pre-gate concepts was conducted to harmonise the challenges in access management. Eight approaches to pre-gate concepts were identified and discussed. Given the potentials of the benefits associated with the adoption of pre-gate concepts in the operation of RoPax ports, this work is based on a multiple-case study comprising three RoPax terminals in northern Europe. By applying qualitative methods, it is aimed to receive a better understanding of challenges in RoPax port operations. The paper analyses identified pre-gate concepts regarding their applicability to specific challenges of RoPax ports by differentiating between various criteria.

**Findings** – Although primarily designed for container terminals, these concepts hold significant research potential for RoPax ports. The study's main finding is that effective pre-gate approaches from container terminals can be successfully adapted to RoPax port operations, offering a new framework for addressing increasing traffic and operational complexities.

**Originality/value** – The identified concepts, mainly known from container terminals, have not been considered for RoPax ports but offer many research opportunities. The added value lies in the fact that this approach can address the current space problems in RoPax terminals and the fluctuating access pattern, particularly in urban environments.

**Keywords** Extended pre-gate, Roll-on/roll-off, Short sea shipping, Intermodal transport, Pre-parking

**Paper type** Research paper

## 1. Introduction

Short sea shipping (SSS) is crucial to achieving the EU climate target of a 55% reduction of all greenhouse gas emissions by 2050 (European Council, 2023) and shifting 30% of road freight transport over 300 km to other modes by 2030 (European Commission, 2011).

SSS is defined differently in the literature. The European Commission (1999) describes SSS as the maritime transport of goods and passengers over relatively short distances, as opposed to intercontinental ocean shipping. Other definitions focus on multimodal integration: Medda and Trujillo (2010) emphasise that SSS is a transport concept that uses



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short maritime distances as part of an intermodal chain. Santos and Guedes Soares (2017) emphasise that SSS is more environmentally friendly than road transport and contributes to reducing congestion. In this paper, the definition of the European Commission (1999) is taken as a reference, as it is the most frequently used in practice and science.

Terminals (ports) are the weak link in the Roll on/Roll off (RoRo) transport process due to their lack of resilience and vulnerability to problems (Balaban and Mastaglio, 2013). Delays in ship clearance can lead to delays in ship schedules, terminal operations, and ultimately, the entire transport chain (Maksimavičius, 2004; Saurí *et al*., 2012).

RoPax is considered a subsegment of RoRo, including the transportation of wheeled cargo and passengers with or without vehicles. Roll on/Roll off/Passengers (RoPax) is characterised by even more complexities related to managing vehicle and passenger flow, short loading and unloading times, and challenges in optimally loading vessels.

The trend towards introducing larger vessels is also entering RoRo shipping (Woxenius and Bergqvist, 2011; Ventura *et al*., 2020). Ports are reaching their capacity limits as expansions become more challenging due to decreasing available space (Paixão and Marlow, 2007). They represent the bottlenecks in supply chains (Paixão, 2008; Medda and Trujillo, 2010), which can lead to a prolonged lead time for trucks delivering and picking up loading units (Wiegmans and Konings, 2014). In this respect, Medda and Trujillo (2010) see a disbalance in the demand for RoRo SSS and the supply of suitable transport infrastructure. Ventura *et al*. (2020) corroborate this observation and highlight the need to develop efficient maritime and land access to the port. The dependence on fixed schedules requires efficient access to port infrastructure, while high traffic variability due to the mix of lorries, trailers, and cars can lead to peak loads. Additionally, limited buffer zones complicate traffic management in RoPax terminals.

The pre-gate concept (PGC) helps to address these challenges by enabling controlled vehicle handling, reducing congestion, and improving synchronisation between hinterland and sea transport (Coronado Mondragon *et al*., 2017). Therefore, PGC are examined to address the simultaneous lack of suitable transportation infrastructure and link SSS with hinterland transportation (Styhre, 2009). While existing studies on pre-gates primarily focus on container ports (Veenstra *et al*., 2012; Krosnika and Smolarek, 2014), there are hardly any studies on the transferability of this concept to RoPax terminals. These terminals are characterised by a different vehicle and passenger structure, which places new demands on traffic management.

How can pre-gate concepts be transferred to RoPax terminals, given the specific characteristics of and challenges in such terminals?

Some of the distinguishing characteristics of RoPax terminals are researched in this study (see section 4.1) and include, among others, the fact that cargo is accompanied by drivers, which affects the timing decisions made in terms of cargo arrival; commonly location of such terminals close to city centres; extremely short vessel turnaround in passenger-dominated ports; and peaks in traffic, including cargo transportation and passenger vehicles, close to the time of vessel arrival and departure.

By conducting in-depth literature research on PGC in, predominantly, container terminals, and then interviews with port actors like port authorities (PA) and ferry operators in RoPax terminals, key elements of PGC for managing cargo traffic to sea terminals are identified, and their applicability in RoPax terminals is analysed. The research points to the high applicability of PCGs for container terminals to be better aligned with trailer-dominated RoPax terminals, where the characteristics of terminal operations are rather similar. The higher presence of passengers (like on cruiseferries) and truck drivers make certain elements of PCGs unapplicable and require novel solutions.

The remainder of this paper is as follows. Section 2 shows what understanding of PGC prevails in the literature. Subsequently, the challenges in RoPax ports are addressed, and several typical profiles of RoPax terminals are elaborated. Section 4 analyses the benefits of PGC for RoPax ports/application concepts for RoPax terminals. Section 5 contains the conclusions and recommendations for future research.

## 2. Status quo pre-gate concepts in ports

This section first provides an analytical definition of the term PGC, according to which all the following concepts are listed. In the following, the relevant scientific and grey literature is examined to determine what approaches to PGC exist. Although the terms dry port, extended gate and pre-parking are sometimes used synonymously, there are significant differences between the concepts in terms of their function, their spatial location, and logistical purpose. Therefore, the different concepts are grouped under "Dry Port", "Extended gate concepts" and "Pre-gate parking" and further discussed in the following.

In this paper, PGCs are considered to be an upstream control and collection point outside a port where vehicles are buffered, sorted and, if necessary, temporarily stored before they are allowed to enter the port. The pre-gate is considered as a system that includes both digital and physical elements and contributes to the management of traffic flows in ports.

### *2.1 Dry port*

Roso *et al.* (2009) consider dry ports to be a logistical extension of seaports that aims to improve the efficiency of freight transport. These inland terminals are connected to the ports via truck, rail, and barge and serve as transfer points for the transport of goods in order to avoid congestion in seaports and optimise the handling process. This is why the gate can be located at the seaport terminal or at the dry port itself, depending on the distance from the dry port. With close dry ports, the gate often remains at the seaport terminal. With mid-range or distant dry ports, the gate can be at both the harbour and the dry port, depending on the connection. They point out that activities such as customs clearance, security checks, information processing and cargo handling (e.g. stuffing, stripping and buffering of containers) can be shifted from congested seaport gates to mid-range or distant dry ports.

Rodrigue and Notteboom (2012) take a more holistic view of dry ports, emphasising their functionality, networking and additional services. The gate is centrally located in the dry port itself. The dry port acts as an upstream extension of the seaport, where key activities such as customs clearance, security checks, document processing are handled. By positioning the gate at the dry port, transport units that are forwarded from there to the seaport can be treated as pre-inspected cargo. This enables seamless integration of the dry port into port logistics, with goods being intermodally transported via rail, barge, or truck. The dry port thus assumes a gatekeeping function by regulating the flow of goods, minimising disruptions and relieving the seaport infrastructure.

### *2.2 Extended gate concepts*

Veenstra *et al.* (2012) define the term "extended gate". They extend the concept of inland terminals by directly connecting to one or several seaport terminals. In this context, the gate of the seaport terminal is at the inland terminal. The inland terminal is accessible by truck, rail, and barge. The inland terminal is also multimodally connected to the terminal. The customer can drop off or pick up the loading units at the inland terminal, like at the seaport. Therefore, check-in already occurs at the extended gate. Thus, the seaport can control the flow of loading units to and from the extended gate.

Van den Berg (2015) also defines "extended-gate" as inland terminals with a nominally larger number of connections to seaport terminals than other inland terminals because of their high frequency of connections and high handling volume of cargo units. As the term suggests, the gate is at the inland terminal. The extended gate acts as a buffer and collection point for loading units that are transferred there from the seaport using a push strategy [1]. The aim of changing the system from a pull system to a push one is to relieve the seaport. Therefore, the departures of the transport units to the seaport are event-based [2]. The extended gate can be reached via truck, barge, and train. The same applies to the connection of the seaport terminal with the extended gate. Trucks, rail, or inland waterway vessels can be used in this connection.

Hällgren and Bengtsson (2020) follow the definitions of van den Berg (2015) and Veenstra *et al.* (2012) on “extended gates” to some extent. Hällgren and Bengtsson (2020) refer to the geographical proximity of “extended gates” to seaports and differentiate them into “hinterland extended gates” and “city-centered extended gates”. The hinterland extended gate is seen as a further development of inland terminals and is intended to attract customers to an associated port. It aims to ensure that customers perceive no difference in handling quality from seaport terminals. The city-centred extended gate approach envisions that all container handling, except quay handling, is done at the city-centred extended gate. This terminal is close to the city. Hällgren and Bengtsson (2020) locate the gate in front of the extended gate, which, according to them, has a collection and buffer function. The hinterland and city-centred extended gate can be accessed by truck, rail, and barge. Hällgren and Bengtsson (2020) define the connection between the extended gate and the seaport in more detail only in the case of the city-centred extended gate, while the design remains unmentioned in the case of the hinterland extended gate. The city-centred extended gate is connected to the seaport exclusively by rail, and transport organisation is event-based.

Krosnika and Smolarek (2014) introduced the term “extended pre-gate”. They consider extended pre-gates as strategically located external parking lots that serve as an external buffer area to increase flow efficiency. The parking lots are near the terminals, typically on the outskirts of a city or metropolitan area, and directly connected to a highway or expressway leading to the port. Krosnika and Smolarek (2014) locate the gate in front of the seaport terminal. The extended pre-gate performs several functions: it buffers traffic, bundles it, and pre-sorts it, allowing trucks to reach the gate in the desired order at the right time (just-in-time), provided there are no random interferences on public roads between the strategic parking lots and the seaport terminal gate. Truck departures to the seaport terminal are time-based [3] induced. Access to the extended pre-gate and connection to the seaport will be by truck only.

Geweke and Busse (2011) use the term “pre-gate” to refer to technical measures for automating truck handling processes in inflow control at the gates of container terminals. Accordingly, they locate the gate before the terminal. Depending on the existence of a truck appointment system (TAS), access to the terminal with TAS is time-based; otherwise, it is event-based.

### *2.3 Pre-gate parking*

The Hamburg Port Authority (2010) uses the term “pre-gate parking”. They see pre-gate parking (PGP) as a way to buffer truck traffic in parking areas outside the port that have their destination in the port. PGP can ensure a regulated truck inflow and consequently the maintenance of traffic flow in the port, as PGP provides a buffer and collection function. The HPA distinguishes between three variants of PGP.

Variant A: Variant A does not provide for mandatory use of trucks and is based on voluntariness. In variant A, the gate is at the seaport terminal and can be reached directly. However, using the PGP offers the advantage of using the dedicated PGP user track at the seaport terminal by doing a pre-check-in.

Variant B: Using the PGP is fundamentally recommended but not mandatory in case of temporary capacity overload of the road network, disturbances around the terminals, and exceedance of service capability in chosen places of the port. For variant B, like variant A, the dedicated lane at the gate prioritises seaport terminal handling by doing a pre-check-in. In variant B, trucks can reach the gate at the seaport terminal directly by accepting longer waiting times at the gate of the seaport terminal.

Variant C: Variant C transfers variant B to a mandatory utilisation. Due to the implementation of TAS and the associated allocation of appointments, truck departures are time-based, while the terminal can only be reached indirectly via the PGP.

The Port of Rotterdam (2018) introduced the term “truck parking”, defining it as a parking area for trucks and truck trailer combinations in the port area. Five truck parking lots are in the port area of Rotterdam, with over 700 parking spaces. The parking areas are equipped with facilities for the basic supply of truck drivers and offer efficient planning and cargo handling, in addition to serving as a buffer area in coordination with the terminals. Access to the truck parking is not mandatory to enter the seaport terminal. The Port of Rotterdam's approach is having a pre-gate with check-in functions in the vicinity of the seaport terminal.

The German Federal Highway Research Institute (BASt) uses the term "telematics-controlled compact parking" (tccp). The focus here is on increasing the parking capacity of trucks at highway rest areas. In tccp, there is no device such as a gate, as there is no relationship to the seaport; the concept generally exists outside the maritime sector. With telematically controlled compact parking, the BASt aims to sort trucks into individual lanes according to departure times. Therefore, the trucks' departures are time-based in the closer sense (Kleine and Lehmann, 2017).

The analysis of the abovementioned concepts reveals that extended gate as well as pre-gate parking is a specific mechanism within the dry port concept, but it has a more narrowly defined function. While dry ports (Li *et al*., 2022; Khaslavskaya and Roso, 2020; Jeevan *et al*., 2019) act as decentralised hubs that relieve freight logistics from the seaport (Bo and Junqing, 2020; Pham, 2023) in the long term, extended gates and pre-gate parking serve as an upstream control and management points that regulate the flow of traffic in real time. It is clear that, as emphasised in Section 1, these concepts are largely used in container logistics (Jin *et al*., 2023; Belmoukari *et al*., 2023) and are not applied in the area of RoPax terminals.

## 3. Methodology

This section presents the methodological approach that was applied to identify potential PGCs that could solve the existing challenges in RoPax terminals.

### *3.1 Development of analytical framework*

Section 2 systematically reviews both scientific and grey literature to identify existing approaches to pre-gate systems. An extensive literature review was conducted using three major scientific databases - Scopus, Web of Science, and Google Scholar - to identify relevant scholarly publications. In addition, Google Search was employed to identify pertinent grey literature, ensuring a comprehensive overview of practical implementations of the concepts under study. The grey literature was screened based on the publication sources, and, in addition to academic sources, we only included literature describing the actual implementation of PGC in major ports (Hamburg Port Authority, 2010; Port of Rotterdam, 2018). The search was conducted using a range of keywords, including pre-gate terminal, pre-gate port, pre-gates, and pre-parking.

The analysis of the relevant literature focused on assessing the extent to which the publications provided insights into PGC and their applicability in practice. Table 1 presents a summary of the analysis, structured around the following aspects. Firstly, the terminology used in relation to the terminal was localised, followed by an examination of how the gate and the associated processes within the terminal were organised. The next step involved analysing the terminology in terms of accessibility and distinguishing between direct and indirect access methods. This showed whether the concepts were provided for mandatory or voluntary use. Additionally, the review examined whether pre-check-in was required when implementing the PGC, the modes of transportation by which the pre-gate could be accessed, and the transportation methods used for onward travel to the terminal. Further analysis included an evaluation of the scope of functions offered by the different PGCs as well as the organisational form of access management, categorised as event-based or time-based.

### *3.2 Research design*

This part of the study was conducted as part of an industry-academia collaboration aimed at developing digital solutions for smart RoPax terminals, with the primary objective of

**Table 1.** Elements of pre-gate concepts in ports

| | Location | | Accessibility | | | Functions and services | | Access mode |
|---|---|---|---|---|---|---|---|---|
| | L1 | L2 | A1 | A2 | A3 | FS1 | FS2 | AM |
| *Extended Gate* Veenstra *et al.* (2012) | Extension of inland terminal concept to include a direct connection to one or more seaports. | Gate of the seaport terminal is at the inland terminal | n/a | Truck, train, barge | Truck, train, barge | n/a | Collect sort | n/a |
| *Extended Gate* Van den Berg (2015) | Enlarged inland terminals are considering more connections to the seaport terminals due to the high frequency of connections and handling volume of cargo units. | Gate of the seaport terminal is at the inland terminal | Voluntary | Truck, train, barge | Train, barge | Yes | Equivalent to seaport | Time-based |
| *Hinterland Extended Gates and City-Centered Extended Gates* Hällgren and Bengtsson (2020) | (A) Hinterland extended gates as a further development of inland terminals<br>(B) City-centred extended gate comprises all container handling, except quay handling<br>Interconnection between (A) and (B) | Gate of the seaport terminal is at the inland terminal | (A) n/a<br>(B) Mandatory | (A) Truck, train,<br>(B) Truck, train | (A) Truck, train<br>(B) Train, truck | (A) Yes<br>(B) Yes | Collect buffer | Event-based |
| *Extended Pre-Gates* Krosnika and Smolarek (2014) | Extended pre-gates as strategically located external parking lots that serve as an external buffer area to increase traffic flow efficiency. | Gate of the seaport terminal is at external parking in port vicinity | Mandatory | Truck, train, | Truck, train | Yes | Collect buffer sort | Time-based |
| *Pre-Gate* Geweke and Busse (2011) | Technical measures for automating processes in the gate handling of container terminals | Gate is directly at the seaport terminal | n/a | Truck | Truck | n/a | Automation of gate access management | Time-based for the TAS; otherwise, they are event-based |
| *Pre-Gate Parking (Version 1)* Hamburg Port Authority (2010) | Buffering truck traffic in parking areas outside the port where pre-gate parking is voluntary | Gate is at the seaport terminal | Voluntary | Truck | Truck | No | Collect buffer | event-based |

(*continued*)

**Table 1.** Continued

| | Location | | Accessibility | | | Functions and services | | Access mode |
|---|---|---|---|---|---|---|---|---|
| | L1 | L2 | A1 | A2 | A3 | FS1 | FS2 | AM |
| *Pre-Gate Parking (Version 2)* Hamburg Port Authority (2010) | Buffering truck traffic in parking areas outside the port where pre-gate parking is mandatory | Gate of the seaport is at external parking | Mandatory | Truck | Truck | Yes | Collect buffer | Time-based |
| *Truck Parking* Port of Rotterdam (2018) | Parking areas for the trucks in the port area | Gate is at the seaport terminal | n/a | Truck | Truck | No | Collect buffer | Event-based |
| *Telematics-Controlled Compact Parking* Kleine and Lehmann (2017) | No relationship to the terminal since the focus is set on increasing the capacity of the rest areas at motorways | n/a | n/a | Truck | Truck | No | Collect, buffer sort | Time-based |

**Note(s):** L1: Location of PGC to terminal, L2: Location of gate to terminal and PGC, A1: Mandatory/voluntary, A2: Transport means to PGC, A3: Transport means PGC to terminal, FS1: Pre-check-in via pre-gate necessary, FS2: Functions: collect/buffer/sort, AM: Event-based/time-based
**Source(s):** Table by authors

improving operational efficiency through collectively developed digital innovations. According to Woo *et al*. (2011) and Heaver (2006), case studies and conceptual approaches are among the most widely employed methods in seaport research. In contrast, survey and interview methods remain underutilised though they show potential for further application in this field. Barratt *et al*. (2011) defined the qualitative case study as an empirical research approach that utilises contextually rich data from a limited real-world setting to explore a particular phenomenon. While the deductive research approach is primarily suited to testing pre-existing theories rather than generating new insights, Stentoft Arlbjørn and Halldorsson (2002) and Kovács and Spens (2005) argue that inductive research begins with specific observations and progresses toward broader generalisations. This approach, as outlined by Wilson (2010), represents a theory-building process that commences with the observation of particular cases to formulate generalised understandings of the phenomenon under investigation.

In this study, which focuses on the introduction of PGC in RoPax ports to optimise traffic inflows at terminals and ports, parallels can be drawn with the domains of container terminals and hinterland terminals, where the regulation of the inflow of loading units carried by trucks is a crucial research element. To address the challenges currently faced by RoPax ports, a multiple case study methodology was employed following the previous elaborations and argumentations. Buganza and Verganti (2009) emphasise that this approach facilitates a holistic and contextual analysis, making it particularly suitable for exploratory research at an early stage.

### *3.3 Data collection*

Data collection in this research relied heavily on semi-structured interviews, designed to achieve what Clark *et al*. (2021) and Kvale (1996) describe as structured comparability through the use of an interview guide, while simultaneously allowing for flexible adaptation to the individual narrative flow. By different operational profiles of in this study several benefits were provided, notably the enhancement of external validity through within-case and cross-case analysis (Yin, 2018). The profiles incorporated perspectives from a diverse range of stakeholders within the port operation ecosystem, including PAs, shipping companies, and digital solution providers. Altogether, 40 interviews were conducted during the project and used in this paper's research. Each interview lasted around one hour. Appendix presents a list of the primary data sources (see Table A1). Based on the interview outcomes, the secondary data sources mentioned by the interviewees were also consulted. Besides interviews with individual actors, six field visits were made to three RoPax ports in the Baltic Sea that participated in this project. This article further uses these three ports as examples of RoPax ports with different profiles. Two multi-stakeholder workshops were organised to identify the challenges and potential digital solutions relevant to RoPax terminals. One workshop focused on passenger traffic and another on cargo flow, where project participants identified the bottlenecks, goals, possible digital solutions, and collaboration steps for improving passenger and cargo traffic flows. The workshops lasted approximately two hours each and were recorded and transcribed.

### *3.4 Data analysis*

As the first step, challenges and specific characteristics of operations in RoPax terminals were analysed based on the data (see Section 4). Then, utilising the knowledge gained regarding the specific characteristics of RoPax ports to address the mitigation of their challenges when applying PGC, a system previously established in container terminals, to the RoPax context. Furthermore, the applicability of PGC to various types of RoPax ports was systematically examined. The findings from earlier sections, which highlight the potential of PGC to address operational challenges and explore its relevance to different RoPax terminal types, are integrated and contextualised within a broader framework (see Section 5).

## 4. Challenges in RoPax ports

The burgeoning of RoPax transportation has been particularly relevant and pronounced for countries around the Baltic Sea Region with an isolated/distant location, access to continental markets, long coastlines, and industrial and production centres near the coast (Paixão and Marlow, 2002). The overall global trade and cargo volume growth, long over-land transport distances, thin cargo flows, and industries' strict supply chain efficiency and cost requirements have all contributed to exploiting road transportation as the most cost-effective and flexible mode of transportation, providing an opportunity for RoPax shipping to be part of efficient intermodal transport chains (Christodoulou *et al*., 2019).

The RoPax connections have mainly evolved around urban areas, major historic port cities, and trade lane nodes (Marcadon, 1998). Today, major challenges arising from the RoPax operations mainly relate to the growing volumes of cargo units carried, i.e. trucks and trailers. Maritime traffic between Finland and Sweden, for instance, has its roots in the turn of the 1950 and 1960s – developing from simple car ferries in utility traffic to today's high-capacity drive-through cruise ferries and RoPax vessels, serving the needs of passengers and growing cargo traffic (Westerland, 2012).Through the research of RoPax terminals in the Northern Europe (see Section 3), we have identified several distinctive challenges that such terminals currently face in terms of traffic flow management. The studied port cities and RoPax ports, most of which are municipally owned, share mutual (environmental) goals and challenges for balanced spatial co-existence. The ports have increasingly been witnessed giving away land areas for other functions, such as housing and recreational purposes, thus putting pressure on finding solutions for managing more traffic within smaller terminals. While moving cargo terminals away from city centres was a solution in the case of container ports, this strategy has been less used in the case of RoPax ports, which need to ensure connectivity for passengers (Tsvetkova *et al.*, 2025).

Another specific challenge concerns the traffic congestion on the roads leading to RoPax terminals close to the time of vessel arrival and departure, which is especially pronounced in those terminals that also serve large volumes of passengers arriving with their own vehicles or getting a ride from someone else. This problem can be further aggravated if the terminal's departure times coincide with the city's rush hour. These, with unsynchronised or unprioritised traffic light systems, generate additional emissions caused by unnecessary idling, waiting times, alternating accelerations/decelerations, and other negative externalities, such as noise and vibration, affecting the overall pleasantness of the urban environment.

As the main customers of RoPax shipping companies, road haulage companies and cargo owners show an increasing demand for more transparent and efficient service to optimise their operations and performance along the entire end-to-end (intermodal) logistics chain. Also, due to relatively short distances over the sea and ship turnaround times in ports, the wheeled cargo segment is more time-sensitive regarding timely and efficient loading and unloading procedures, as delays may be difficult to compensate for with speed out at sea given that RoPax shipping operates as liner traffic.

It was also found in this study that the regulations regarding truck drivers and their resting hours come into play when planning RoRo and RoPax operations. Professional drivers operating heavy goods vehicles of over 3.5 tones must follow EU regulations (European Council, 2002, 2006) on driving and rest times and verify the compliance of the aforementioned. In particular, in one of the studied ports, a major challenge was the scarcity of short- and long-term rest and parking areas appointed for heavy goods vehicles within reasonable reach of RoPax terminals. Thus, truck drivers tend to drive to the terminal well before the actual ship departure to rest or park the truck, which is less desirable from the PAs standpoint with diminishing terminal areas.

To explicate this challenge, with few exceptions, drivers can drive 9 h per day or 56 h per week. For truckers to comply with the regulations, they must abide by the terms set for short breaks of 45 min following 4.5 driving hours and longer daily 11-h (which can be divided into 9- and 3-h rest periods) and weekly 45-h rests (over two consecutive weeks). For example, with voyage times below 9 h, the daily resting time may be challenging to fulfil during the sea voyage alone; thus, resting and parking areas near the terminal are required. Conversely, the resting time is uninterrupted when drivers board the vessel with the truck. This puts limitations on how far parking areas can be, which in turn affects the applicability of certain PGCs and limits their benefits.

Finally, the uncontrolled and random arrival of vehicles at RoPax terminals affects the vessel loading process and efficiency. Although the vessel capacity is booked in advance, and the expected types and sizes of arriving vehicles are known beforehand, it is not uncommon for vehicles to miss the departure, arrive at the last moment, or not correspond to the originally booked size. As vehicles differ in size or might require special placement on vessel decks (e.g. refrigerator trucks need power outlets, and hazardous cargo is placed in designated areas), the loading of RoPax vessels dictates a certain order for vehicles to come onboard. Thus, a perfectly optimised loading plan for a RoPax vessel is never realised in practice but performed in real time based on the actual arriving order of vehicles and the constraints dictated by vessel layout and limitations for loading vehicles (Ventura *et al.*, 2020). Handling the inbound hinterland traffic and setting optimal cut-off times is another well-known challenge for ship operators and ports alike. Ship operators wish to fill up the car decks, yet they want to keep to the schedule and avoid speeding up sea legs. The challenge with suboptimal loading is much less pronounced in trailer-dominated RoPax terminals due to longer vessel turnaround time (allowing more time to load) and more standardised cargo profile, which is discussed further in this section.

Notably, given the variable profile of RoPax terminals, not all the challenges discussed above are always represented in such terminals to the same extent. The ports differ in several aspects, such as location in relation to the city, the prevalence of passenger or cargo traffic, ship turnaround time and, correspondingly, time for loading and unloading vessels, as well as time to check-in before departures. These characteristics define the cargo and passenger flow to and from the terminal regarding traffic pulses, congestion, and infrastructure leading to the port. While defining all types of RoPax ports globally is difficult, Table 2 shows three examples of typical RoPax terminals studied empirically in this study, illustratively demonstrating the named distinctions.

Depending on the location of the port and accessibility to connecting land-based transport infrastructure, the problems of traffic jams around the port area during ship arrivals and departures might be more or less prominent. Terminals near city centres tend to face tighter spatial size restraints. Then, RoPax terminals dominated by passenger and self-propelled vehicle traffic, principally on shorter sea routes, are normally characterised by shorter ship loading and turnaround times. This contrasts with terminals that predominantly serve unpropelled trailer traffic. The length of turnaround times at terminals is proportional to the share of unpropelled trailers that need to be towed onboard by tug masters. In the latter case, trailer logistics can be compared to container logistics, as they can be delivered to the port area

**Table 2.** Types of RoPax terminals studied

| Type | Location | Profile | Ship turnaround | Check-in open and closing | Example RoPax terminal |
|---|---|---|---|---|---|
| Type A | In the city | Passengers and vehicles | Short 1 h | 1.5 h to 10 min before departure | Turku |
| Type B | Outside the city | Vehicles and trailers | Medium 4 h | 2.0 h to 60 min before departure | Naantali |
| Type C | Outside the city | Trailers and vehicles | Long 8 h | 2.0 h and 45 min to 1 h and 15 min before departure | Vuosaari |

**Source(s):** Table by authors

in advance and left without a driver for later onboard loading performed by the port operators. Thus, the challenges related to the compliance of truck driverswith working and resting time regulations are, to a lesser degree, applicable to trailer-dominated terminals. Finally, the challenge of optimally loading RoPax vessels is more pronounced in the terminals where the turnaround time is very short, based on the characteristics of the three ports Table 2 describes. Table 3 shows the relevance of the discussed challenges for each type of RoPax terminal.

## 5. Potential of pre-gate concepts to face the challenges of RoPax ports

The introduction and implementation of PGC – already capitalised on in some of the larger container ports – can alleviate the challenges that RoPax ports face, such as too early arrivals and the accumulation of trucks in the port. However, given the specificity of RoPax transportation, clarifying whether and to what extent PGC can address the challenges in Section 4 above is necessary. Hence, how the different elements of PGC presented in Section 2 help alleviate the challenges discussed in Section 4 is analysed (Table 3).

### *5.1 Impact of pre-gate concepts to challenges of RoPax ports*

A PGC's location impacts the challenges of RoPax terminals and ports within the port and city area. When rush hour traffic coincides with the import and export traffic induced by ferry operations, the congestion situation in the port and city area is exacerbated. If a PGC is outside the port, the increased traffic can be counteracted by controlling the import of vehicles from the PGC to the terminal. Moreover, vehicles arriving too early from the hinterland are held up there to bridge the time until they enter the port area. However, if the pre-gate is too far from the port, it can break the resting time of truck drivers.

Various elements and different types of PGC can mitigate the challenges of RoPax terminals. The optional use of a PGC can reduce the challenge for RoPax terminals for early arriving trucks. Its use can bridge the time until the terminal opens before the ship departs. Conversely, the truck driver can observe the prescribed resting times if required. However, with optional use, early arriving trucks are not required to use the PGC, so they can still drive directly to the terminal and use the limited terminal space on site. Whereas, in the case of mandatory use of the PGC, all vehicles must park temporarily on the PGC. This could negatively impact compliance with resting time regulations by disrupting the resting time of truck drivers. Otherwise, it could positively impact the space availability in the terminal. The controlled call-off of all vehicles that are compulsorily pre-parked on the PGC also brings more control to the stowing plan and loading of the ship.

Some PGCs are accessible from the hinterlands only via rail or inland vessels. Here, a traffic shift of vehicles from road to rail or inland vessel occurs, resulting in reduced congestion and emissions in the hinterlands. Reduced congestion and emissions in the port and city area will occur by connecting the PGC and terminal only by rail or ship. It also counteracts

**Table 3.** Relevance of different challenges for the different types of RoPax terminals

| Category | Challenge | Type A | Type B | Type C |
|---|---|---|---|---|
| Port/City | Congestions on roads leading to the port | X | X | X |
| | Emissions on roads leading to the port | X | X | X |
| Trucker | Early arrival of trucks at the terminal coming from the hinterland | | X | |
| | Compliance with driver's resting time regulations | X | X | |
| Terminal | Limited (stowing) space in ports | X | X | |
| Vessel | Suboptimal loading of vessels | X | X | |
| | Fast vessel turnaround | X | | |

**Source(s):** Table by authors

the challenge of trucks arriving too early and the need to respect truckers' resting time regulations. Truckers can park their vehicles at the PGC and do not have to time their resting times based on when the terminal opens. In contrast, the challenge of fast vessel turnaround times can be exacerbated. Mandatory interim parking on a PGC can become challenging if the vessel has a fast turnaround time. In particular, trailers in RoPax terminals still have the intermediate step of being driven onto the vessel by a tug master rather than a dedicated trucker, meaning another handling process and more time are required.

Depending on the concept of the PGC, various functions can be assumed. PGC can be used to collect vehicles or buffer or sort vehicles arriving from the hinterland before entering the terminal. All these functions face challenges for the terminal that vehicles coming from the hinterlands. The terminal no longer has to park and sort randomly arriving vehicle types with different vehicle lengths, heights, and various specifications, such as hazardous goods or reefer containers (electric supply needed), in a limited space while considering the stowage plan. This relieves the limited stowing space. Besides, PGC positively affects the cargo density at the terminal while favouring the optimised loading of vessels. Truckers can save on travel distances if services such as sanitary facilities, restaurants, refuelling points, etc., are available at the PGC. Truckers do not have to drive to a petrol station or to a place with sanitary facilities while combining this with their obligatory resting times. In a PGC with sanitary facilities, a restaurant, and a petrol station, the driver does not have to time his/her journey from the hinterland primarily according to the opening times of the terminal. PGC allows more flexible scheduling, such as breaks or overnight stays after the arrival via the hinterland but before the call-off of the terminal.

An event-based PGC potentially reduces congestion and emissions on roads if the event relates to congestion or emissions, e.g. if the PGC is mandatory when the congestion at an intersection has reached a certain length or, e.g. when a certain amount of emissions ($CO_2$, NOx etc.) are excessive in the city or port area. Thus, the traffic generated by the RoPax terminal is temporarily shifted. The same principle of an event-based PGC can mitigate the challenge of trucks arriving too early at the RoPax terminal, e.g. if using PGC is mandatory for trucks arriving up to a specific time before gate closure. In contrast, a time-based PCG counteracts the challenges of the suboptimal loading of vessels and fast vessel turnaround times. The controlled call-off of specific vessel types and the number of vessels ensures a sorted arrival of vessels at the terminal. This call-off can be adapted to the stowage plan, optimising the stowage.

### *5.2 Applicability of pre-gate concepts to types of RoPax ports*

Whether and how much the different elements of PGC generally influence the challenges of RoPax ports have been analysed. Section 4 elaborated that different types of RoPax ports also have different challenges. Therefore, the applicability of various elements of PGC in different types (type A-C) of RoPax ports is analysed below.

A passenger-dominated city port (type A) primarily handles passengers. Introducing a PGC for the relatively small number of vehicles only makes sense if the PGC is close to the port. Using the pre-gate should be voluntary because there may not always be a motive for the driver or terminal to use it (e.g. arriving too early at the port, limited space in the stowing area of the terminal). The vehicle is buffered on-site, and the driver can use the services if necessary. Moreover, the distance from the pre-gate to the terminal should be short so that the vehicles can be called-off at short notice.

The applicability of the elements of a PCG is highest in type B. Almost all aspects of PCGs apply to this type. Applicability is not given if the transport means to the pre-gate or from there to the terminal occurs by train or inland vessel. Overall, the high applicability of various elements also means a PCG tends to mitigate the most challenges of type B.

A trailer-dominated port (Type C) is somewhat similar to Type A. The pre-gate's location should be close to the port, and the PCG should be voluntary. A self-check-in facility at the pre-gate is also useful. The drivers can check their trailers in at the pre-gate, leave the pre-gate, and devote themselves to the next driving job.

## 6. Discussion

The basis of this work is the compilation of different concepts of Pre-Gates. The concepts presented are derived from approaches used in the hinterlands of container terminals and analysed for applicability in RoPax terminals.

By analysing PGC in container shipping, the paper first provides a structured overview of what such concepts entail and the commonalities and differences among the concepts in the literature. Second, the paper proposes how to address the challenges in the field of RoRo shipping, by using some aspects of PGC. Therefore, the paper contributes to further developing inflow control for RoRo terminals. The application of PGC targets the critical success factors of port and infrastructure capacity in the form of existing road infrastructure, as Styhre (2009) identified. PGCs can improve the landside connectivity of terminals concerning port infrastructure resilience, thus reducing congestion.

Furthermore, this paper considers the requirements for the availability of sufficient parking spaces identified by Ventura *et al.* (2020). However, the authors do not explicitly state whether these parking spaces can be provided as external parking areas outside the port area and as part of the port in a broader sense. They also point to the need, when operating terminals, to facilitate a smooth flow of traffic, which translates into overall terminal reliability. Applying PGCs addresses this by reducing congestion as vehicles can be taken off the road in time to avoid congestion and ensure traffic flow.

Paixão and Marlow (2009) argue for streamlined and lean port operation concepts. The approach of a PGC by Krosnika and Smolarek (2014) with extended pre-gates and the Hamburg Port Authority “Pre-Gate Parking” in its second version (2010) picks up the argumentation and can be considered an approach that fulfils these prerequisites of lean management. By incorporating lean strategies into terminal operations, this academic work contributes to a tactical and operational perspective on RoPax terminals, which has hardly been explored.

Looking more closely at the practical implications, optimising the flow of cargo through PGCs in RoPax ports is challenging due to the multitude of stakeholders involved and their potentially conflicting interests and optimisation objectives.

PAs may have limited space available for buffering and sorting traffic within the port area since the local municipality intends to reserve the area for residential development, forcing PAs to use space within the port area more efficiently and setting the objective of fewer trucks waiting for departure. Simultaneously, shipping companies prefer direct access to the trucks to load their ships at maximum capacity. Therefore, achieving the best possible positioning of the PGC in sufficient local proximity to the port is essential.

Regarding truck arrival time, haulage companies aim to maximise their operational time of trucks. Therefore, entering the ferry terminal early enough to fulfil the mandatory rest periods is of their interest. However, shipping companies need the trucks at a certain predefined time and ideally in a specific order, so a just-in-sequence approach would be better than a just-in-time approach in the RoPax sector. PAs function as enablers of efficient throughput. Consequently, their interest is in the most efficient use of the scarce resource space, with a focus on minimising the use of the port area as a parking lot.

Furthermore, conflicts arise regarding the placement and control of Pre-Gates. While PAs may advocate for PGCs close to the terminal to ensure regulated access, trucking companies may resist restrictions that could limit their operational flexibility. A collaborative governance model involving both stakeholders could help define PGC regulations that balance efficiency and operational autonomy.

In this respect, the fundamental question is who can implement a PGC. Inevitably, questions will arise regarding mitigating specific challenges and additional efforts for individual stakeholders. Introducing PGC may well lead to opposite effects as it could lead to a shift in congestion hotspots depending on the placement of PGC. For example, the mandatory introduction of PGC may have consequences for the operational processes of many stakeholders in the export process and may reduce the efficiency of logistics chains. Therefore, further investigation of whether the congestion is not shifted from the port to the pre-gates and what effects this will have is necessary.

A structured stakeholder negotiation process, including pilot projects, could help to assess the feasibility and implications of different PGC placements. Further empirical research is needed to determine how congestion could be mitigated without simply relocating bottlenecks.

Another point that must not be overlooked is the interruption of the break times for truck drivers, which results from using pre-gates. Here, adjustments would have to be made in the legislation to take advantage of PGC near ports. Alternatively, the PGC needs to account for these limitations.

Manually operated gate counters are inherently error-prone. Digital solutions for gate operations are an obvious choice in implementing PGC, as they enhance throughput by reducing check-in times. Furthermore, using a comprehensive traffic management system can not only lead to reduced personnel on the terminal but also improve the integration of traffic flows from the PGC to the RoPax terminal.

The results in Table 4 show that identified challenges in RoPax terminals, as detailed in Chapter 4, can be addressed by PGC because of the high overlap in the truck access to the port when comparing RoPax and container terminals. However, the characteristics of the different RoPax port types lead to structural limitations in adopting PGC in terminal operations. For example, container terminals have longer dwell times than RoPax terminals. Moreover, container terminals have a significantly higher throughput of loading units. Table 5 shows that truck-dominated ports are most suitable for PGC, compared to passenger- or trailer-dominated ports. Although applying PGC elements in passenger-dominated ports is only seen in four aspects. Tsvetkova *et al.* (2024) provide a categorisation framework which can be seen as basis for investigating the potential of digitalisation in RoPax ports. Further research is needed to find additional potential for the expansion of other PGC applications. Moreover, this paper primarily focuses on solutions related to export and import flows, which have not been extensively considered thus far. However, the findings could contribute to strategies for mitigating congestion and enhancing port resilience. A potential approach for import flows could involve a post-gate parking concept, where vehicles are buffered or utilize services upon arrival at the port via vessel. This solution may be particularly beneficial if truck drivers are unable to fully compensate for their mandatory rest periods during the passage, requiring compliance upon disembarkation. Additionally, it could help alleviate congestion in cases of high port infrastructure utilisation or worsening parking conditions. Therefore, in addition to close cooperation with ferry operators, further attention should be given to concepts for onward transportation processes.

### *6.1 Limitations and further research*

This paper's findings are limited because it generally focuses on the term "pre-gate" as general terminals close to the ports. However, there are also concepts of hinterland terminals and dry ports with similarities to extended gates.

This paper focuses on RoPax terminals at an early stage; furthermore, RoRo terminals are neglected as such. Moreover, it could be analysed to what extent PGC could apply to RoRo terminals with cargo only because, within this paper, the high cargo amount has proven crucial in a PGC's applicability and usefulness. Conversely, further research could focus on a special PGC for passenger-dominated ports. The concepts of Kronsika and Smolarek (2014) and the Hamburg Port Authority (2010), which have already been highlighted, lend themselves to simulative testing and later for a pilot study in truck-dominated ports. A need for research is

**Table 4.** Expected impact of applying elements of pre-gate concepts

| | | Challenges in RoPax terminals and ports | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Port/City | | Trucker | | Terminal | Vessel | |
| Category | Elements in PGC that can alleviate the challenges | Congestions on roads | Emission on roads | Early arrival of trucks | Compliance with driver's resting time regulations | Limited (stowing) space | Suboptimal loading of vessels | Fast vessel turnaround |
| Location | L1 | – | – | | | | | |
| | L2 | + | + | + | – | | | |
| Accessibility | A1 | | | ++ | – | ++ | + | + |
| | A2 | | | + | ++ | – | | |
| | A3 | ++ | ++ | | | | | |
| | A4 | ++ | ++ | ++ | + | | | – |
| Functions and services | FS1 | | | ++ | ++ | ++ | ++ | ++ |
| | FS2 | | | ++ | + | ++ | | ++ |
| | FS3 | | | ++ | | ++ | ++ | ++ |
| | FS4 | | | ++ | | ++ | ++ | ++ |
| | FS5 | + | + | ++ | ++ | | | |
| Access mode | AM1 | + | + | + | | | | |
| | AM2 | | | | | | ++ | ++ |

**Note(s):** ++ Alleviates + Potentially alleviates " "n/a – Potentially worsens - - Worsens
L1: PGC is close to the port, L2: PGC is outside the port, A1: PGC mandatory, A2: PGC voluntary, A3: Transport means to PGC: train/ship, A4: Transport means PGC to terminal: train/ship, FS1: Pre-check-in via pre-gate, FS2: Function Buffer, FS3: Function Collect, FS4: Function Sort, FS5: Services provided, AM1: Event-based, AM2: Time-based
**Source(s):** Table by authors

**Table 5.** Applicability of different elements of PGC in different types of RoPax ports

| Category | Elements in PGC that can alleviate the challenges | Type A | Type B | Type C |
|---|---|---|---|---|
| Location | PGC is close to the port | X | X | X |
| | PGC is outside the port | | X | |
| Accessibility | PGC mandatory | | X | |
| | PGC voluntary | X | X | X |
| | Transport means to PGC: train/ship | | | X |
| | Transport means PGC to terminal: train/ship | | | X |
| Functions and services | Pre-check-in via pre-gate | | X | X |
| | Function: Buffer | X | X | X |
| | Function: Collect | | X | X |
| | Function: Sort | | X | |
| | Services provided | X | X | X |
| Access mode | Event-based | | X | |
| | Time-based | | X | |

**Source(s):** Table by authors

also seen in the PGC configuration to analyse the impact on compliance with EU restrictions. A study could to quantitatively measure the actual impact of PGCs on factors such as space utilisation, traffic flow and terminal efficiency.

## 7. Conclusions

RoPax ports are confronted with higher traffic volumes and growing urban development within port areas with less space availability and shorter turnaround and handling times.

This paper presents an approach for RoPax terminals to improve their gate and stowing operations by targeting truck arrivals at the terminal and streamlining operations. Based on the findings and the theoretical and managerial implications, it can be concluded that PGCs with origins in the container sector are an approach that can be transferred to the RoPax sector. Depending on the characteristics of the different types of depicted RoPax terminals, various levels of applicability exist. For truck- and trailer-dominated ports, PGCs are a viable approach to address current challenges.

From a theoretical point of view and the perspective of the data supported by the interviews, a pre-gate approach promises to improve efficiency in RoPax ports and terminals. This approach provides lean concepts, focuses on the situation of the truck drivers, and aims to improve the traffic situation of the local infrastructure in the port area. The conducted analysis, which showed that PGC could alleviate challenges in the operational environment for RoPax terminals, supports this conclusion.

Therefore, the stakeholders in port environments are encouraged to actively seek opportunities for efficiency potentials and be prepared to address the challenges associated with these PGC implementation efforts.

### Notes

1. Push strategy: proactive provision of goods according to demand forecasts.
2. Event-based: actions occurring after a specific event.
3. Time-based: actions occurring at a specific time or specific intervals.

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## Appendix



**Table A1.**

| Company type | Informants' position | Number of meetings | Number of participants | Data source |
|---|---|---|---|---|
| Port authorities | PA: technical director, COO, sales and deputy managing director, IT manager | 2 | 5 | Interviews |
| | Benchmarking RoPax ports | 5 | 5 | Interviews |
| Shipping company | Head of digitalisation | 2 | 1 | Interview, site visit |
| | Head of IT group, captain, cargo planner | 1 | 4 | Interview, site visit |
| | Terminal manager | 1 | 1 | Interview |
| | Sales manager | 1 | 1 | Interview |
| | Operative manager | 1 | 1 | Interview, site visit |
| Digital solution providers | Research leaders | 1 | 2 | Interview |
| | CEO and project manager | 1 | 2 | Interview |
| | CEO | 1 | 1 | Interview |
| | CEO and research leader | 1 | 2 | Interview |
| | CPO and CFO | 1 | 2 | Interview |
| | Director and research leader | 1 | 2 | Interview |
| | CEO | 1 | 1 | Interview |
| | CEO | 1 | 1 | Interview |
| | Research leader | 1 | 1 | Interview |
| Municipality, authorities, and external stakeholders | Land planning department and traffic planner | 1 | 4 | Interview |
| | Regional logistic coordinator | 1 | 1 | Interview |
| | Carbon-neutral development | 1 | 1 | Interview |
| | Urban mobility developer | 1 | 1 | Interview |
| | City infrastructure builder | 1 | 1 | Interview |
| | Traffic management department | 1 | 1 | Interview |
| | Road digital solution provider, CEO | 1 | 1 | Interview |
| Multiple | Workshops devoted to identifying digital solutions | 2 | 36 | Presentations, memorandum |
| Total | | 40 | 78 | |

**Source(s):** Table by authors

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