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Scalable In-Database Machine Learning for the Prediction of Port-to-Port Routes

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Abstract

The correct prediction of sub sequential port-to-port routes plays an integral part in maritime logistics and is therefore essential for many further tasks like accurate predictions of the estimated time of arrival. In this paper we present a scalable AI-based approach to predict upcoming port destinations from vessels based on historical AIS data. The presented method is mainly intended as a fill in for cases where the AIS destination entry of a vessel is not interpretable. We describe how one can build a stable and efficient in-database AI solution built on Markov models that are suited for massively parallel prediction tasks with high accuracy. The presented research is part of the PRESEA project ("Real-time based maritime traffic forecast").

Keywords: Digitalization, Big Data, Artificial Intelligence, Markov Process, Port Destination Prediction, Traffic Management

1. Introduction and Motivation

According to the UN more than 80% of the worlds merchandise trade has been carried by sea in 2019 [1]. This shows the integral part maritime logistics plays in world economics and motivates the continuous pursuit for logistical optimization.

The project PRESEA ("Real-time based maritime traffic forecast") aims to support this cause by developing a real-time based forecast for global maritime traffic that will be integrated as a service in FleetMons infrastructure [2]. In particular, a routing network is developed that is intended to incorporate weather conditions and specific events like ships accidents. The corresponding forecast system will allow shipping companies to optimize their organization of just in time delivery, which will also optimize the fuel demand of specific vessels which can ultimately reduce the emissions of the respective ships. Furthermore, maritime security authorities can easily obtain detailed information on expected traffic volumes.

Project partner in PRESEA is the Institute for Safety Engineering / Ship Safety e.V. (ISV) located in Warnemünde (Germany). The Laeisz shipping company, Synfioo GmbH, the classification society DNV-GL and Daimler AG have pledged their active support for this project.

In this paper we present an approach that improved one basic but key aspect of this forecast system using AI technology: the accurate prediction of next port destinations or even whole subsequent port-to-port-routes. Currently, FleetMons port destination prediction is

The PRESEA project is funded by the German Federal Ministry for Economic Affairs and Energy (BMWi). The project management organisation is administrated by the Project Management Jülich (PtJ) within the framework of the call "Real-time technologies for maritime security". The project is running from June 2019 until lNovember 2021.

based on the interpretation of AIS ("Automatic Identification System") data sent from vessels and their last identified visited port.

As will be described in detail in Section II this approach harbors several challenges that are unlikely to be solved with logical approaches thus motivating a (statistical) AI based approach.

The rest of the paper is structured as follows. In the following Section III a short summarization of the state of the art is presented. In Section IV the use of Markov processes is motivated and discussed for the presented context. An evaluation of the derived models are presented in the following Section V. Finally, a short description of future projects and possible improvements of the presented work is given in Section VI.

2. AIS Data and Interpretation Challenges

Firstly, we would like to discuss the downsides of deriving the port destination from AIS data and motivate the partial use of AI in order to overcome problem cases. Therefore we give a small overview on the Automatic Identification System and challenges we have faced at inferring port destinations from its data

A. *The Automatic Identification System (AIS)*.

Currently, the main basis for the prediction of a vessels port destination is data the respective ship sent by means of the AIS. AIS is now standard equipment for all ships over 300 gross tonnes in international voyages. Via VHF, a ship transmits AIS data for its own identification and essential voyage information. The data is received from other ships and is integrated on board in an electronic navigational chart (ECDIS), which allows surrounding ships to be identified and thus the assessment of the overall navigational situation. At the same time, AIS data can also be received from satellites or shore stations and can be merged and visualised by corresponding providers. This enables a worldwide display of all ship movements. The content of the minimum data to be transmitted is internationally prescribed and comprises the following three groups:

- **Static data**: IMO number, ship name, call sign, MMSI number, type of ship, dimensions of the ship
- **Dynamic ship data**: Navigational status, ship position, me of ship position, course over ground, speed over ground, forward direction, rate of course change
- **Voyage data**: current maximum static draught, dangerous goods class of cargo, destination, estimated time, of arrival (ETA).

The destination and the expected time of arrival are manually set by the vessels navigator which is often the cause of non-matchable port destinations.

FleetMon operates one of the world's largest AIS networks consisting of thousands of globally distributed terrestrial AIS antennas as well as satellite data provided by the three largest AIS satellite data providers and several AIS research satellite constellations. While receiving, storing and processing over 480 million AIS messages a day from up to 225 thousand vessels, we need to make sure that PRESEAs routing system can accurately predict large parts of port destinations of the global fleet in order to allow precise traffic forecasts within the system. In the following we describe some challenges we have faced while interpreting the AIS destination data.

B. *Challenge in the interpretation of the AIS destination*

Currently, FleetMon uses a complex set of logical rules based on string matching that searches for identifiable ports in the destination entry. As vessels with fixed port-to-port cycles (for instances ferries) often use static entries in the form of "port 1 <-> port 2" we use information of the last known port call to identify which one of these ports is the actual destination. Anyhow, as any string sequence can be entered in the AIS destination text field, we faced a multitude of possible misspellings or misuse of the field. Trying to cope with these by mapping misspelled port names to the originally intended LOCODE turned out to be insufficient.

Besides it cannot be guaranteed that each voyage related AIS data set, which is broadcast only every 6 minutes, is received by an AIS network. Furthermore, when not updated correctly it is possible that the current destination entry is not matching with the real port destination. All these points leads to a number of challenges that have occurred over time. Some of them will be described now by way of example:

- The ship reports "CNSHA USLAX" (for the journey from Shanghai to Los Angeles). However, the ship does not have its last port call in Shanghai, but in Hangzhou (CNHAZ). So, it is not possible to determine which was the last port and therefore which is the next port, considering the AIS destination
- Due to missing AIS coverage in the port no port call could be generated. Therefore, it is not possible to determine the last port if two LOCODEs are entered in the destination.
- Incorrectly spelled LOCODEs, for instance KRBUS for Busan (correct would be KRPUS)
- Different kinds of misspelled city names like Philadelphia
- Several ports in the world have the same city name, for example Cartagena (Spain or Colombia) or Sydney (Canada or Australia)
- The use of port name variations in different languages, for instance: Brugge (German, Dutch), Bruges (English, French, Portuguese), Briž (Macedonian, Serbian), Bruggia (Italian), Bruggy (Slovak), Brugia (Polish), Brugy (Czech), Brujas (Spanish), Brygge (Finnish). The correct name for the Port is in English Zeebrugge or Seebrugge

These examples lead to the fact that with the method used less than 80% of the destination sent in AIS can be correctly interpreted by ships over 100m. This means that for more than 20% of the ships no estimated time of arrival in the next port can be calculated.
With these restrictions in mind the rest of the paper is dedicated to present and evaluate an AI based approach to allow meaningful and efficiently computable predictions of a vessels port destination(s) without relying on AIS destination entries.

3. State of the Art

To the best of our knowledge there has been no work published for the concrete prediction of port-to-port routes via Markov models based on historical and current AIS data.
Contrary, indepth research has been done in the detection of anomalous in vessel behavior, the prediction of vessel routes or the prediction of the estimated time of arrival (ETA). Here we would like to list a few prominent representatives of this work.
In [3] an incremental statistical learning approach has been developed which detects anomalies and projects current trajectories of vessels into the future using AIS data. Different Machine Learning techniques have been evaluated for ETA predictions in [4]. Similarly, ETA predictions based on historical AIS statistics have been evaluated in [5]. Here, the next port destination has been predicted based on the last consecutive port calls, an approach we have also followed for our baseline model presented in Section IV and evaluated in Section V.
Hidden Markov models, which are extended models based on Markov processes, have also been found useful for the detection of anomalous behavior [5] or the prediction of motion patterns [6] of vessels. As these projects do not have a direct influence on our work, we would like to refer the interested reader for further state of the art analysis to the aforementioned literature.
In the following section we describe key aspects of modelling port-to-port-route predictio via Markov models. The derived method is evaluated and discussed in the subsequent Section V.

4. Modelling Port-to-Port-Routes

The most fundamental aspect for meaningful performance in machine learning is an adequate model choice. This does not only include the actual prediction precision, but also the usability of the model in an industrial context. This means that the model needs to balance the trade-off of being

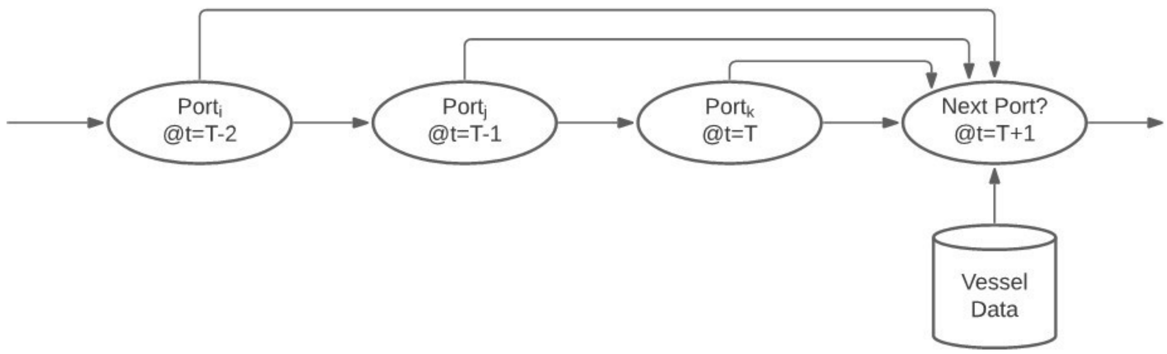

Figure 1: Dependencies of an order 3 Markov process for next port prediction.

- fairly accurate,
- massively scalable (real-time and parallel prediction of a multitude of vessels) and
- efficiently reinforce able.

The last point is especially important to ensure a long-lasting and accurate service. While the next port destination is somewhat determined, unpredictable events (like technical issues) may occur which can ultimately lead to a rerouting of the respective ships. In order to simulate this kind of possibilities it is reasonable to use statistical models, in order to cope with these kinds of uncertainties. We quickly found that discrete Markov processes fulfill all these requirements. In the upcoming subsections we give a short motivation for the usage of Markov processes followed by a short theoretical description of these models and a discussion on how and why we modelled and implemented the models that were evaluated in section V.

A. Discrete Markov Processes

Discrete Markov processes are representatives of Bayesian networks. They

- model temporary relations between states (port to port routes),
- are comparatively easy and fast to calculate as they mainly are built on basic linear algebra operations and
- are efficiently reinforce able.

Once learned, these models can not only give an estimation of the most probable port destination but can also give an estimation of the following ports and the probability of their occurrence (in the respective model).

Furthermore, these models can be extended to so called hidden Markov models which define a separate "observable" stochastic process (e.g. AIS data) from which one can infer the underlying system state (e.g. port areas). This might be of interest in future work as one could directly estimate the last port from AIS data without any event preprocessing (port calls) or even use the AIS data after departure to decide which of the most probable ports (according to the here presented underlying model) matches the real destination.

At this point, we would like to give a short introduction to the theoretical background of Markov processes in order to provide a better understanding of the implemented model. For further information the interested reader is referred to the relevant literature (for example [7])

A Markov process is a stochastic process

$$X=(X_t)_{t \in T}$$

where X_t denotes a random variable at timestamp with values of the feature space.

$$S=\{S_1,S_2,\ldots,S_n\}$$

The discrete space of time T does not hold the actual time of the respective port calls but does only determine the chronological order of the events. The main assumption of a Markov process is that the next system state X_t does only depend on the last k states:

$$P(X_t \mid X_{t-1}, X_{t-2}, \ldots, X_0) = P(X_t \mid X_{t-1}, X_{t-2}, \ldots, X_{t-k})$$

This property is often called memoryless or Markov property. In this case X is called a discrete k-th order Markov process. The transition probabilities of a first order process can be stored in a matrix $A \in \mathbb{R}^{(n \times n)}$ with entries:

$$a_{ij} = P(X_t = S_j \mid X_{t-1} = S_i)$$

With these conventions one can easily predict the next system state or rather the probabilities of all potential next states by multiplying the transition matrix by the probability distribution vector $\pi_t \in \mathbb{R}^n$:

$$\pi_{t+1} = A\,\pi_t$$

Here, the i-th element of π_t holds the probability of the system being in state S_i at timestamp $t \in T$:

$$(\pi_t)_i = P(X_t = S_i)$$

This allows fast and parallelly computable predictions as there exist many linear algebra libraries and software environments that handle these kinds of operations efficiently. This is especially important as any higher order Markov process can be transformed in a first order process by combining the sequences of the last states via cartesian products ($X_{t-1} = (X_{t-1}, X_{t-2}, \ldots, X_{t-k})$) [7]

B. Port-to-Port Markov Processes

After this basic introduction to Markov processes, we present and discuss our solutions for the prediction of port to port routes, in the case of untrustworthy AIS destination flags.

As we set the framework of the statistical model, the main aspect that drives the prediction accuracy is the adequate choice of the feature space. We tested three different scenarios which all share the following structure:

$$S = \wp^k \times \bigotimes_i^m \Lambda_i$$

Here S denotes the feature space, $\wp$ the discrete space of ports (LOCODEs), k the number of last port calls that should be included and the $\bigotimes_i^m \Lambda_i$ cartesian product of m distinct vessel characteristics (for instance vessel type) that are used for further clustering. As the vessel data is invariant over time it might be cleaner to describe the approach as a set of independent Markov processes for varying vessel characteristics with feature space $S = \wp^k$.
The exponent k represents in this case the order of the model that is built for the specific vessel data combination. If $\Lambda_i = \{\lambda^i_1, \ldots, \lambda^i_{|\Lambda\_i|}\}$ describes the space of the i-th vessel characteristic, the overall model (neglecting the initial/ current distribution) can be described by the following set of transition matrices:

$$A_{\lambda^1_{i_1}, \lambda^2_{i_2}, \ldots, \lambda^m_{i_m}} = \left(P\left(X_t = S_j \middle| X_{t-1} = S_i, \lambda^1_{i_1}, \lambda^2_{i_2}, \ldots, \lambda^m_{i_m}\right)\right)_{ij}$$

At this point one needs to find a good set of parameter values for the amount of last ports considered (k) and static vessel data for clustering purposes. It is necessary to understand, that the number of transition matrices is equal to the size of the space of the static vessel data $\bigotimes_i^m \Lambda_i$ which means that if one distinguishes 10 vessel types, one needs to calculate 10 transition matrices. If one adds 5 size classes per vessel type, the number of matrices needed increases to 50. This is why it is generally not advisable to use a high number of static vessel data, although the sparsity of the matrices (that is the number of 0 probabilities [which do not need to be physically stored]) usually increases with finer categorization.
Based on this theoretical groundwork we tested three different approaches. While theoretically possible, all of these neglect the AIS destination entry as it is assumed to be invalid. The beauty of this is that there is no need to find an ever-increasing complex set of rules that map prominent mistakes like incorrect grammar or mistakenly stated subports to the respective port destination. Instead, the three scenarios can be described as follows:

1. Using the last k port calls only
2. Using the last k port calls and vessel type information
3. Using the last k port calls and the MMSI number for vessel

The evaluation of port calls without further categorization is meant to establish a baseline on how good port-to-port routes describe real vessel journeys in general. For the second scenario we used the level 2 vessel type categorization of the widely known IHS Fairplay Database which distinguishes 10 types (+1 for unknown types). Using vessel types should be suited for separating service vessels like tugs that are mainly operating at the same port and ocean-going vessels like container ships or oil tankers which follow more complex routes. In contrast to this general approach we tried to deliberately overfit the model by using the MMSI number as a categorization parameter. This means that every ship gets its own Markov process and therefore its own transition matrix. The latter are in this scenario very sparse as only the port-to-port-sequences that exist in the historical track of the respective vessels hold non-zero probabilities.

In general, it might be more advisable to use the IMO number of vessels as this number serves as an unique identifier. Anyhow, due to better coverage we choose to use MMSI numbers in this experimental setup. Due to the structure of the problem, the sparsity of the matrices and the comparatively high ratio of data selection to floating point operations the whole scenario can be conveniently implemented and processed in relational database systems.

C. In-Database Machine-Learning

At this point we would like to describe how and why we suggest implementing the described model in a (distributed) relational database system. As discussed in [8] and [9] these systems are ideally suited to provide efficient long term implementation of Markov models. The standardized and widely supported query language SQL ensures implementation independence of the concrete system used and its longevity. Furthermore, in-database solutions enable the processing of (preprocessed) data as close to the original data as possible, which in general ensures data security (provided by the database management system) and low network traffic. For a more detailed discussion on advantages of pure database solutions the interested reader is referred to [8] and [9]. Rather than storing a multitude of sparse matrices, we grouped the whole model in one big sparse tensor with the following relational schema:

```
A(
        [
        mmsi            BIGINT,|
        vesseltype      VARCHAR,
        ]
        lastport        CHAR(5),

        k_th_lastport   CHAR(5),
        nextport        CHAR(5),
        p               DOUBLE PRECISION
)
```

where p denotes the probability of “nextport” is the subsequent port after the port sequence specified by the attributes “lastport” to “k_th_lastport”. Due to its compactness and its role as an identifier we only used the LOCODES for port identification. As the prediction process consists of a simple sparse matrix multiplication for a possibly selected mmsi number or a vessel type which is internally processed in the database system via a grouped aggregation of a joined table it is necessary to provide the model with a reasonable index structure. Therefore we used a nested b-tree index structure on ([mmsi, vesseltype], lastport, …, k_th_lastport). This allows the prediction of the nextport (or a sequence of next ports) in milliseconds, allowing for a high number of simultaneous real time prediction queries. In production scenarios it is feasible to use distributed database systems to ensure low latency and fault tolerance in the context of big data (“velocity”).

5. Model Evaluation

In the following subsections we present and discuss the actual experimental evaluation and the implications we have derived from the results. For this we start with a brief description of the training process and the underlying training data.

A. Model Training

We used company internal port call events that were derived from the global AIS network of FleetMon. These events were triggered (once) when a vessel entered a port zone and came to hold for a given period of time. Possible port call duplicates due to GPS jittering or brief departures from the port zone were accounted for in post processing. The port call events include amongst other AIS-data at arrival and departure (for instance the destination entry or the MMSI number) as well as processed zone data like the current port (LOCODE) and the last k ports.

For the training process we used all port call events from the years 2018 and 2019, which overall make a total of over 50 million port calls from over 600 thousand vessels and more than 4000 ports.

The calculation of the transition matrices (or the tensor) is done using the classical maximum likelihood approach (see for instance [10]):

$$a_{ij} = \frac{\# S_i \rightarrow S_j}{\# S_i}$$

Basically, the procedure counts all the transitions from one state (port call sequence + MMSI/Vessel Type) to another and the times the base state occurred in the training set. This simple structure is not only convenient to implement in SQL, but also allows a fairly easy reinforcement process.

For this one only needs to store the nominator and denominator separately, so that the counts can be regularly or even continuously updated. This is especially important to account for new vessels, ports or even newly established routes.

B. Evaluation data

We evaluated the trained models against all of the aforementioned port calls that used destination entries that could at some point in time not be mapped to their real port destination. Therefore, the evaluation data with a total of over just above 20 million port calls is a real superset of the actual set of not matchable destinations. The most prominent problem class here are vessels that specify in some form Yangshan Port (e.g. “YANGSHAN”, “YANG SHAN”, “YANGSAN”, …) as their main destination, which is technically incorrect as Yangshan Port is a sub port of the Port of Shanghai. This alone accounts for well above two million port calls with non-matchable next port destinations. The other main problem classes consist of grammatical errors and deliberately unidentifiable entries like “00000000” or similar.

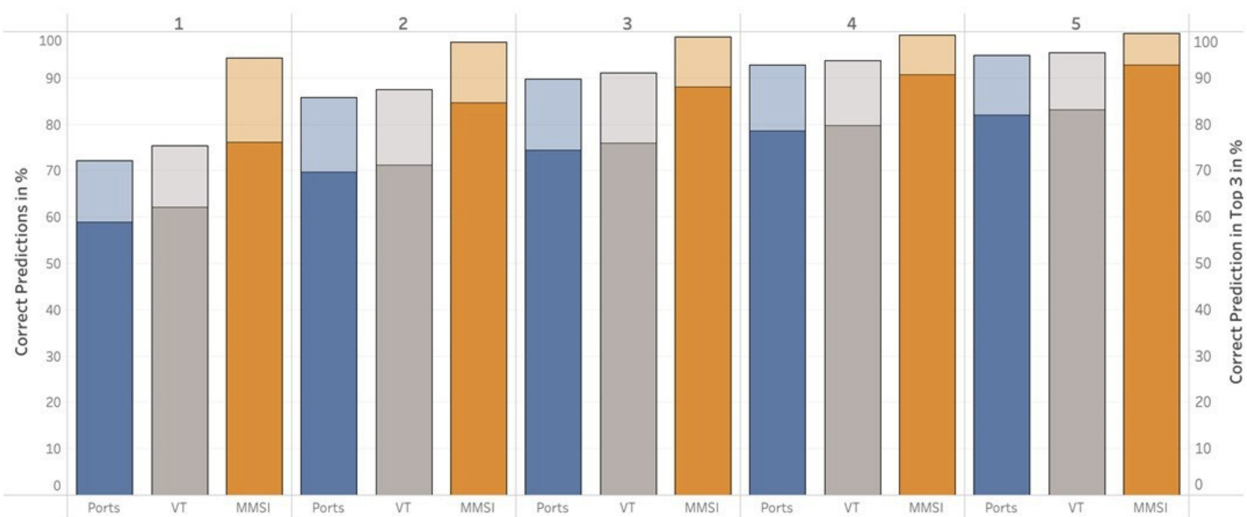

Figure 2: Results of classification differentiated between correct prediction (solid bar) and correct result being in top 3 of predicted next ports (transparent bar). The Order (top caption) represents the number of last ports that were considered for the next port prediction. The bar labels describe whether no additional static vessel data ("Ports"), the vessel type ("VT") or the MMSI number (“MMSI”) has been used as an additional classification source.

C. Evaluation Results and Discussion

The results of the three different approaches with varying number of most recent port calls are depicted in Figure 2. The solid bars represent the correct prediction by using the most probable port, while the transparent bar indicates whether the correct port destination was included in the top 3 most probable destinations. The latter might be of interest for post processing purposes when the most probable port can be dismissed as the real destination due to the observed vessel route.

In general, it can be seen that all models increase their accuracy when using more information of the last port-to-port route. The MMSI model significantly outperforms the other two models and reaches a fairly high accuracy of 93% and 99% for the top 3 case when including the most recent 5 port calls. While the use of vessel types is beneficial for the accuracy in comparison to no additional data, the increasement is close to negligible.

This might be caused by a suboptimal choice of vessel type categorization, as the level 2 categorization of the IHS statcode model uses only 10 different vessel types which leads to for instance to a category that combines passenger ships and dry cargo vessels. Two types of vessels which surely show very different behavior in their journeys (ports and frequency of port calls).

Anyhow, with correct predictions from 60% to 80% and top 3 predictions between 70% and 95% both of the non MMSI models still show potential for further use, especially after some recalibration.

This might come to effect as the vessel specific approach (MMSI) might suffer from long settling periods. That means that new port-to-port-routes of a specific vessel might need to be seen for quite some time until the model can accurately predict the route in production. While this is not that big of a problem for newly built vessels as the overall count of port calls is low, it is especially problematic for older vessels that have seen several route cycles before. Especially for this circumstance one might need to introduce some sort of possibility to forget old routes into the model. Alternatively, one can use a hybrid model where unknown routes use the vessel type approach instead of the vessel specific one. Overall the results as well as the practical feasibility of the models are very promising and will be further developed for practical use.

6. Conclusion and Future Work

This paper presented and discussed AI-based approaches for the prediction of port-to-port routes via markov processes. It has been shown that these kind of models are ideally suited for scalable services and accurate predictions for vessels destinations in the case of unidentifiable AIS destination entries.

We are currently planing on optimizing the presented solution in three main steps. Firstly we will train the model on more data. Secondly we will analyze how we can implement a vessel specific way to forget unused old port-to-port-routes that interefere with the current prediction model. Thirdly we will try to built a better vessel type categorization for a more accurate general model. This might be done by using more vessel subtypes or by adding additional information like classes of gross tonnages or vessel size.

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Developing the Transport Infrastructure of Central and Eastern Europe With a View to the Region's Convergence

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Abstract

The purpose of my study is to what extent EU co-financing projects have helped to bring the transport infrastructure of Central and Eastern Europe closer to the more developed countries. I will evaluate projects implemented in the CEF Transport Program in CEE countries on the basis of my research. A further aim of my paper is to respond to dilemmas of what is more worthwhile to develop super railways or airports in the region.

Keywords: Air Transport, Central and Eastern Europe, Connecting Europe Facility, Infrastructure, Intermodal transport, Railway transport, Transport projects

JEL: L9; L91; L92; L93;L98;O18;R5

1. Introduction

Eastern Central Europe has been and still is comprised of Poland, the Czech Republic, Hungary and Croatia (Herczegh, 1998). Since the dissolution of Czechoslovakia and Yugoslavia some have considered Slovakia, Slovenia, Romania, Bulgaria and the Baltic States to be part of the region, because of their shared, decades long socialist development. We also selected this broader interpretazion during the preparation of the present study, despite the often various cultural, social, economic differences. They have shared development trajectories until recently, primarily meaning the rate of economic development, and these countries have also all joined the European Union, and as a result of this they have become eligible for CEF subsidies.

The transport sector of the EU has arrived to a crossroads in our times. We have to develop a high performance infrastructure that will provide sufficient capacity for the economy, to adequately utilize opportunities for job creation and growth. At the same time, we have to make sure that the sector continues to provide competitive, innovative, cost-efficient and environment friendly transport solutions for users and integrates various modes of transport (European Commission, 2019a). The Trans-European Transport Network (TEN-T) is comprised of the planned European road, railroad, air and water transport networks. The Trans-European Transport Network (TEN-T) policy addresses the implementation and development of a uniform Europe-wide transport network, recognizing the importance of a strategic approach. Thus the TEN-T infrastructure development policy is closely connected to the implementation of the EU's transport policy and its further development (European Court of Auditors, 2017b). In 2015 the European Commission's Directorate-General for Mobility and Transport (MOVE) issued an assignment for the preparation of a study that analyzes the regulatory and administrative processes which obstruct the effective and successful planning of the TEN-T Core Network projects, and formulates recommendations to handle these

obstructions, including the suggested policy possibilities (Tractabel, 2016).
In the present study, after the general introduction of the Connecting Europe Facility (CEF) and the description of uniform recommendations, I will take an account of the transport projects subsidized by CEF in Eastern Central Europe between 2014 and 2018, and I will evaluate them in their entirety as well as separately for each mode of transport. A further objective of my study is to assess the most important development directions for the future. At the same time, I aim to answer the question whether it is more feasible to develop super-trains or airports.

2. Connec.ng Europe Facility

Connecting Europe Facility (CEF) has been providing funding for 3 sectors since 2014: the energy sector, the transport sector, as well as the information and communication technologies (Telecom) sector, based on Regulation (EU) No 1316/2013 of the European Parliament and of the Council (Regulations, 2013b). The investment priorities to be applied in the next decade in these 3 sectors are determined by CEF, such as Core Gas and Electricity Network Corridors, the use of renewable energy sources, Connected Transport Corridors and less polluting transport modes, high-speed broadband connections and digital networks (European Court of Auditors, 2017a). CEF investment projects will fill the missing connections of the European energy, transport and digital trunk networks. The Connecting Europe Facility is favourable to every member state, because it makes travel easier and more sustainable, increases European energy security, and at the same time enables the broader use of renewable energy sources, as well as facilitates cross-border cooperation between administrative bodies, enterprises and citizens. Besides funding, CEF also provides financial support for projects by innovative financial instruments, such as loan guarantees and project bonds. These instruments have a considerable effect on the use of the EU budget, they serve as catalysts to receive further financing sources from other actors of the private as well as public sector (European Commission, 2019b).

The CEF is divided into three sectors:

- CEF Energy
- CEF Telecom
- CEF Transport

One of the key priorities of CEF is enabling and strengthening the synergies between the three sectors. Actions across sectors may enable costs or results to be optimized through the pooling of financial, technical or human resources, thus enhancing the effectiveness of EU funding.
The first Call for proposals to support synergy actions between the transport and energy sectors was launched in 2016, based on Regulation (EU) No 2016/1649 of the European Parliament and of the Council (Regulations, 2016).

3. CEF Transport

Connecting Europe Facility (CEF) is the financial instrument for the implementation of European transport infra-structure-policy. Its objective is to support projects aimed at the construction of the European transport infra-structure, or the renovation and modernization of existing infrastructure, as well as the main goals of the TEN-T policy (Regulations, 2013a):

TEN-T comprises two network ‘layers’:

- The Core Network includes the most important connections, linking the most important nodes, and is to be completed by 2030.

- The Comprehensive Network covers all European regions and is to be completed by 2050

CEF Transport focuses on cross-border projects and projects aiming at removing bottlenecks or bridging missing links in various sections of the Core Network and on the Comprehensive Network (link), as well as for horizontal priorities such as traffic management systems. CEF Transport also supports innovation in the transport system in order to improve the use of infrastructure, reduce the environmental impact of transport, enhance energy efficiency and increase safety.

The total budget for CEF Transport is €23.3 billion for the period 2014-2019, of which €11.3 billion was reallocated from the Cohesion Fund. INEA is responsible for implementing €23.7 billion of the CEF Transport budget in the form of grants during the same period. INEA - the Innovation and Networks Executive Agency - was responsible for the implementation of the CEF Transport budget.

4. Innovation and Networks Execu.ve Agency (INEA)

The Innovation and Networks Executive Agency (INEA) is the successor of the Trans-European Transport Network Executive Agency (TEN-T EA), which was created by the European Commission in 2006 to manage the technical and financial implementation of its TEN-T program. Headquartered in Brussels, INEA, officially commenced its operations on 1 January 2014, for the purpose of implementing certain elements of the Connecting Europe Facility, Horizon 2020 and other previous programs (TEN-T and Marco Polo 2007-2013) (European Court of Auditors, 2016).

CEF programs have been financed through INEA since January 2014 (Regulations, 2013c). In practice this means that INEA manages the budgets of most CEF programs, which as of now has totaled €28.5 billion (€23.3 billion for Transport, €4.7 billion for Energy and €0.5 billion for Telecom). In total the expected budget man-aged by INEA will be approx. € 35 billion for programs in the 2014-2020 period (€30 billion from CEF and €5 billion from H2020).

The principal transport projects with horizontal priority funded by CEF (INEA, 2019):

– European Railway Traffic Management System (ERTMS)
- Intelligent Transport Services (ITS)
– Motorways of the Sea (Motor-ways-of-the-Sea)
– New technologies and innovation (New-technologies-and-innovation)
- RIS, River information services, safe and secure infrastructure (/inea/en/connecting-europe-facility/ceftransport/projects-by-horizontal-priority/safe-and-secure-infrastructure)
– Single European sky - SESAR (Sin-gleeuropean-sky sesar)

5. CEF Transport projects through Core Network Corridors

In order to simplify the harmonized implementation of the core network, so-called "Core Network Corridors" have been introduced. These accumulate state and private resources, focus EU subsidies from CEF, particularly for the following (European Commission, 2019b):

– Removing bottlenecks
– Construction of missing cross-border connections
– Facilitating modal integration and interoperability
- Integration (as a continuous modal measure, these corridors must be integrated into the multimodal TEN-T rail cargo transport corridors)
- Promoting clean fuels
– Other innovative transport solutions
– Developing telematics applications for the use of an efficient infrastructure
- Integration of urban areas into TEN-T
– Increasing safety

In the Annex of the CEF Regulation 9 core network corridors are identified, which include the predetermined list of projects for possible EU financing for the period between 2014 and 2020, based on their added value to TEN-T development and expiration status (Regulations, 2013b).

- A Baltic - Adriatic 4,588 km
- B North Sea - Baltic 6,244 km
– C Mediterranean 9,355 km
– D Orient/East-Med 9,355 km
– E Scandinavian - Mediterranean 9,290 km
– F Rhine - Alpine 2,994 km
– G Atlantic 8,188 km
– H North Sea - Mediterranean
- I Rhine - Danube 5 802 km

6. European transport projects in Eastern Central Europe

Eastern Central European countries participated in 368 projects as beneficiaries, and received €10,373.2 million for their implementation co-financed by CEF Transport, between 2014 and 2019 the total value of these projects was €14.7 billion.

Poland implemented the largest scale transport development projects, specifically 54, with funding in the value of €4,200 million. From this aspect Romania is the second with 33 projects with funding in the value of € 1,200 million, the third is the Czech Republic with 57 projects in the value of €1,100 million, while Hungary is in the fourth place with 45 projects in the value of €1,100 million (Figure 1.).

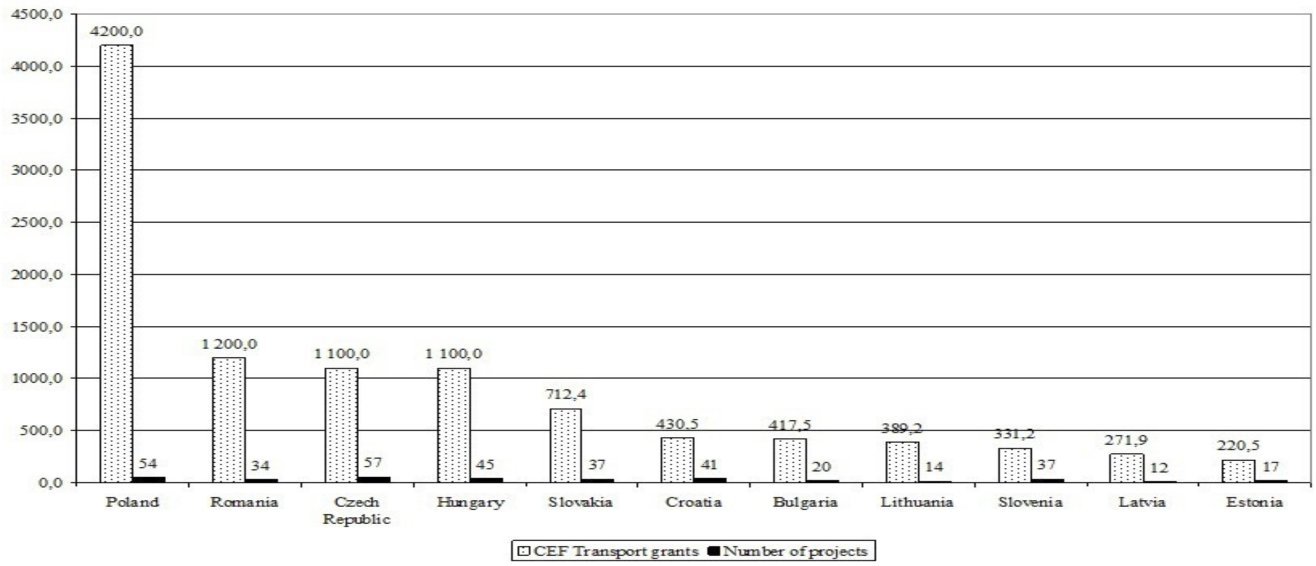

Figure 1: CEF transport grants and number of projects, 2014-2019, € million (European Commission, 2019)

Country	Rail	Road	Inland Waterways	Air	Maritime	Multimodal
Bulgaria	373.5	30.2	6.3	3.2	2.3	2.1
Croatia	266.1	28.7	10.4	25.8	98.1	1.4
Czech Republic	1,062.1	42.6	12.4	11.5	-	14.9
Estonia	189.0	5.2	-	3.2	23.1	-
Hungary	860.0	133.0	83.3	15.6	-	-
Latvia	259.0	9.4	-	2.6	0.9	-
Lithuania	342.9	23.4	-	9.6	13.2	-
Poland	3,505.5	510.1	-	13.1	147.8	35.1
Romania	1,130.3	16.1	58.8	17. 0	10.8	-
Slovakia	378.3	125.3	183.8	5.1	-	19.9
Slovenia	278.2	37.1	-	4.5	11.3	-
Total	8,644.9	961.1	355.0	94.2	307.5	73.4

Table 1: CEF **CEF transport grants per transport mode, 2014-2019, € million (European Commission, 2019)**

When inspecting the received funding according to modes of transport, it is evident that Eastern Central European countries primarily used CEF Transport funds for railway transport development projects, secondly for road transport development projects, thirdly for inland waterway transport development projects, and fourthly for sea transport development projects. The data also shows that these funds were least used for air transport development projects and multimodal type transport development projects.

All of this is not favourable because as a result these countries were focusing the least exactly on the areas where development is the most dynamic nowadays and their lagging behind developed countries is the largest. Consequently, while in certain areas they have closed the gap somewhat compared to developed countries, they are lagging behind developed countries, thus their competitiveness will be reduced exactly in the areas that would be the most important for the future. Eastern Central European countries participated in 106 rail transport development projects as beneficiaries, and received €8,644.9 million for the implementation of these in the co-financing of CEF Transport between 2014 and 2019 (Table 1.).

In Eastern Central Europe, Poland used the highest value CEF funding for rail transport development projects, in the value of €3,505.5 million for the implementation of 23 various rail transport development projects. The total value of these projects was €4,639.4 million. The highest value rail transport development project realized by Poland was on the E20 railway, on the Warsaw-Poznan section, while the remaining works are being implemented on the Sochaczew-Swarzedz section (European Commission, 2019c).

The project commenced in November 2015 and will be completed in December 2020. The total cost of the project will be €614,308 million. The maximum amount of EU subsidy may be €461,776 million, 75.1% of the project's total cost.

Numerous significant development projects have been and are implemented with the co-financing of the European Union, which will considerably contribute in many areas to the cohesion of the transport infrastructure of Eastern Central European countries to the level of more developed countries. At the same time, by today it is also evident that these projects are insufficient for the complete cohesion of the region from multiple aspects, since they are focused less or not at all on the most competitive areas. Thus, for example, there are no projects at all among them that would facilitate the spread of super-fast rail transport, thereby the lagging behind of the region from this aspect will actually significantly increase in comparison with countries which are substantially ahead of us, such as Spain, France, Germany, Finland and Italy.

Another outstandingly important area is the development of air transport. Today this sector is one of the fastest developing transport sectors in the world. Currently, airports located in Western Europe and Southern Europe manage 64% of passenger air traffic. In recent years Eastern Central Europe has gradually grown its significance on the European market by increasingly dynamic development. Between 2000 and 2017 Eastern Central European airports achieved a growth rate in excess of 10.1% per year on the average. This fact can be mainly attributed to the rapid growth of Russian commercial airports, but other growing markets also contributed to this outstanding development, such as Bulgaria, Croatia, Poland, Romania and Ukraine. The growing presence of budget airlines on these markets, with improving economic conditions, has substantially expanded the European market in recent years. The regional airports of Bulgaria, Croatia, Poland, Romania and Ukraine have been very consciously making efforts to expand the accessibility and flight selection of airports. Despite this extraordinarily dynamic growth, the region currently only manages approx. 14% of the total air traffic of the Continent (Lucas, 2018).

The lagging behind of Eastern Central European countries in the area of air transport, similarly to high-speed rail transport, is one of the greatest in comparison with developed countries. Meanwhile, the least amount of financial resources and the least number of projects are devoted to the development of these areas, which will clearly result in the region falling behind ever further. This falling behind will be further intensified by the corona virus pandemic as well as the experts who for the sake of a climate friendly economy are openly arguing for the scaling back and the taxation of air transport.

The rather low ratio of multimodal transport development projects will result in the region falling behind further. In this area the lagging behind of Eastern Central European countries is already considerable in comparison with developed countries, thus the countries of the region should focus more on the implementation of these types of projects. In the case of Hungary, an addition problem is that as a result of the complete elimination of the sea transport branch of MAHART (Hungarian Shipping Company Ltd.) in 2003 and the termination of the connected ship building industry, we are not present at all in the life of the maritime transport sector, thus we will be unable to profit from the fruits of the expected dynamic development of the sector in the future. Even though the government announced the national sea transport strategy in 2012, currently there are no visible substantial signs of the comprehensive implementation of the strategy, except for the purchase of the land area needed for the Trieste seaport.

7. Competition and/or cooperation between high-speed rail transport and air transport

The statistical data regarding the extent of high-speed rail transport lines are rather contradictory. There are different data to be analysed in every existing database for the same simple question: what is the length of high-speed rail transport lines in specific countries. Therefore, it is rather difficult to navigate between various databases. During my various data mining research studies regarding the subject, I have arrived to the conclusion that the data of UIC (International Union of Railways) can be regarded the most reliable in the subject, and contain the largest amount of information (such as including the lines under construction and planned lines). With the use of UIC's data, Table 2 compares the length of high-speed rail transport lines in specific countries, in kilometres in 2020. This means the length of high-speed rail transport lines and line sections where trains can travel at or beyond 250 kilometres per hour. High-speed rail transport line: A main

Country	In operation	Under construction	Planned	Long-term planning	Total
Spain	3,330	1,293	676	-	5,299
France	2,734	-	-	1,725	4,459
Russia	-	-	1,080	1,549	2,629
Germany	1,571	147	81	210	2,009
Poland	224	-	805	875	1,904
Italy	921	327	-	-	1,248
Finland	1,120	-	-	-	1,120
Czech Republic	64	-	666	318	1,048
Sweden	-	11	150	589	750
United Kingdom	113	230	320	-	663
Austria	254	281	71	-	606
Portugal	-	-	-	596	596
Lithuania	-	-	392	-	392
Norway	-	-	-	333	333
Latvia	-	-	265	-	265
Estonia	-	-	213	-	213
Belgium	209	-	-	-	209
Switzerland	144	15	-	-	159
The Netherlands	90	-	-	-	90
Denmark	56	-	-	-	56

Table 2: High speed lines in Europe, Length (km), based on the data reporting of UIC as of 27 February 2020

rail transport line which allows 200 km/h or faster 250 km/h speed rail transport, on special lines constructed for this purpose (Eurostat, 2019).

Based on UIC's data, in February 2020, the length of high-speed rail transport lines was the highest in Spain, with 3,330 kilometres. It is followed by France with 2,743 kilometres and Germany with 1,571 kilometres. The length of these special lines is longer than one thousand kilometres even in Finland, with 1,120 kilometres, while in Italy their length approaches one thousand kilometres (921 km).

There are already high-speed rail transport lines in 3 Eastern Central European countries, 254 kilometres in Austria, 224 kilometres in Poland and 64 kilometres in the Czech Republic. In Poland the 224 kilometre line was constructed between Grodzisk Mas and Opoczno, while in the Czech Republic a 64 kilometre section between Beroun and Plzen. In total, the lagging behind of Eastern Central European countries is still substantial in comparison with more developed European countries. At the same time it is favorable that from the aspect of planned rail lines a significant change can be observed in these countries, especially in Poland and the Czech Republic (Table 3). It is also clearly favourable that the preparation of the feasibility study for the Budapest - Bratislava - Brno - Warsaw high-speed rail transport line has started, and the high-speed rail project connecting Budapest through Cluj-Napoca to Bucharest is under preparation (Jámbor, 2019). Another piece of good news is that the tender announced for the renovation of the Budapest-Belgrade rail line was completed successfully. According to the plans, the construction works may commence in the end of 2019 or in the beginning of 2020 (MTI, 2019).

It is beyond doubt that the new high-speed rail (HSR) line may have a great effect on the use of air travel services. Many authors devote their attention to the competition between these two mo-Based on UIC's data, in February 2020, the length of high-speed rail transport lines was the highest in Spain, with 3,330 kilometres. It is followed by France with 2,743 kilometres and Germany with 1,571 kilometres. The length of these special lines is longer than one thousand kilometres even in Finland, with 1,120 kilometres, while in Italy their length approaches one thousand kilometres (921 km).

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It is beyond doubt that the new high-speed rail (HSR) line may have a great effect on the use of air travel services. Many authors devote their attention to the competition between these two modes of transport, even though in most cases the new high-speed rail lines may also play a significant intermodal supplementary role in air transport. Givoni and Banister point out that high-speed rail lines may result in a kind of new and unique component in the system of air transport hubs (Givoni and Banister, 2006). High-speed rail lines may reduce the delays caused by crowded conditions at large airports in the case of shorter range flights, and supplement long range flights well (Clewlow, R. et al, 2012). Furthermore, the reduction of air transport servnices at hub airports is usually greater that at non-hub airports. Supplementary effects (higher demand of connecting passengers) will partially compensate for the reduction in passenger numbers caused by being in direct competition with high-speed rail (Albalate, D. et al, 2014).

Country	Status	Section			Max. Speed (km/h)	Date	Length (km)
Czech Republic	Planned	Praha	Poříčany	(RS1)	320	2027	22
Czech Republic	Planned	Poříčany	Světlá nad Sázavou	(RS1)	320	2030	71
Czech Republic	Planned	Světlá nad Sázavou	Velká Bíteš	(RS1)	320	2033	81
Czech Republic	Planned	Velká Bíteš	Brno	(RS1)	320	2030	32
Czech Republic	Planned	Brno	Přerov	(RS1)	200	2030	80
Czech Republic	Long-term planning	Brno	Přerov	(RS1)	320	2050	74
Czech Republic	Planned	Přerov	Ostrava	(RS1)	320	2028	73
Czech Republic	Planned	Modřice	Šakvice	(RS2)	320	2029	35
Czech Republic	Planned	Šakvice	Břeclav	(RS2)	200	2028	23
Czech Republic	Long-term planning	Šakvice	Břeclav	(RS2)	320	2050	23
Czech Republic	Planned	Praha	Beroun	(RS3)	200	2043	25
Czech Republic	In operation	Beroun	Plzeň	(RS3)	160	-	64
Czech Republic	Planned	Plzeň	Domažlice st.hr.	(RS3)	200	2027	58
Czech Republic	Planned	Praha	Litoměřice	(RS4)	320	2030	58
Czech Republic	Planned	Litoměřice	Ústí nad Labem	(RS4)	250	2045	23
Czech Republic	Planned	Ústí nad Labem	Dresden	(RS4)	200	56	56
Czech Republic	Long-term planning	odb. Nová Ves	Most	(RS4)	250	2040	85
Czech Republic	Planned	Praha	Poříčany	(RS5)	320	2027	29
Czech Republic	Long-term planning	Poříčany	Hradec Králové	(RS5)	320	2039	67
Czech Republic	Long-term planning	Hradec Králové	Trutnov st. hr.	(RS5)	250	2050	69
Estonia	Planned	Tallin	Border with Latvia		249	2026	213
Latvia	Planned	Border with Estonia	Border with Lithuania		249	2026	265
Lithuania	Planned	Border with Latvia	Border with Poland		249	2026	252
Lithuania	Planned	Kaunas	Vilnius		249	2026	140
Poland	In operation	Grodzisk/Maz	Opoczno	Zawiercie	200	2015	224

	Planned	Warszawa - Lodz	Kalisz/Ost-row	Poznan/ Wrocław	350	2030	448
Poland	Planned	Warszawa	Białystok	Elk	200	2030	277
Poland	Planned	Elk	Border Lithuania		250	2030	80
Poland	Long-term planning	Wroclaw	BorderCzech Republic		350	2030 after	148
Poland	Long-term planning	Poznan	Border Germany		350	2030 after	171
Poland	Long-term planning	Katowice	BorderCzech Republic		300	2030 after	61
Poland	Long-term planning	Naklo	Katowice/ Krakow		300	2030 after	138
Poland	Long-term planning	Warszawa	Gdansk		350	2030 after	357

Table 3: High speed lines in Eastern Central Europe (Details), Length (km), based on the data reporting of UIC as of 27 February 2020

8. Conclusion

Eastern Central European countries participated in 368 projects as beneficiaries, and received over €10 billion for their implementation co-financed by the CEF Transport fund between 2014 and 2019. When analysing the received funding, it is evident that Eastern Central European countries primarily used CEF Transport funds for railway transport development projects, secondly for road transport development projects, thirdly for inland waterway transport development projects, and fourthly for sea transport development projects. It can also be established that these funds were least used for air transport development projects and multimodal type transport development projects. Numerous significant development projects have been implemented. All of these will considerably contribute in many areas to the cohesion of the transport infrastructure of Eastern Central European countries to the level of more developed countries. At the same time, by today it is also evident that these projects are insufficient for the complete cohesion of the region from multiple aspects, since they are focused less or not at all on the most competitive areas. Thus, in the future the countries of the region should focus substantially more on the implementation of the types of projects, which will be of key importance in the medium and long term. They should devote by far more resources to the development of high-speed rail transport, air transport and multimodal transport networks and facilities, so their total lagging behind will not increase, but decrease in comparison with developed countries. In the case of Hungary, in addition to this, further efforts should be made to revive the sea transport sector, which has seen better days in the past.

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Effects of Connected and Automated Vehicles in a Coopera.ve Environment

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Abstract

Cooperative and automated vehicles (CAVs) are often considered a mean to improve quality of life in cities, the traffic flow parameters in particular. This paper provides some evidence based on microscopic traffic simulation on how the effects can really be. Important is that the particular use cases are not built in vehicles only. We focus on so called cooperative environment and advanced traffic control measures.

This paper describes the impact of CAVs on a cooperative urban environment, resulting from a European research project - MAVEN. We clearly demonstrate that a proper integration of CAVs into city traffic management can, for example, help with respect to the environmental goals and reduce CO2 emissions by up to 12 % (a combination of GLOSA and signal optimization). On corridors with a green wave, a capacity increase of up to 34% was achieved. Already for lower penetration rates (20% penetration of CAVs), there are significant improvements in traffic performance. For example, platooning leads to a decrease of CO2 emissions of 2,6% or an impact indicator by 17,7%.

Keywords: Traffic management, Smart Solutions for safe, Efficient and sustainable traffic flow

JEL: R410 Transportation: Demand, Supply, and Congestion; Travel Time; Safety and Accidents; Transportation Noise

1. Introduction

Cooperative and automated vehicles (CAVs) are often considered a mean to improve quality of life in cities. CAVs do not only serve as a new source of information (for example to estimate the queue-length at an intersection with higher precision), but through for example speed or lane change advisory or routing algorithms, they can make traffic more energy-efficient and fluent, and the traffic flow in the network more balanced. So much the expectations. But what is the real effect of vehicle automation?

Before we answer this question, let us provide some definitions. The terminology in the field is not unified. The particular letters in the abbreviation CAV can gave different meaning. There is for example a big difference in the usage in Europe and in the USA.

For example, the letter “C” in the abbreviation can mean cooperative or connected, the letter “A” then automated or autonomous. Within this paper we adopt terminology from Andata (https://www.andata.at/en/answer/whats-the-difference-between-autonomous-automated-connected-and-cooperative-driving.html):

Automated vehicles denote self-driving vehicles, i.e. vehicles that can drive without human intervention. **Autonomous vehicles** describe vehicles that are allowed to make decisions independently and on one's own mind. Further, different levels of automation are defined for example by SEA international (https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic) and provided in Fig. 1.

Figure 1: Levels of automation according to SAE (source: SAE International: https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic)

Connected vehicles are exchanging information among each other and/or infrastructure in an automated way.

Coopera.ve vehicles act cooperatively within traffic, which implies that they are coordinating their microscopic aims and actions in the light of improved overall macro-scopic effects.

Within this paper, the abbreviation CAV denotes cooperative and automated vehicles. We focus on automation level 4 and 5.

Now let us get back to the question whether cooperativeness and automation will have a positive or negative effect on traffic and environmental parameters. The early expectations were really optimistic. It was expected that autonomous vehicles will improve safety, reduce congestions, harmonize traffic, reduce the number of vehicles on roads, allow for savings in infrastructure incl. parking or for example make more affordable mobility services.

In the last years, however, researchers started to doubt the expected positive impacts and often refer back to them as "wishful thinking". Even when the challenges from above are overcome, the impact on, for example, traffic flow can be really different. At best, there is much uncertainty about the impact of AVs as it is demonstrated in the following paragraphs [1].

Sousa et al. [2] stated that since automated vehicles can provide mobility for new groups of users, travel demand may increase.

This statement was supported by the work of Sivak and Schoettle [3], who analysed the reasons for not having a driving license and estimated this increase in new mobility users to go as high as 11% when AVs become widely accessible. Harper et al. [4] used the data from the 2009 National Household Transportation Survey to study this phenomenon. His results suggest that in the USA, the increase in vehicle miles travelled is expected to be 14%.

The cities and the entire land use will need to be changed to address another important aspect of autonomous vehicles. Nowadays, cars in cities are used only for short periods of time. People typically drive to work in the morning and back home in the late afternoon. In the meantime, they stay parked.

Finding a parking spot may, in addition to fuel and time waste and increase in the overall stress, increase traffic up to 15% [5].

AVs address these problems by driving passengers to their destination, and then driving to a dedicated parking place at home or outside of the city centre. This can reduce the need for parking places in the centre, but introduces new challenges. The empty AVs would be negatively influencing the overall traffic flow, using extra fuel and polluting while looking for parking far away [6].

Additionally, the city would need changes in the entire land use, for example, an additional space and solution for drop-off and pick up by AVs [7].

Automated vehicles should save space not only by reducing the number of parked vehicles but also by reducing the space required for parking them. AVs allow parking in so-called depots where the space needed to park such vehicles can be reduced to half the space needed with conventional parking lot designs [8].

David Metz [9] confirms the expectations that the impact of AVs cannot be simply just postive or just negative. He addresses the concept of autonomous driving with respect to other new trends - the topic of vehicle ownership and ride-sharing. He puts together the partial conclusions from previous sections and concludes that it is to be expected that individually owned AVs will add significantly to the overall distance travelled by car and hence to increased traffic levels. In contrast, AVs operating as robotic taxis would not be expected to have such an impact, given that conventional taxis travel without passengers between paid trips.

Additionally, the lower travel costs associated with using shared vehicles can attract passengers from public transport, increasing the demand for a private car or taxi use.

This effect was also in details elaborated by Wadud et al [10]. The authors explore the effects of automation on congestions, energy consumption and emissions through several illustrative scenarios, finding that automation might plausibly reduce road transport emissions and energy use by nearly half; or nearly double them; depending on which effects come to dominate.

A critical question is whether autonomous vehicles increase or reduce total vehicle travel and associated external costs. It could go either way, depending on public policies. By increasing travel convenience and comfort, and allowing vehicle travel by non-drivers, they could increase total vehicle mileage, but they may also facilitate vehicle sharing, which allows households to reduce vehicle ownership and therefore total driving.

2. Cooperative Environment

The previous section provided evidence from existing literature that just the fact you have automated vehicles in cities does not automatically mean an improvement in traffic parameters. Apart from the adopted policies also the way in which they are integrated into the existing traffic management are crucial. Just that a vehicle does not have a driver does not lead to decrease in travel time.

Within this paper we would like to enhance the definitions from above and define so-called:

Cooperative environment - where not only a single traffic participant is automated and exchanging information, but the infrastructure also plays an important role by providing additional functionality and higher efficiency of its algorithms.

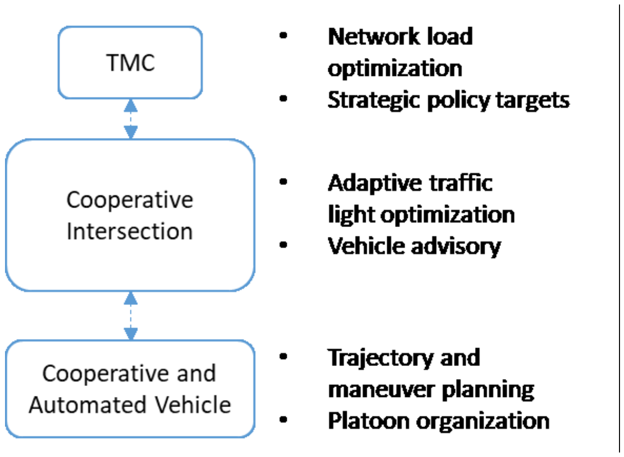

Figure 2: Focus of the use cases defined in the MAVEN project

It must be mentioned we are not necessarily talking only about new functionality, but the existing must be newly defined and improved with the new information it gets from cooperative vehicles. This is true for example for queue length estimation algorithms. Newly, they get data not only from the static traffic sensors, but also from the cooperative vehicles. The precision of such algorithms can be significantly improved, especially for higher penetration rates of automate cooperative vehicles.

The scope and focus of the project MAVEN defined above is provided in Fig. 2. The algorithms are not located on one particular point, but are distributed among the traffic management centers and intersections on the infrastructural part, and among particular cooperative vehicles in the network. For example, so called cooperative perception means, that a vehicle gets information about possible object either from its own sensors, from sensors of another vehicle or even from sensors (e.g. hemispherical cameras) located at the infrastructure. In such was, it is not limited to its own field of view but can make decisions based on more data. This is though related also the concept of “data security” and “trust” and is thus suitable for application of so-called multiagent systems.

Within the project maven, several use cases were implemented and evaluated. We are not going to describe the particular algorithms here, as they are described in [11] in details. Here we provide just an overview of the use cases (UC) and methods implemented.

Platooning (UC1-6) A promising possibility to enhance future traffic efficiency is the formation of platoons by automated vehicles. For simplicity, in the traffic simulation model, we regard a platoon as a group of automated vehicles following each other with a reduced time headway and possibly employing additional control schemes to maintain a coherent state within the group.

GLOSA (UC7) - Green Light Optimal Speed Advisory The main concept of this algorithm is that vehicles receive SPaT messages containing switching times of the next traffic light. An on-board assistance system in the vehicle computes an optimal approaching speed so that the vehicle can pass the traffic light without stopping.

Lane Change Advisory (UC8)- This feature of automated vehicles allows the exchange of information between the approaching vehicle and the C-ITS infrastructure on the intersection in order to inform the vehicle about the queue lengths on different lanes of the intersection approach. By mutual exchange between vehicle and infrastructure, precise queue length can be estimated, and thus vehicles can be redirected to less congested lanes of the approach.

Signal optimization (UC 14) is a feature that brings the benefits for traffic management and is specifically designed to support GLOSA for automated vehicles. Existing adaptive traffic light control algorithms, can adapt more efficiently and accurately thanks to enhanced information source - CAV of UC 11 and the GLOSA algorithm itself also uses the enhanced queue information. Applied signal control algorithm has the potential to bring benefits even without the utilization of CAV information. In order to depict these benefits, we introduce to the graphs in this section not only data from simulations with different CAV penetration rate but also a baseline scenario data reflecting the current control algorithms.

Network coordination / Green wave (UC15) is a well-known phenomenon described for example in D4.4 [4]. The literature describes this Use Case as coordination of signal phases on intersections in such a manner, as to provide coordinated waves of green lights on the intersections that are positioned on a main traffic flow trajectory over the network.

Combined use cases (UC ALL) In order to demonstrate the joint impact of the particular use cases the effectiveness and impact on traffic flow of all Use Cases that can be combined on the signal intersection network of Helmond, i.e. the platooning (UC1-6), GLOSA (UC7), Lane change advisory (UC8), network coordination (UC13) and signal optimization (UC14).

3. Simulation Environment

In order to ensure the validity of the results, each of the performed simulations was thoughtfully planned, analyzed and calibrated in order to minimize the discrepancies from the realworld behaviour of vehicles in a baseline simulation. The baseline scenario was calibrated using real-world data collected in particular networks. Each simulated scenario with tested UC was performed 10 times for each parameter setting, and the results were averaged to ensure a statistically significant outcome. The equation to compute the exact number of required simulation runs is provided for example in [54]. This is important to ensure that achieved results are not overwhelmed by stochastic discrepancies.

It is important to note, that Use Cases 1-6 and 15, which are platooning of the CAV vehicles and Negotiation between CAV and C-ITS is implemented in all of the simulations. Therefore, their indirect impact on the simulations is tested in each of the simulated scenarios. To implement the algorithms necessary for testing the full range of planned UC, a corridor with multiple intersections in Helmond was built up using SUMO, shown in Figure 36. Seven intersections: intersection 701, 702, 704, 101, 102, 103 and 104 are distributed on this stretch of corridor, with the same main direction, east-west through directions 2 and direction 8 for each aforementioned intersection. Respectively, signal group 2 of each intersection is east-west bound and signal group 8 is west-east bound. The configuration of the two signal groups, SG 2 and SG 8 of intersection 701 are almost identical. They contain the same number of lanes (two lanes each), have the same saturation flow (1800 vehicle/hour), the same number of signal heads and they both appear in the same stages/ stage assignment. The simulated traffic is detected in SUMO, then the detected vehicle information is sent back to ImFlow to calculate and optimize the signal timing plan. After making the decision of which plan to choose, ImFlow sends back the chosen plan to SUMO to continue the simulation. The detection type of SG 2 and SG 8 are both set to adaptive unconditional in ImFlow configurator. Therefore, stabilized GLOSA can be provided to these two signal groups. More detailed configuration of the simulation in Helmond network was provided in deliverable [11].

4. Selected Simulation Results

The following sections describe just some selected findings of the project MAVEN. For more details and further figures, please refer to [12].

4.1. Effects of Platooning

Let us look at the effects of the vehicle platooning on average delay. Fig. 3 depicts the average delay in seconds (y-axis) for the increasing ratio of CAV vehicles (x-axis) and nominal as well as 60% traffic volume. There is a significant decrease in the average delay, let us look in details on the nominal traffic volume. An especially large reduction of 23% can be seen with the first introduction of 20% ratio of CAV penetration (10runp20). With the assumption of 100% penetration rate of CAVs in the traffic flow, the resulting average delay decreases by 52%.

In general, the highest expected improvements in almost all aspects (i.e. impact, emissions and queue lengths) happens at the penetration levels of 20%. For example, the queue lengths decrease by about 20% for this penetration rate, while in case of automated vehicles only (penetration level of 100%) is the decrease about 39% in queue length. This is an important conclusion looking at the transition phase (i.e. mixed traffic): significant effects can be

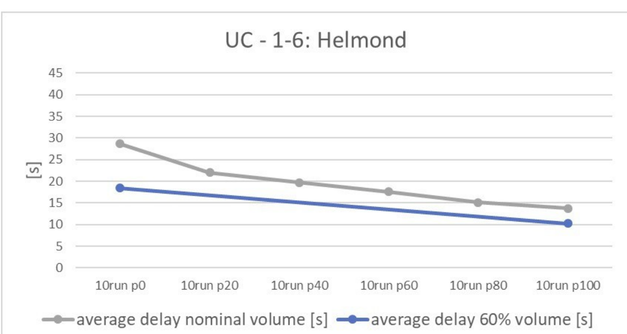

Figure 3: Effect of platooning on average delay

expected at an early stage.

For the full penetration of automated vehicles, the impact on CO2 emissions reaches over 8 %, which is a significant improvement.

4.2. Effects of Speed Change Advice and Green Wave Optimization

An important use case combines the green wave optimization (i.e. network coordination) with the speed change advice, so that the vehicles arrive at the end of starting queue. For the nominal traffic volume and 60% penetration of CAVs, there is a decrease in CO2 emissions of about 5,4%.

Especially for the penetration level of automated vehicles equal to 60%, there is a significant improvement in the average number of stops of about 48,4%, or average queue lengths of about 50,7% (see Table 1). For the penetration level of automated vehicles equal to 100%, there is an

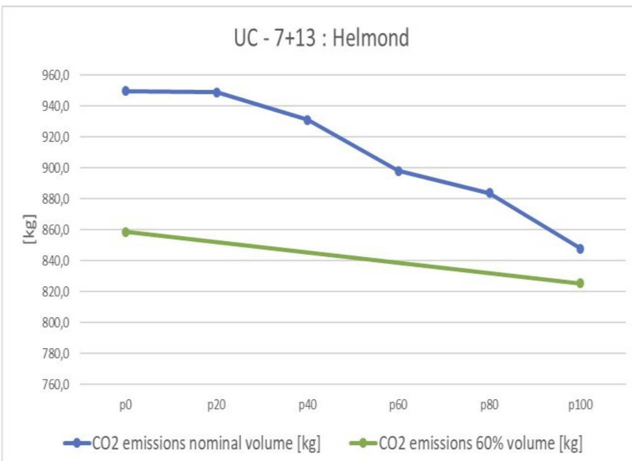

Figure 4: Effect of Speed change advice and Green wave optimization on CO2 emissions

Penetration rate	*Average delay [s]*	*Average number of stops [-]*	*Average queue length [m]*	*CO_2 emissions [kg]*
p0	40,8	0,9	13.2	949.7
p20	36,2	0,8	12,7	948,9
p40	32,0	0,7	10,4	931,1
p60	24,5	0,5	6,5	898,1
p80	21,8	0,4	5,6	883,7
p100	17,9	0,3	3,4	847,8

Table 1: Overview of benefits of UC 13+7 and nominal traffic volume

expected reduction of emissions of about 10%. Specific simulations isolated the capacity and revealed an increase of 34% thanks to the combined use cases.

4.3. Effects of Speed change advice and Signal optimization

Signal optimization is a feature that brings the benefits for traffic management and is specifically designed to support GLOSA for automated vehicles. Existing adaptive traffic light control algorithms, can adapt more efficiently and accurately thanks to enhanced information source. The first and most anticipated benefit of signal optimization through cooperation with CAV is the reduction of average delay over all network. This expectation seems to be met by results achieved in Helmond network depicted in Fig. 3. The vertical grey line depicts also the baseline scenario without the signal optimization algorithm. You can see, that even for a 0% penetration lane (i.e. network without automated vehicles), there is already an improvement in delay of about 6.4%. Compared to this baseline value, the algorithm with a 100% penetration rate of CAVs can improve the delay by over 43%. This combination clearly improved the measured indicators. This is true for low demand as well as the nominal traffic volume. For example, we achieved reduction of CO2 emissions for the full penetration of automated vehicles was about 5%.

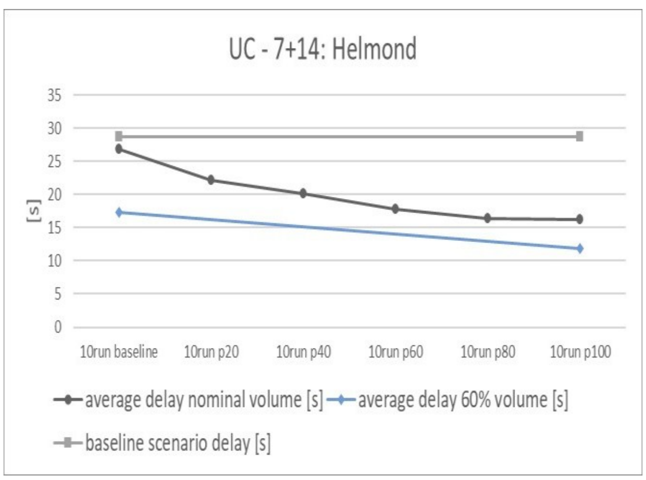

Figure 5: Effect of Speed change advice and Signal optimization on average delay

4.4. Effects of all combined use cases

In order to demonstrate the joint impact of the particular MAVEN Use cases, the following section examines the effectiveness and impact on traffic flow of all Use Cases that can be combined on the signal intersection network of Helmond, i.e. the platooning (UC1-6), GLOSA (UC7), Lane change advisory (UC8), Queue modelling (UC11), signal optimization (UC14) and negotiation (UC15). Here only the nominal traffic volume is evaluated.

The combination of all use cases has a very positive effect on the average delay, queue length, and impact. For example, already for 20% penetration rate of autonomous vehicles, there is a decrease of average delay by about 23%. For a penetration rate of 100%, there is a decrease of over 52 % (Fig. 6). On the other hand, it has a negative impact on the number of stops (Fig. 7) and CO2 emissions. This indicates that it might be advisable to apply the different use cases carefully for each traffic and network situation and also with respect to the expected impact on traffic. Minimizing the delay does not necessarily lead to most harmonized traffic flow.

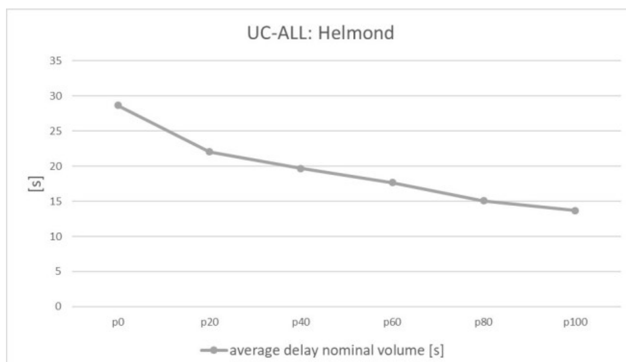

Figure 6: Effect of the combination of all use cases on the average delay

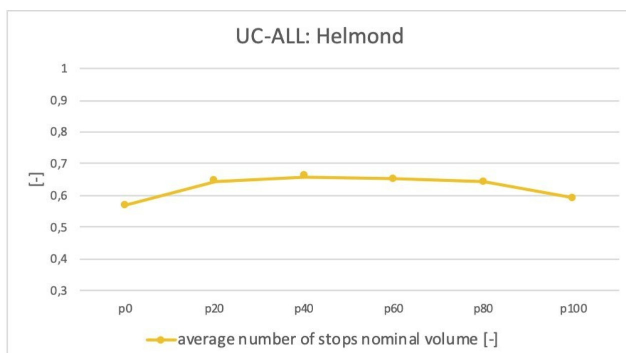

Figure 7: Effect of the combination of all use cases on number of stops

5. Conclusions

Cooperative and automated vehicles (CAVs) are often considered a mean to improve quality of life in cities. CAVs do not only serve as a new source of information (for example to estimate the queue-length at an intersection with higher precision), but through for example speed or lane change advisory or routing algorithms, they can make traffic more energy-efficient and fluent, and the traffic flow in the network more balanced.

This paper describes the impact of CAVs on a cooperative urban environment, resulting from a European research project - MAVEN. The evaluation covered different dimensions, including user surveys, field tests and simulations. Here, the results from a microscopic traffic simulation (using tool SUMO) demonstrating the impact on different indicators (such as number of stops, delay or emissions) are presented. One of the key advantages of this approach is in addressing the effects not only for different layouts or traffic volumes, but also for the transition phase, i.e. different penetration rates of CAVs.

We clearly demonstrate that a proper integration of CAVs into city traffic management can, for example, help with respect to the environmental goals and reduce CO2 emissions by up to 12 % (a combination of GLOSA and signal optimization). On corridors with a green wave, a capacity increase of up to 34% was achieved. Already for lower penetration rates (20% penetration of CAVs), there are significant improvements in traffic performance. For example, platooning leads to a decrease of CO2 emissions of 2.6% or an impact indicator by 17.7%.

The real impact of CAVs however depends not only on the algorithms used, but also on policies adopted. Some use cases can be aiming on contradictory performance indicators and it is crucial that traffic managers understand the big picture and integrate policies enabled by automation (car sharing, electro-mobility, and others). The findings can be used not only by other researchers but mainly by traffic managers and decision-makers in cities, as they can provide a better idea about the actual impacts of particular solutions in a cooperative environment and to help with the transition phase.

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Vessel Traffic Services (VTS) and e-Navigation to safely and efficiently connect Regions

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Abstract

Vessel Traffic Services (VTS) are shore-based systems to ensure safe and efficient flow of shipping along coast lines and from and to ports. They are standardized and regulated by United Nation's International Maritime Organization (IMO) with major contributing work from International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). VTSs serve as an additional safety barrier by contributing to the avoidance of maritime accidents and incidents. In the era of digitalization and automation shore-based services are becoming increasingly popular and an important tool to protect the marine environment. The Straits of Sunda divides the region of Western Java and Sumatra island. The straits serving national and international shipping and are characterized by high traffic density in its coastal waters, including crossing passage of the national heaviest ferry traffic. Consequently, it is one of the major safety concerns in Indonesia. Four accidents of ships' collision, grounding, and fire on board have been recorded in the area from 2011-2019 as officially reported by the national safety committee (KNKT). At the same time, VTS provides valuable services to mariners. The implementation of operational standards that comply with international rules and regulations, such as IMO Resolution A.857(20), and IALA Guideline 1111, should be further developed to benefit from the broader set of VTS function. A basic marine engineering study has been done to investigate the roles of Merak VTS implemented at Sunda Strait using German VTS operation as sample cases. In this respect, empirical studies were used to collect primary qualitative data and analysis of secondary data concerning the aspects of human element, the technical and administrative work. The research is to investigate how Merak VTS could potentially improve its contributions to traffic safety and in what way the new routeing and the mandatory ship reporting systems can be integrated to ensure positive effects. The outcome of first basic studies suggests that well adapted procedures, proper equipment, and especially well-trained VTS staff may provide a huge potential to further improve as well as optimize the operation of Merak VTS.

Keywords: Vessel Traffic Services, Sunda Strait, IMO, IALA, Qualitative Research, Human Element, Maritime Safety

1 Introduction

1.1 Shore-based support for Shipping - the development of VTS

World Trade is one main source of all developments of human lives and societies. Shipping is considered as the blood of world economy. According to [1] and [2] ninety percent of all goods are carried by ships via the several searoutes crossing the oceans and connecting regions. Safety and security are the overarching needs for an efficient and smooth flow of vessel traffic, especially in sea areas with high density of vessels of crossing searoutes. Originally, shore-based services were established to minimize delays and to ensure continuous traffic flow from and to the ports and harbours located some miles inside and away from river estuaries. Radar-based assistance was given to vessels off the coast and developed into vessel traffic services (VTS). It became obvious that such shore-based services may also be used as risk management tool, i.e. to reduce the number of accidents and minimize potential connsequences of hazardous events. The concern that a disaster might happen in approaches and port areas itself, furtherly expanded the use of shore-based radar surveillance and carefully organizing traffic flow to avoid potentially dangerous encounters of ships in inconvenient sections of fairways and sea areas [3].

On the other hand, usually, ship routing systems such as Traffic Separation Schemes (TSS) and recommended routes respectively, Ship Reporting Systems are being introduced to address safety concerns of coastal states. Finally, as one component of the maritime transportation system in port approaches and coastal traffic zones, VTS systems were introduced to support smooth traffic flow [5].

VTS are mainly established in national waters in order to protect the marine environment of a coastal state by monitoring vessel traffic and sending out information, warning, and advice or even instruction in case a developing risk or an existing danger has been recognized by an operator in a VTS centre. Nowadays, besides VTS, so called Fleet Operation Centres (FOC) are increasingly introduced. FOCs are operated by shipping companies to monitor vessel traffic, but they are specifically established to exclusively observe the safe and efficient progress only those ships belonging to the own company's fleet. However, so far, no guidance or procedures how to handle any potential relations between the VTS of a coastal state and a FOC of a worldwide operating shipping company exist yet [6].

In recognizing the ultimate value of VTS in managing of potentially high-risk geographic areas and protection of the marine environment, IMO has taken over to provide the legal frameworks for VTS operation. IMO's International Convention for the Safety of Life at Sea (SOLAS 1974), provides basics of VTS standards, rules and regulations for worldwide harmonized VTs operations. Masters of ships and officers of the watch respectively can expect a minimum level of similar procedures for interventions of any VTS into vessel traffic. SOLAS Chapter V: "Safety of Navigation" provides the foundation of when and it what way to implement a VTS and offers regulations as practical guidance for ships owners, crews and others to participate in IMO-recognized VTSs. The use of VTS can only be mandatory in territorial waters and shall follow guidelines as laid down in Resolution A.857(20) adopted by IMO. This resolution requires that any VTS shall have facilities allowing to interact with the traffic and respond to traffic potentially dangerous situations developing in the VTS area. The presently valid VTS guidelines differ between three main types of services:

- Information Service (INS),
- Navigational Assistance Service (NAS) and
- Traffic Organization Service (TOS).

Each of which has specific functional and operational characteristics. Moreover, IMO also describes also criteria for VTS, as well as for qualifications and training of VTS operators. Often reference is made to more detailed guidelines and recommendations developed by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA).

However, after more than twenty years of further technical and Technological developments this existing resolution is under revision by IMO [7].

Any IMO recognized VTS is providing information to vessels in the monitored area, by broadcasting via VHF radio or on demand of an individual ship.

1.2 VTS and e-Navigation

Currently, among others, there is a rapid increase of digitalization and automation in the maritime domain. The so-called e-Navigation concept is introduced by IMO. E-Navigation is commonly defined as the "harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment". E-Navigation focuses on better and more comprehensive support of the human operators. However, modern Information and Communication technologies (ICT) are not only core to the implementation of this concept but provide a solid platform for automation of maritime systems. The progressing digitalization further pushes ahead applications of integrated and automated systems to steer even large sea-going ships. However, e-

Navigation is aiming at more comprehensive and reliable support of the human operators on board and ashore by using electronic means. IMO member states are convinced, that the implementation of this concept substantially may contribute to improve and allow more strategic sea traffic management from ashore [8]. A collateral effect of the e-Navigation activities is the combination of digitalization and automation which supports the introduction of autonomous navigation and even unmanned ships. E-Navigation provides a perfect infrastructure for sophisticated automation on board and enhanced data communication between ship and shore of all the private and public service providers including VTSs.

1.3 Implementing VTS and e-Navigation in Indonesia

Indonesia is operating numerous VTSs and joins the development and implementation of the e-Navigation concept as well.
According to the Indonesian Directorate General of Sea Transportation (DGST) report released in 2018, significant traffic density that serves national and international shipping with crossing passage of the heaviest ferry traffic in Indonesia is the major concern in the Sunda Strait area. There have been collaborative actions between Indonesia and IMO to ensure the safety of navigation and to reduce the number of ship collisions by adopting the TSS and mandatory Ship Reporting System (SRS) [9]. On the other hand, the ecological, social, economic, cultural, scientific, and educational value, as well as international shipping traffic, are on the ascendency in the Baltic Sea area. According to the Baltic Marine Environment Protection Commission guide published in 2016, there have also been collaborative actions by coastal countries of the Baltic Sea to ensure the safety and efficiency in the Baltic, e.g., in regards to winter navigation and to protect the marine environment by adopting TSSs, deep-water routes, recommending pilot support, mandatory SRS, and particularly sensitive sea area [10].

Figure 1: Overview of Sunda Strait (Source: Pushidrosal Navy) and VTS operators at work in Merak VTS.

The research presented in this paper takes into account all those mentioned developments basically by referring to two previous studies, firstly, Praetorius: "Vessel Traffic Service (VTS): a maritime information service or traffic control system?" [5] and secondly Kuma: "Vessel traffic service as a maritime security tool: vessel traffic management information systems (VTMIS) in Ghana" [11]. The first study mainly addresses the everyday performance of the VTS system, especially how to increase and identify its service modeling. Meanwhile, the second study mainly discussed the contribution and capabilities of VTS, the shortfalls of its use and ways to overcome. The difference related to the research focusing on Sunda Strait aside the location, is that the previous studies did not analyze primarily based on the rules and recommendations.
Therefore, this study is more focusing on the implementation of rules in the operational procedures, functions, and technical equipment of VTS.
Sunda Strait where, among others, is characterized as a congested crossing lane. The hydrography chart of the Sunda Strait showing Merak and Bakauheni is presented in Figure 1, which has become the monitoring area of Merak VTS in Indonesia [12, 13]. Recently, three accidents have been recorded in the area with some fatal accidents of ships' collision and grounding from a total of 101 accidents in Indonesia between 2007-2018 [14]. In comparison with Sunda Strait in the same period, the whole Baltic Sea had six accidents from the total of 105 accidents in Germany caused by ship's collision, grounding, fire on board, and foundering. As depicted in Figure 2, Warnemünde VTS is covering vessel traffic in southern Baltic Sea area with its related ports [15].

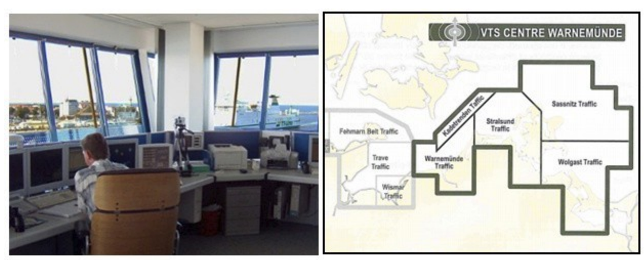

Figure 2: . Snapshot from VTS Warnemünde and schematic presentation of areas and sectors of Warnemünde VTSC. (Source: VTS Guide Germany, No. 2011, BSH, 2018).

Earlier studies obtained fleet data containing the composition of ship traffic from recorded AIS messages, as well as the fleet of ferries from ASDP Company. The recapitulated data in 2017 showed 47,575 vessels sailing in the Sunda Strait area showing some regular and irregular lanes of vessels. In 2019, there were 7,255 passengers and 767,582 tons of goods transported between islands by ASDP Company in which ports of Merak and Bakauheni play as two of the main ports with the highest contribution. They currently manage 35 ports, 246 routes, and 152 vessels through 29 locations nationwide Indonesia, exclusively two routes from Merak to Bakauheni with one port and nine ships.

Fundamental research for considering the establishment of routeing measures and ship reporting systems in Sunda Strait has been conducted by Sunaryo et al. [16] and Sobaruddin et al. [19]. Moreover, the official document of the proposal for the establishment of the routeing system has been submitted to IMO through NCSR 5th session [17]. Though, the research with a focus on everyday performance to highlight the service contribution to the safe navigation of vessel traffic within VTS approaches has not been conducted yet. That is why this study is significant and helping to understand better, how the optimal design, installation, and operation of Merak VTS potentially can more efficiently contribute to safety, efficiency, and sustainability of maritime traffic.

Establishing a VTS is usually a very complex process of implementing, optimizing, adapting and tuning technical components and takes into account the human element. The development and implementatition of operational procedures specifically drafted to ensure smooth interactive functioning of these elements are essential for this. Using the VTS for Sunda Strait in Merak and South Baltic VTS Centre in Warnemünde as a baseline, the ongoing study is to compare the operations of the two VTSs. The study aims at identifying potentials for improvement and optimization of operations in Merak VTS.

2 Baseline Studies for Comparison

First pilot studies have been carried out in order to benchmarking the guidance of IMO Resolution A.857(20) and IALA Guideline 1111 into the implementation of Merak VTS to monitor the vessel traffic in Sunda Strait. After figuring out the level of compliance with rules and regulations, the further study discusses the preliminary outcome of empirical investigations and elaborates on a case study, similarities, and differences between Merak VTS and Warnemünde VTS to identify areas with potential for improvement.

For the research in this study, data were collected from both primary and secondary sources. The primary data were collected through own participating observations and interviews. Meanwhile, the secondary data used are Standard Operational Procedures of Merak VTS by DJPL [13], VTS Guide Germany by BSH [15], the IMO Resolution [4], the IALA publications [3, 18], and literature [5, 21-23]. The rules from each regulation were categorized into three aspects to gain preliminary study and do further study afterward on the developed essential issues. The defined aspects are explained as below:

- Technical aspect contains all rules from chosen regulations in terms of technology and equipment.
- Human element's aspect contains all rules from chosen regulations in terms of staff recruitment, skills, and training.
- Administrative work's aspect contains all rules from chosen regulations in terms of procedures and responsibilities of Competent Authority.

The benchmarking has been accomplished by analyzing the Standard Operational Procedure (SOP) of Merak VTS, doing study visits, also conducting informal conversational interviews with Head of Merak VTS and the experts in the same VTS. The compliance with regulations was studied by providing implementations level within three categories and criteria, whether each of the rules has been "fully complied", "partially complied", or has "not been complied at all".

The IALA Guideline 1111 has not been mentioned nor adopted by Merak VTS on its SOP. Meanwhile, the Ministry of Indonesia adopted the IALA Recommendation V-128 as the standard of equipment for all VTS in Indonesia [22]. Nevertheless, this recommendation recognizes and refers to the IALA Guideline 1111 as the updated version and information for VTS systems. The guideline addresses the relationship between operational and technical

Technical	Human Element	Administrative Work
- General considera-tion for VTS	- General considera-tion for VTS - Objectives and authority - Framework - Prerequisites for the system - System parame-ters: Recruitment and selection, qualifications, training, certifica-tions	- General considera-tion for VTS - Guidance for plan-ning and imple-menting VTS - Determining skill and knowledge requirements asso-ciated with VTS functions
(Covered 4% of all rules)	*(Covered 54% of all rules)*	*(Covered 42% of all rules)*

Table 1: Overview Regulated Rules of IMO Resolution A.857(20).

performance requirements for VTS equipment. It presents system design, sensors, communications, processing, and acceptance, without inferring priority of VTS equipment [21]. The regulated rules subtracted for each of the three aspects is presented in Table 1, exemplarily.

Furthermore, a series of study visits to Merak VTS in Indonesia, as well as the Maritime Simulation Centre Warnemünde (MSCW) and Warnemünde VTSC in Germany has been carried out in order to looking for different approaches and intentions. Beside participating observation, we also conducted interviews on the phone and face to face meetings to develop essential issues from the conducted preliminary study. The study intended to investigate how is the implementation level of VTS by compliance with rules and regulations; to identify training scheme and operational procedures; to identify VTS capabilities in increasing maritime safety through navigation in the area, and derive recommendations for the identified potentials of the system. The main questions that were used for the interviews in both VTSs and the detailed version of the questions, which is guided by a questionnaire form, were provided and elaborated in the frame of this research project [20].

3 Selected Results

3.1 Compliance with IALA Guideline 1111

As technical issues becoming the focus of our research, this guidance is significant because it is clearly linked to VTS for most of the technical aspects. From the study, the graph compliance of the technical aspect in Merak VTS presented several levels of implementation. However, Figure 3 shows that most of the implementation of the technical aspect is fully complied with the rules, as much as 61% of compliance.

It is followed accordingly by 33% and only remaining 6% of the rules have been partially complied and not complied at all. Besides the technical aspect, implementation of administrative work and human element aspect in Merak VTS have 13% and 50% of full compliance with all rules in each aspect accordingly. Despite the lower full compliance compared with another aspect, the aspect of administrative work has 88% of partial compliance.

Some elements which detected to be not complied with this guideline are the environmental protection system, long-range identification and tracking (LRIT), satellite-based synthetic aperture radar (SARSAT), few of inter-system data exchange as part of the VTS data management, and trackwarning for air draught clearance as a function of decision support tools.

The environmental protection system requires the early detection sensors or software processing of the VTS radar signal to detect any pollution incidents that may be caused by visiting vessels. Meanwhile, the LRIT and SARSAT are the long-range sensors for locating or detecting vessels that

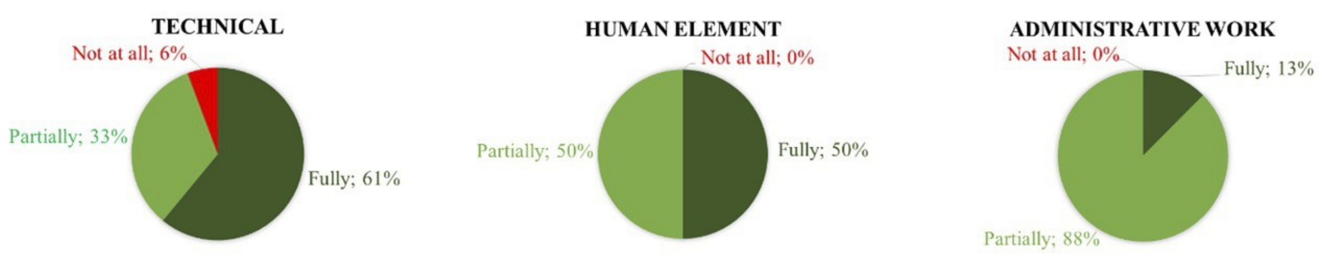

Figure 3: Technical, Human Element, and Administrative Work's Compliance with IALA Guideline 1111. Note: Score of 100% defines the particular aspect that has been entirely in accordance with this guideline.

have not arrived on schedule, arrive unannounced or even in case of an incident. According to this guideline, the tracking function and other data processing functions may need to be considered within the VTS design. Data processing is the collection and extraction of data to provide information. This VTS data management may include information such as voyage data, vessel data, incident data, and equipment fault records. The identified missing elements are the information of the data of berths and capabilities, traffic analysis data, and VTS spares and consumables stock.

The mentioned elements in this preliminary study were found to be not yet installed and were identified as not complying with the rules of IALA Guideline 1111. However, the upgrade and installation of such technical equipment to improve the compliance were on progress.

3.2 Implementation Level of VTS by Compliance with Rules and Regulations

According to the preliminary study, Indonesia, through the services of Merak VTS, has a relatively high compliance in the terms of human element and administrative work.

However, the technical aspects have shown the lowest compliance compared to others. Therefore, this section interprets the preliminary outcome of empirical study and discusses the aspects of rules and regulations governing the technical issues of system of Merak VTS.

The interviews found that the Merak VTS operators are trained according to the basic course for navigating vessel traffic through VTS area, which is the basic training as VTS operators according to the IALA VTS 103 Modules, the communication competency training according to the IMO Standard Marine Communication Phrases (SMCP), as well as the maritime radio communication training of GMDSS's General Operators Certificate (GOC) in accordance with the IMO. Though, the personnel who is a contracted employee had only been formally taken through the training of GMDSS GOC.

The Merak VTS is expected to be regulated by the requirements of the IMO. The IMO legislations such as in SOLAS Chapter V in regulation 12, guidelines contained in the Resolution A.857(20), MARPOL, and COLREGs. To carry out the duties as VTS personnel, they refer to the SOP of Merak VTS as the operational guide.

The participants of Merak VTS were all able to give a general structure of the nature of vessel traffic in the Sunda Strait area. Merak VTS covers one sector for the entire area of Sunda Strait from Java Island to Sumatera Island. Merak VTS monitors all vessels, the crossing route for the ferries and passing routes for all vessels. The ferries across the strait and connect the port of Merak with the port of Bakauheni in a day. The operation of the ferries had been monitored by the ferries company, namely ASDP Indonesia Ferry. Nevertheless, Merak VTS keeps on this monitoring. Although there is an available VTS near Bakauheni, namely Panjang VTS, communication between the VTSs had rarely been made.

All participants had been continuously made the coordination with some government agencies, which are port state control, port company, sea and coast guard, water police, Navy, search and rescue team, a port operator and agent, as well as the pilotage. The coordination has been done cooperatively and right in time to minimize the consequences of danger and prevent such an accident from being happened.

The core activities of Merak are monitoring and informing traffic, as defined for the INS of VTS. The VTS personnel can not actively organize the traffic and needs to rely on support from other services, such as the pilot service. It seems like there is no strict enforcement or fine is charged to the particular vessel when any non-compliance has been registered by VTS.

The interviews revealed that the Merak VTS staff has the basic infrastructure necessary for conducting decent surveillance on safety and maritime security in the Sunda Strait area. The communication devices installed in Merak VTS is VHF radio for communicating with vessels. The sensors available consisted of long-range camera, radar, and radio direction finder. These devices were installed on Merak VTS, Cipala Hill, Tempurung Island, and Cikoneng Lighthouse.

Currently, several types of equipment are planned to be installed for full operation, which are i.a. AIS base station, long-range CCTV surveillance, weather sensor, additional workstation units, VHF radio, and generator. At the time of the study, the weather forecast was taken daily from the

Indonesian Weather Forecast. Some of the existing equipment would also be changed or upgraded, such as the VTS software with alert systems, radar, medium-range CCTV surveillance, and power supply. This equipment is intended to repair or maintain the quality of existing equipment and to fully support the implementation of TSS in Sunda Strait in 2020. Moreover, Indonesian government plans to carry out an electronic pilotage (E-Pilotage) for four of Indonesian sea areas, However, Merak VTS is not yet included but may benefit from experiences gained during operation of E-pilotage.

4 Training Scheme for VTS Staff

According to the Resolution A.857(20), the competent authority should specify the level of skill and knowledge a VTS operator must have based on the background and prior experiences and should also consider the training requirements regarding the tasks to be performed. Authorities should be aware of the provided training by considering the prior qualification, skills and knowledge of the VTS staff in order to reach an equivalent skill and knowledge.

The applicable minimum qualification when entering the Merak VTS is having a formal education background in high school degree or equal, having two years of work experience, and ability to communicate in the English language before serving as VTSO. All of the study's participants have a high school or a higher degree, such as diploma degree or bachelor degree, and also have taken GMDSS's GOC before becoming a VTSO. Based on the interviews, all participants of Merak VTS had not had a mariners background. Most of them had a qualified civil servant background, which is Civil Servant Echelon II/b. In case of not having work experience prior to the recruitment process, this qualification is compensated as long as the person has graduated from a higher degree and has been accepted as a civil servant.

On the contrary, the German Authorities set comparably higher qualifications for its personnel to become the operator. All of the VTS staff had to have a mariners' background, have taken GMDSS's GOC and show their certificates prior to the recruitment of VTS staff. Therefore they have experiences sailing on board as the deck officer or equivalent according to the STCW. They also had to have graduated from a technical college for becoming an operator. Meanwhile, they had to have a university of applied science degree to become a supervisor. As for the language, the VTS staff had to have a basic command of the English language for VTSO and good command of the English language for becoming a VTS supervisor.

The stud in Germany shows that having a mariner's background is essential for any VTS staff. The personnel would have the intuition to the best practice of operation on board of a ship, what is needed in a specific sit, and how to manage such a situation in the monitored navigational area. Therefore, they have better focus and more goal-objective oriented to achieve the safety of the maritime traffic.

As identified by the expert interviews, the training system level in Indonesia is different from the IALA VTS 103 modules and could be provided by the government agency or the third party. Most of the time, the training offered to Merak VTSO is part of the BP2TL program, which was established by the Ministry of Research, Technology and Higher Education in Indonesia. The training for VTSO consists of a maritime English course, basic VTS course for 30 days, and a VTS operator course for 40 days. However, the VTS staff has to come into the selection phase to participate in such trainings.

On the other hand, the VTS staff in Warnemünde VTS Centre needs to have participated in a maritime English course, On the Job Training and VTS Operators Training according to IALA V-103 modules. All personnel also had to participate in the refresher training of V-103/5 once every two years to memorize the knowledge, especially the necessary skills during unusual operation situations. In

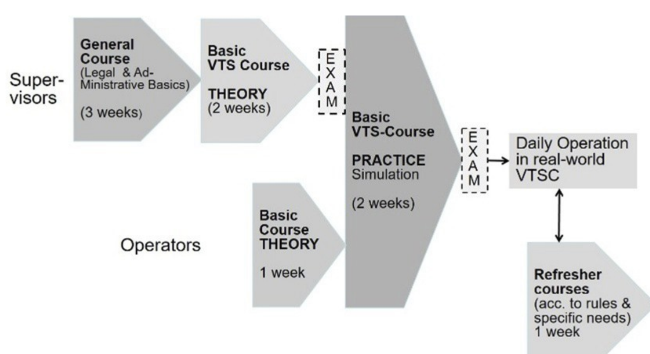

Figure 4: Training Scheme of VTS staff in Germany (graphic adapted from [20]).

addition, the VTS staff has to take part in VTS Supervisor Training of V-103/2 for upgrading a level into the supervisor. The training scheme of VTS staff in Germany could be seen in Figure 4.

5 Summary and Outlook

Comparative empirical studies of Indonesian Merak VTS in the Sunda Strait and the German VTS in Warnemünde monitoring vessel traffic in the South Baltic Sea have been carried out, in order to identify potentials for improvement and further development of VTS operation to address the challenges of increasing traffic density and ship dimensions. The focus of the studies was the technical and organizational aspects of VTS operations.

The main outcomes of the studies are the implementation level of Merak VTS in context of human element and administrative works is sufficiently in compliance with IMO Resolution A.857(20) according to expert opinions. However, the technical aspects showed lower level of compliance with IALA Guideline 1111. The provided services of Merak VTS and Warnemünde VTS Centre are in accordance with the need of each navigational area connecting the economic and cultural regions. The Merak VTS staff were trained according to IALA VTS 103 modules, but it has not been fully obtained by all personnel yet. The period of trainings as has been provided by the Warnemünde VTS Centre is significantly increasing the skills and knowledge of personnel. There is some lack of power to enforce regulations effectively and can be enhanced. From the outcome of the studies it seems to be necessary to adapt functionalities for better and broader monitoring and reporting.

The study very well recognizes that the comparison is made between a longterm operating VTS in Germany, which has undergone several phases of optimization during its course of existence. In comparison to this, Merak VTS is at an earlier stage of operation. Therefore, the recommendations are derived based on the research carried out so far, and none of the following recommendations are meant as criticism but intended to contribute to the potential improvement of existing VTS operation in the Sunda Strait.

- The results of the study suggest further assessment of the human element aspects in Merak VTS. The planning and establishing of systematic training and education for all categories of personnel will be beneficial for all the involved parties, which are VTS operators, domestic and international ships, as well as waterway and shipping administrations. It might also be beneficial to have additional employment of Merak VTS staff, especially the VTSO, to increase productivity and provide a better working environment. The higher employment also has to be in line with the appropriate training provided by IALA VTS 103 module course for the operator doing the required tasks, which may help resulted in a further contribution to maritime safety.
- The integrated collaboration of VTS and ferry companies seemingly may utilize the system of monitoring and communication, not only to manage the traffic and the vessels in the time of accidents but also to take prior action in preventing potential accidents from happening and maybe even contribute to efficient traffic flow without delays and supporting navigation regimes that minimize emissions from ships.
- For future developments, a higher level of services from Merak VTS seems to be possible and is recommended. Since TSS and mandatory SRS have been adopted by IMO, upgrading the services into NAS and TOS would greatly support the system's implementation.
- The study further recommends more regular communication between adjacent VTSs, such as Merak VTS with Panjang VTS, to significantly increase monitoring and reporting across the area. The distribution of information is also recommended to be done, for example, the automatically integrated database between adjacent VTSs or even all VTSs in Indonesia.
- The provided technical equipment provides already enhanced monitoring functions, such as for triggering warning for potential collisions or groundings. Extending the services and training of staff on how to make use of such functions

efficiently may also contribute to improve future VTS operation of Merak VTS and increase maritime safety.

The results gained from the baseline studies indicate that there is room for improvement. It is expected that the technical and technological developments in the field of shore-based monitoring, including e-Navigation and rapid digitalization, as well as more enhanced traffic organization, will soon allow or even requiring more pro-active traffic control in the sense of managing and coordinating vessel traffic. Consequently, operational procedures need to be further developed, and shore-based operators will have to be trained adequately to be well prepared for addressing their complex tasks to ensure the safety and efficiency of maritime transportation.

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