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Improved load planning of RoRo Vessels by adopting Blockchain and Internet-of-Things

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Abstract

Ports are vital to the global economy, as up to 90% of goods are transferred through seaports. With increasing vessel sizes, cargo volumes and higher demand for supply-chain optimization, seaports are required to be more efficient and competitive. In the present study, a proposed solution incorporating IoT and Blockchain is considered into automating many of the activities in the load planning process, which is then evaluated via simulation. Real data is collected concerning different types of cargo for RoPax vessels with the intended goal of reducing planning time in a seaport. The results contribute as one piece of the mosaic on the avenue towards becoming a "Smart Port", which deploys various digitalization technologies in order to become a fully automated port. The suggested approach to be integrated, builds upon IoT sensors in combination with the lightweight version of a Blockchain to improve balance indicators on a trim of a vessel. A developed simulation tool was used for evaluating a number of scenarios, with each scenario run set to 2500 times. The simulation results indicate an improvement of 50-160% from the current load planning operations for RoPax vessels.

Keywords: Port Automation; Blockchain; Simulation; Internet-of-Things; Ballast

1. Introduction

This paper investigates a major issues that is characteristic for numerous port and terminals serving RoRo type of vessels around the world known: how can the ballast water be efficiently and sustainable reduced through the improvement of the load planning process when serving ships. Using the Port of Karlshamn as part of a case study, a number of factors and decision variables were identified in helping to develop a solution for a more efficient loading of RoRo vessels.

The goal for many ports is to optimize various processes, as they are involved with modern technologies in their everyday routines, such as Blockchain and the Internet-of-Things (IoT). In this paper, we consider a port to be a "Smart Port" in terms of utilizing automation and advanced technology to improve its performance by including Artificial Intelligence (AI), IoT, and Blockchain (Natalucci, 2019). The concept of Smart Port is gaining more interest nowadays, since research on this phenomenon is expected to assist terminals in providing flexible and efficient operating means for identifying solutions for modern ports (Philipp, 2020a. In this paper the case study seaport Karlshamn is considered for inculcation of mentioned technologies.

Based on a number of interviews conducted with a shipping company operating in Karlshamn, Sweden, one of the major processes that identified for improvement was the load planning process for vehicles that are transported from one port to another via RoRo or RoPax vessels. RoRo is an acronym for Roll-on/roll-off. Roll-on/roll-off ships are vessels that are used to carry wheeled cargo. There exist different types of RoRo vessels, including ferries, cruise ferries, cargo vessels, and barges. The RoRo vessels used exclusively for ocean-wide transport of cars and trucks are known as Pure Car Carriers (PCC) and Pure Truck & Car Carriers (PCTC), respectively. RoPax is an acronym for a passenger being rolled-on/rolled-off, often with passenger accommodations.

During the registration process, vehicle owners provided measures for their transport – specifically: width, length, and height. Later on, these measures are used by shipping companies in the frame of the load planning process. However, often these measures are not correct, which affects work efficiency at terminals since it requires load re-planning which slows down the overall workflow. Another issue that affects the load planning process is the lack of information about incoming vehicles, such as their weight. Most of the time, the load planning of vehicles affects unbalance on the ship when heavier vehicles are placed on one side of the deck and lighter ones on another one. This issue appears due to a lack of information about the cargo. The unbalance on board can be solved by using ballast waters. According to the National Research Council (1996) the etymology of the word "ballast," meaning "useless load" in Middle Dutch, reflects the fact that since time immemorial ship owners have endeavored to avoid using ballast. However, ballast waters are used to compensate that weight unbalance and this, it helps to maintain the trim and stability on board, which is important for the safe sea voyage.

With regard to the ballast water management system, weight awareness is one of the most important indicators for load planning as it affects the balance of the whole vessel and thereafter the amount of ballast water that would be needed to maintain balance. Apparently, excess of ballast water leads to fuel wastage and additional issues when navigating the vessel. Thus, shipping companies are aiming to minimize the amount of the ballast aboard. Another reason to use less ballast water has an ecological motive since it impacts serious ecological problems due to the multitude of marine species carried in ships' ballast water. When a vessel is departing a port, water and any sediment that may be stirred up, is loaded into the ballast tanks and unloaded again when it takes on cargo at the next port. However, the process of loading and unloading untreated ballast water poses a major threat to the environment and public health as ballast water impacts the transfer of organisms between ecosystems, from one part of the world to another. The ballast water includes bacteria, microbes, small invertebrates, eggs, cysts and larvae of various species.

A method to reduce the amount of ballast is to plan cargo on the deck more evenly. Furthermore, it is possible to maximize the effectiveness by using the cargo itself as an effective weight for a vessel. It is assumed that the weight of the cargo would partly replace the weight of ballast waters. Thus, by adding vehicle weights to the planning system the process of planning would get drastically faster and smoother.

To answer the question of how to obtain data of each vehicle, measurement sensors and a scale connected to the IoT network is considered as a viable solution. The idea is to install the sensors at the check-in gate and a large scale beside it, which will collect the vehicle measures together with weight and transmit the information to the planning system. The main advantage of the IoT technology is that it is both physically small and fast enough to collect and pass the data to the planning system in real time. Nevertheless, it has a major drawback, known as information leakage. In order to secure the data, a possible solution is to encrypt the data on its way to the database. The data should not be retained forever but be purged from the database as the ship leaves the port.

The paper is structured as follows: A theoretical background is provided in the next section. In section 3, a description and discussion about RoRo shipping is presented. Within chapter 4, the methodology is set out, which contains a roadmap on how the research was conducted, as well as includes the quantitative and qualitative methods applied. In section 5, the description of an experimentation phase is presented. In the frame of section 6, an analysis on the simulation results is conducted, including validation and verification that allows to suggest the optimized solution for a more efficient loading system of ships. Finally, in section 7, a discussion and conclusion with pointers for future research is presented.

2. Background

Seafaring is an effective and convenient way of transportation for larger cargo and it is commonly used by logistics companies. Transportation of goods and passengers by sea is represents 90% of the total volume of international traffic, which is more than 60% of the total global freight turnover (Statista, 2020). This mode of transportation is the best cost-effective way for transcontinental exchange of freight. For many countries maritime transport is the main sector of the economy, since it provides global connection.

Hence, many economic benefits are associated with well-functioning seaports as they are lowering the costs of trade, generating added value to the surrounding industry and contribute to employment. Doubling port efficiency of two countries is found to increase their bilateral trade volume by 32% according to the study from Merk (2010).

Despite all the advantages, this kind of transportation has, there exist also several disadvantages. One of them is the duration of time to transport goods from point A to point B. Thus, sea transportation is characterized by the lowest speed of transportation. At the same time, the duration of the movement of goods by a sea vessel is not significantly affected by the speed of the vessel itself, but by the time required for loading and unloading operations in the seaports (ICC, 2016). Thus, improvement of these operations is expected to affect positively the costs of maritime transportation.

To help ports work more efficiently is deemed possible through innovations and new technologies, insofar they improve the quality of ports operations. There exist factors that may affect effectiveness of seaports, which can be categorized into two groups: the quality of inputs such as labor, equipment and land, and the quality of organization and institutions, which implies port planning. Latest technologies, modern ship design as well as special systems developed for loading/unloading cargo at ports are providing the reduction of the final price of maritime transportation. Thus, good port planning can have an important impact on the overall port performance. In this context, two research questions were identified:

How to minimize in a sustainable manner the usage of the ballast water on RoPax vessels?

How can the combination of Blockchain and IoT improve the workflow of small ports or terminals that focus on RoRo cargo?

The first question aims to pinpoint an optimal solution for minimizing the ballast water by considering different types of approaches. With regard to economic aspects, the conducted expert interviews with top-level managers from Det Forenede Dampskibs-Selskab A/S (DFDS) revealed that the abundance of ballast water is the key reason for waste of fuel and obviously something they are willing to improve. This motivated the research to find a solution to reduce ballast water by improving the process of load planning. It is expected that by providing more data about the cargo, the planning process would become more efficient, since – for instance – especially the weight of the cargo plays the key role in the suggested solution. Furthermore, by using the simulation method, it will be possible to test whether the usage of the IoT sensors affects the amount of ballast water needed to maintain the balance aboard or not.

The second question addresses the employment of a combination of aforementioned technologies – here: IoT and Blockchain. Since both of these technologies are relatively new (Moldabekova et al., 2020; Moldabekova & Philipp, 2020), there is a risk of contractionary information from different sources. Also, they are not commonly used along smaller ports, which casts doubt on its actual potential and evaluation (Philipp et al., 2018). However, the conception of the IoT and Blockchain in ports is growing and getting more popular, since it is a core of automation, which most ports aim to achieve (Gerasimova et al., 2021; Philipp, 2020b; Philipp et al., 2019a & b). Nevertheless, each of these technologies has drawbacks, which implies to analyze the mentioned technologies and understand their real potential before suggesting them to seaports and shipping companies.

The IoT suggests having a major impact on efficiency of terminals. In the suggested concept for improvement, it plays a major role, since it provides needed data to the planning systems. The main disadvantage of this technology is the potential data leaking, which points to the suggested use of a Blockchain. In the present study, the related question of appropriateness will be answered by having a closer look on related literature and previous research studies. Secured data is vital, especially for seaports, where leaking data might create a range of risks. For instance, in this context, the WEF (2020) points out that this data could fall into the hands of cyber criminals, if it is not collected and stored appropriately, or the risk of being abused by data brokers. In both cases, the misuse of this data could be to create physical and psychological harms. Hence, for such reasons, data security is one of the most important issues in the context of the digital transformation towards becoming a smart port (Philipp, 2020a; Philipp et al., 2020a).

3. What is RoRo?

Roll-on/roll-off (RoRo or Ro/Ro) is when cargo is "rolled on or rolled off" from and to a ship. The vessels are designed to carry cargo that is wheeled, such as cars, trucks, railroad and project cargo on trailers that are driven on and off the ship on their own wheels or by using a truck. As the RoRo vessels are operated either via built-in or shore-based ramps that allow the cargo to be efficiently rolled on and off the vessel when in port, it is often viewed as a less expensive port investment when compared to container operations. While smaller ferries that operate across rivers and other short distances often have built-in ramps, the term RoRo is generally reserved for large ocean-going vessels.

When analyzing the operations in a seaport there exist a large number of interrelated variables that need to be taken into account. Thus, it is advisable to consider terminals as continuous production systems, made up of a succession of separate stages or subsystems, where each must be optimized in order to increase the overall performance and to avoid any possible bottleneck. This perspective on terminal's operation allows focusing on each single process separately and helps understanding, improving and ultimately determining the capacity of each subsystem and the terminal as a whole. Most authors, such as Henesey (2006), consider that the operation of a terminal can be divided into main subsystems, which roughly correspond to the distinct physical areas in the terminal: loading/unloading from/to ship to/from shore; transfer (from berth to storage area); storage; and delivery and receipt – depending on the kind of traffic/terminal being dealt with. RoRo terminals are usually incorporate three subsystems only (cf. Figure 1).

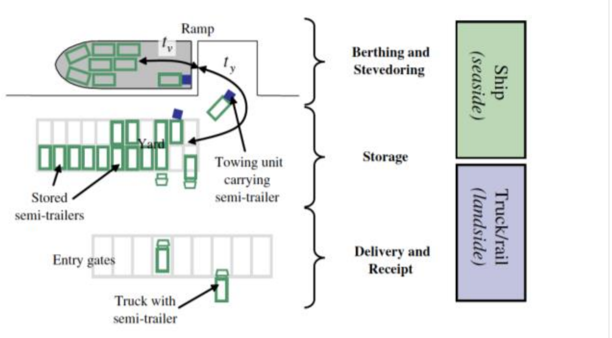


Figure 1. Operation Types in RoRo Terminal (Morales-Fusco et al., 2010)

Increased complexity of this system is observed due to entwined cargo and different stakeholders. An example, the workflow for RoRo operations is presented in Figure 2 (Henesey, 2019), which indicates that many (often simultaneous) operations and processes are executed.

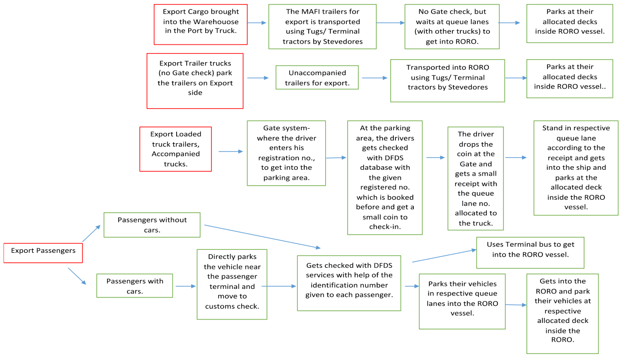


Figure 2. Workflow RoRo operations

In the distribution of digital technologies for transport, such as Blockchain and IoT, small and medium-sized ports and their service portfolios are argued to be very limited, not shared and not integrated on the cross-border level (Philipp et al., 2018). Although, the Baltic Sea Region (BSR) is considered a forerunner position in Europe (Gerlitz et al., 2018; Philipp et al., 2020b & 2019c), a recent EU-funded study that was conducted within the INTERREG-project Connect2SmallPorts, generated results that concluded very differing digital readiness of ports in the BSR – e.g. ports of Wismar and Stralsund (Germany), Karlskrona (Sweden) and Klaipeda (Lithuania) (Philipp, 2020a). Most of the small and medium-sized ports still pursue the classical infrastructural path without any clear vision and digitalization strategy. Hence, the performance and development gap concerning digitalization between small and medium-sized ports in comparison to large ports on the avenue towards becoming a smart port is considerable grave (ibid.).

4. Methodology

The research study builds upon qualitative and quantitative data. Thus, the respective qualitative and quantitative results were applied and combined according to triangulation methodology to resolve tentative weaknesses or intrinsic biases related to the research questions, as well as by following Altricher et al. (2005). Initially a systematic literature review was performed using databases and websites such as ResearchGate, Scopus and Google Scholar for the identification of either different approaches that target to minimize the ballast water on RoPax ferries, or studies that focused on ports and digitalization in general and different novel technologies in particular (cf. Henesey 2019). Furthermore, in the frame of the qualitative data gathering process, expert interviews with top-level managers from DFDS were conducted. The structured expert interviews had been carried out in February 2020. The interviews lasted about 1 hour and were recorded and transcribed. The interview analysis was conducted according to Kvale (2008) and Miles et al. (1984). In the course of qualitative data analyses, experiments using simulation method based on the case of Karlshamn port had been conducted. This includes the execution of verification and validation of the simulation model and the results. For this purpose, a final concluding expert interview was conducted with DFDS in order to obtain credibility and confirmation of applicability regarding the results.

Thus, the first step comprised a number of interviews with DFDS in order obtain information. These interviews provided a problem description and its consequences. Furthermore, a potential solution of sensor usage was suggested to DFDS in order to set a start point for the subsequent research activities. The IoT technology was studied and identified as one of the best options to achieve improvements in ports' workflow regarding the intended purpose of optimizing the load planning processes. The detected major advantage that convinced can been seen in the fact that this technology enables to automate the load planning in real time. As a consequence, it allows to make the port more efficient, enables to save time and financial resources, by reducing in the long run the amount of needed ballast water during each vessel journey. However, these first insights automatically induced another contradictory complexity, which can be seen as data security issues. Hence, the major drawback is the lack of security on privacy, which means information leakage – despite all the advantages this technology has, such as: speed (i.e. data transmission in real time), automation (i.e. lower manual works), and thus, cost reductions and improved information flow.

Accordingly, based on the literature review findings, it was exposed that the Blockchain technology has the potential solution to numerous problems such as: insufficient availability of cargo monitoring and lack of transparency resulting from poor data handling (Henesey, 2019). Hence, Blockchain has a range of advantages, which may bring diverse benefits (Fridgen et al., 2018; Kouhizadeh & Sarkis, 2018): 1. decentralization, 2. transparency and auditability (through tamper-proof process history), 3. data integrity, security and immutability.

Nevertheless, also this technology has some challenges. For instance, Blockchain developers are rare (Paybis, 2020), which makes the Blockchain implementation difficult to execute. Moreover, this technology demands a very powerful computer, which requires significant financial resources regarding procurement and maintenance. Hence, it was concluded that a combination of the IoT with a light version of a Blockchain could have a suitable potential for smaller seaports. After analyzing the gathered information from DFDS and related studies, the next step was to build a simulation for analyzing the suggested solution.

5. Preliminary Model Considerations

A simulation model was developed and programmed in C++ language for replicating a load planning process in conducting simulation experiments. The first scenario simulates the process without IoT, i.e. without the comprehensive information about incoming vehicles. The general data, such as length and width of the incoming vehicles is used. Based on these measures, the current system places vehicles on a deck according to their size, under the assumption that larger vehicles are heavier and vice versa. The second scenario considers additional data about each vehicle. The assumption is that the IoT sensors and scale provide more accurate measures about the vehicles, including their actual weight. This scenario allows to place the vehicles more correctly, because the exact weight and dimensions for each vehicle is known. Important to mention is that both scenarios are dynamic. This means that vehicles arrive at different times and thus, must be assigned and placed in the vessel at the moment of arrival.

Regarding the second scenario, when a new vehicle arrives at the check-in gate, IoT captures its parameters and sends it to the cloud-based planning system and the underlying blockchain, which then assigns the vehicle to a specific category and thus, lane on the vessel. Hence, also within the second scenario, each lane on the deck is allocated for a particular category of vehicles, but this time structured according to the actual weight of the vehicles and not their size. In order to arrange the distribution in the simulation model, every lane was given a priority number, whereby each priority lane has exactly the same mirrored line with the same priority number. Figure 3 shows how the lanes are configured inside the RoPax, which forms the base for load planning management.

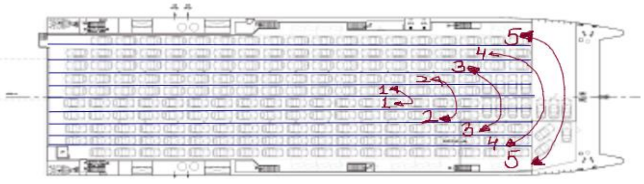


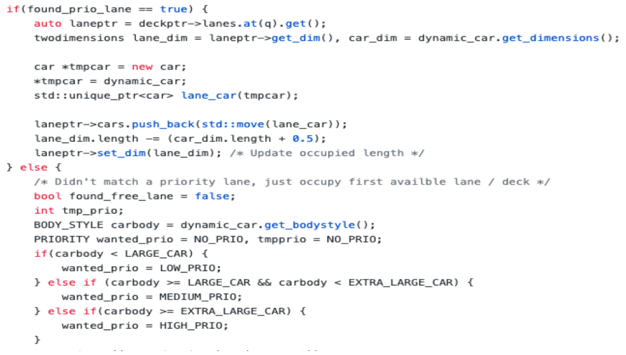
Figure 3. Diagram of lanes in a RoRo vessel

Vehicles in the simulation model, before placing on the deck, are assigned to a corresponding priority lane. Thereby, two lines of the respective priority lane are checked for already parked vehicles. After summarizing the weight of vehicles on each line, choice will be made in favor of a lighter line for the new vehicle. This method allows to stow cargo weight evenly on the deck, leading to less ballast water. The middle of the deck has the highest priority, which implies that heaviest vehicles are stowed. According to Sea Freight Safety Rules and expert interviews with DFDS, such a distribution is safer, since it provides stability by fixing the center of gravity. In order to compare the results of these scenarios, a calculation for balance indicator was conducted. The results of this simulation model with two scenarios helps to explain the influence that IoT and Blockchain combination could have on a port and its workflow in the frame of load planning processes.

6. Simulation Model Results

Within the model, the scenarios are compared by using the same randomized data as input. This implies that there are two scenarios that are implemented in such a way that they produce similar results, whereby for the purposes of comparison a metric for the total ship balance is used, which is an absolute figure. The model is auto-validating itself against the contemporary design. Hence, if the new model design produces worse metrics than the traditional model design, one can easily draw a conclusion that need to validate against a "0-hypothesis" is superfluous and an "Ding an sich" (*I. Kant, prolegomena to any future metaphysics that will be able to present itself as a science*).

A final interview was performed as part of the verification process with DFDS in order to gain assurance that the simulation has valid input variables and results of the measures are correct for the load planning process. For the simulation model 320 vehicles of different sizes and weights were used for the load planning on a double deck vessel with 8 lanes per deck. Each line is 153 meters long and 3 meters wide. The choice of weight ranges is motivated by the curb weight data and the corresponding permitted load for each type of vehicle. Thus, this input is realistic. The curb weights for different types of vehicle were provided in a spread sheet form. Additionally, the class "carpool" is created in order to keep a range of vehicles from the class "car". Each deck contains several lanes, whereby each of these lanes are assigned with priority numbers in the class "lane". Lanes in the middle are given higher priority than the outer ones, which are assigned when instantiating the class deck. On each deck, each priority lane is represented by two lines. The vehicles are assigned and placed to the lanes according to their priority number. In case of the first scenario, the bigger vehicle the higher is the assigned priority lane, which means that the bigger vehicles are placed in the middle and smaller ones on the sides. The logic can be found in Figure 4.



```
if(found_prio_lane == true) {
    auto laneptr = deckptr->lanes.at(q).get();
    twodimensions lane_dim = laneptr->get_dim(), car_dim = dynamic_car.get_dimensions();

    car *tmpcar = new car;
    *tmpcar = dynamic_car;
    std::unique_ptr<car> lane_car(tmpcar);

    laneptr->cars.push_back(std::move(lane_car));
    lane_dim.length -= (car_dim.length + 0.5);
    laneptr->set_dim(lane_dim); /* Update occupied length */
} else {
    /* Didn't match a priority lane, just occupy first availble lane / deck */
    bool found_free_lane = false;
    int tmp_prio;
    BODY_STYLE carbody = dynamic_car.get_bodystyle();
    PRIORITY wanted_prio = NO_PRIO, tmpprio = NO_PRIO;
    if(carbody < LARGE_CAR) {
        wanted_prio = LOW_PRIO;
    } else if (carbody >= LARGE_CAR && carbody < EXTRA_LARGE_CAR) {
        wanted_prio = MEDIUM_PRIO;
    } else if(carbody >= EXTRA_LARGE_CAR) {
        wanted_prio = HIGH_PRIO;
    }
```

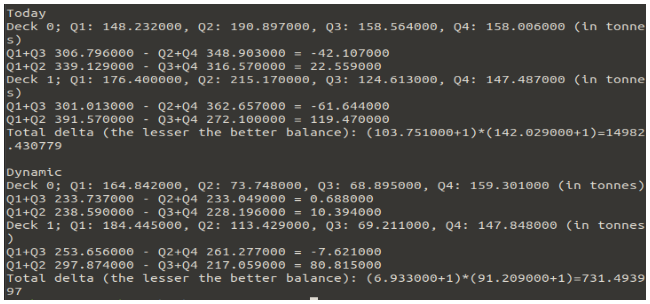
Figure 4. Logic in the RoRo simulator

In the second scenario, weight of in-coming vehicles is obtained, which is different than in the first scenario. Heavier vehicles are assigned higher priority lanes. First, the vehicle's category in the Look-Up-Table is checked, then appropriate lanes are cross-checked against existing weight in order to assign a line in the appropriate lane. The vehicle is placed on the "lighter" line of the lane. This ensures even distribution of the vehicles' weight on the two decks. To display the outcomes of these scenarios, each deck was divided into four equal quadrants: Q1, Q2, Q3 and Q4. Subtracting a total of Q1 and Q3 with Q2 and Q4 displays the balance indicator for the vessel's length (ΔL). Similarly, the balance indicator for the vessel's width (ΔW) can be found by subtracting a total of Q1 and Q2 with Q3 and Q4. When both deltas are known, their multiplication can be used to determine the general balance or unbalance of the ship. In a perfect scenario, delta should tend to zero. In Figure 5, the results are identified as either: "Today", representing the current or traditional solution by building upon the vehicles' size, and "Dynamic", which is the proposed solution that builds upon real-time data including vehicles' weight. The suggested calculation sequence is as follow:

$$\Delta L = (Q1+Q3) - (Q2+Q4) \quad (1)$$

$$\Delta W = (Q1+Q2) - (Q3+Q4) \quad (2)$$

$$\Delta = \Delta L * \Delta W \quad (3)$$



```
Today
Deck 0; Q1: 148.232000, Q2: 190.897000, Q3: 158.564000, Q4: 158.006000 (in tonne
s)
Q1+Q3 306.796000 - Q2+Q4 348.903000 = -42.107000
Q1+Q2 339.129000 - Q3+Q4 316.570000 = 22.559000
Deck 1; Q1: 176.400000, Q2: 215.170000, Q3: 124.613000, Q4: 147.487000 (in tonne
s)
Q1+Q3 301.013000 - Q2+Q4 362.657000 = -61.644000
Q1+Q2 391.570000 - Q3+Q4 272.100000 = 119.470000
Total delta (the lesser the better balance): (103.751000+1)*(142.029000+1)=14982
.430779

Dynamic
Deck 0; Q1: 164.842000, Q2: 73.748000, Q3: 68.895000, Q4: 159.301000 (in tonnes)
Q1+Q3 233.737000 - Q2+Q4 233.049000 = 0.688000
Q1+Q2 238.590000 - Q3+Q4 228.196000 = 10.394000
Deck 1; Q1: 184.445000, Q2: 113.429000, Q3: 69.211000, Q4: 147.848000 (in tonnes
)
Q1+Q3 253.656000 - Q2+Q4 261.277000 = -7.621000
Q1+Q2 297.874000 - Q3+Q4 217.059000 = 80.815000
Total delta (the lesser the better balance): (6.933000+1)*(91.209000+1)=731.4939
97
```

Figure 5. Results "Today" vs. "Dynamic"

In order to achieve an accurate comparison within the model, each scenario was run 2,500 times, whereby the average value was counted. The output shows the difference of the balance indicator, which yields 62.877%.

7. Evaluation of Simulation Results

In response to the first research question: *How to minimize the usage of the ballast water on RoPax vessels*; on first glance, the answer seems trivial - by obtaining more data about the incoming vehicles, its possible to achieve more reliable load planning, which may reduce the need of ballast water significantly. Past studies have shown that ballast water is needed for vessel safety. However, excessive amounts of ballast water are still seen as a useless overhead. Hence, on the basis of the present study, it can be stated that for the aspired reduction of the extra amount of ballast water, the usage of IoT sensors and scales can be suggested as an appropriate measure for obtaining more reliable data and thus, to improve the load planning processes of RoRo vessels. The obtained simulation results confirm this. The results from the IoT scenario show approximately a 50%-160% better balance indicator.

Concerning the second research question: *How can the combination of Blockchain and IoT improve the workflow of small ports or terminals that focus on RoRo cargo*, the issues related to maintaining or improving the workflow, planning system and end results should be seen as different parts of one unity. Having a fault-tolerant, redundant, backup-solution with a cloud architecture will integrate these parts with the IoT parts in a clean and efficient way, where a gateway/firewall function needs to be setup for controlling different roles when communicating with the IoT devices or other devices that are not physically or virtually part of the cloud per se. Some sort of cryptographic authentication needs to be implemented for the external devices to be able to further send/receive encrypted data. The most common examples are LDAP and kerberos, which are often used in tandem as in Microsoft Active Directory. Concerning the speed of data transmission in case of terminal's workflow, IoT applications do not have an impairing influence. This technology opens up particular risks: data security and privacy concerns, untrustworthy communication, sabotage, access to sensitive data, power outage / hardware failure, etc. Since Blockchain provides better traceability, it solves the privacy and security issues. Nevertheless, Blockchain applications lead to delays in data transmission and an increasing overhead on a year-to-year-basis. In case of seaports and the terminal's workflow, this potential risk must be evaluated as grave. Furthermore, implementing this technology is expensive and demands highly skilled software engineers as well as hardware resources. Cryptography has shown during the last three decades that it is difficult to implement correctly and to avoid implementing side-channel attacks on a speculative CPU like the ARM (and worse x86) that is popular in IoT. Exempli gratia are the side-channel issues in implementations of the WPA3 security protocol used in 802.11 WiFi (Vanhoef & Rone, 2020). The combination with a Blockchain offers an opportunity to minimize these risks. It is per se a reliable technology; however, since a Blockchain by nature becomes slow over time, it may affect the workflow in the terminals. Thus, a lightweight version of Blockchain technology is suggested an optimal solution.

8. Conclusion and Future Work

According to the results of the present study, it can be concluded that an optimized load planning process can improve the usage of the ballast water by 50%-160%. Hence, it can be recommended to implement IoT sensors and scales into the load planning system. In order to tackle the related data security issues, also a combination Blockchain can be generally suggested. However, concerning the latter case, the implementation requires powerful hardware and experienced developers. By taking into account these and other flaws of the Blockchain technology, a potential alternative was identified by a lightweight version of a Blockchain.

However, future research activities should target to investigate whether a lightweight version of a Blockchain bears the potential to reduce the overheads and remedy the main shortcomings of a Blockchain in an appropriate manner. For instance, the fundamental problems with using Merkle trees on an ever-growing dataset must be solved. In this context, some kind of purge mechanism should be in-place, whereby the concept of a cyclic Blockchain, where new data is automatically replacing old data could be an appropriate alternative solution. Further issues are related to economic aspects. Before investing into the implementation of a Blockchain, it is important to investigate the costs and benefits. Savings may include fuel consumption and employment reduction due to the transition to process automation (Henesey & Philipp, 2019). Another important aspect to be considered is the customer willingness to have their vehicles measured. One way to minimize the risk is to let the customer use a hash token to access the measured data online, which would improve the transparency. How the token should be shown to the customer, be it a billboard or something on the receipt when registering the vehicle, is an issue that is left open for future discussions and research activities.

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