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By this point I’m sure you’ve heard plenty about 5G’s potential, but relatively little about its application. That’s certainly been the case with me. This is why myself and Port Tech MD James Khan sat down towards the end of 2018 and decided we’d have one of our new e-Journals focussed directly on the topic.

5G is really the foundation of the future and this is why our front cover presents 5G in big bold letters in the centre of the page, with AI, ML (machine learning) and Exponential Tech following on. These spheres will boom when high-powered and stable 5G networks come into play, and this hierarchy very much harmonizes with the composition of this edition.

As soon as I began sourcing authors for edition 83, I knew it was going to be a landmark issue. With a blend of thought-leaders (Deloitte and INFORM), innovators (Shachar Tal), academics (Dr Leonard Heilig and Dr Eduardo Lalla-Ruiz), and a telecoms giant (Telefónica) offering ground-breaking insight into the issue of 5G and its attendant exponential tech means we’re delighted with this well-rounded offering.

The edition wouldn’t be complete however without a leading port voice, and we have secured that in the shape of the Port of Hamburg – one of the world’s leading smart ports and one of the pioneers of 5G in the maritime sector (as their paper herein explains).

This e-Journal will be our last online publication this quarter before our Container Terminal Automation Conference (CTAC) in London, which takes place from 6-8 May, 2019, and many of the papers in this edition will provide a nice foundation for many of the key debates at CTAC. With this in mind, please imbibe the key information herein and formulate your questions and comments for the event.

I hope you enjoy this edition.

Richard Joy
Editor

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This paper discusses various types of business use cases of IoT and 5G and outlines how relevant they are to digital ports, connected infrastructure, connected port ecosystems, and connected human and cybersecurity. With the rapid digitization of the transportation and logistics (T&L) network, traditional supply chain thinking – being linear and independent – is giving way to an interconnected, open system of supply operations: data now flows from a port’s authority, through the terminal operator, and then to the shipping line in a real-time dynamic way.

Within the wider T&L sector, companies have begun experimenting with a range of connectivity and data-enabled technologies. In aggregate, these technologies form the Internet of Things (IoT), which represents a convergence between the physical and digital worlds, ultimately using data and artificial intelligence (AI) as a source of value. As AI standardizes across industries, becoming an AI-fuelled organization will likely be necessary for survival. This means rethinking the way humans and machines interact within working environments such as ports and shipping. Supporting the connectivity of a new technology ecosystem is one of the three primary 5G use cases – the other two are capacity enhancement (mobile broadband) and ultra-high reliability (low latency). However, there are still several bottlenecks that need to be addressed prior to the intended 5G launch in 2020. Leveraging technologies in this context requires fully embedded technologies at the core of the organization. The new disruptive and innovative environment of today requires mastering the art of change to transform and create a meaningful business impact.

**AREAS OF OPPORTUNITY**

Combining IoT and the tremendous technology enabler that is 5G creates many opportunities to be seized in order to be truly ahead of the game. Even though IoT and 5G are at the peak of (inflated) expectation, they are not yet at their plateau of productivity. Thus, many organizations have started to implement their own proofs of concept. High investments are spurred on by the belief that it is the best – and only – way to innovate, grow and execute operations in the most efficient and productive way.

These selected business cases are examples of active solutions in the port environment with promising results. It is important to
note that digital implementations follow a two-phased approach. Firstly, operational implementation, and then, new business model development. We therefore believe that innovation should always follow strategy and not be out of fear of missing out.

CONNECTED INFRASTRUCTURE

IoT is creating a connection between port assets (vessels, containers, cranes) and a vast amount of data. This is leading to intelligent terminals, with total automation as the ultimate goal. This can be achieved through new technology applications such as drones (monitoring discharges, asset inspection), robots and ‘cobots’ (managing and delivering goods), sensor technologies, mobile equipment, video analysis, wireless RF technologies, and 3D printing (repair and maintenance of parts and accessories).

The efficiency of all these new technologies will also increase with better network connectivity. The biggest advantage of 5G is not its speed, but its capability of transporting vast amounts of data simulations. Hence, these new 5G-powered technologies are one of the future building blocks of digital ports. The connected smart camera in the Port of Antwerp for an intelligent wharf wall is one example.

CONNECTED PORT ECOSYSTEM

Smart port technologies are digital, multi-stakeholder systems that support basic infrastructure, as well as, for example, tools for handling cargo, managing traffic, dealing with customs, assuring safety, and monitoring energy use. Intelligent technology is currently helping the port ecosystem transform from a simple logistics and transport node to an open and efficient community that can participate in the global landscape of integrated world trade – in other words, a connected port ecosystem. This entails various features such as a further improvement of operational efficiency – e.g. automation in port operations and smart machines (e.g. predictive asset maintenance, assets as a service), as well as the enlargement of the scope of services beyond container handling.

Ports will collaborate and cooperate with all parties along the supply chain to completely link land and sea transport nodes, providing consignors, logistics companies, shipping companies and other alliances with high-quality services (such as TradeLens). Moreover, a connected port will be able to extend it’s business scope by fully utilizing its unique advantage, namely that it is in the centre of the supply chain. Growth will be driven by the collection, analysis and integration of information on all aspects of the supply chain, giving rise to novel industry insights. These benefits will build capacity in convenient, smart and reliable operations, as well as reliable customer experiences and efficient organizations across entire supply chains. For example, the Port of Rotterdam has created a coordinated system with international supply chains and operating networks (e.g. inland terminals, port terminals and inland transport) with clear points of entry.

CONNECTED HUMAN

IoT is connecting things to things but also humans to things and vice versa. We can become connected to everything, from ships to intelligent interfaces, right through to wearables aimed at improving safety and locational awareness. However, how can a human be connected to a ship? The cruise company MSC just achieved this by launching their new programme: MSC for Me. As part of this initiative, one of their vessels is fitted with 16,000 points of connectivity, providing a full digital integration for the customer (book an event, contact the crew, locate their children, and so forth). All this is possible through your
mobile phone or tablet, which connects to MSC’s smart system. This human-IoT link can also be applied to the wider port industry. Intelligent interfaces such as voice recognition are now proliferating in warehouses, customer services and field operation deployments. Technicians use voice-enabled wearables to interact with company systems and staff without having to hold a phone or printed instructions. Intelligent interfaces offer opportunities to us humans to interact with technology, information, and our surroundings. A similar port related business case is built upon connected safety devices like smartwatches which enable safety officers to track worker’s locations in remote areas. This is very useful for emergency and security situations.

**CYBER SECURITY**

Cyber security is a growing storm, it is one of the biggest challenges of the digital age with 70 billion connected devices expected by 2020. This means 70 billion potential windows for a cyber-attack. AI technologies and cyber-analytics can be used as protection against this threat. Such instances include anomalous behaviour detection that helps identify data access activity and malicious application activity by focusing on user logins, changes in user behaviour, and unapproved changes. AI can monitor activities and entities to establish ‘normal’ behaviour and detect sources of anomalies such as fraud, drug trafficking, money laundering, and insider threats. This technology is used to identify anomalies in AIS data from ships in order to detect illicit activities. Another preventive technology against cybersecurity is threat hunting: by importing known tactics, techniques, procedures, and attack patterns, threats are neutralized early in the attack cycle. Threat hunting can also be done by performing preventive analytics on security data to determine vulnerable entry points and the likely path an attacker might use to gain access. This approach is mainly used in cyber threat prevention centres and is already implemented across major ports in Europe and North America. Given the importance of cybersecurity, a good strategy is to start small and scale fast. The key is to develop a practical strategy in applying AI technologies and analytics by identifying opportunities with high impact, low complexity, readily available data, and insufficient capabilities in place.

**THE WAY FORWARD**

It may soon become rare to find an organization that does not make some use of the IoT and AI potential. It is clear that new technologies are disrupting business as we know it with ports slowly becoming aware of this. With an increasing number of business cases in the port industry, it is of the highest importance that organizations first understand how they can leverage this disruption. Gartner’s hype cycle showed for the second year in a row that no technologies would reach the plateau of productivity in the next 5 years, meaning no new significant disruptive technology will become readily available for organizations to embrace them. IoT applications provide more benefit than only updating existing frameworks and streamlining established business models. For ports, next to the physical flows, more emphasis will be put on (data-driven) models like value-added services, subscriptions, apps and anything as a service (XaaS). Finally, the drivers and challenges help the entire port ecosystem to determine where to play and find the right strategy to win. It is our strong belief that becoming a smart port, driven by smart technology (like IoT and AI), should be a fundamental part of every seaport’s game plan.

_We thank our colleagues Pedro Guimarães and Baptiste Brunet for their support in the composition of this paper._

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**ABOUT THE ORGANIZATION**

Deloitte is the largest professional service firm in the world and market leader with digital and port related advisory services. We have more than 150 years’ experience in hard work and commitment to making a real difference. What makes Deloitte truly different is not how big they are with activities in over 150 countries worldwide, and services across the entire spectrum but rather its drive to make an impact that matters in the world.

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The future of mobile communication is 5G. And in this regard, the Port of Hamburg is a trailblazer. A gigantic 5G network is currently under officially testing in the Hanseatic City of Hamburg, as well as in the northern Italian city of Turin, by the 5G Mobile Network Architecture (MoNArch) research project which is funded by the EU.

5G is seen as the communication standard of the future—a entirely new network concept that combines terrestrial and mobile networks. Unlike technological advances of the past, which solely focused on increasing broadband width and speed, 5G will support a wide range of use cases that all have different speed, latency, security and capacity requirements. 5G will also play an important role in new application scenarios created by the Internet of Things (IoT) and Industry 4.0. technological change. Besides the manufacturing industry, the logistics sector in particular will benefit from 5G mobile technology.

THE MONARCH PROJECT
5G offers safety, reliability and speed which didn’t exist in mobile networks before. It opens completely new fields of application. We at the Port of Hamburg are already able to gain experience with this future technology and can also shape the standard. Not only does the port profit from this but also the whole city prospers.

After six months of preparation, the MoNArch project partners – Hamburg Port Authority (HPA), Deutsche Telekom and Nokia – launched a testbed that stretches across some 8,000 hectares of port area in January 2018. For this purpose, a base station has been installed on Hamburg’s television tower, which is over 150 metres high.

The testbed at the Port of Hamburg has primarily been set up to test 5G applications in an industrial environment. Telecommunications networks for industrial applications must be ultra-reliable and highly secure as well as support multiple use cases. The application needs of the Port of Hamburg are diverse, and the requirements for networks are particularly high. For instance, mobile networks will facilitate the coordination of traffic lights within the port area and the collection and processing of environmental data in real time. On top of this, virtual reality applications will be deployed to manage the infrastructure better and thereby make it much safer.

The project partners run the trial 5G network to explore the various applications, each of which has different data transport requirements, and evaluate the reliable function in a single network. The 5G trial network is partitioned into virtual networks—so-called network slices—which are then customized to meet specific port application needs. Network slicing in 5G networks delivers greater network flexibility and supports the port’s numerous and varied applications and cases. The Port of Hamburg will be the first location in Germany where a network with several network slices will be tested under real life industrial conditions.

The 5G trial programme in the Port of Hamburg forms part of the two-year 5G MoNArch research project (5G Mobile Network Architecture for diverse services, use cases, and applications in 5G and beyond). 5G MoNArch aims to put 5G mobile network architecture into practice by deploying 5G network slicing in real life test environments and use the insights...
gained to review and improve existing concepts. While the testbed in Hamburg is primarily used to trial the integration of 5G into traffic and infrastructure management systems, the second testbed of the project in Turin focuses on multimedia applications. As a 5G Infrastructure Public Private Partnership (5G-PPP) Phase II project 5G MoNArch is co-funded by Horizon 2020, the European Union’s Framework Programme for Research and Innovation.

**FIRST FINDINGS**

In November 2018, HPA, Nokia and Deutsche Telecom compiled a first interim report after the test bed had given us a first glimpse of the huge potential that 5G and, in particular, network slicing offers. I believe the new standard will form the basis for solving tricky industry challenges and is the last push we need to generate a breakthrough in terms of digitalization. I’m also very proud that the City of Hamburg and the Port of Hamburg are among the first to benefit from this technology that will also be of great benefit to those who follow in our footsteps.

Three case studies using real-life applications have demonstrated the reliability of the new standard. In the first, partners have installed sensors on ships belonging to HPA’s subsidiary, Flotte Hamburg GmbH & Co. KG. These sensors transmit movement and environmental data in real time from across large swaths of the port. In another example, traffic lights have been linked to the mobile network and can be operated remotely by the HPA control centre in order to control traffic as it flows through the port. Trucks, for example, are guided quickly and safely around the site. In the third example, the new standard makes high demand of bandwidth available quickly outside of existing networks, transmitting 3D data to an augmented reality application. Smart glasses use the information to show wearers building data relating to future or former structures in a real environment. In the future, this technology will help engineers to monitor or optimize construction planning directly on site at the port.

**BACKGROUND TO 5G MONARCH**

The 5G MoNArch trial at the Port of Hamburg is part of a two-year research project that aims to implement concepts for 5G mobile communications architecture in practice. Findings from the deployment of 5G network slicing in a real-world test environment are used to review and improve the underlying concepts.

While the focus in Hamburg is on integrating 5G into transportation and infrastructure management systems, a second testing ground in Turin is looking at multimedia applications. The Horizon 2020 EU Framework Programme for Research and Innovation is funding the 5G MoNArch project as part of phase II of the 5G Infrastructure Public Private Partnership (5G PPP).

**TRIAL AIMS:**
- Testing the architecture of the fifth mobile network generation with real-life applications
- Ensuring rapid and reliable communication
- Expanding the 5G architecture through use of architecture concepts like Inter-Slice Control and cross-domain management

**OPPORTUNITIES FOR HAMBURG**
- Knowledge transfer and contributing to the Europe-wide implementation of 5G
- International attention for the port of Hamburg, its innovativeness and forward-looking approach
- Increase in the port’s recognition as a modern base for existing and future companies, neighbors and citizens

**ABOUT THE AUTHOR**

After completing his studies in Computer Science and the supplementary subject of economics at the University of Hamburg, Jens Meier started his professional career at Software Design & Management AG with the Ernst & Young group. Since 2008, Jens Meier has been serving as CEO of the Hamburg Port Authority.

**ABOUT THE ORGANIZATION**

The Hamburg Port Authority AöR (HPA) has been providing future-oriented port management services offering one face to the customer since 2005. To ensure efficient, safe and economic processes in the Port of Hamburg and meet the demands of a growing port, the HPA relies on intelligent and innovative solutions.

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Last year we wrote a paper regarding artificial intelligence (AI) on how it had made, and was continuing to make its way into the terminal industry. We paid specific attention to how machine learning (ML) as a branch of AI could be implemented. In a paper that likened AI's current state to that of Frankenstein, the article closed by saying that AI was coming, and that as an industry we can either be prepared or caught off-guard when it does. For INFORM, as a leading AI solution provider, the question wasn’t how to prepare for AI, but rather, how we can leverage the promise of ML and build it into our core AI driven solution.

As such in 2018, INFORM undertook an ML assessment project looking at maritime container terminals and how ML could be used to improve optimization and operational outcomes. The assessment aimed to achieve two results. Firstly, could INFORM’s broader ML algorithms, developed for use in other industries such as finance, be applied to our Optimization Modules that are used in terminals around the world. Secondly, if they could be, does that mean we can apply them to real-world terminal data and identify areas where improvements could be made to parameters that influence the optimization calculations of INFORM’s add-on Optimization Modules.

Working with a randomized sample of 1 million containers handled in the 2017 calendar year with 50 data variables (explanatory variables) at a selected terminal, we set off to answer these two questions. The dataset was split further; using a time slicing method, a training dataset (75% of the dataset) and a testing dataset (25% of the dataset) were created in accordance with good ML practices. Further, we worked with a human expert to review and identify variables amongst the 50 explanatory variables that would prove meaningful in the assessment. We identified 16 variables that have been used to build the random forest ML models...
presented later in this paper (see figures 2 and 6).

In short, the answer to the first question was a resounding yes; INFORM’s ML algorithms could be applied to work with our solution for the maritime terminal industry. To answer part two, it is worth exploring some of the areas of terminal optimization where it was identified that we could further improve our solution offering through the implementation of ML. While we identified many areas, we will focus on container outbound mode of transport and dwell time in this paper.

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PREDICTING OUTBOUND MODE OF TRANSPORT

We started with the outbound mode of transport predictions. The mosaic plot (figure 1) shows what was expected based on the TOS information received upon container arrival versus how the container actually departed the terminal. The areas represented are proportional to the volume of containers handled. “NA” areas in grey, were unknown to the TOS when the container arrived. The data the TOS is configured to use to make decisions is accurate in only 62.9% of the total 1 million boxes sampled.

A random forest with 500 trees ML model was trained using the training dataset and subsequently tested against the testing dataset. The forest was tasked with identifying the importance of the pre-identified 16 variables (see figure 2).

Random forest ML models are very flexible algorithms that produce balanced results for classification and regression tasks. They are created by building a multitude of decision trees, in our case 500 trees, and then outputting the mode (classification) or mean (regression) of the individual trees. Importantly, random forests correct for a single decision trees’ tendency to ‘overfit’ to the training data. Finally, random forests improve upon the predictive power of single decision trees by making clever use of random chance.

THE FINDINGS

Using the revised ML generated prediction model opposed to the data available from the TOS upon container arrival would increase prediction accuracy to 83.6% - corresponding to a relative improvement in prediction accuracy of 33%. Figure 3 maps the improvement in accuracy from the TOS to the ML model against each outbound mode of transport (OMT). Looking into the data more closely, the TOS had a good accuracy at predicting OMT for containers leaving by ship (81.9%), average accuracy
for truck OMT (65.5%), and poor accuracy for feeder (42.4%) and rail (4.7%). In comparison, the accuracy for all OMT shifts to average or much better: ship (94.3%), truck (87.2%), feeder (76.3%), and rail (53.0%).

**PREDICTING CONTAINER DWELL TIME**

Container dwell time is used within INFORM’s Optimization Modules to assist with container yard positioning calculations. The basic logic is straight-forward; when building stacks in your yard, place containers with longer dwell times at the bottom and containers with shorter dwell times at the top. In this way, you minimize the number of rehandles needed to retrieve containers for their outbound journey.

Given its relevance, dwell time is a central variable in optimizing the placement of containers in one’s terminal. However, the data point used to calculate dwell time – expected departure time – is frequently missing. In our dataset, 47% of containers were missing an expected departure time. This is visually represented in figure 1; data was available for ship (purple) and feeder (blue). Traditionally, for these instances, our optimization modules use a strategically calculated and pre-configured dwell time variable as a stand-in.

Working with the dataset, we drew up an empirical model to determine the mean dwell time for loaded containers where there was no expected departure time upon container arrival. The mean was calculated at 84 hours (see figure 4). Not too far off of the selected systems pre-configured 96 hour stand-in variable, so using basic statistical modelling, we can already achieve a small improvement.

From there, we decided to see what would happen when we factor in the dwell time versus the expected departure mode. A different picture emerged, see figure 5.
Containers leaving by ship stay longer, while containers leaving the terminal by truck and rail have, on average, a significantly shorter dwell time. There was a correlation between the complimentary storage duration offered by the terminal and the associated outbound mode of transport; that said, it was not the aim of this assessment to evaluate this finding and further assessment is needed to confirm causation vs association.

Working from the hypothesis that a better stand in dwell time could be predicted if the system took into consideration the OMT, a random forest with 500 trees ML model was trained on the training dataset and subsequently tested against the testing dataset. Again, the forest was tasked with identifying the importance of the pre-identified 16 variables (see figure 6).

Interestingly, weekday proved to be highly relevant. The ML model found that containers arriving on Thursday or Friday were likely to remain longer than those arriving Saturday through Wednesday. Our human expert attributed this to reduced operational hours over the weekend period.

Using the revised ML generated prediction model for dwell time instead of the standard dwell time variable resulted in relative improvement in prediction accuracy of 26.8%.

**OPPORTUNITIES FOR FURTHER ASSESSMENT**

Future assessments should aim to review available data from 2018 and run it against the same process to assess whether the findings from the 2017 data are consistent with more current data or what alternative patterns are seen. Further, considering external data sets could add additional insights beyond that of the core container data. For instance, vessel ETA vs ATA and ETD vs ATD differences could reveal additional patterns that would improve the dwell time prediction model. It is reasonable to assume that seasonal (monthly or quarterly) differences are also plausible due to container traffic patterns or the impact of weather.

**APPLICATION IN TERMINAL OPERATIONS**

It is expected that the ML models will lead to improved container location selection (OMT) and improved precise stack location (dwell time) both resulting in fewer re-handles. Let’s assume you can reduce re-handles by 1% in our example dataset of 1 million containers; that is 10,000 fewer moves. Further, let’s assume that the re-handle cost in a typical EU terminal is approximately 80 Euros, this would result in an annual savings of 800,000 Euros ($US900,000) for every 1% decrease in re-handles.

Using the Machine Learning Module within INFORM’s optimization solution, the application of ML to review and improve predicted outbound mode of transport, or OMT, and container dwell times should be run on a regular basis. Further, the output should be reviewed by a human expert before being used to modify optimization parameters. As noted in our previous paper, this expert discussion review process will assist operators in understanding the changes made inside of the optimization systems. Secondly, it will allow human operators to learn from the output as well as gain confidence in the ML Module’s ability to recommend appropriate parameter improvements for future use.

**REFERENCES**


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**ABOUT THE ORGANIZATION**

INFORM specializes in Agile Optimization Software to improve operational decision making. Based in Aachen, Germany, the company has been in the optimization business for nearly 50 years and serves a wide span of logistics industries including maritime and intermodal terminals.

**ENQUIRIES**

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We first heard of the digital revolution years ago when it started in the sectors where adoption speeds were higher, the entry barriers were low, and levels of dynamism in product development and commercialization were significantly higher than the average. These sectors were the online retail, IT and other tech-based verticals. Nowadays, the transformational effect of digital technology has permeated almost all environments. This is why the digital revolution is not actually a revolution anymore, but a transformation that is focused on people and how technology can help them to improve their lives.

The digitalization of industrial processes is turning the way we produce goods and services upside down as we look for higher efficiencies and better management of resources. This transformation is the so called ‘Industry 4.0,’ and the Internet of Things (IoT) can be considered its ‘cornerstone’ due to the clear need to capture information from all industrial assets.

The maritime sector is not an exception in this transformation and the change is starting to accelerate. This is precisely what is happening in the Port of Algeciras which is deploying the first LTE Private Network in the Spanish port system. The Port of Rotterdam is also using IoT technology to create a ‘Digital Twin’ of the port, and thanks to that make better decisions. Similarly, the Port of Seville is using a ‘FIWARE Platform’ to deploy IoT services for container tracking and to manage railway traffic, as well as monitor the main parameters of the Guadalquivir River.

Given the amount of fast-moving assets and calculations, a modern port network is the Formula 1 of the contemporary IoT ecosystem. Different moving assets like containers, trucks, cranes and so forth coexist with workers, loads and ships. It is thus very difficult to radio conditions together within such a dangerous environment.

We can define four different levels of Maritime Sector 4.0. adoption depending on the technologies that are being deployed where IoT plays a key role. These are expressed in Figure 1 and break down as below:

1. **Port Authority Digitalization:** Port authorities are very complex entities composed of a very different set of stakeholders with a final common goal: maximize efficiency, minimize environmental impact and enhance security for the end to end supply chain process. This first level comprises all technologies and practices oriented to implement digital tools in the usual activities of the port authority.

2. **Port–Terminal integration:** Agility is a must in the maritime business which means that intermodal and organizational integration between ports and terminals (their clients) is key for competitiveness and performance improvement. This second level of adoption includes all the mechanisms and technologies oriented to integrate the port’s systems with external systems. What’s more, this implies a consolidation of the information that can be exchanged via these integrations into an evolved operation model.

3. **Port–Terminal–City Integration:** This third level of adoption involves...
information sharing and also the deployment of specific use cases oriented to manage the transfer of goods arriving/leaving the port through the city, increasing efficiencies, decreasing complexities and risks, and extracting real time information from all parties involved.

4. End-to-End Supply Chain Integration: This is the best-case scenario where all the stakeholders participating in the supply chain process are integrated, leveraging on the information of the other parties to optimize the supply chain process. This last level of adoption implies a much deeper presence of information exchanged across parties into the operating model.

TECHNOLOGY IS KEY

There are a number of use cases to be deployed and each one of them will depend on the specific location, structure and nature of the port. In order to make sure that capabilities are deployed properly, technology comes into play. The four levels listed above have three things in common: connectivity, information and data processing, where security, feasibility and availability must be guaranteed. Below we review connectivity, information and data-processing:

1. Connectivity: At Telefónica we are convinced connectivity is the foundational layer for Maritime Sector 4.0 services and when we talk about mobility Private LTE solutions are the only ones that can guarantee the higher level of quality. We break these down as follows:
   a) Reliability: Allowing configuration of the private network quality of service, managing end to end priorities at a device level, guaranteeing minimum latency
   b) Coverage: With a dedicated licensed spectrum, free of interference. Wide range in outdoor and indoor
   c) Capacity: Supports multi-service network (voice, data, messaging) with all types of traffic, and a very high number of devices
   d) Security: Redundant solution with secure access based on SIM and user credentials. The traffic can be routed locally
   e) Mobility: This is a solution with native handover by definition which allows extreme mobility without a session loss. It is possible to extend the service outside the private area through the public network
   f) Evolution: Technology supported by 3GPP with evolution to 5G, including new standards such as MCPTT, IoT, and so forth can be considered pre-5G networks

   At Telefónica we are believers in full interoperability, so typically our solutions support connecting assets not just for private infrastructure but also to public ones, which becomes critical in mobility scenarios requiring connectivity beyond the port area.

   This flexibility also includes satellite connectivity. This way connected ships get full connectivity not just while in or near the port, but also when the boat is far from regular cellular connectivity.

2. Information: Once we have the ‘Communication Highway’ up and running, the possibilities to transport information are huge. Thanks to IoT, it is possible to get almost any type of data from the world and connect it to the internet. Keeping that in mind, with IoT we can collect all the information we consider important for both the maritime sector and the city (for example temperature, salinity, humidity, vessel and container tracking, fleet management, security, waste and light management, etcetera). This information can then be aggregated into a common point that is the service platform.

3. Data Processing: Information is a great asset, but the magic comes when that information is turned into actionable insights. That is why data processing is so important, and why the information should be shared with all the stakeholders of a given process.

A clear example is the concept of the
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digital twin; that is a digital representation of a physical asset, typically composed of a set of variables that, aggregated and processed, describes and predicts the behaviours of the asset being monitored. In order to anticipate the behaviour, potential failures or problems and abnormal behaviors, a mathematical model is required in order to describe how the asset works. This concept is inherited from the industrial manufacturing world, where this technique is applied to assets that can go from engines to robots. It can also be applied to the whole manufacturing plant itself, as it can be a complex asset that can be modelled and predicted thanks to the real time data information that an IoT system can capture. Following a similar procedure, an entire port can potentially be modelled and accordingly a digital twin of the whole port can be very useful to predict water flows, issues with the cargo of the whole port can be very useful to be modelled and accordingly a digital twin system can capture. Following a similar procedure, an entire port can potentially be modelled and predicted thanks to the real time data information that an IoT can be modelled and predicted thanks to the real time data information that an IoT system can capture. Following a similar procedure, an entire port can potentially be modelled and predicted thanks to the real time data information that an IoT system can capture. Following a similar procedure, an entire port can potentially be modelled and predicted thanks to the real time data information that an IoT system can capture. Following a similar procedure, an entire port can potentially be modelled and predicted thanks to the real time data information that an IoT system can capture. Following a similar procedure, an entire port can potentially be modelled and predicted thanks to the real time data information that an IoT system can capture. Following a similar procedure, an entire port can potentially be modelled and predicted thanks to the real time data information that an IoT system can capture. Following a similar procedure, an entire port can potentially be modelled and predicted thanks to the real time data information that an IoT system can capture. Following a similar procedure, an entire port can potentially be modelled and predicted thanks to the real time data information that an IoT system can capture.

Due to the growth of the maritime sector, we at Telefónica are going a step further in proposing what we call the “Port – City Communication HUB” which is based on FIWARE technology. Just to highlight why this is so important, two examples can be given where the “Port – City Communication HUB” can act as a facilitator of information, not only for the port and the city, but also for the final customers, the citizens:

a) Passenger Cruises: Have you ever experienced the chaos when a passenger cruiser arrives in a port with more than 4,000 people? If you live nearby a tourist port you will experience that quite often. Now, imagine that not only the city has information about the passenger cruisers (schedule, number of persons, interests, etcetera) but it is possible that the information is shared with the cruise passengers, including information like the main places, museums and monuments to visit, the best bars and restaurants to eat, if they are crowded or empty, and so forth

b) Hazardous goods: With this type of solution it would be possible to avoid dangerous situations (for example, a truck transporting hazardous goods stuck in the middle of a city due to water leak) by simply having an open data service providing information from both the port and the city

These are just two examples of what is possible thanks to the digitalization of the maritime sector and the deployment of data aggregation services and data analytics. This all starts from an optimized and reliable connectivity.

THE FUTURE

Thanks to the Maritime Sector 4.0, revolution, stakeholders now have the tools to orchestrate the different components of this beyond connectivity approach defined above, with data driven decisions at its core. The technology is ready to start, including the sensing technology, the connectivity, the platforms to aggregate the information and all the required data analytics techniques to extract all the information. The coming enhancements will speed up the process. Once the new sensing technology and the connectivity technology to connect what today cannot be connected is more widely deployed, new use cases will be identified. The building blocks to implement those will then be ready to use.

Digital twins and predictive models to improve mooring and casting of, remote controlled cranes, connected vessels, asset tracking, these are only a few examples that can help the customer to minimize operational costs, improve customer satisfaction, optimize revenues, and even generate new revenue streams. The collaboration among the different players around the port, from shipping companies, port authorities, integrators, operators and providers, will also manifest new business models. The revolution is here, and it comes full of opportunities that need to be together found out.

ABOUT THE AUTHORS

Jose Antonio González Florido is a strong believer in technology to help people. He is an Engineer in Telecommunications, with an MBA in Marketing and Sales, and he’s a PhD candidate in Telematics. Jose is PMP, ITILv3 y Six Sigma - Green Belt certified, with more than 15 years of experience in technical and business roles, and a global view of e2e lifecycle of digital services. He is an active member of the ‘Blockchainers Group’ in Telefónica, participating in publications like “Blockchain prepara su revolución para las ciudades inteligentes”, for the World Economic Forum 2018.

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ABOUT THE ORGANIZATION

Telefónica IoT is the Internet of Things global department at Telefónica, dedicated to developing and implementing IoT solutions in all industry segments. It offers its clients global end-to-end solutions around the world with the very best connectivity, and is available in all countries via its presence there or via roaming agreements and partnerships. Some of the main business areas covered by Telefónica IoT include Smart Mobility, Smart Retail and Smart Energy.

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Imagine your hands holding a big wheel. It is the wheel of a truck carrying valuables of utmost importance, and you, the person holding the wheel, are one of the best drivers available. The road is new and sparkling clean; the weather could not be better. You stare straight at your windshield but discover that, for some reason, it is almost completely dark. Just a tiny crack allows you to peek out and see the road.

How would you drive in this situation?

Could you take advantage of your awesome driving skills, of the great weather, of the new road? No. You would drive super slowly, trying your best not to crash into anything, always peeking through the crack; stopping every so often to get out of the truck and manually check if you hadn’t hit anything. What a mess.

Welcome to the world of shipping containers: big boxes with extremely valuable cargo. More accurately, US$6 trillion worth of cargo is transported annually in these big boxes, via 110 million trips. Such journeys form the de-facto ‘veins’ of the global economy. The only problem is no one knows what the heck is going on. The windshield of container shipping is too dark.

**CONTOPIA**

A recent study by a major shipping company calculated the losses of ‘shipping container blindness’ at $100 billion just on security-related aspects alone. Add in enormous logistics inefficiencies; the fact that you can’t triangulate well; the fact that when an insurance event happens it costs a fortune just to (not) know what exactly happened; and the fact that customs checks are still almost totally manual and definitely not ‘frictionless’, all of that amounts to huge blindness and inefficiencies everywhere you go.

Now imagine the same situation, but with a clean, transparent windshield. Now you can make use of your awesome driving skills, the excellent road and weather, and now you can get the cargo to its destination much faster – without worrying about something going horribly wrong. That is what Contopia feels like.

Contopia (short for Container Utopia) is a term we use to describe a world where every shipping container is real-time IoT connected. A world where all cargo conditions are monitored and where irregular events are known as they happen. Contopia is one of the rare ‘Blue Ocean’ scenarios where companies grow by creating more value in the market, compared to a ‘Red Ocean’ scenario in which a company only grows by taking market share from its competitors.

As marine professionals, when thinking about Contopia the mind immediately wanders to the obvious GPS tracking use cases. Allow me to suggest a different perspective which may lead to other possibilities.

**TALKING BOXES**

Our starting (and current) point is a fleet of less than 30 million “dumb” boxes traveling everywhere through those veins of the global economy. If only these boxes could talk, they could tell us
the idea of Frictionless Borders, making the last part of this paper, I would like to share connected unlocks many possibilities. We the global container fleet real-time IoT-

USE CASES
Global supply chain QoS is but one of Contopia’s use cases. In fact, having the global container fleet real-time IoT-connected unlocks many possibilities. We call these: Contopia use cases, and in the last part of this paper, I would like to share a few of those.

The second Contopia use case ties in with the idea of Frictionless Borders, making the voyage between borders or checkpoints as painless as possible, while still maintaining the checkpoint’s purpose. In the shipping container world, this means making sure that a container was not opened or broken into since the moment of stuffing and sealing. It still amazes me that today’s sole physical indication for the cargo’s integrity is an easily-forged aluminum seal, which requires manual checkup, while providing security value of close to nothing. In a Contopia scenario, IoT sensors can be used to monitor the integrity of the container and the cargo, keeping the information in a data packet, a ‘Cyber Seal’ if you will.

A Cyber Seal data packet can be instantly sent to customs or homeland security at checkpoints, allowing green lanes for untouched containers in a much faster and more visible way than the current physical method. In this use case, it is forecasted that at least $100 billion will be saved/recouped.

The third Contopia use case relates to cargo insurance. Today, acts of damaging or stealing cargo are almost never discovered in real time. Moreover, whoever is responsible for the wrongdoing is usually never discovered, despite insurance companies’ best investigative efforts. That changes completely in a Contopia scenario, which couples every container with a real-time black box, knowing - if not in real time - exactly what happened and where, allowing the insurance company to pinpoint the liable party in the vast majority of cases. Gone will be the days of everybody suing everybody; we now know the butler... (ahem, trucker) did it. In this use case, it is forecasted that Contopia will reduce gross loss from insurance claims by a whopping 40%-50%.

The fourth and last example of a Contopia use case is the management of the shipping container fleet itself by the shipping company. Managing the fleet is a complex task. There are all sorts of constraints, demands, demurrages and balancing tied to this act, making it very hard to perform efficiently. Add the fact that in many cases, the shipping company itself does not know the status of its own containers, not even knowing their whereabouts in some cases, and you get a very inefficient process. Real-time visibility dramatically increases the efficiency and changes the conduct of managing a container fleet. In this use case, it is forecasted that Contopia will save hundreds of dollars per container per year due to more efficient operations.

FINAL THOUGHTS
As recent years have gone by, research efforts have been put into these use cases making the value of Contopia clearer. Yet, when we want to approach and test a use case, searching for an IoT “sandbox” to allow us to do so, we discover that none exists. So we decided to create one.

We launched a competition called “The Contopia Factor” (TCF for short), during which small-to-mid-sized shipping companies apply to be the first digital shipping company in 2019 to realize Contopia and to test its use cases.

All that remains is to find out what Contopia’s Blue Ocean values really are in a real-life scenario at that one digital shipping company. If proven valuable, even if it is a fraction of the value we estimate it to be, it may be a significant milestone for the marine industry as a whole, and the first step to a long-awaited shipping container digital revolution for container shipping.

ABOUT THE AUTHOR
Shachar Tal is an Israeli global entrepreneur, co-founder of award-winning supply chain IoT startup Loginno and in charge of creating and delivering on the company’s vision of Contopia (Container Utopia). He is a true fan of cutting edge industrial technology and progressive rock music.

ABOUT THE ORGANIZATION
Loginno is creating Contopia (Container Utopia), the world’s Internet-of-Shipping-Containers infrastructure, by partnering with shipping companies to convert entire container fleets to IoT-enabled fleets, mining cargo and voyage data through a patented low-cost device. Contopia data unlocks countless possibilities and business models throughout the shipping container logistics chain.

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http://loginno.com/thicontopiashort
With many new opportunities emerging from the current wave of digitalization throughout global logistics chains, terminal planning and management need to be revisited with a data-driven perspective. The amount of operational data, such as from a terminal operating system (TOS), together with data from a variety of new data sources, such as sensors and mobile technologies, is growing fast but for the most part remains to a considerable extent too under-analyzed to be of real value.

Meanwhile, many current projects and initiatives in the port industry indicate a growing interest in data analytics solutions. One example of applying data analytics is the SAFER project of the Maritime and Port Authority of Singapore (MPA). Under the project, MPA has piloted three IBM analytics-based modules to improve the management of Singapore’s growing vessel traffic.

Another example is the Navis ATOM Labs, which is investigating the use of Machine Learning (ML) for the optimization and automation of terminal operations. In this technical paper, we provide a brief overview of potential applications of ML in container terminals and discuss some relevant challenges.

To establish a data-driven perspective on terminal planning and management, we analyzed the current state-of-the-art in academia regarding applications of ML in the context of container terminals. After giving a brief introduction to ML, we briefly summarize the scope of those works within the operational areas of a container terminal.

**MACHINE LEARNING**

One central aspect of human intelligence is the ability to learn, i.e., to infer stable relationships from observations which are often reflected in data. Given the growing volume and complexity of data, discovering patterns, regularities, or even irregularities has become increasingly important, not only in container terminals.

ML is a branch of artificial intelligence (AI) devoted to the development of algorithms that can automatically detect patterns in data and then use the uncovered patterns for supporting decision making, e.g. by predicting future data. Generally, two main types of ML are differentiated.

- **Predictive/supervised learning**: The goal is to infer a mapping from inputs $x$ to outputs $y$ from a labeled training set, which consists of set of past observations, known as training examples. An algorithm is then used to infer a function or model for predicting output values for new input values. The output can be categorical, known as classification or pattern recognition task, or nominal, known as a regression task. Thus, there are different ways of modeling dependent on the real-world case. A vessel delay prediction, for example, can be modeled as a regression task to predict the vessel delay either as a real number in hours or minutes or as a class of lateness, for instance, “late”, “very late”, etc.

- **Descriptive/unsupervised learning**: The goal is to find interesting patterns from unlabeled data, meaning that the desired output for each input is not defined in
Discovering clusters in data is a common task of unsupervised learning.

Besides the above, we find other terms that are often discussed in this context, such as deep learning, which extends commonly-known approaches of neural networks. Another inflationary term used in the port industry is big data, which mostly refers to the computing architectures and technologies required for storing and processing data that exceeds the processing capacities of conventional systems. Nowadays, affordable and highly scalable data storage and processing services, including those offered by public cloud providers as well as software frameworks like Hadoop, are available to handle big data. Still, performing big data analytics requires ML approaches to analyze data.

QUAYSIDE MACHINE LEARNING

The performance of quayside planning is dependent on many (external) factors, such as vessel arrival times, vessel call patterns, peak demands, and the handling capacities and capabilities of the quayside equipment. Disruptions and uncertainties may result from a lack of reliable information and forecasting. This comprises delays and over-punctual vessel arrivals, weather and tidal conditions, traffic congestion and equipment breakdowns. A strong research focus is on the analysis of satellite automatic identification system (S-AIS) data for identifying patterns and anomalies of vessel operations, for example, to avoid vessel accidents and to identify authorized activities like pilotage or unauthorized activities like illegal bunkering. Applications of ML in the quayside include:

- Prediction of vessel arrival times: To reduce the uncertainty of vessel arrivals, research has been conducted to evaluate different algorithms for predicting vessel arrivals, also by taking into account weather conditions, such as wind speeds and peak wave periods. Models can also be further used to identify causes of vessel delays based on an analysis of input variables.

- Berth planning: Existing approaches predict the performance of vessel loading and discharging operations taking into account operational data, such as berthing time, number of containers, vessel beam size and wind conditions. ML can also be used to improve the selection of optimization methods used for berth allocation planning.

YARD MACHINE LEARNING

Several complex planning and optimization problems result from yard operations, such as yard allocation problems, post-stacking problems, crane scheduling, etc. To efficiently plan operations in the yard, it is important to reduce uncertainties and predict future scenarios, e.g. regarding demand and dwell times. Applications of ML in the yard include:

- Prediction container dwell times: Different algorithms have been developed and evaluated in research to predict and determine the...
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determinants of container dwell times in the yard. Models can be also used to assess the impact of changing determinants on the container dwell times, yard capacity and terminal demurrage revenues. A classification of container data using different dwell time classes, for example in days, has been used to determine stacking policies.

**Container stacking:** In combination with optimization methods, algorithms have been developed to predict the quantity of incoming containers and weight groups of containers in order to optimize the container stacking policy.

**Landside Machine Learning**

Improving landside operations can lead to better hinterland accessibility and inland connectivity, crucial for the competitiveness of container terminals. The increasing container volumes and peak demands, however, lead to growing traffic and congestion at container terminals and within port areas.

Modern technologies, such as sensors, actuators, and mobile technologies provide new sources of (real-time) contextual data, which can be used by ML approaches to better understand and coordinate traffic flows, for example within a gate appointment system. Discussed applications include:

- **Prediction of truck traffic:** Existing approaches determine relevant factors and predict inbound and outbound heavy-truck volumes, for instance, using geospatial sensor-based data from trucks.
- **Prediction of truck waiting and turnaround times:** Approaches to analyze truck arrival rates and predict gate waiting times have been proposed, taking into account temporal effects.
- **Prediction of truck delays:** Different algorithms have been proposed to identify causes of abnormally high truck turn times in container terminals.

**Challenges**

The gap between the data, produced in and around terminal operations, and its use for terminal planning and management is growing. ML provides a set of methods to use better information and knowledge in decision making processes. As such, it provides means to establish a data-driven perspective, complementing and supporting the traditional optimization and automation perspective. Although there is currently a lack of academic studies, some promising ML applications can be found in the context of container terminals. However, there are some challenges before data-driven decision making can be realized including:

- **No free lunch:** There is usually no "one size fits all" regarding ML models. The development of appropriate models involves several recurring phases, where the importance and workload of the preliminary steps of selecting, preprocessing and transforming data is often underestimated. In these phases, the background knowledge of experts from the individual terminal is essential for setting the goals, defining the modeling approach and preparing the data.
- **Integration of systems and data sources:** The quality of predictive models can be influenced by information provided by the input data and its quality. However, many useful insights are hidden in internal sub-systems or external systems. Examples include weather stations and port traffic systems.

**References**


**About the Authors**

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**About the Organization**

The Institute of Information Systems of the University of Hamburg in Germany specializes in interdisciplinary research for supporting decision-making processes within various application areas. A strong research focus is on quantitative methods, data mining, and cloud computing for supporting the planning and management in port logistics. Numerous publications in journals emphasize the quality of the institute’s research. Several projects in the port industry have been successfully carried out in recent years.

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