Developing A Dynamic- based Maritime Analytics Dashboard Using Power Business Intelligence Tools

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Abstract

The effective and economic optimisation of the maritime transportation take significant place among all studied topics in the literature. Big data has the potential to create new opportunities to drive innovation and deliver tangible operational efficiencies across the shipping world. The usage of big data analysis is to help the maritime industry understand the opportunities it can offer. Numerous information technology and information systems solutions were developed to enhance the knowledge of the functionalities of different maritime operations and activities. Thus, various applications, platforms, and technologies are used. The literature highlights that there are still key challenges facing big data applications in the maritime industry. Hence, the purpose of this paper is to develop a dynamic-based maritime analytical dashboard using business intelligence (BI). It aims to provide very comprehensive functionalities for creating reports for better understanding of the maritime data. The main outcome is to provide an interactive visualized Maritime Analytic Dashboard (MAD) analysing large amounts of data and producing meaningful reports to port managers. A set of variables have been considered to present a comprehensive dashboard. As a further research, cyber threats and risks can be considered in the future developed dashboards.

Key Words

Big data pipeline, business intelligence, data visualisation

1. Introduction

In a global supply chain context, ports can be seen as a crucial partner in a cluster of organizations that affect the whole network performance. Information management and the process of digital transformation play a serious foundation for such alignment between supply chain partners. Ports are considered complex networks that requires better integration among all network members. Recent developed platforms and technological systems support the competitiveness and efficiency of such a network. On the other hand, innovative information technology and information systems help ports' managers and authorities address current and future challenges such as handling increasing trade volumes, higher traffic visibility, enhanced environmental awareness, managing port operations, and improved responsiveness to avoid congestions. This includes establishing an electronic single window to fulfil import, export and transhipment-related regulatory requirements. Enhancing the flow of trade over the world, cross-border standards and channels are developed for covering and harmonising the exchange of information on cargoes and their requirements of the shipping process between different ports and national authorities (Heilig and Voß, 2017).

The maritime transport is a dynamic industry where promoting the building of larger containerships that need faster loading and unloading facilities, which can only be achieved with a huge level of automation. For example, the OOCL (Orient Overseas Container Line) with a capacity of up to 22,000 TEUs rely increasingly on time. This creates the need for container terminals capable of operating with these big vessels in term of velocity. Hence, investment in technological systems at ports became indispensable factor. The innovative systems provide ports with cost reduction, improvement of service level, greater transport and monitoring control, and the improvement of safety and security issues (Carlan et al., 2017).

Ports and terminals can also be improved by developing their management systems, equipment used, and infrastructure. Port terminals use different types of information systems such as Terminal Operating System (TOS). It is defined as the computational management system in charge of all the processes produced within the terminal (Hervás-Peralta et al., 2019). Heilig and Voβ (2017) divided the information systems in ports into ten different schemes: national single window, port community systems, vessel traffic services, TOSs, gate appointment systems, automated gate systems, automated yard systems, port road and traffic control information systems, intelligent transportation systems, and port hinterland intermodal information systems. Generally, information systems have become necessary to the competitiveness of ports, facilitating communication and decision making for enhancing the visibility, efficiency, reliability, and security in port operations under various conditions. The main purpose of this paper is to develop a dynamic-based maritime analytical dashboard. The dashboard helps to provide very comprehensive functionalities for creating reports for better understanding of the maritime data. This paper is divided into four sections. In section one, the paper reviews the related literature concerning a comprehensive overview of information technology and information systems solutions used in port operations. In section two, the most common application areas for big data in the maritime industry are discussed. In section three, the Maritime Analytics Dashboard (MAD) is developed. The findings and conclusion take place in section four.

2. Research Problem

This paper aims to address the following problem: *how can a dynamic maritime information dashboard be developed?*

3. Research Methodology

Regarding the maritime dashboard development, a quantitative approach is applied to quantify the problem by way of collecting and transforming measurable big data into visualised dashboard. The research design starts with discussing those information systems and technologies developed in the maritime industry. Then, the research aims to identify the variables and measures required to develop the maritime dashboard.

Following the Big Data–Analysis Pipeline developed by Vouros et al. (2018), the Maritime Analytics Dashboard (MAD) has developed. A Business Intelligence (BI) tool was applied for developing a dynamic maritime analytical dashboard. This helps to provide a real time monitoring of the maritime traffic, advanced analytics and visualisation capabilities enabling real time visualisation in different forms and methods, and visual analysis of datasets to create visualisation of the maritime data for meaningful insights.

4. Literature Review

In the year 2005, a recommendation for establishing a National Single Window (NSW) was released in order to enhance the efficient exchange of information between trade and governments. The development of NSWs helped the streamlining, harmonization, exchange information, and coordination of reporting formalities and procedures between countries by using electronic means. Hence, various information platforms have been established to better facilitate global trade and transnational administrative procedures. In the maritime industry, different platforms are established such as e-marketplaces and e-logistics platforms. These platforms aim to form transnational networks among companies involved in the shipping process including; ocean carriers, freight forwarders, and shippers.

Heilig and Voß (2017) presented a categorisation and a comprehensive overview of information technology and information systems solutions used in port operations according to their scope of operations. They grouped the port information systems into two sets; a set of systems that are accessible by the overall port community and external stakeholders, and a set of systems that focus internally on either terminal, seaside, or hinterland operations. Hervás-Peralta et al. (2019) aimed to enhance the knowledge of the functionalities of Terminal Operating Systems (TOSs) by identifying 107 functionalities and by using the Analytic Hierarchy Process (AHP). They, in turn, grouped them into six main dashboards, including Warehouse, Maritime Operations, Gate, Master Data, Communications, and ERP (Enterprise Resource Planning). The main outputs of their model are to provide time tracking of vessels, space optimisation, development of loading and unloading lists, and optimisation of container locations. Carlan et al. (2017) claimed that the most important goal of seaport platforms is to optimise the infrastructure capacity usage in order to reduce port congestion, which is one of the objectives of a TOS.

In the middle of the 1990s, Global Navigation Satellite Systems (GNSS), effectively Global Positioning Systems (GPS), were installed in ports. The GPS enables position detection and tracking of movable objects such as containers, vessels, vehicles, and equipment (Steenken et al., 2004). In container terminals, differential GPS (DGPS) technology was initially used to accurately identify and track container yard positions. DGPS can further serve as a navigation system for unmanned vehicles and equipment, particularly for automated guided vehicles (AGVs). Zhang et al. (2006) proposed an automated container transport system where unmanned trucks are equipped with DGPS and on-board sensors to fully automate container transports on dedicated roads. On the other hand, major ports have adopted electronic data interchange (EDI) technologies in order to enable a paperless communication between ports' customers.

Radio-frequency identification (RFID) is another contactless automatic identification (Auto-ID) technology that enables identification of tagged objects and exchange of information carried by radio waves. Several RFID applications to improve efficiency of port operations can be discussed. Security seals are for example devices that are used to seal shipping containers. Shipping container identification and tracking RFID application is another application, where automatic identification of tagged objects and their tracking by installing RFID readers take place at focal points in the logistics chain. The automatic collection and verification of truck and driver information based on RFID can further help to improve access controls in the gate area (Shi et al. (2011).

Optical Character Recognition (OCR) systems, Real-time Location systems (RTLS), a Wireless Sensor Network (WSN), Vessel Traffic Service (VTS), Gate Appointment Systems (GAS), Automated Yard Systems (AYS), Automated Gate Systems (AGS), Port Hinterland System (PHS), and mobile devices are different systems invested in ports' industry. These systems aim generally to improve the efficiency and performance of ports, reduce risks of accidents and congestion. Globally, a Port Community Platform (PCP) has received widely attention as an inter-organizational system (IOS) (Carlan et al., 2016). It aims electronically at integrating the public and private actors, technologies, systems, processes, and standards. The PCPs build an electronic communication link between organizations that operate in the port environment including shippers, shipping lines, terminal operators, imports and exports, freight forwarders and various authorities. The benefits of PCPs are obvious in term of facilitating paperless procedures by providing a common information platform used to exchange port-related information and documents that are required for efficiently managing port operations.

Fernández et al. (2016) introduced a web platform as a smart port project that integrates the tools for the analysis and visualization of the sensor network of Las Palmas de Gran Canaria seaport. They applied a FIWARE platform that provides many technological resources. Heilig et al. (2017a) provided an extensive analysis of digital transformations applied in seaports in order to identify the important aspects and challenges. They differentiated between three main generations in the development of digital transformation in seaports including; paperless procedures, automated procedures, and smart procedures. As enablers, applying modern technologies in ports can affect the global competition, efficiency, cargo flow and overall ports' performance (Heilig et al, 2017a). John et al. (2017) claimed that complexities in seaports’ systems do not allow for flexible response to security incidents. Therefore, they developed a generic risk model and applied a Fuzzy Analytical Hierarchy Process (FAHP) at enhancing seaport security. Fitton et al. (2015) claimed that developing such modern maritime platforms, in a drive for efficiency, would integrate autonomous systems to track, dispense and provide logistical support for managing ports' operations.

Bisogno et al. (2015) developed a port community model of an integrated information system that able to provide the entire information requirements of all the actors in the port' network. Heilig et al. (2017b) proposed a cloud platform that integrates both real-time data from truck drivers using a mobile application and current traffic data, using two greedy heuristics and two hybrid simulated annealing algorithms. The proposed mobile cloud platform aimed to enhance real-time information exchange and optimization that are necessary to efficiently coordinate the container movements being involved in respective inter-terminal transport (ITT). Huynh et al. (2016) addressed the gate congestion problem at container terminals by reviewing a set of truck appointment systems to manage truck arrivals. Those systems include, for example, marine mobile platform, eModal, and Navis WebAccess. One of the main findings is the differences between ports and terminals make developing a one-size-fit all platform is unlikely. Heilig and Voß (2014) projected an initial approach towards a cloud-based Service Oriented Architecture (SOA) that aimed at collecting, storing, and analysing of real-time operational data at marine inter-terminal operations. Their proposed platform was based on an integration of radio-frequency identification (RFID), wireless sensor network (WSN) and mobile technologies.

Glaves (2019) highlighted the significance of the Ocean Data Interoperability Platform (ODIP) project that has been funded in parallel by the European Commission, National Science Foundation in the USA and the Australian Government. ODIP aims to promote the development of a common framework for marine data management that leverages the existing marine e-infrastructures. It becomes obvious that there is a need for a national marine science information management strategy in order to certify that all data collected is stored and systematically defined so that information is readily identifiable and accessible to stakeholders and users (Glaves, 2019). Valada et al. (2014) presented a low cost multi-robot autonomous platform for a broad set of applications including water quality monitoring, flood disaster mitigation and depth buoy verification. Five challenging areas are identified including; hardware design, sensing and autonomy, user interface, communication and coordination, and exploration and coverage. Their platform aims to guide the vessels where need to go.

Su et al. (2014) constructed a 3D seabed stratigraphic platform that provides two state-of-the-art applications on website explorer and smartphone prove its ubiquitous feature. The resulting '3D Seabed' is used for simulation, visualization, and analysis, by a set of interlinked, real-time layers of information about the 3D Seabed and its analysis result. Tesse et al. (2019) emphasised on creating a centralized communication platform for IoT solutions to allow inter-organizational knowledge exchange. They analysed 24 solutions from eight port authorities. Williams (2019) presented an application of Systems-Theoretic Accident Model and Processes to a ferry operator. The main purpose was to analyse the organizational performance of the risk and safety management systems. He highlighted that there is a gap in communication paths, lack of tracking of risks and limited involvement of senior management in the risk process.

5. Big Data in the Maritime Industry

The maritime industry lags behind other transport industries in terms of its use of information and communications technology. Only a handful of marine companies currently leverage big data. There are several benefits that the industry can derive through the use of big data. The industry generates roughly 100-120 million data points every day, from different sources such as ports and vessel movements.

Companies can analyze these data points to identify efficiencies such as quicker routes or preferred ports.

By embracing analytics and turning data into actionable insights, shipping and logistics players have an opportunity to drive improved efficiency and quality. In the long run, this will help transform their organizations into smarter, more dynamic entities that have a more informed picture of market trends and demands and are better prepared to meet the challenges of tomorrow. (Ohlhorst, 2012). Table 1 highlights the most common application areas for big data in the maritime industry.

Table 1 - Application Areas for Big Data in the Maritime Industry

Role	Function	Big Data Application(s)
Ship Operator	Operator	• Energy saving operation • Safe operation • Schedule management
	Fleet planning	• Fleet allocation • Service planning • Chartering
Ship owner	Technical management	• Safe operation • Condition monitoring and maintenance • Environmental regulation compliance • Hull and propeller cleaning • Retrofit and modification
	New building	• Design optimization

Source: Hepworth (2019)

5.1. The Role of Big Data Platform in the Maritime Industry

New big data technologies are emerging quickly, but most of them are targeted to land-based applications (Wang et al., 2015). In the maritime industry, the big data plays indispensable role but it is still limited to certain functions. In chartering, the key function of charterers is to find the right ship for cargo at the most economical price. The task is highly dependent on right information provided to them by known brokers and ship owners. Big data analytics can provide charters with readily available, accurate and actionable information to improve decision-making. In operations, the ships speed determines the fuel consumption. Big data analytics can help ship owners determine the optimum speed for fuel consumption, taking into consideration factors such as bunker cost, freight rates and schedules. In maintenance, fuel consumption data can also be used for cost-benefit analysis of vessel maintenance. Data analytics can make it easier for operators to decide the timing and the benefits of performing maintenance.

For terminal operators, port agents need estimated time of arrival and cargo information. Vessels can be tracked using dashboards instead of relying on notes, emails or phone calls. Dashboards can also provide information about any deviations from optimum performance. The ideal route, the weather service-provided route and the actual route can be tracked in real-time. On the other hand, other main areas along which big data driven knowledge management initiatives can be addressed in maritime organizations (Lambrou, 2016). This includes identifying the investment appraisal and risk management, analysing customers' and competitors' business behaviour patterns, and assessing the maritime human capital development needs. Table 2 shows the big data key trends in the maritime industry.

Table 2- Big Data Key Trends in the maritime industry

Trend	Description	Initiatives
Increase in partnerships to develop technology capabilities	• To implement big data analytics, shipbuilders and shipping companies have been entering into partnerships with leading technology suppliers and universities.	• Hyundai Heavy Industries (HHI) created software to improve the safety and well-being of crew members as well as to meet the needs of ship owners and safe ship operation standards.
Use of big data to reduce bunker costs	• Ship owners and operators are exploring the use of big data analytics to reduce their bunker costs. • Low bunker costs can offset the record low freight rates in the market. • Maritime software allows companies to achieve fuel savings through energy efficiency retrofits, using big data collection and analysis.	• Netherlands-based We4Sea BV announced the launch of its big data fuel monitoring platform, with an aim to reduce bunker costs and ship emissions • Maersk announced that it was looking at big data analytics to lower its bunker bills
Companies offering maritime big data analytics software	• In recent years, there has been an increase in the number of companies offering high-level technologies for optimizing ship operations.	• Ericsson has increased its focus on the shipping sector due to increasing implementation by carriers in the Middle East and Asia.
Maritime companies setting up internal	• As big data implementation is still at a nascent stage in the maritime industry, the approach to data capturing is fragmented. Similar	• ClassNK established its Ship Data Center as a separate entity with a secure shipping operations database that serves

infrastructure for big data implementation	data has to be sent to different vendors and processes are time consuming and inefficient. • To counter this, maritime companies are developing internal platforms and entities to ensure efficiency and data security.	as an independent information hub.
Funding to encourage big data application in shipping	• According to observers and industry stakeholders, big data is the next major revolution in the shipping industry. There have been recent cases of funding to promote the use of big data in different applications of shipping.	• the European Union (EU) project aiming to increase the use of big data in safety. The project, named EfficienSea2, involved the Danish Maritime Authority and several shipping and maritime companies. • Over three years, these companies will map the scope of the potential related to the massive amounts of data found on ships, in offices and in ports.

Source: Hepworth (2019)

5.2. Big Data Key Challenges in the Maritime Industry

A set of challenges facing big data applications in the maritime industry can be identified. Four categories of challenges are discussed by Koga (2015). This includes security challenges such as data quality and unlawful control of device; technology challenges such as data integration; human challenges such as lack of data analysis specialists; and competitive challenges such as data governance. Other challenges are identified and discussed Table 3.

Table 3- Key Challenges of Big Data Applications in the maritime industry

Challenges	Description
Misreporting of data	• ships broadcast fake IDs • Less than half of all vessels report their next port of call accurately • 55% of ships misreport their actual port of call throughout their journey
Cyber threats	• Marine IT and telecommunication infrastructures are at high risk of penetration from cyber criminals, terrorists or other malevolent interests. • More than 90% of the largest container lines are vulnerable to hackers. • There is the potential for a major cyber-attack on the maritime industry
Slowdown in investment in big data analytics	• market fluctuations • over supply • margin pressures • labor shortages

Lack of cross-enterprise technology implementation	• ship builders, ship owners and ports are solely focusing on running reasonably efficient operations and not on running a highly flexible, responsive trading business of 'container-as-a-community'. This means that there is a lack of cross-enterprise processes. • Companies are concentrating on automating processes within functional silos instead of taking a holistic view of the enterprise. This prevents the true potential of big data from being realized.
Lack of big data-skilled workforce / Skills shortage	• Ensuring enough quantity and quality of human resources is essential for developing the use of big data solutions for maritime. • There is a shortage of highly trained data scientists. This shortage is expected to further increase in the future.

Source: Hepworth (2019)

6. A Maritime Analytics Dashboard

There is a significant amount of data generated in the maritime industry that consist of types of handled cargoes, values of handled cargoes, volumes of handles cargoes, and the purpose of handled cargoes either imports or exports. These data can be displayed by country over time series. A set of variables have been considered when designing the dashboard, including:

- The total volumes of exports and imports of the world countries.
- The total value of exports and imports of the world countries.
- different types of cargoes are including containers, dirty bulk, clean bulk and tankers
- different types of goods including agricultural, raw materials, crude oil, and manufacturing goods.
- Capacitated designs of the 15 Egyptian ports and their connectivity are collected
- Millions of data are collected for the above variables between the years 2003 to 2007

A set of challenges emerge as the number of moving entities and related operations increase at unprecedented scale. Frequent data arise increasingly from many different sources on daily basis, results in generating vast data volumes of a heterogeneous nature, at extremely high rates, whose intertwined exploitation calls for novel big-data techniques and algorithms that lead to advanced data analytics. This is the central paper purpose to develop the Maritime Analytics Dashboard (MAD).

The development of the Maritime Analytics Dashboard (MAD) has followed the Big Data–Analysis Pipeline developed by Vouros et al. (2018). The pipeline has five major steps identified as follows:

1. Data recording and define the right questions;
2. Information extraction and cleaning and Set Clear Measurement Priorities;
3. Data collection, integration and representation;
4. Data modeling and analysis; and

5. Data interpretation and visualize and interpret results.

Step 1: Define the right Questions

In business data analysis, it should begin with the right question(s). Questions should be measurable, clear and concise. Design the questions to either qualify or disqualify potential solutions to specific problem or opportunity.

Step 2: Set Clear Measurement Priorities

This step breaks down into two sub-steps:

- Decide what to measure: Considering what kind of data need to answer the key question
- Decide how to measure it: deciding about how to measure data is just as important, especially before the data collection phase. Key questions to ask for this step include:

    - What is the time frame?
    - What is the unit of measure?
    - What factors should be included?

Step 3: Collect Data

With the question clearly defined and the measurement priorities set, now it's time to collect data. Key points are required at this stage including: what information could be collected from existing databases or sources on hand, naming system ahead of time to help all tasked team members collaborate, and keeping collected data organized in a log with collection dates.

Step 4: Analyze Data

After collected the right data to answer the question from Step 1, it's time for deeper data analysis. Begin by manipulating data in a number of different ways, such as plotting it out and finding correlations. and calculate the mean, maximum, minimum and standard deviation of data.

Step 5: Interpret Results and Visualize

After analyzing data, it's finally time to interpret the results that requires to ask these key questions:

- Does the data answer original question? How?
- Does the data help defend against any objections? How?
- Is there any limitation on conclusions, any angles haven't considered?

If interpretation of the data holds up under all of these questions and considerations, then it likely has come to a productive conclusion. The only remaining step is to use the results of data analysis process to decide best course of action.

Finally, interactive visualization helps to interpret data. Therefore, there is a need to analyze large amounts of data and produce reports that provide meaningful value. Interactive visualization could become the remedy for generating actionable information from mountainous data sources. By following these five steps in data analysis process, data that has been robustly collected and analyzed for MAD. The following samples of MAD Developed by the researcher using Power Bi Business Intelligence tools.

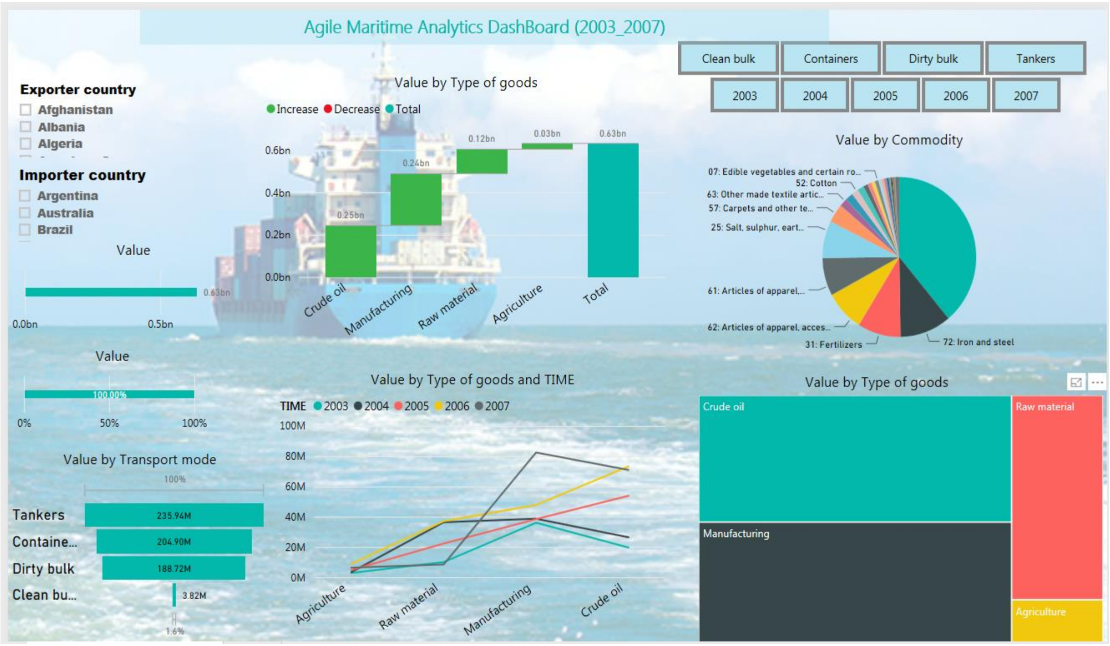

Figure 1: Agile Maritime Analytics Dashboard

The MAD dashboard provides a Visualized data as shown in Figure 1 using BI tools from high level drill down to low level representing vast data volume as follows:

- The interactive visualized data starts with selecting export or import country and the specific year or a period of time. Then, the analytics will calculate the value per transport mode such as tankers, containers, and bulk.
- By selecting a country, dashboard generate valuable insights about its records for different type of variables including value of Commodity, value by type of goods and value of transport mode.
- Visualizing the data using MAD dashboard enable the user to select one category like Container and data presented will change according to that selection on spot.
- By selecting a type of goods such as manufacturing, all records changed according to that selection including demonstration for type of variables.

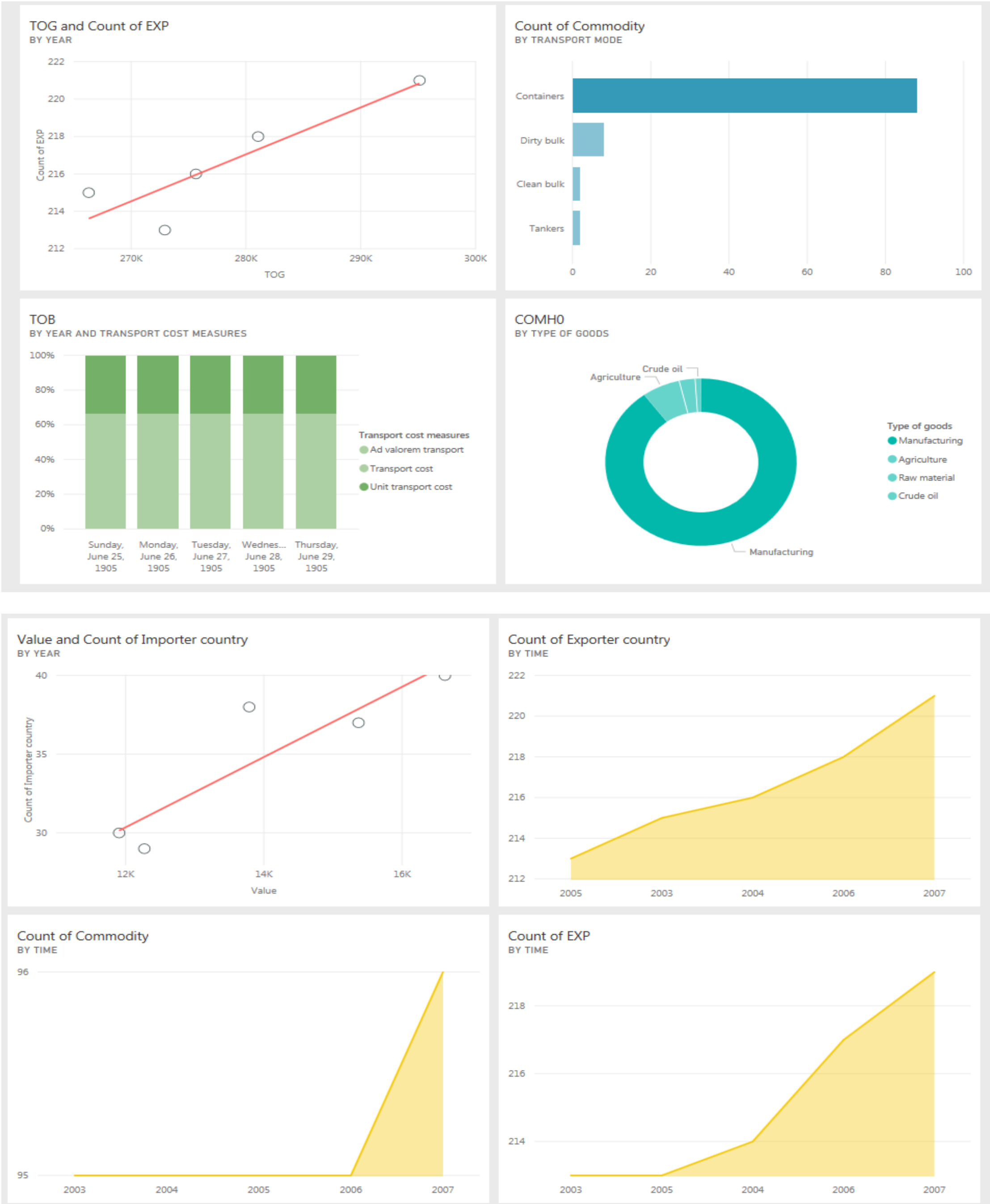

Figure 2: Agile Maritime Analytics Dashboard

In addition, MAD dashboard helps understand the variation, frequency and deviation of any variables as shown in Figure 2. This, in turn, helps the users to get quick insights and actions. Each variable used by MAD can be displayed over other variables and in exchangeable way.

7. Conclusion

A maritime transport plays a vital role as trade facilitator in providing cost-efficient transportation, where over 90% of the world trade volume is carried by merchant ships. Hence, the analysis of shipping networks therefore can create invaluable insight into global trade. In a maritime context, the data analytics solutions became a significant for monitoring key maritime performance and helps in a decision-making processes. For this purpose, a maritime analytical dashboard (MAD) is developed following Big Data–Analysis Pipeline to utilizes the valuable collected data for providing important information to the attention of decision-makers. For this purpose, a set of variables has been included such as the value of goods and the volume of carried goods.

As a theoretical implication, the dashboard enables a full analysis of available data to gain insight and actions. As a practical implication, the dashboard can provide faster reporting, better business decisions, and improved data quality and operational efficiency.

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