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A web based solution to track trawl vessel activities over pipelines in Norwegian Continental Shelf

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Abstract. Vessel activities such as trawling and anchoring potentially affect pipeline integrity. Therefore, the detailed information about the trawl activity in the area is essential for accurate assessment of pipeline, where to inspect and where to implement corrective intervention, based on up to date trawling intensity and equipment used. The main contribution of this paper is to present a detailed analysis of trawling vessels activities based on the automatic identification system (AIS) data combined with DNV GL ship register, data from HIS Maritime World Register of Ships and information gathered on the trawl equipment. In this aspect, an interactive web-based solution has been designed and developed to monitor and track trawl vessel activities in the Norwegian Continental Shelf which can be used for assessing integrity of pipelines. Data Analysis and visualization techniques have been utilized to transfer high-dimensional data by encoding it as visual objects contained in graphical presentations. The extracted knowledge result in the density mapping, vessel tracking, computing crossing points of trawl vessel paths, computing a buffered polygon around the pipeline for the chosen threshold and cross-over statistics of pipeline and vessels, etc. The use of such a framework is mostly advantageous for the port authorities, marine transportation, relevant fisheries management authority, etc.

1. Introduction

Trawling is an approach for fishing that includes pulling a fishing net through the water behind at least one vessel. Trawlers change in size from little open vessels with as meagre as 30 hp (22 kW) motors to enormous processing plant trawlers with more than 10,000 hp (7.5 MW). Trawling is dubious in view of its effects on the subsea condition including coral breaking, harm to environments and expulsion of ocean growth [1]. Trawling can be classified into mid-water trawling also called pelagic trawling and bottom trawling [2]. Bottom trawling is of worry to subsea structures and pipelines as both offshore oil and fishing ventures are regularly working in similar zones. As a result, a lot of attention have been paid to the safety and security of marine transportation. Currently, vessels are equipped by Automatic Identification System (AIS), sonar, radars and other conventional aid-navigation equipment assisting the deck officers in making rational judgements to improve the navigational safety and security [3]. However, such equipments are not always reliable to ensure safety in maritime navigation.

Data visualization techniques have been utilized to communicate data or information by encoding it as visual objects (e.g., charts, lines or bars) contained in graphical presentations. Data visualization and information visualization are useful for referring to any visual representation of data. The objective of visualization systems is to reveal the structure within massive high-dimensional data clearly and



efficiently to users acquire a qualitative information knowledge and better identifying patterns and detecting outliers. As for maritime transportation, several exciting research in the field of simulation of marine traffic have been presented [4-9]. A framework for maritime data analysis and simulation has been developed in [4]. The proposed framework analyzes historical data about ships and area conditions, of varying time and space granularity, measures critical parameters that could influence the levels of hazard in certain regions and clusters such data according to their similarity. Data visualization methods in the areas of spatiotemporal vessel trajectories and vessel traffic density were extensively investigated within the short review [5]. Kernel Density Estimation-based density visualization, massive vessel density visualization, visualization of fishing activities and visualization-guided ship safety domain have been fully investigated.

A probabilistic model is proposed in [6] to analyze the risk of two frequent types of marine accidents, such as collision and grounding. The probability of vessel colliding is evaluated in terms of a model based on minimal distance to collision. The model uses a mathematical vessel motion model to define the collision zone and considers traffic flow as a non-homogeneous process. Similar approach is followed for the probabilistic assessment of grounding. Furthermore, Montewka et al. [7] presented a simulation model that efforts to evaluate the potential impact of deepening the terminals and ports of Delaware River and Bay areas, by considering multiple parameters such as tide, navigation, terminal and anchorage rules as well as vessel profiles. A procedure for processing, analyzing, and visualization of AIS data with example outputs and their potential uses is demonstrated in the work of [8]. The knowledge is extracted in terms of density mapping, vessel tracking, interpolations of vessel dimensions, and ship type analysis. Willems et al. [9] demonstrated the visual presentation of the AIS data to assist operators of coastal surveillance systems and decision-making analysts to have a comprehensive understanding of the vessel movements, thus improving monitoring effectiveness. A noteworthy remark is that amongst the reviewed publications, a major common point was identified: that the information service depends heavily on the quality of AIS information and information processing, integration, and presentation applications. It has also been shown that AIS alone has never been sufficient to define a complete, extensive and a full, comprehensive maritime picture.

The present research focuses on the Norwegian Continental Shelf, the continental shelf that Norway exercises sovereign privileges as established by the United Nations Convention on the Law of the Sea. The shelf region is four times the metropolitan area of Norway and represents about one-third of the continental shelf of Europe. It is wealthy in oil and gas and is the basis of Norway's petroleum economy. Currently, the Norwegian Petroleum Directorate (NPD) regulations demand that all subsea establishments on the Norwegian division of the North Sea be planned with the goal that angling rigging won't be harmed [1]. During ongoing years, it has been recorded that the pattern for trawl apparatus plan and weight has expanded. Especially the utilization of cluster loads frequently expands the proficiency and is relied upon to be famous and regular later. New submarine pipelines should be structured by as of late utilized trawl apparatuses and recently introduced pipelines exposed to obstruction must be re-examined [1]. Towards this direction, DNV GL consistently utilizes AIS information and vessel explicit data on trawl gear as a contribution for breaking down potential hazard to marine structures which begins from ship action. The fundamental driver of the new technique is to secure the pipelines, outsiders, for example, trawl vessels and the earth by guaranteeing safe plan and task of pipelines [2].

The main objectives of this paper are summarized as follows: 1) Develop an interactive web-based solution to track and monitor trawl vessel activities in the Norwegian Continental Shelf which can be used for assessing integrity of pipelines for a chosen area of interest. 2) Implement web scrappers to automate the process of collecting vessel details. The remainder of this article is organized as follows: Section 2 briefly presents the datasets used in this work. Section 3 details the proposed web solution and data visualization system, and Section 4 describes our experiments based on available use cases and the last section concludes this study.

2. Datasets

The AIS data [10] used in this study is combined with DNV GL ship register, data from HIS Maritime World Register of Ships and information gathered on the trawl equipment. These datasets are used to track trawl vessel activities over pipelines in Norwegian Continental Shelf. As the ship registers, do not contain information about trawling equipment and size, the ship owners/operators are contacted and asked to provide information about the type of trawling performed (bottom or pelagic), if they use single or double trawl and type, size and weight of equipment used. Density maps are then made based on categorization related to the risk to the pipeline from each type of equipment. The study area for this research is the Norwegian Continental Shelf and the overview is given in Figure 1.

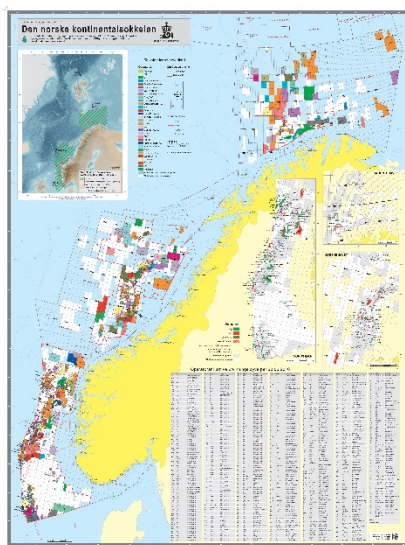


Figure 1. Norwegian Continental Shelf Area

Table 1. Pipeline Dataset Overview.

Field	Description	Type
Pipe Id	Unique Id of the pipe	int
Pipe Name	Name of the pipeline	text
Pipe Dimension	Dimension of the pipe	float
From Facility Id	Id of the starting pointing of pipeline facility	float
From Facility Name	Name of the starting pointing of pipeline facility	text
To Facility Id	Id of the ending pointing of pipeline facility	int
To Facility Name	Name of the ending pointing of pipeline facility	text
Pipe Operator Name	Name of the pipeline operator	text
Pipe Medium	Medium Information of the pipeline	text
Pipe Line Geometry	Geometry of location information of the pipeline	WKT

2.1 Pipeline dataset

This Dataset contains information of the pipelines constructed in the Norwegian Continental Shelf which are extracted from Norwegian Petroleum Directorate (NPD Facts) [11]. The data contains various information about pipes, such as the name, operator, pipe dimension, spatial information in WKT format. The original downloaded NPD dataset did not include any information regarding the type of pipelines, but it will be mostly trunk pipelines. In addition, DNV GL has discharged the DNVGL-RP-F114, which gives all-encompassing direction and proposals inside a geotechnical system for pipe-soil association assessments [1]. The overview of the data fields in pipeline dataset is shown in Table 1.

2.2 AIS dataset

This Dataset contains information of the vessel crossing in the Norwegian Continental Shelf for the period of 2013 to 2018 [10]. The data contains various information about the vessels such as the vessel name, mmsi number, imo number, utc time, latitude and longitude coordinates, etc.

2.3 Web scrapped vessel information

Web scraping technique is used to extract vessel information from various web sources. This module collects vessel specific information from the following five sites: 1) Norwegian Fisheries Directorate Website, 2) Marine Traffic Website, 3) Vessel Finder Website, 4) Proff.no, 5) 1881.no, 6) Google images.

3. Visualization of vessels trajectories and pipelines

This section presents a detailed insight regarding pre-processing, data transformation to track trawl activities as well as data visualization and visual mapping which can be used for assessing integrity of pipelines for a chosen area of interest. The overall workflow of the various components associated with the proposed web solution is demonstrated in Figure 2.

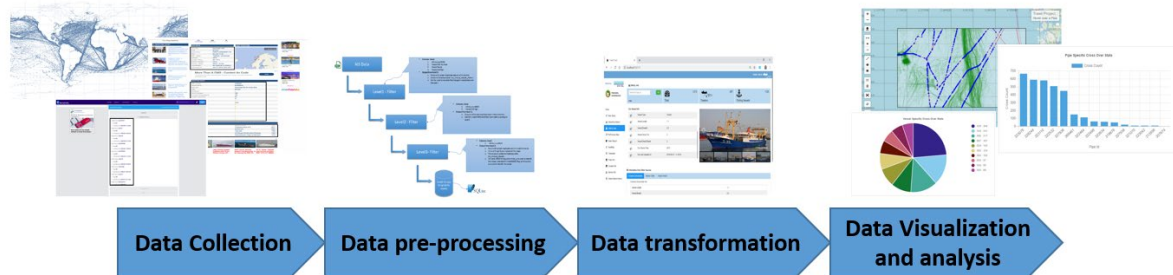


Figure 2. General processing pipeline for data visualization.

3.1 Data collection from different resources

We collected pipeline information and vessel information passing through Norwegian Continental Shelf area from various sources. Furthermore, additional information about crossing point information of trawler vessels over the pipelines, all trawl related statistics including clump door weight distribution, and trawl door weight distribution and KPI distribution are gathered. All this information is then stored in a Cross-Over Statistics Database in a SQLite3 database management system. Finally, we combine all gathered vessel details from different sources and categorize the vessels based on the availability of information according to the priority summarized as follows: 1) Equipment Source Info, 2) Fisheries Directorate Info, 3) Marine Traffic Info, 4) Vessel Finder Info.

3.2 Data transformation and pre-processing

In this step, we deal with data transmission errors and the problems of missing values to transform raw source data into desired standard format. It is well known that the raw maritime traffic data is often degraded with undesirable artifacts, i.e., transmission errors, missing values, duplicated records, outliers and conflicting values. For instance, there are some ambiguities in AIS data to identify unique vessels. First, automatically we drop all duplicates based on the Mmsi Id, IMO Number, Vessel Call Sign and Vessel Name columns. Thus, to group these duplicates, we create a primary key called DnvGl Id which can be used to identify the unique vessels. In addition, according to the specification from DNVGL-RP-F111 [1], trawling activity takes place at a speed of less than 6 knots. The raw AIS data is pre-processed to identify trawl vessel paths i.e. path traversed by the vessels. The vessel paths of the ships are split as: 1) Trawl Path - speed lesser than or equal to 6 knots. 2) Transit Path - speed greater than 6 knots.

The ship paths are then stored in WKT format for quicker access during the later period of computation. The last step of the data gathering approach is to update the internal database with information from the above process. It is worth noting that, data visualization and web-based dashboard often suffer from high computational cost due to the large volume of vessel trajectories. To reduce the computational cost, the size of the pre-processed files is reduced to a greater extent compared to the raw AIS data while preserving the crucial features.

3.3 Data visualization

The automation of data reporting plays an important role in achieving the goal of tracking trawl vessel activities over pipelines. In this step, data are converted into the appropriate visual structures for statistical graphs including line charts, bar charts and pie charts, etc. A sample screenshot of the vessel information page, containing the all vessel details is shown in the Figure 3.

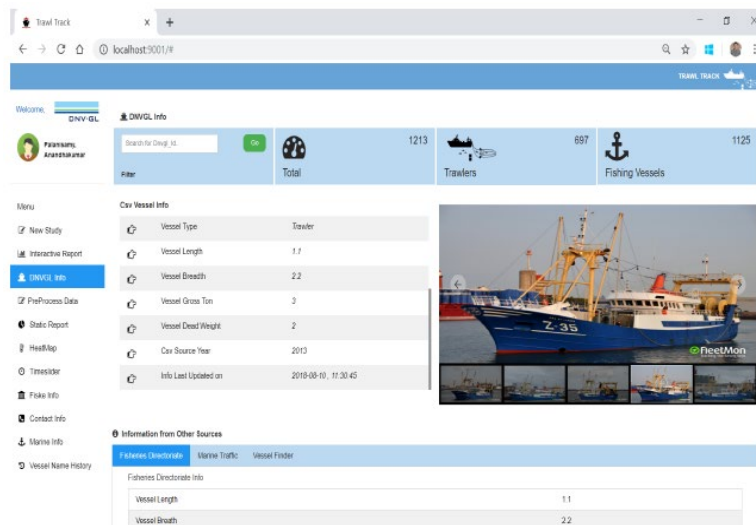


Figure 3. Web application - Vessel information.

3.4 Web-based visual mapping of vessel traffic density

We have developed a visualization framework for tracking trawl vessel activities over pipelines in Norwegian Continental Shelf which is capable of monitoring with high efficiency. By projecting the geographical position of trawl vessel activities into world map, the visual analytics of fishing activities have been analysed from global point of view. The interaction course is depicted in the two figures Figure 4. By presenting data visually, i.e., pipeline locations and vessels activities, it is of great convenience for relevant fisheries management authority to monitor and assess the activity of fishing vessels.

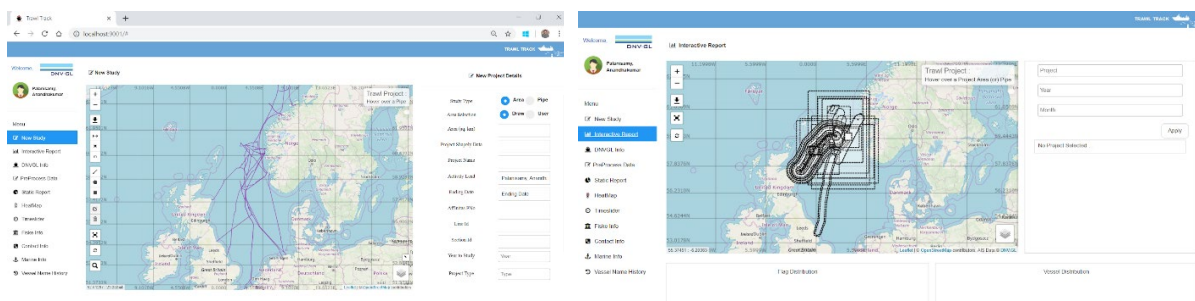


Figure 4. Web application – Dashboard.

4. Experimental use case

This section discusses the outcome of the experimental evaluation of the simulation web tool. The choice of creating new study may be either specific to any chosen area of interest or an area bounding a specific pipeline of interest. Therefore, we have conducted our experiments for one of the cases and present our analysis and discussion based upon the results.

Case study: Area Specific Study; the polygon area for the chosen area of interest can be specified in two ways by the web application: By using the drawing tool on the map or by manually entering the coordinates in the respective field.

Step 1: Selecting the Polygon Area. This is a user interactive tool and hence as soon as we have specified our polygon selection, the area covered by the polygon will be available in the respective field (or) will be shown on hovering over the polygon.

Step 2: Extracting pipelines passing through the polygon: The path of the pipeline lying inside the chosen polygon is then extracted from pipeline dataset. The extracted pipeline paths inside the polygon area will be highlighted in red lines as shown in Figure 5. The lengths of each pipeline path will then be available in the respective fields.

Step 3: Extracting trawl vessel paths passing through the polygon: These pipelines paths are extracted from the pre-processed AIS dataset. The extracted trawl paths inside the polygon area will be highlighted in green lines as shown in Figure 5. For this experiment we have selected a polygon with the following specifications:

Polygon Coordinates: $[[60.08, 1.48], [58.92, 1.48], [58.92, 4.76], [60.08, 4.76]]$, Polygon Area: 22588.69 km², Years Studied: 2015, Total Pipelines under this area: 15

Step 4: Density Map: Crossing points of trawl vessel paths over the pipelines are then computed and will be highlighted in blue dots. User can use the layer filters to view the chosen layer of interest as shown in Figure 6. User can also filter out the path of a particular vessel using the vessel path search functionality. These density maps also provide a detailed inference about the most affected and least affected zones and necessary measures can be taken to alert inspection on those areas. For example, in this experiment, a dense narrow strip of trawl vessel paths can be visualized, indicating a suggestion for inspection of pipelines along that area.

Step 5: Visualizing and statistical analysis of the vessels distribution: Overview of top 10 ships which are doing frequent trawl activity over the pipelines in the chosen area of interest can be obtained in the proposed framework as shown in Figure 7. This indicates a suggestion of focusing more in monitoring the activity of these vessels. In addition, an overview about the months which exhibit more trawling activity over the pipelines by the top 10 vessels and overview about the pipelines which exhibit more trawling activity by the trawler vessels can be plotted as shown in Figures 8 - 10.

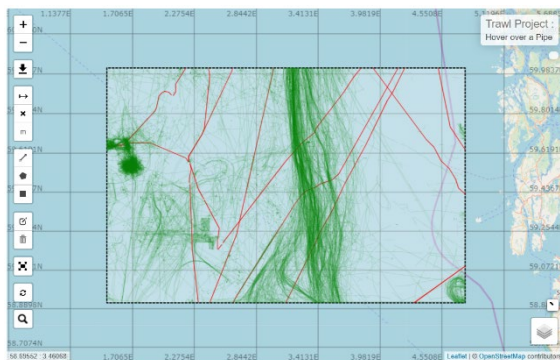


Figure 5. Pipelines and trawl vessel paths passing through the polygon.

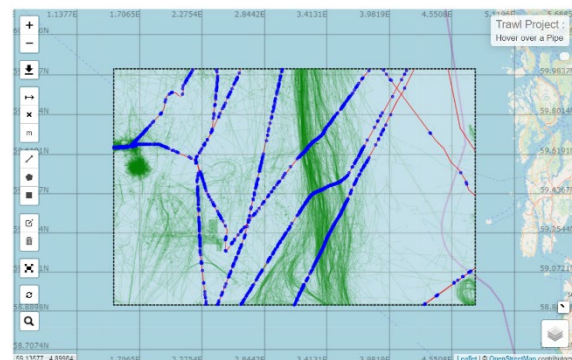


Figure 6. Crossing points of trawl vessel paths over the pipelines.

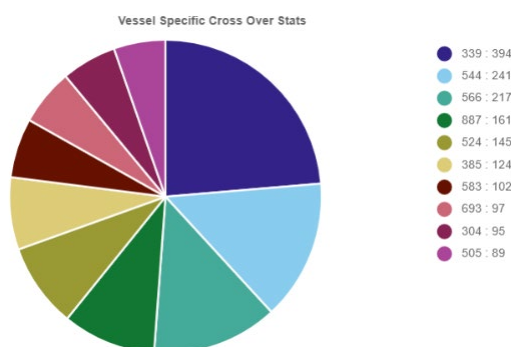


Figure 7. Top 10 ships which are doing frequent trawl activity.

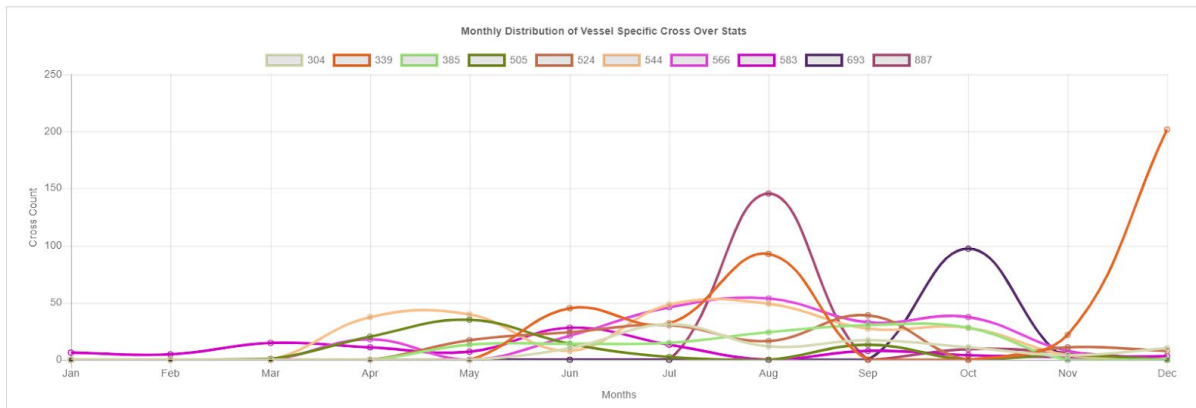


Figure 8. Monthly distribution of top 10 vessels.

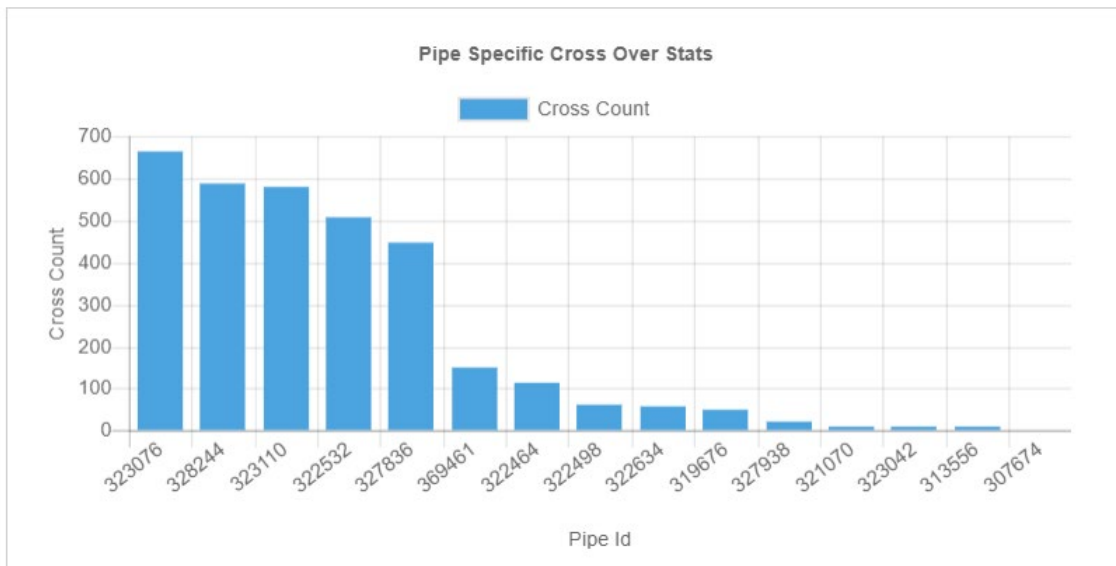


Figure 9. The cross over counts over pipes.

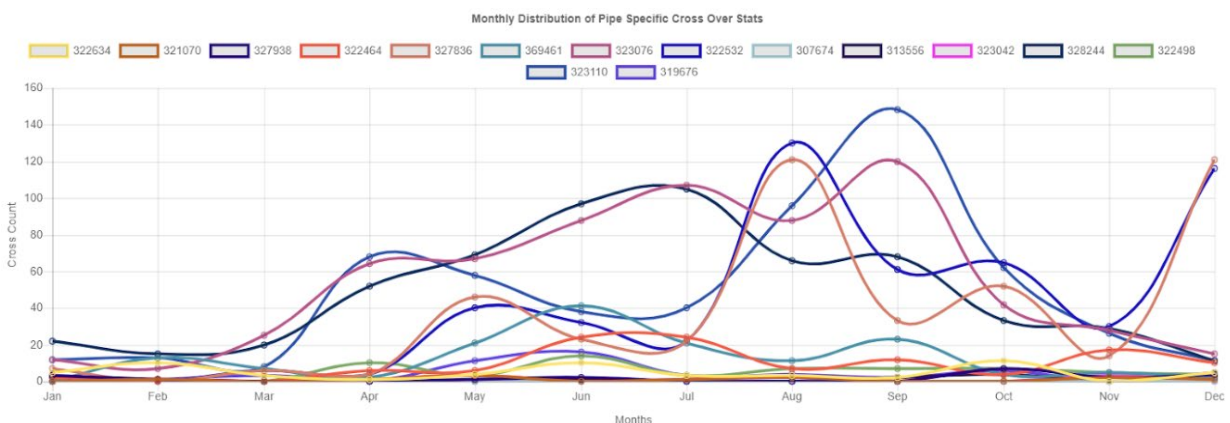


Figure 10. Monthly distribution of pipes based on the cross over counts.

Overview about the cross over statistics of trawler vessels for each km along the pipeline, in the chosen area of interest can also be available. This graph indicates a suggestion of kilometre intervals along the pipelines that need more focus in monitoring the integrity of the pipeline shown in Figure 11 and Figure 12. The key performance indicator (KPI) distribution of all pipelines inside the polygon is available

through a drop-down filter. The starting km of the KPI is measured by computing the difference between the starting coordinates of the whole pipeline with the starting coordinates of the pipeline inside the polygon. The KPI distribution covers the length of the pipeline that lies inside the chosen polygon area.

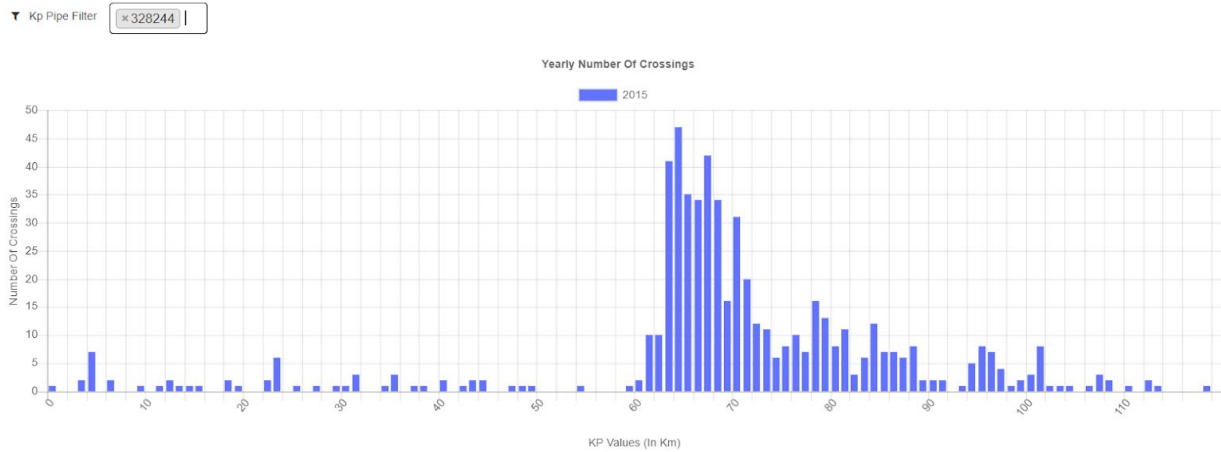


Figure 11. KPI Distribution for a sample pipe

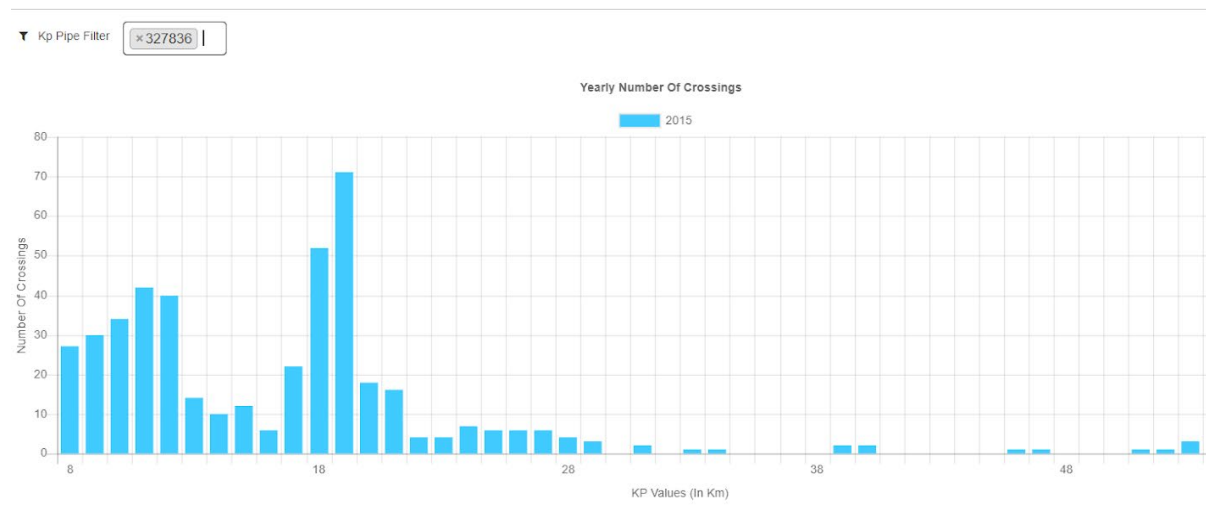


Figure 12. KPI Distribution for another sample pipe

Trawl Door Weight Distribution, Pelagic Door Weight Distribution, Door Weight Range Distribution and Clump Weight Range Distribution can be also seen in our web tool Figures 13 - 16.

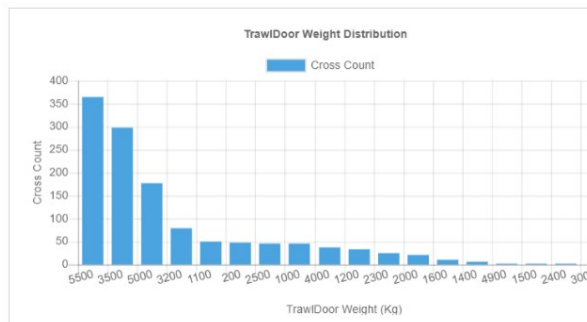


Figure 13. Trawl door weight distribution

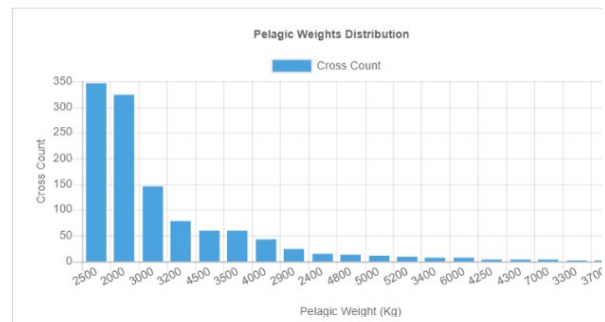


Figure 14. Pelagic door weight distribution

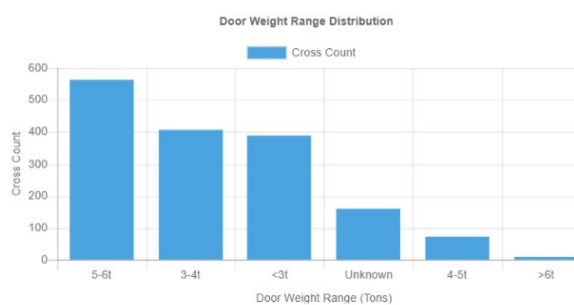


Figure 15. Door weight range distribution

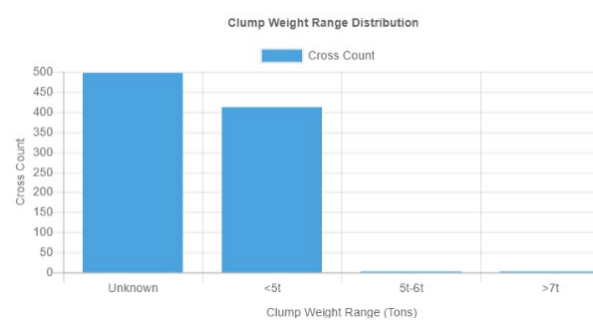


Figure 16. Clump weight range distribution

5. Conclusion

Monitoring and tracking the marine and transportation data are of major importance and the main goal of the current research. The advances of data analytics and visualization methods could be exploited for monitoring vessels activities over the pipelines to discover the knowledge from vast number of vessels trajectories. In this direction, we have developed a visualization framework for tracking trawl vessel activities over pipelines in Norwegian Continental Shelf which is able to achieve highly efficient monitoring. The AIS system, along with other sensor data such as pipeline dataset provided by DNVGL-RP-F114 can fully support the above actions. Existing and recently developed solutions have been investigated in order to create an efficient framework. Based on all the above arguments, it is mature to state that the proposed work, is utilizing data mining techniques, requiring less programming and deploying effort from the user's perspective, recent web technologies and Information and Communications Technology (ICT) services in order to ensure effective modeling, analysis and simulation of marine traffic data and provide experts with useful insight on the data.

6. Acknowledgments

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