ShipTech

The Standard Decision Makers Handbook on How to Use Blockchain and Artificial Intelligence

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Ch1. Emerging Technologies

Introduction

> "*A **radically novel** and **relatively fast growing** technology characterised by a certain degree of **coherence** persisting over time and with the **potential to exert a considerable impact** on the socio-economic domain(s) which is observed in terms of the composition of actors, institutions and patterns of interactions among those, along with the associated knowledge production processes. Its most **prominent impact**, however, lies in the future and so in the emergence phase is still somewhat **uncertain** and **ambiguous**.*" (Rotolo *et al*, 2015)

Emerging technologies are new inventions/products of the mind that are still at quite an early stage (inception stage). They are considered as capable of challenging the status quo, revolutionising pretty much every sector, as well as the way we interact.

Such technologies are usually characterised by novelty, exponential growth, coherence, prominent future impact and, high degrees of uncertainty and ambiguity. We have great examples where technologies that are of vital importance today, have been heavily scrutinised and challenged in the past.

Such examples include:

- **Telephone**: 1876: "The Americans have need of the telephone, but we do not. We have plenty of messenger boys." — William Preece, British Post Office. 1876: "This 'telephone' has too many shortcomings to be seriously considered as a means of communication." — William Orton, President of Western Union.
- **Computers:** 1943: “I think there is a world market for maybe five computers” — Thomas Watson, Chairman of IBM. 1949: “Computers in the future may weigh no more than 1.5 tons.” — Popular Mechanics. 1977: “There is no reason anyone in the right state of mind will want a computer in their home” — Ken Olson, President of Digital Equipment Corp.
- **The Internet:** “I predict the internet will soon go spectacularly supernova and in 1996 catastrophically collapse” — Robert Metcalfe.
- **Smartphones:** 2006: "Everyone's always asking me when Apple will come out with a cell phone. My answer is, 'Probably never.'" — David Pogue, The New York Times. 2007: “There’s no chance that the iPhone is going to get any significant market share.” — Steve Ballmer, Microsoft CEO.

Same discussions take place on new technologies such as Blockchain and Artificial Intelligence (AI) which are covered in this short textbook.

Figure 1.1 is known as the **Gartner's Hype Cycle** and illustrates the psychological behavior when a new technology appears. There are four main psychological phases; *stealth*, *awareness*, *mania* and *blow-off* phases. At early stages, only a few people believe in the potential of the technology, see for example the blockchain and cryptocurrencies example. Then it becomes viral if there is a path for profits and thus everybody is interested in investing. As a result the new technology becomes overhyped and overvalued. After enough time, we have the "**return-to-the-mean**" effect where the buzz is off and real applications and use-cases appear. This is exactly the case with AI and Blockchain and precisely for this reason we try to give real applications of these technologies for the shipping industry.

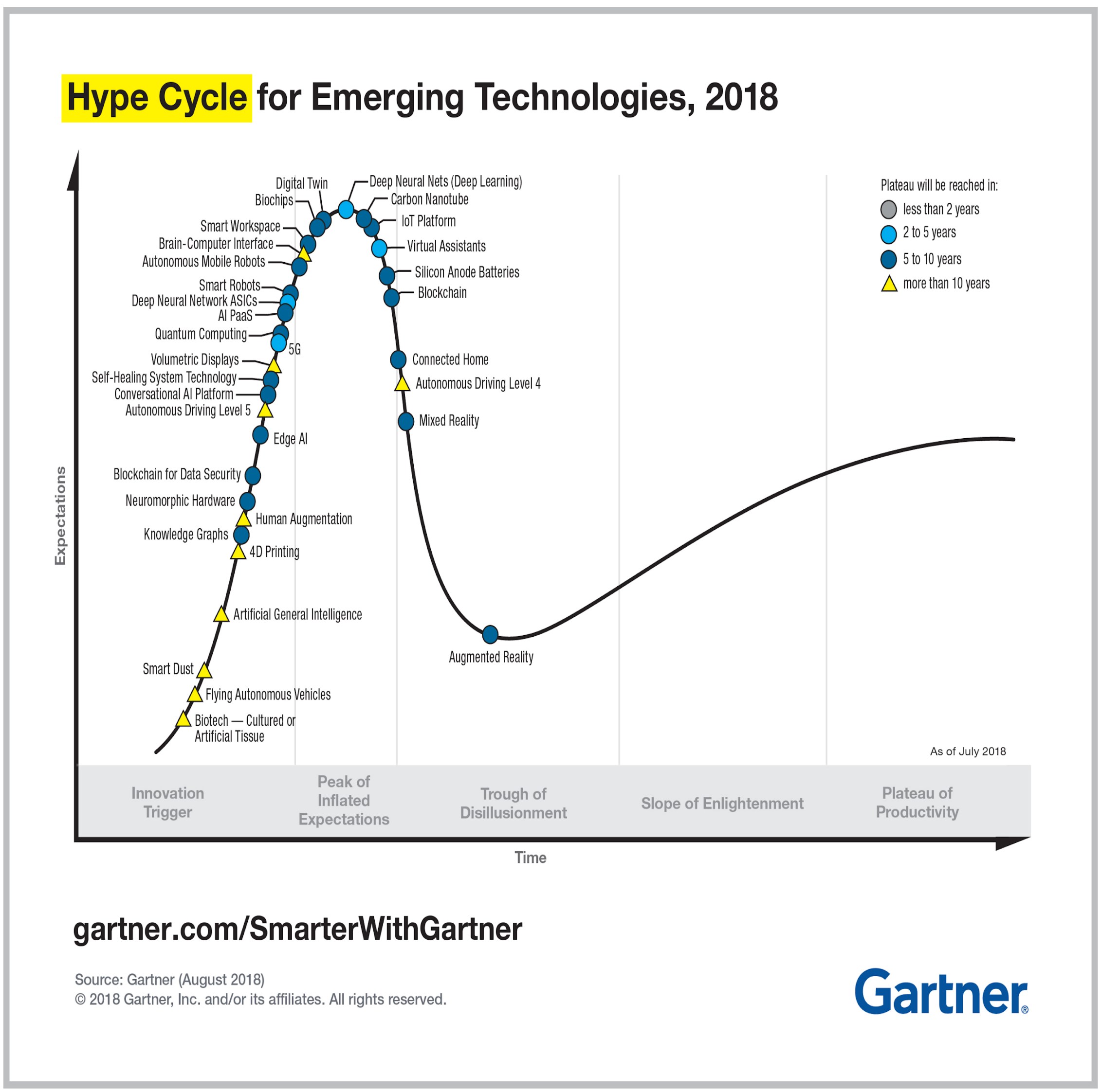


Figure 1.1: Gartner's Hype Cycle

> "*We stand on the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before. We do not yet know just how it will unfold, but one thing is clear: the response to it must be integrated and comprehensive, involving all stakeholders of the global polity, from the public and private sectors to academia and civil society*."
>
> **World Economic Forum**

This technological revolution mentioned by the World Economic Forum, is known as the **4th Industrial Revolution**, empowered by emerging technologies based primarily on **data** collected and analysed. Data is the oil of the 21st century.

Such technologies are (cf. **Figure 1.2**):

- Big Data & Analytics,
- Machine Learning (ML),
- Artificial Intelligence (AI),
- Augmented Reality (AR),
- Virtual Reality (VR),
- Sensors & Internet of Things (IoT),
- Robotics,
- Quantum Technologies,
- Cloud Computing,
- Blockchain or Distributed Ledger Technologies (DLTs)
- Connectivity & 5G.

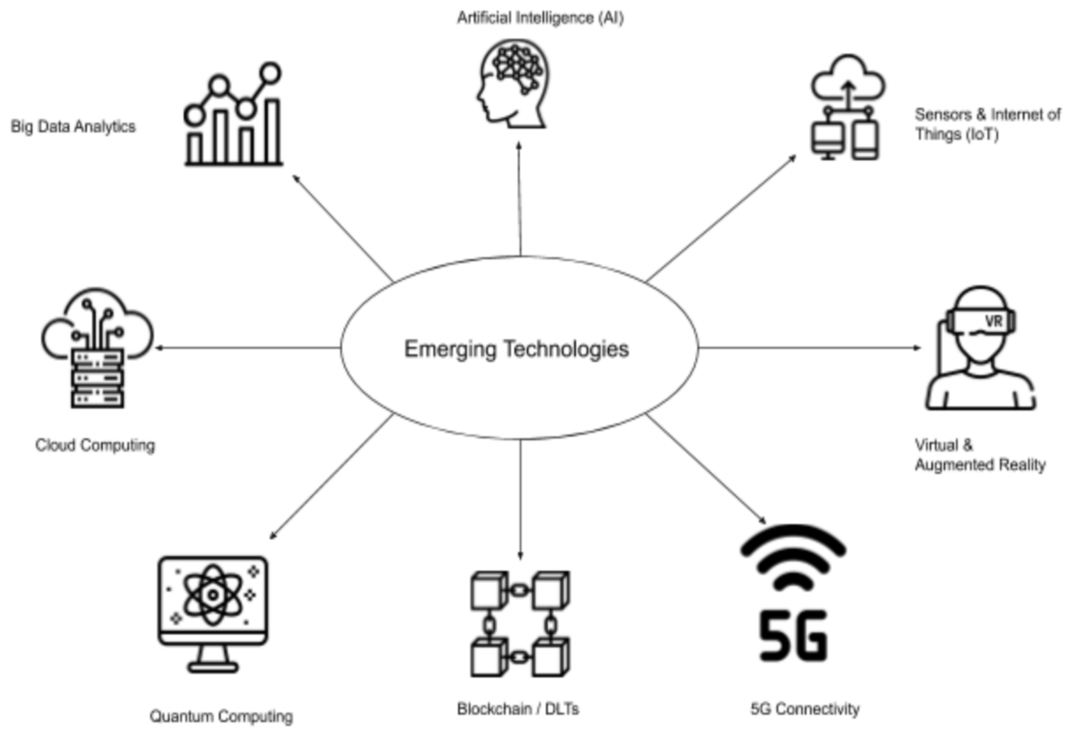


Figure 1.2 : Emerging technologies of the 4th Industrial Revolution

Big Data Analytics & Machine Learning (ML): Analytics is considered as the set of methodologies and techniques applied for examining large datasets of different formats collected from different sources. The aim is to uncover hidden patterns and structures, unknown correlations, as well as important insights that will enable an enterprise or organisation to shift away from the empirical way of reasoning towards a more scientific decision making. Such insights can help us to understand in a better way future behaviors and expectations, market trends and competition, customer preferences and business processes, optimise operations and decrease unnecessary costs (time, money). **Machine Learning (ML)** refers to a computer's ability to learn and improve beyond the scope of its programming. It relies on creating algorithms that are capable of learning from the data they are given.	**Use-cases:** ● Key Performance Indicators (KPIs) for financials, ● KPIs for Human Resource, ● Voyage planning, ● Predictive maintenance ● Weather forecasting, ● Predict extreme weather conditions, ● Energy management, ● Fuel consumption optimisation, ● CO_2/SOx emissions reduction, ● Improve architecture decisions, ● Prediction of delay/waiting times at ports, ● Customised risk and pricing models related to insurance, ● Crew Scheduling, ● Reducing interviewing times.

Artificial Intelligence (AI):	**Use-cases:**
Artificial Intelligence (AI) is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans and other animals. The primary functions that AI should perform are logical reasoning, self-correction and learning. While it has a wide range of applications, it is also a highly complicated technology because to make machines smart, a lot of data and computing power is required. AI is considered as a superset of machine learning and has greater vision.	• Autonomous surface vessels, • Navigation without human interaction, • Understanding of the environment and maritime conditions in an automated way, • Unmanned ships, • Inspection robots, • Simulations for training.

Augmented Reality (AR):	**Use-cases:**
Augmented Reality (AR) is an interactive experience of a real-world environment whereby the objects that reside in the real-world are "augmented" by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory (Schueffel, 2017).	• Remote operations of centres, • Ship design, • Training Simulations.

Virtual Reality (VR):	**Use-cases:**
Virtual Reality is an interactive computer-generated experience that occurs within a simulated environment. It usually incorporates auditory and visual, but also other types of sensory feedback like haptic. This immersive environment can be similar to the real world or it can be fantastical, creating an experience that is not possible in ordinary physical reality. AR systems may also be considered as a form of VR that layers virtual information over a live camera feed into a headset or through a smartphone or tablet device giving the user the ability to view three-dimensional images.	• Training technology, • Ship design by evaluating networks and ship's architecture, • Emergency scenarios training.

Sensors and Internet of Things (IoT):	**Use-cases:**
Sensors and Internet of Things (IoT) is the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these things to connect and exchange data creating opportunities for more direct integration of the physical world into computer-based systems, resulting in efficiency improvements, economic benefits, and reduced human exertions. The number of IoT devices increased 31% year-over-year to 8.4 billion in 2017 and it is estimated that there will be 30 billion devices by 2020. The global market value of IoT is projected to reach $7.1 trillion by 2020 (Nordrum, 2016), (Hsu et al, 2016).	• Automated and effective monitoring of onboard machinery, • Performance management, • Predictive maintenance, • Container tracking, • Reefer monitoring.

Cloud Computing:	Use-cases:
Cloud Computing is the on-demand delivery of compute power, database storage, applications, and other IT resources through a cloud services platform via the internet with pay-as-you-go pricing. This means we have less to worry about the physical assets involved in an infrastructure and thus this solves big issues in modern industry such as up-time, scalability and security if we select a reliable vendor	● Data storage, ● Security, ● On-demand computation, ● Scalability, ● GDPR compliance.

Quantum Computing:	Use-cases:
Quantum computing is the use of quantum phenomena such as superposition and entanglement to perform computation. Computers that perform quantum computations are known as quantum computers.	● Faster analytics, ● Data Security.

Robotics:	Use-cases:
Robotics is an interdisciplinary research area at the interface of computer science and engineering. Robotics involves design, construction, operation, and use of robots. The goal of robotics is to design intelligent machines that can help and assist humans in their day-to-day lives and keep everyone safe. Robotics draws on the achievement of information engineering, computer engineering, mechanical engineering, electronic engineering and others.	● Inspection robots, ● Hull cleaning robots, ● Anti-piracy robots, ● Robotic vessels.

Blockchain or Distributed Ledger Technologies(DLTs):	Use-cases:
Blockchain or **Distributed Ledger Technologies**(DLTs) is a digitized, decentralized, public ledger of all transactions that occur within a defined ecosystem or network of nodes. This ledger is public (in case of public Blockchain) or viewable by the authorised nodes of a network (in case of a private Blockchain).	● Improvements upon paper-based operations (e.g. certificates issuance and validation, Bill of lading, Air waybill, Certificate of origin Invoices, Shipping labels, Export license, Inspection certifications, Insurance certificates, Seamen certificates) ● Supply-chain logistics, ● Cargo trade over maritime routes, ● Cross-border transactions, ● New methods for financing.

Connectivity & 5G:	Use-cases:
5G is the fifth generation technology standard for cellular networks, which cellular phone companies began deploying worldwide in 2019, the planned successor to the 4G networks which provide connectivity to most current cell phones.	● Faster communication, ● Faster data sharing, ● Enable IoT adoption.

Ch 2. Big Data & Analytics: Use-Cases in the Maritime Industry

Big Data Definitions

Data is considered as the oil of the 21st century. Economist's May 2017 cover (cf. **Figure 2.1**), data is presented as the world's most valuable resource. Enterprises and organisations have realised the tremendous importance of data and precisely for this reason enormous amounts of resources, time and money, are invested towards data-science related projects.

According to Research and Markets, the Global Big Data Analytics Market was valued at US$ 37.34 billion in 2018 and expected to reach US$ 105.08 billion by 2027 at a CAGR of 12.3% throughout the forecast period from 2019 to 2027. Increasing volume of data and adoption of big data tools to spur revenue growth during the forecast period.

Figure 2.1: Economist's cover on the importance of data (Economist, May 2017).

It is estimated that during the year 2017 we have generated more data than we did over the previous 5,000 years of our human history and the reasons for this is that every device we own, like PCs, tablets, smartphones, wearables and many others generate data, and all our interactions with said devices generate even more data. Thus, data generation is increasing exponentially.

> *““The amount of digital data in the universe is growing at an exponential rate, doubling every two years, and changing how we live in the world. ‘The rate at which we’re generating data is rapidly outpacing our ability to analyze it,’*
>
> *‘The trick here is to turn these massive data streams from a liability into a strength.’ $10-15 trillion can be added to the global GDP over the next few decades, just by identifying efficiencies created by the convergence of machines, data, and analytics. That’s as big as the US economy today. Just about 0.5% of all data is currently analyzed, and Wolfe says that percentage is shrinking as more data is collected.””*
>
> Professor Patrick Wolfe, UCL

In shipping there is plenty of data as illustrated in **Table 2.1**.

Voyage data	- Automatically collected data (IoT) - Noon report
Machinery data	- Automatically collected data (IoT) - Manual report data - Maintenance data / trouble data - Main Engine (temperature, pressure, vibration, clearances, deflection) - Turbocharger (temperature, pressure) - Steering Gear (flow rate, pressure electrical) - Pumps (vibration, electrical, flow rate, pressure) - The dimensions of the ship - The static draft of the ship
Automatic Identification System (AIS) data	- Satellite AIS/shore AIS (IoT) - Precise location of the GPS antenna on the ship
Weather data	- Forecast/per statistics - Anemometer/ wave measurement (IoT) - Meteorological data - Buoy
Business data	- Cargo transport data - Port calls data

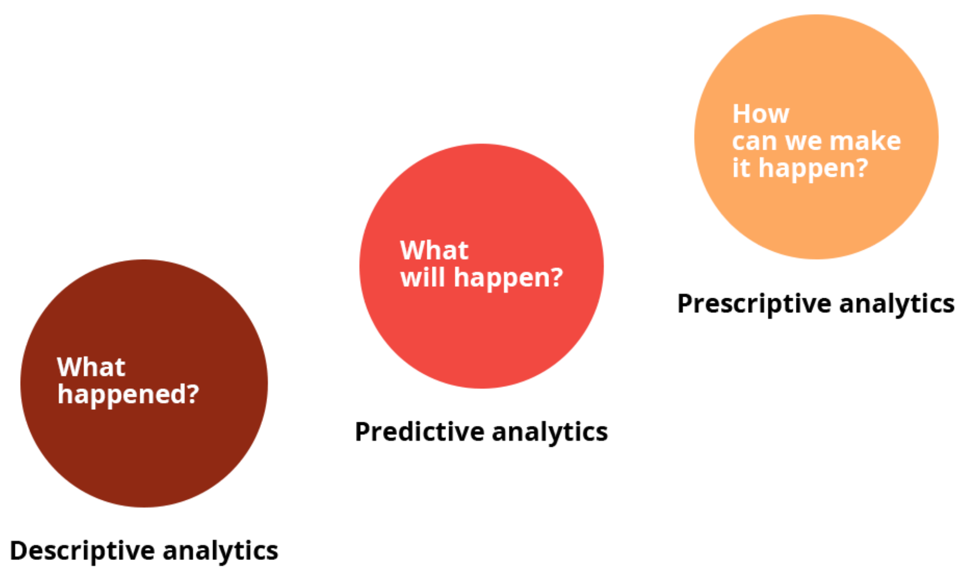
Table 2.1: Examples of Big Data in the Shipping Industry.

Definitions of Data Analytics/Data Science

When we refer to analytics we can use any methods from the fields of AI, ML and Statistics in order to address a scenario of interest from a more scientific way.

We usually have 3 + 1 basic types of analytics as follows:

- **Prescriptive**: This type of analysis reveals what actions should be taken.
- **Predictive**: An analysis of likely scenarios of what might happen.
- **Descriptive**: This is more related to what is happening now based on incoming data and data visualisations.



- **Diagnostic**: A look at past performance to determine what happened and why. This is usually in the form of root-cause analysis.

Big Data Analytics

Big Data Analytics is the set of techniques and processes applied for examining large and of different formats data sets (i.e. Big Data) collected from different sources, with the aim to uncover hidden patterns, unknown correlations, important insights that collectively can improve the decision making capabilities of an enterprise or organisation. When we describe Big Data we refer to the 4Vs; Volume, Variety, Velocity and Veracity that we examine in detail in the next section (Table 2.2).

Volume The main characteristic that makes data to be characterised as "big", is the sheer volume. However, big data is not defined in terms of larger than a given threshold (e.g. a few terabytes) since the total amount of information is growing exponentially every year, as well as the storage capabilities.	**Velocity** It is about the frequency of incoming data that needs to be processed. The data movement is now real time and the update window has reduced to fractions of the seconds.
Variety Data can be stored in multiple formats. Some examples are database, excel, csv,, SMS, pdf and many others.	**Veracity** It refers to the trustworthiness of the data. Related to the biases, noise and abnormality in data. It is a very important property since no statistical algorithm can save bad quality data.

Table 2.2: 4Vs in Big Data

Big Data Framework

Figure 2.2 depicts a framework that can be applied in order to solve a business problem of interest using data that are available. Note that whether the data is small or Big, the same methodology can be applied.

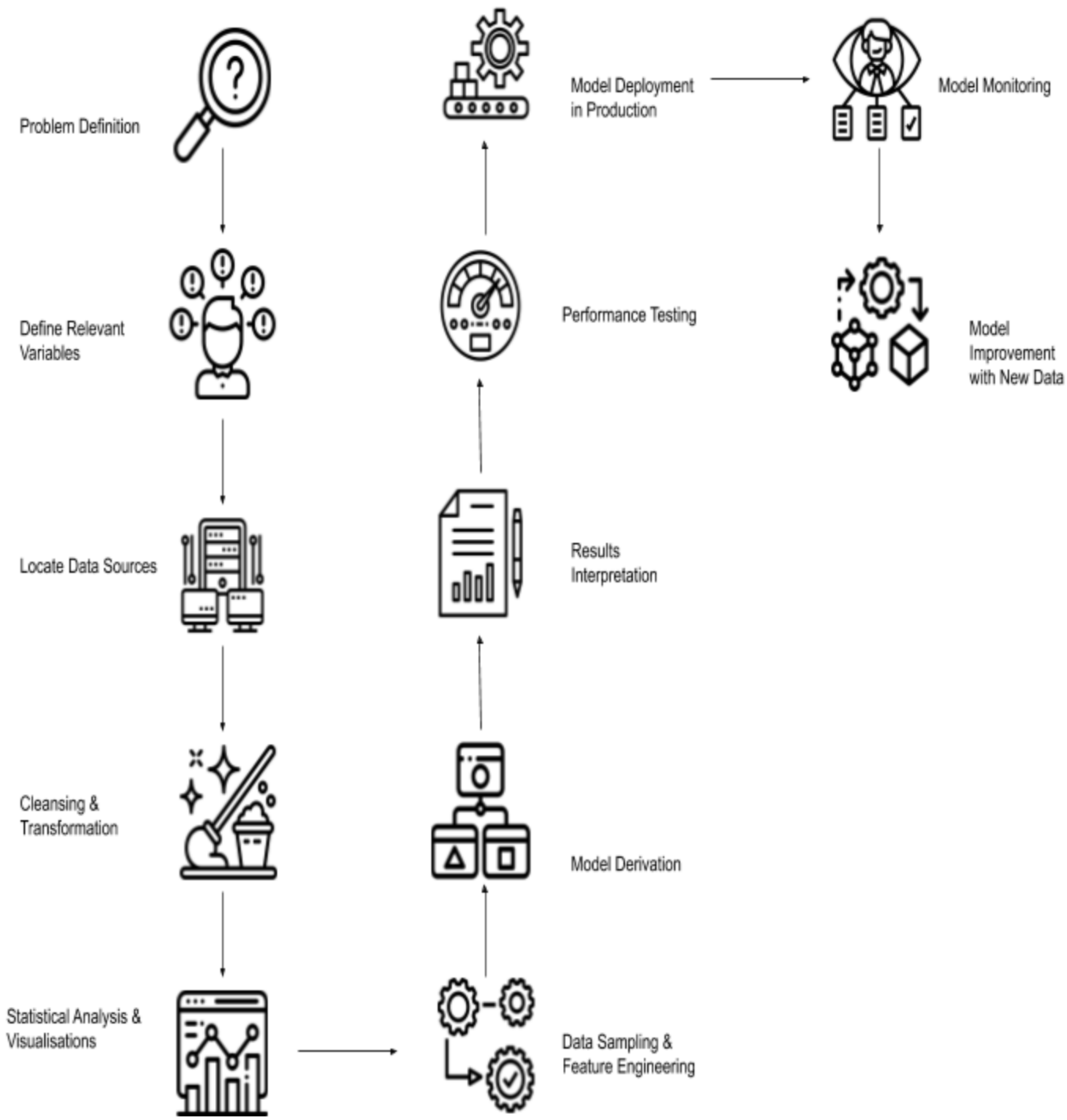


Figure 2.2: Big Data Analytics Framework

- **Problem Definition:**
    - Ask the right question
      How do I improve upon my energy management strategies ?
    - What departments and operations are associated with this question
      Which departments within the organisation keep data related to fuel consumption and energy?
    - Locate relevant data sources
      Historic data for fuel consumption, noon report, machinery data collected via sensors, cargo characteristics etc

- **Define Relevant Variables:**
    - Define variables from the located data sources
      real-time consumption, distance travelled, speed, path, flow meter, shape and size of the ship, velocities, noon report, machinery data collected via sensors, cargo characteristics etc

- **Locate Data Sources:**
    - Identify available data sources
    - Enhance with external data

- **Cleansing & Transformation:**
    - Inspect for missing or inconsistent values
    - Plot some graphs to observe abnormal values or outliers
    - Check according to the reference data (if provided)

- **Statistical Analysis & Visualisations:**
    - Plot some variables of interest to identify any significant relations
    - Such relations can be used to understand which variables are the most important ones to be used for modelling

- **Data Sampling & Feature Engineering:**
    - Select variables of interest and populate their values in a quantitative form

- **Model Derivation:**
    - Apply models from Computational Statistics and Machine Learning to derive a statistical Model

- **Results Interpretation:**
    - Understand the implications of the derived model on the operations

- **Performance Testing:**
    - Use metrics associated to the model to measure its accuracy and performance

- **Model Deployment in Production**

- **Model Monitoring**

- **Model Improvement with New Data**

Example: Minimising interview time using analytics

Interviews and CVs review takes significant time for the enterprises. Any type of clever heuristics for early filtering or ranking of candidates would be of tremendous importance. Data analytics techniques can be used to attach scores to the candidates with respect to the predicted role performance. The idea is to have clear relations between KPIs and related CVs of existing employees. This can be achieved by having sophisticated tags related to the CVs of the employees and finding which of them usually outperform with respect to the KPIs. Then, for each new CV find a set of CVs that are similar with respect to several tags and then try to forecast the KPIs for the candidate. This provides early indications regarding the potential of a candidate. **Figure 2.3** depicts this idea which is as follows.

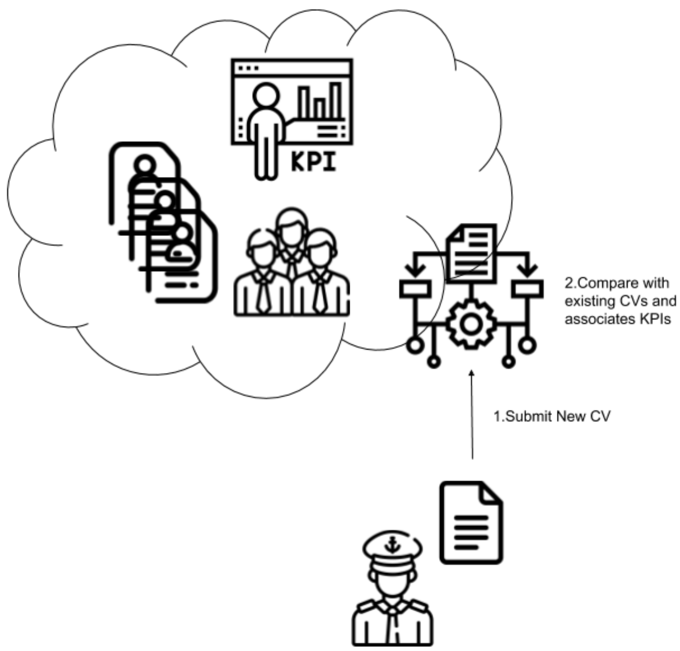


Figure 2.3: Decreasing interview time with data analytics

Challenges in Big Data

Despite the fact that many companies realise the value of big data analytics, most of them struggle to apply them due to the many complexities involved:

- **Data Quality**: Data is very frequently stored without following data management procedures and data governance methods. This is known in Computer Science as “Garbage-In-Garbage-Out” principle.
- **Data Transfer:** Ships have a large number of sensors onboard and a major cause of uncertainty comes from data transfer from those sensors due to different network or hardware malfunctions.
- **Lack of Standardisation:** The industry has to adopt big data analytics.
- **Data Protection & Cybersecurity**: Very frequently, data needs to be shared among individual parties. Sensitive or Confidential or Personally Identifiable Information (PII) related data will probably need to be shared externally making security and privacy priorities for data protection and to maintain the data quality, as well as being compliant with data security related regulations.
- **Data Integration:** The current data collection systems in the marine industry are inconsistent and often unreliable.
- **Lack of data-driven Culture:** Convince the top management to invest in data-science projects (and which areas) is sometimes tricky.
- **Data Volume:** Ability to handle volume, velocity and variety of big data is a big technological challenge. This usually requires investment in technological infrastructure and training of the IT personnel.
- **Data Ownership**: Ownership of data is crucial to the shipping industry since allows access to the data (e.g. read, create, update and delete) .
- **Human factors and Practice:** It will become more important to increase the connectivity between the crew and shore staff in shipping companies.

How Big Data Solve common Shipping Problems

Engine Management

Analytics can be applied in the shipping industry for improving ship efficiency in many ways:

- Weather Forecasting: Weather related data can be analysed and help answer questions like: Are any extreme conditions expected? What is the weather like in the area where the ship is sailing? What is the wind like? What is the sea salinity or temperature? How high are the waves?

- Fuel optimisation & Energy management: by collecting data from sensors such as ambient air temperature, the humidity, the speed of the ship, weather conditions, the barometric pressure, the fuel mass, the power and the fuel quality amongst other attributes that can be used in combination with regression models to predict the fuel consumption given a voyage path. Bialystocki *et al*, in their paper suggested an operational and statistical approach for obtaining an accurate fuel consumption and speed curve, on the basis of major factors affecting it such as ship's draft and displacement, weather force and direction, hull and propeller roughness using data from 418 noon reports of a Pure Car and Truck Carrier case ship (Bialystocki *et al*,2016). In addition, using measurements of the ship's speed, which turned out to be the most significant parameter in determining both the power and fuel consumption, they computed a statistical model that describes the relation between fuel oil consumption (kg/h) and ship's speed over ground (KT). Based on the model derived they found out that fuel consumption increases also in case of increased draft and displacement, worsening of weather conditions and worsening of hull and propeller roughness, except for the speed increase.

- Condition monitoring that will help as understand the Maintenance needs, reducing downtimes

In shipping there are several data that can be used for data analytics that might enable us to derive models regarding performance such as:

- sensor data
- fuel consumption
- vessel speed
- wind speed as
- navigation/depth maps etc.
- historic voyage related data
- weather related data
- vessel speed
- mean draft and trim
- water resistance
- wind resistance
- the load on the cargo
- marine growth on the ship that depends on the specific voyage and the condition of the sea (depth, temperature, location etc)
- sea state (the effect that the local winds have on sea conditions)
- and many others.

Table 1.5.1 presents possible applications of big data applications.

Role	Function	Big Data Application
Ship Owner	**Technical Management**	• Safe operation • Condition monitoring and maintenance • Environmental regulation compliance • Hull and propeller cleaning • Retrofit and modification
	New Building	• Design optimisation
Ship Operator	**Operations**	• Energy saving operation • Safe Operation Schedule management • Logistic planning systems
	Fleet Management	• Fleet allocation • Service Planning • Chartering

Table 1.5.1: Possible applications of big data in shipping industry.

Energy Management and Fuel Consumption Optimisation:

The International Maritime Organization (IMO) has adopted a voluntary scheme for calculation of Energy Efficiency Operational Indicator (EEOI) with the main objective of its future use as a monitoring performance indicator in shipping.

According to EU MRV, ship operators need to comply with environmental legislations including the requirement to switch fuel in emission controlled areas (i.e. the Sulphur content of the fuel should not be more than 0.1% on and after 1 January 2015) and to quantify the CO2 emissions for ships above 5000 gross tonnage. These data-oriented regulations require the ship operators to monitor CO2 emissions and the system will give an indication of fuel switching as well as monitoring the current emissions based on different parameters relying on collected data and computed forecasts.

It is inevitable that shipping needs to move towards flexible and alternative energy systems and integrate energy management systems that will be based on real-time data of load requirements and power availability from all sources. Regression algorithms can be applied on all this data collected (such as flow meter, GPS, real-time consumption, distance travelled, speed) in order to find conditions that lead to fewer fuel consumption and better performance. In addition, access to historical data for example related to machinery and vessels will allow ship operators to forecast and hence optimise vessel performance.

Voyage Planning:

Regression techniques can be applied on meteorological data in order to get reliable forecasts of the wind and ocean current data. Then, advanced data analytics can be applied that will select the optimised voyage planning based on different route related data, vessel performance and meteorological data. This will enable us to identify the most efficient route for the journey.

Operational Predictability and Predictive Maintenance:

Data related to the health of the machinery such as engines, pumps, boilers, compressors and others that are collected by sensors in real-time, if analysed correctly can be used to monitor vessel’s operational performance in real-time and provide us the ability to predict the vessel performance based on current operational conditions.

In this way we will be in position to obtain early warnings if there is a need for maintenance and thus potential failures will be avoided, reducing the cost of asset failures and minimise unscheduled downtime.

Energy Management & Fuel Consumption Optimisation

Shipping is a heavily regulated industry and responsible for around 3% of global carbon emissions. Both the EU and the IMO have ambitions to reduce even further the GHG (greenhouse gases) emissions from the ships. Precisely for this reason they have introduced the following mandatory requirements, as the first step in a process to collect and analyze emissions data related to the shipping industry:

- EU MRV – EU Monitoring, Reporting and Verification of CO_2 emissions (data collection started 1 January 2018)

- IMO DCS - IMO Data Collection System on fuel consumption (data collection starts 1 January 2019)

The outcome of both aforementioned schemes will be annual reports stating CO_2 emissions per vessel (EU MRV) or aggregated fuel consumption (IMO DCS). According these regulations, ship owners and operators need to provide several parameters with precise measurements in their reports including parameters such as:

- Ship type
- Gross tonnage (GT)
- Net tonnage (NT)
- Deadweight tonnage (DWT)
- Power output (rated power) of main and auxiliary engines (kW)
- EEDI (if applicable)
- Ice class
- Fuel oil consumption, by fuel oil type, in metric tonnes and methods used for collecting fuel oil consumption data
- Distance travelled (over ground)
- hours underway

Shipping industry must continue to develop at a rapid pace in order to be able to adapt to upcoming regulations and market pressure and it seems that ship intelligence will be the driving force shaping the future of the industry.

Ship owners and operators are obliged to generate and store data based on several regulations but they anyway generate a large volume of data from different sources and in different formats.

So big data has become the talk of the industry nowadays and Big data will also bring new opportunities and challenges for the maritime industry.

Kim *et al*, in their paper studied the ship speed optimization problem with the objective of minimizing the total fuel consumption by assuming that the daily fuel consumption is approximated by a well-known cubic function of speed of the form $f(v) = c.v^3$, where c is a factor of converting speed to the fuel consumption (Kim *et al*, 2016). In order to solve this problem they modelled the total amount of fuel consumption of a vessel sailing from one port to another and by using nonlinear mixed integer programming techniques.

The objective functions was used to model the total amount of consumption of the ship where constraints have been used to ensure several conditions such as, ensuring cargo service at each port starts after the ship arrives at the port, the starting time of cargo services lies in exactly one of the time windows at each port, the ship speed on a leg is bounded by its allowance minimum and maximum speeds and many others that force feasible ranges of decision ranges. They achieved to find an optimal solution that lead to significant decreases in the fuel consumption.

Another study by Lundh et al (Lundh et al, 2016), proposes a new approach for minimization of the fuel consumption of diesel electric marine vessels that again involves optimisation methods that achieves fuel saving of 4-6%. Their approach can provide optimal guidance in relation to which diesel engine to run, which ones to stand by and which not to use and how to achieve power optimisation in order to determine how to distribute the load over the available diesel engines to provide more accurate results when the input data are more trustworthy.

Voyage Optimisation

Routing optimisation has been a traditional problem in the shipping industry and the traditional route optimisation was primarily based on data related to the weather conditions only with the main target being to avoid bad weather. However, the field has progressed a lot and optimisations that take into account more complex datasets and parameters have been conducted. Recent research that has compared historical passages of ships that sailed using weather related only routing optimisations with others that used more advanced optimisation techniques revealed that the latter had an annual improvement of up to 5 per cent regarding fuel saving (Chen, 2013). Such savings are huge if you consider the order of amount of money spent on fuel per year that is of the order of Billion dollars.

Actually, this result was quite expected since there are many limitations in case of weather routing only. For example, such technique ignores other important parameters such as the ship response in case of increased wave/wind resistance or voluntarily due to navigation hazards or fear of heavy weather damage from excessive ship motion, propeller racing, slamming or boarding sees but also does not explore all available and relevant data to build more robust optimisations. Additionally, engine overload and speed management are not taken into consideration in the modelling stage of the optimisation problem (Chen, 2013) and such parameters can affect the accuracy of the model and manage to build a better solution.

Voyage and routing optimisation is a technique used to assist ship masters in route selection taking into account many parameters such as the predicted ship performance over various routes in various sea states and current conditions, safe operation, weather conditions, emission controlled areas, contractual agreements and many others. The routing optimisation can help in effectively reducing fuel consumption, improving energy efficiency and improving upon the environmental footprint of the ships by reducing their CO_2 emissions.

Examples of such data are:

- Traffic density in sensitive areas (ports, canals, wind farms, floating platforms)
- Piracy or accidents related events
- Sea states
- Hull form
- Fuel consumption
- Time of Arrival (ETA)
- Ship motions
- Wave induced loads
- Comfort Indexes
- Number of course/speed changes
- Maximum allowed delay
- Wave speed
- Wind speed

So far, we have discussed optimisation problems from a conceptual point of view. In the rest of this section, we will provide the formal mathematical definitions regarding optimisations, as well as the associated techniques that can be deployed.

Predictive Maintenance

All types of mechanical equipment (e.g. HVAC - Heating Ventilation and Air Conditioning systems, propeller, lube oil pump etc) require regular upkeep and planned or periodic maintenance in order for marine vessels to run efficiently with reduced probability of experiencing machinery failures. At the same time, failures and downtimes in any of the subsystems or components or mechanical parts of the vessels may have large direct or indirect financial consequences such as high costs, loss of revenues, high logistics costs due to remote locations, extra man-hours lost or even environmental impacts. It is well known that the shipping industry is spending huge amounts of money on maintenance every year.

However, planned periodic maintenance is more on the reactive side rather than the pro-active one and thus proven to be not enough. Leveraging the power of Big Data, the marine industry can develop advanced condition-based monitoring programmes in which maintenance strategy will be entirely based on the monitoring of key components and systems on the vessels. With condition-based monitoring one can predict failures before they happen using predictive algorithms. If it is done correctly, ship operators and managers can reduce the probability of system failures, cost overheads, increase vessel's effective uptime but also decrease insurance premiums.

Due to the increasing complexity of electrical and control systems on-board ships, as well as the plethora of interconnected devices such as sensors and Internet-of-Things (IoTs) machines, maintenance of ship electrical installations has become a major and a very complex issue. Several components are very advanced and operate around their own technology which means when a major issue appears, a trained and competent team on many different systems and technologies is required to be onboard in order to ensure correct operation of these systems. Usually having on board such teams turns out to be very expensive.

In general there are several ship maintenance programs such as (Polygon Blog, 2018):

- **Planned maintenance system:** A common time-based monitoring system. It usually includes periodic overhauling, inspections and component replacements on machinery.

- **Breakdown, or corrective, maintenance:** It involves repairing shipboard machinery that failed.

- **Preventive maintenance:** The idea behind this program is that the crew inspects a ship and applies preventive measures based on the results of their conditional analysis and maintenance schedule. It is also enforced via several regulations that require ship owners and operators to undertake specific measures. Such examples are periodically cleaning and lubricating components, as well as projects related to surface preparation and coatings using marine temporary climate solutions.

- **Predictive maintenance:** A great application of Big Data Analytics (including Machine Learning, Artificial Intelligence and Computational statistics techniques) that is designed to determine the condition or the state of in-service equipment, named also as condition-based maintenance. It is based on proactive statistical analysis of equipment or machinery in order to compute the probability of an equipment or machinery requiring maintenance in the near future. The primary target is for scheduling corrective maintenance of the ships before they are on open waters, where it's more difficult and costly to conduct repairs.

Ch 3. Blockchain & DLTs: Use-Cases in the Maritime Industry

Blockchains: Properties & Challenges

Blockchain or **Distributed Ledger Technology** (DLT) is a nascent technology that is the result of 40 years+ in cryptography and distributed systems research. This technology has the potential to streamline processes and procedures, lower costs, eliminate extra overheads, improve upon the speed of transactions, enhance transparency, and fortify security. It firstly appeared as the accounting ledger supporting the Bitcoin protocol, introduced by Satoshi Nakamoto in 2008 in the paper "Bitcoin: A Peer-to-Peer Electronic Cash System" (Satoshi Nakatomo, 2008).

> "*Blockchain is the technology most likely to change the next decade of business is not the social web, big data, the cloud, robotics, or even artificial intelligence*".
>
> **Harvard Business Review** (HBR, May 2016)

The World Economic Forum survey suggested that 10 percent of the global GDP will be stored on blockchain by 2027. In addition, multiple governments and big enterprises have published reports on the potential implications of Blockchain, and the past two years alone we have seen more than half a million new publications on Blockchain, 3.7 million Google search results for Blockchain and more than 2,500 patents on Blockchain have been submitted (Carson *et al*, 2018).

An amazingly increased interest for applications of this technology is observed world-wide. Governments and enterprises discuss how to apply it to different sectors such as: Digital Identity, Payment, Supply Chain, Health Records, Digital Rights Management, Legal Contracts, Land Registry, Transportation, Taxation, and Voting.

Behind Blockchain

Blockchain is a continuously growing list of records (called blocks) securely linked using irreversible cryptographic functions, called *hash functions*. As soon as records are approved and stored on the ledger it is computationally infeasible to modify them.

The transactions populated under a block are checked and verified by the whole network and the decision whether a transaction or block is valid arises democratically from the entire network without the need of a trusted third party to oversee the activity. Cryptographic sealing takes place binding all the transactions (present and past) together, resulting in an immutable and transparent version of the ledger.

Ownership of assets is guaranteed via special cryptographic primitives, named digital signatures that in a nutshell consist of two key pieces of information; the **public** and the **private** key. The public key is used as an address for someone to be identified over a network and thus being in position to receive funds or granted access; while a private key is a secret piece of information that can be used to claim ownership of funds and thus be in position to spend them.

Figure 3.1 describes how information flows in a Blockchain-based ecosystem.

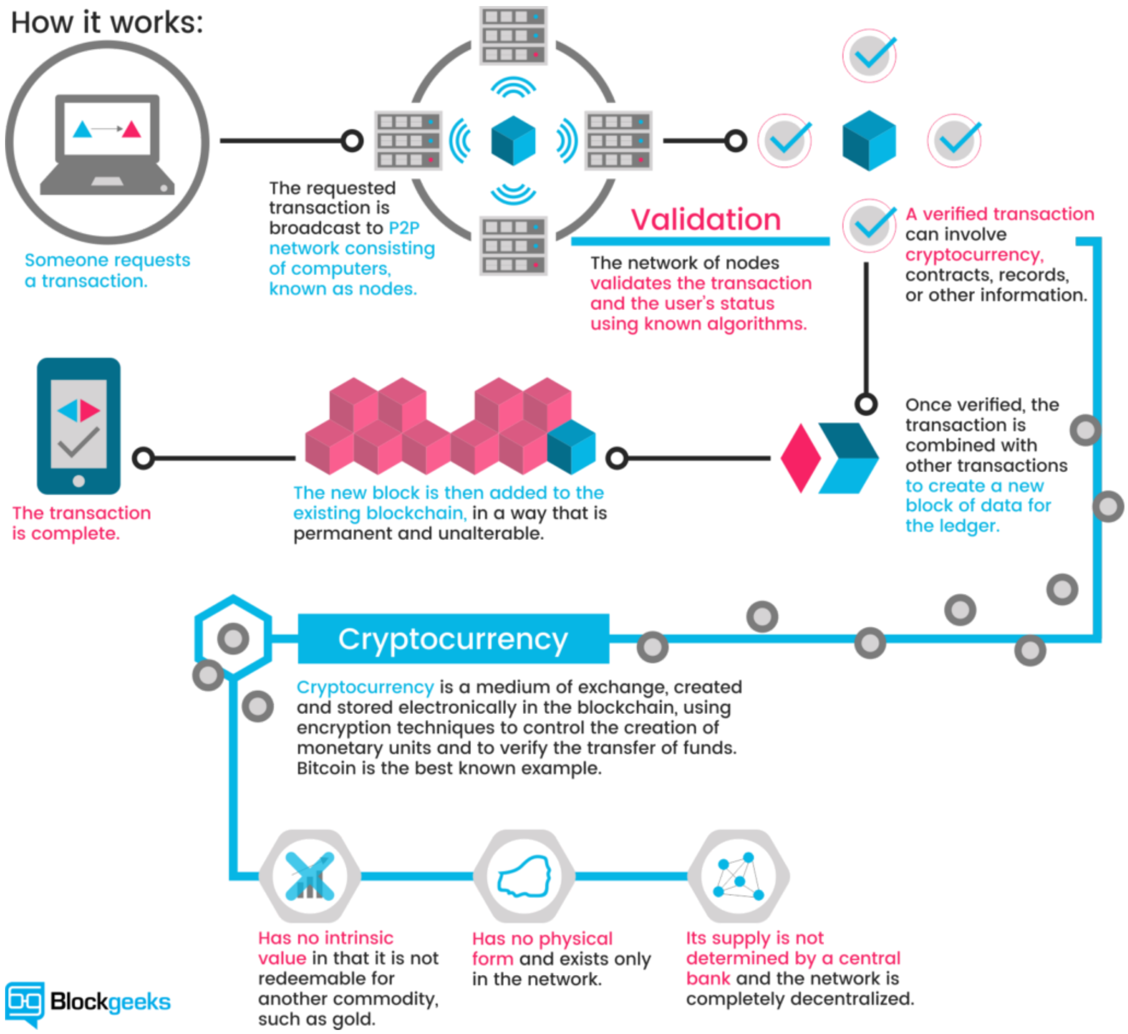


Figure 3.1: How Blockchain Technology works (vid. Blockgeeks)

A new generation (second generation) of Blockchains allows also for the encoding of smart contracts (encoding of terms and conditions into executable code) automating legal procedures in a very transparent and fully auditable way.

A smart contract (cf. **Figure 3.2**) is a computer protocol intended to digitally facilitate, verify, or enforce the negotiation or performance of a contract. The idea is to convert a legal contract into a programmable script that can be uploaded on a Blockchain and will programmatically describe terms and conditions, triggering events and self-executing the contracts when the conditions are verified that they have been met.

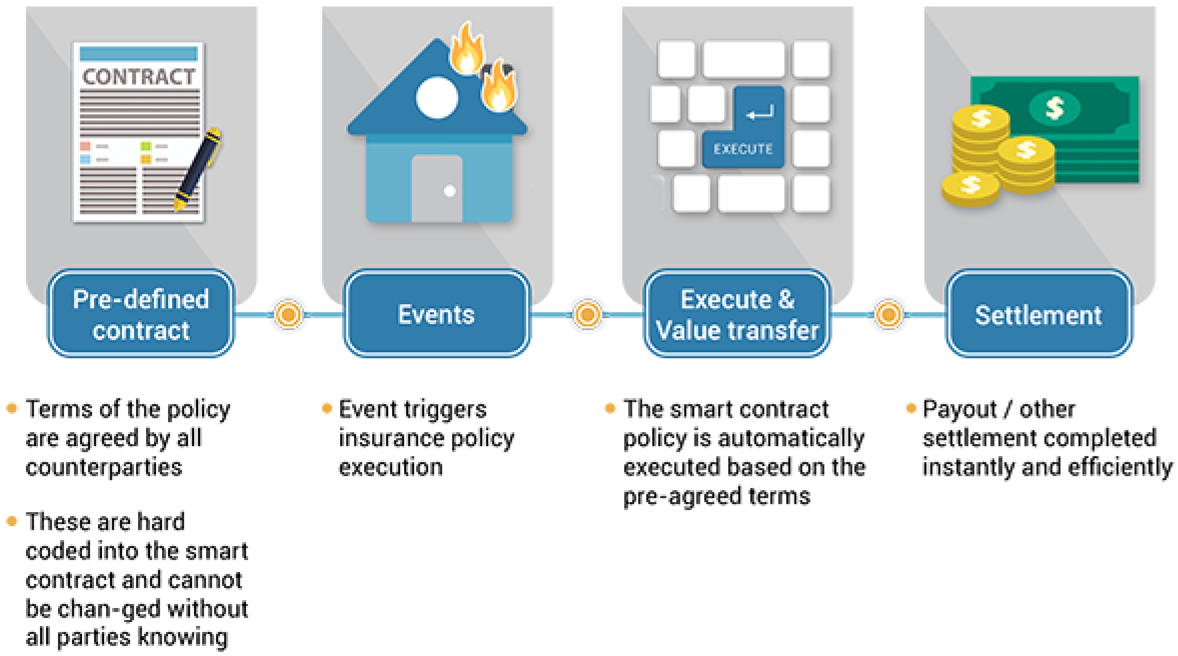


Figure 3.2: Smart Contract Illustration

Consensus Algorithms

A vital part in a Blockchain ecosystem is that of consensus algorithms, which are the mechanisms that guarantee how the decision for approving an action or transaction will be taken into the ecosystem. There are different types of consensus algorithms that can be deployed in a Blockchain ecosystem.

Figure 3.3 summarises some of them while going into more details is not in the scope of this course.

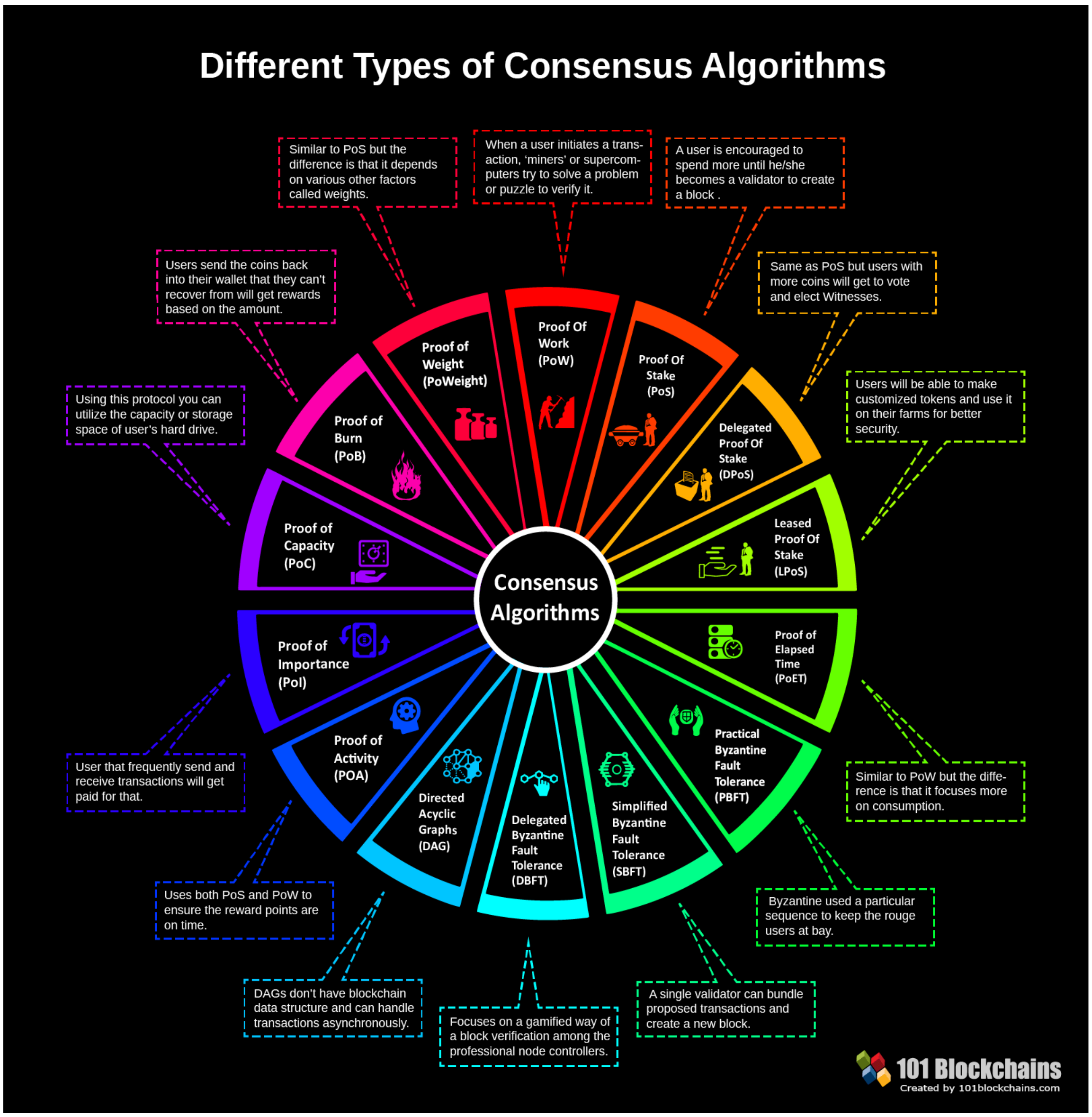


Figure 3.3: Different Consensus Algorithms

Blockchain can add value by allowing streamlining and linearising the process of communication among several parties. However, since the technology is very nascent there are a lot of complexities and challenges that need to be addressed before it goes mainstream such as:

- **Transparency/Finality:** The true state is that of the ledger and shared among the participants of the network.
- **Scalability:** The validation of the transactions conducted by the peers of the network is a very heavyweight process from a computational point of view, especially in public blockchains. At the moment there are limitations in terms of the number of transactions that can be handled.
- **Immutability:** Creating immutable ledgers is one of the main values of Blockchain. Any database that is centralized is subjected to get hacked and they require trust in the third party to keep the database secure.
- **Interoperability:** Several frameworks exist but there is no clear direction or set of standards that will enable the industry to adopt this new technology. ISO/TC 307 committee is working towards this direction.
- **Security:** The whole ecosystem is very complex which makes it impossible to protect against every plausible scenario.
- **Automation:** Smart Contract technology allows encoding of relations among complex ecosystems and automates actions.
- **Construction of direct trust:** Unknown (and untrusted) parties can operate without the need of third-party intermediation.
- **Elimination of Single Point of Failure:** No Central Authority or intermediaries are needed to oversee the transactions. A copy of each ledger is stored and maintained by each node of the network.
- **Decentralisation:** No single point of trust and thus no single point of control.
- **Auditability:** Participants of the network can verify the veracity of records directly, without external querying.
- **Accountability:** All actions can be related to the person who initiated them and are recorded on the ledger.

Different Types of Blockchains

There are 2+2 types of blockchains:

- **Public:** Completely open and anyone can freely join and participate in the ecosystem. Any node can receive and send transactions from anybody in the world, and can also be audited by anyone who is in the system. For a transaction to be considered valid, it must be authorized by the whole network through the consensus process. Once this authorization takes place, the record is added to the chain.

  Public blockchains typically have incentives to encourage people to join the network as well as to authenticate transactions.

  Examples are Bitcoin, Ethereum, EOS, Stellar and many others.

- **Private:** Run as permissioned closed networks and in order to gain access, one must be invited and validated by either the network starter or by specific rules that were put into place by the network starter. Once the invitation is accepted, the new entity can contribute to the maintenance of the blockchain in the customary manner. A typical way for enterprises to use private blockchains is intrabusiness, ensuring that only company members have access.

  This is a useful business solution if there is no reason anyone outside of the company should be part of the chain as data can be restricted to certain individuals on a need-to-know basis. With fewer people as part of the chain, they are typically quicker and more efficient with an easier consensus process.

  Examples are Hyperledger Fabric, R3 Corda and many others.

- **Hybrid:** A hybrid blockchain has a combination of centralized and decentralized features. The exact workings of the chain can vary based on which portions of centralization decentralization are used.

- **Sidechains:** A sidechain is a designation for a blockchain ledger that runs in parallel to a primary blockchain. Entries from the primary blockchain (where said entries typically represent digital assets) can be linked to and from the sidechain; this allows the sidechain to otherwise operate independently of the primary blockchain (e.g., by using an alternate means of record keeping, alternate consensus algorithm, etc.).

How Blockchain Solve common Shipping Problems

Despite the fact that the last few decades we experienced and we are still experiencing constant technological advancements that impact our every-day life and every industry at a very high degree, the shipping industry still relies heavily on traditional processes and old legacy systems. Compared to most of the advanced industries, shipping and maritime related processes and operations seem to be downright archaic and fail to sufficiently meet the needs and standards of the companies and enterprises involved in the supply chain in terms of technology adoption and digital strategy.

The majority of shipping transactions and operations including crew and ships related certificates issuance and validation, charter party agreements, sales contracts, crew scheduling, bills of lading, letters of credit, TAX documents, invoicing and purchasing procedures, items and products sourcing, port documents are still based on paper-based operations. All these mounds of paper documents need to pass through several hands through a supply chain and at each point they need to be checked and validated. Since it is very important to do holistic checks and keep track of all this paperwork, these procedures become extremely time-consuming and costly. As the chances of errors are increased due to heavy human intervention.

Digitisation of these paper-based procedures must be of top priority and the industry needs to start pushing to get shippers, customers, banks, insurers, port authorities and others to stop filling out forms on paper and start using digital methods for issuance and verification of documents. Should they succeed, documentation that takes days will eventually be done in minutes, much of it without the need for human input.

Furthermore, nowadays shipping accounts for approximately 90% of all global trade and the number of ships and carriers increased exponentially to facilitate these trade volumes. The increased sea traffic undoubtedly increases the probability for accidents. To all involved businesses and parties, any incident at sea results in large financial losses. Thus, a method of real-time data exchange and validation, as well as intelligence sharing is another priority for the shipping industry.

*Blockchain technology, even though still at infant stage, seems to offer the desired properties for the shipping industry; **digitisation** and **real-time orchestration** of processes and operations. In the rest of this section, we make a brief recap to the properties of Blockchain and we explain how it could be utilised to solve challenges in the shipping industry.*

Below we discuss several issues that we meet in the shipping industry:

- **Heavy paper-based operations**: As already mentioned many inspections that are scheduled as part of a supply chain are about checking and validating mounds of paper documents. Undoubtedly this is translated to direct costs, lots of errors and resources being wasted.

- **Safety and security issues**: The increased sea traffic, undoubtedly increases the probability of accidents. Thus, an intelligent way for sharing information about incidents, states of the sea, state-of-extreme weather is very important.

- **Increased Human Errors:** Studies consistently estimate that around 80% of causes in marine accidents are attributable to the human factor. A report by Allianz Global Corporate & Specialty highlighted crew negligence and inadequate vessel maintenance as two increasing areas of risk.

- **Time-consuming operations:** Since we have the majority of operations being based on paper document inspections and most of the supply chains rely on traditional legacy systems, the time taken to conduct such operations is unavoidably increased.

- **Ownership of Complex Supply chains**: Since in shipping related supply chains, many entities are involved, it is very complex to understand which stakeholder owns which data. This is also quite problematic with the increasing data protection regulations such as GDPR and might lead to huge fines and penalties.

- **Lack of real-time intelligence sharing:** The data recording instruments and sensors require direct physical contact in order to retrieve any data from them for investigation in case of an accident.

- **Lack of transparent auditability**: Insurance claim processes can face several issues in a non-fatal example such as a near-collision between two ships. The data recorded by the VDR is one of the data sources used to determine liability but there is possibility of malicious actors that could find ways and means to tamper with the data or device in a bid to reduce their liability. In addition, the data regarding CO_2 and SOx emission need to be published verifiable at any time, otherwise compliance issues might arise.

Below we discuss how this celebrated technology can improve upon the aforementioned challenges and issues (Intelligent Audit, 2018), (Levins, 2018), (Opensea Pro, 2019).

- **Elimination of Paperwork using a common ledger:** One of the most promising aspects of blockchain for the shipping industry is its potential to completely digitise any paper document based operations such as the one mentioned above.

  Going paperless would automatically improve upon efficiency and costs while making it easier for everyone involved in the transaction to access the necessary information through the ledger.

  Buyers and sellers of cargo, charterers, banks, ship owners, port authorities, customs agents, and other parties could interact with each other, store and exchange information, complete transactions, securely exchange payments and more without need to worry about keeping track of stacks of paperwork.

  In addition, nowadays, the check of mistakes and inaccuracies lead to time-consuming reconciliation steps before payments are released. Blockchain and DLT has the potential to eliminate that reconciliation process by providing a commonly shared ledger between the two parties that would serve as an immutable, timestamped record.

  Operations that could be potentially streamlined and improved are around freight invoicing, payment, and reconciliation. This is due to the fact that in supply chains, multiple parties are involved in transactions and they usually maintain their own records and ledgers, as a result invoicing and payments are paper-intensive processes that often entail manual entry.

- **Anti-Tampering and No-single point of failure:** Centralized legacy systems and databases are more likely to be hacked resulting to data being altered, misused or breached resulting to huge fines. This is not the case with Distributed Ledger Technology as a malicious attacker needs to attack every member of the network.

- **No Physical Contact Needed for Accessing Data for Investigations:** Installing a satellite that records real-time location data can prove to be a game-changer. The data can be remotely access which makes physical contact obsolete. Locating the primary problem with current black box recovery is complex. With a satellite, its last location data can be transmitted and be recorded on a blockchain almost immediately. Thus, making the process of locating the black boxes far easier. If the data has already been recorded on the blockchain, then there should be no need to retrieve the black boxes.

- **Increased Global Trade:** Global trade has had an undeniable benefit to the overall global economy and shipping accounts for the 90%. As trade across borders increases, the individual countries involved all see greater economic growth. Global trade has brought with it a whole slew of unique challenges.

  As with many of the other benefits of blockchain, security and trust are the main drivers. In a global environment, certain countries have significantly less protections than others. Such risks have often kept companies from gaining a foothold in the greater global economy. Additionally, customs rules and regulations are as diverse as the countries they are meant to protect. In other industries, pharmaceuticals for example, a global supply chain means greater concern about contamination or questionable ingredients. All of these issues can be solved by the open and transparent manner in which blockchain works.

  In addition, Blockchain technology can speed up the process around payments by designing a shipping-centric cryptocurrency that is fully regulated and can be used for payments.

- **Transparency and Sourcing:** The missing component in transportation and logistics is transparency. Think about the life cycle of most of the goods around you; all start in a manufacturing facility overseas, then move via truck from the warehouse to a port of departure, then from port of departure to port of arrival via a vessel, then from the receiving port via truck to one of the shipper's distribution centers and then finally to the end consumer.

  With so many touch points in the life cycle of each shipment and little transparency to where a shipment is, shippers are left struggling to understand where their shipments are at any given point and have no ability to action. Using blockchain, all information is stored in a location that may be viewed by anyone with the necessary access level, ensuring full transparency to all participants.

Challenges with Blockchain Technology (Opensea Pro, 2019)

- **Standardization:** It is perhaps an interesting data point that the shipping-blockchain project didn't start that way: Rather than all the big shippers coming together to agree on and build a vast new platform for the industry to use, each of them seems to be building its own system and hoping that everyone else adopts it. However, this is not the ideal scenario since at the end it will lead to complex blockchain integration and interoperability issues. Precisely for this reason we have the International Standard Organisation started drafting standards around Blockchain and DLT technology under the ISO/TC 307 committee.

- **Special contractual terms:** The contractual terms of the ship chartering and the sale & purchase of commodities are unique and very specific. These terms should be adapted by the blockchain network which should be able to recognize, for example, what the lien is and how it works, the laytime and demurrage and their exceptions, the Notice of Readiness and when the vessel is actually considered arrived at port etc.

- **Higher flexibility:** It is very usual in shipping, the parties to come across situations where they can only solve through a commercial approach. This will not be easy to take place when the transactions are taking place through a sealed system which does not allow any interference from the parties.

- **Global adoption:** The blockchain is not adapted or it is not yet allowed by all jurisdictions around the world. However, since various governments and agencies are involved around the globe, in order for such technology to be used in trading and shipping services, all these parties should be brought into a common platform and a universal adoption should be achieved.

Certificates on the Ledger

Forgeries of certificates is a major challenge across almost all Industries. Examples of industries that suffer the most include the employment sector, academia, shipping and maritime, healthcare, insurance and many others. In order to mitigate this serious issue, the forgery, counterfeiting or altering of documents and instruments is considered as a criminal activity and huge penalties are imposed in case of critical documents. In academia, numerous incidents of forged academic credentials that led to prosecutions and even imprisonments have been identified in the past few years.

In shipping, forgeries of crew certificates is under the agenda of regulatory bodies such as the International Maritime Organisation (IMO). **According to IMO's statistics, there is an 82% probability of an incident of forged competency certificates to appear in any organisation.** Another industry where the rate of forged certificates is high is healthcare. Such forgery/modification may happen either from the patient's side (e.g. for claiming insurance funds) or from a doctor to avoid the consequences of possible court prosecutions. Blockchains and private-Blockchain architectures in particular tackle this important challenge by leveraging the transparent orchestration of multiple independent stakeholders and guarantee the authenticity of the documents as well as the non-repudiation of the Certificate Authorities using state-of-the-art cryptographic techniques.

Documents are central to the shipping industry. This applies in all circumstances, but the importance of documentation increases even further when goods are being moved across borders.

Some common documents the shipping industry requires includes:

- Bill of lading
- Air waybill
- Certificate of origin
- Invoices
- Shipping labels
- Export license
- Inspection certifications
- Insurance certificates

There are many situations where these documents are wholly or partially digitised, but to make real advances in the shipping industry, full digital transformation (also known as digitalisation) of document handling is required.

Figures 3.4 and **3.5** below describe how traditional certification operations take place.

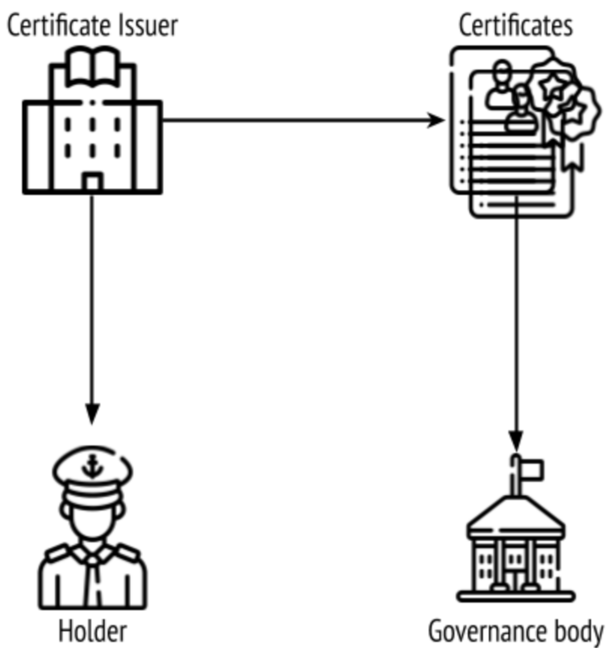


Figure 3.4: Certificate issuance process

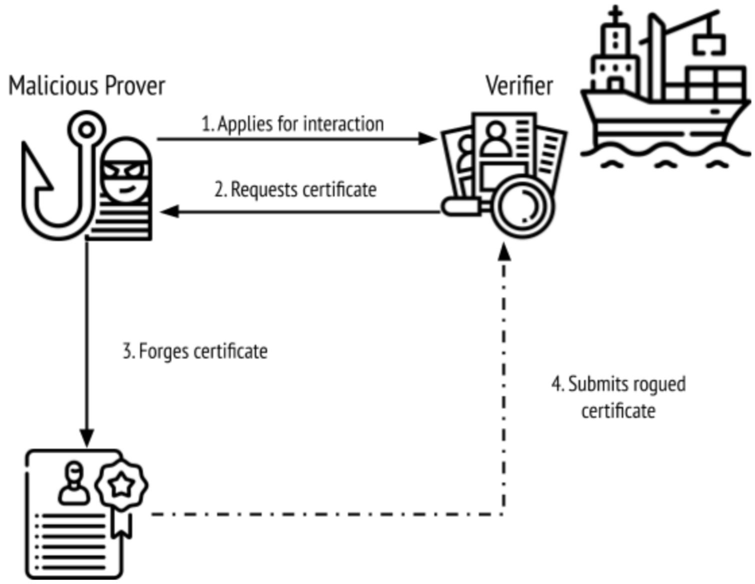


Figure 3.5: Forgery of certificate

Another very promising application of Blockchain and DLT technology is the capability of issuing and verifying certificates on either a public or a private ledger, eliminating possibilities of frauds or errors related to the authenticity of the content of certificates, as well as speeding up the currently manual inspection procedure.

As mentioned, at the moment such verification in the shipping and maritime industry is based on paper documents and manual inspection that requires a lot of time, money and other resources.

Blockchain for Certification

For this particular use-case the best Blockchain to be used is a private Blockchain.

Step 1: *Issuance of the Fingerprint of the Document on the Blockchain*

a) Digitise the document by converting it into a digital form

b) Use the data (or other metadata) of the digital document and apply special algorithms to derive unique fingerprints (or signatures). The document can be signed according to any rule we want for example being signed by the certificate authority and then by a government or port authority.

c) Create an address and push the certificate on the Blockchain (cf. **Figure 3.6**).

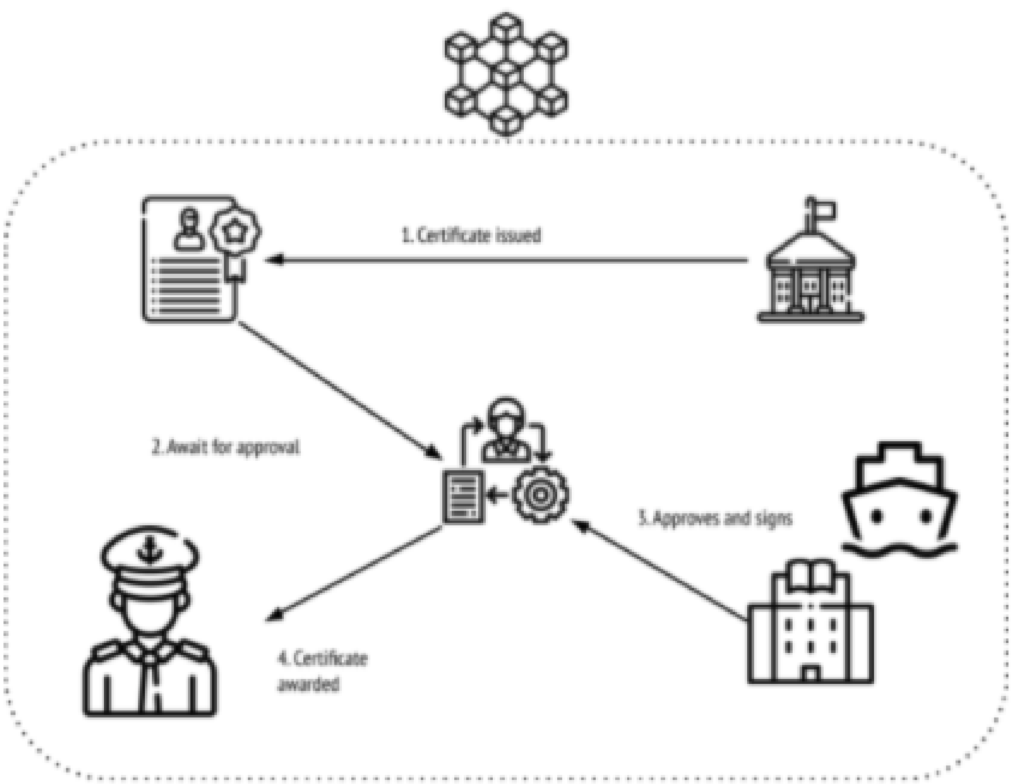


Figure 3.6: Blockchain based certificates issuance

Step 2: *Verification of the content using the Blockchain (cf. Figure 3.7)*

a) Compute the unique fingerprint/signature of the document using the algorithm used by the issuer to compute the signature of the certificate.

b) Search for this fingerprint on the Blockchain using the application of the issuer.

c) If that fingerprint matches the computed one, then the certificate is considered as valid, otherwise it is not considered as valid.

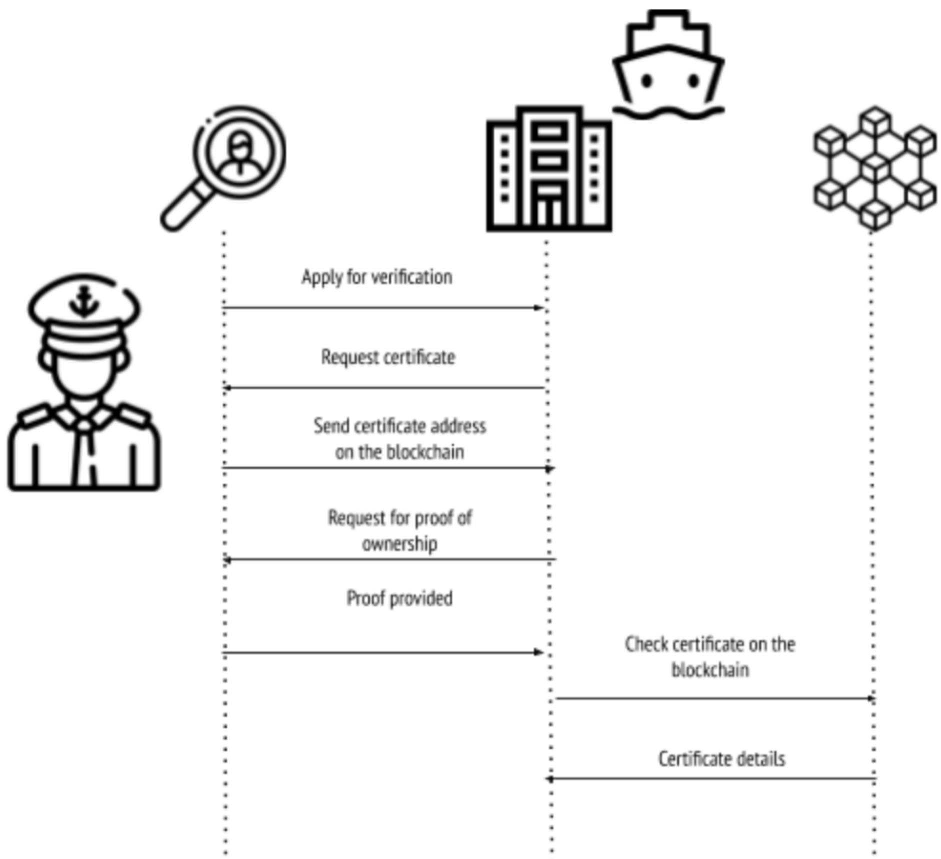


Figure 3.7: Blockchain based certificate validation

Supply Chain Efficiency

When we talk about supply chain management, we are also talking about the logistics industry, shipping, freights, trucking, and every other mode of transport we use to transfer goods. Where there is a system that needs streamlining and a need for transparency, there are a multitude of use cases for distributed ledger technology.

With blockchain technology, we have the solution to iron out bloated and incompetent supply chains. Blockchain-based supply chain solutions are changing the way industries do business by offering end-to-end decentralized processes via the distributed ledger and smart contract technology.

Some supply chains are already using the technology, and experts suggest blockchain could become a universal "supply chain operating system" before long.

Consider how this technology could improve the following tasks:

- Recording the quantity and transfer of assets - like pallets, trailers, containers, etc. - as they move between supply chain nodes.
- Tracking purchase orders, change orders, receipts, shipment notifications, or other trade-related documents.
- Assigning or verifying certifications or certain properties of physical products; for example determining if a food product is organic or fair trade.
- Linking physical goods to serial numbers, bar codes, digital tags like RFID, etc.
- Sharing information about manufacturing process, assembly, delivery, and maintenance of products with suppliers and vendors.

Case Study: Maersk & IBM (TradeLens)

- TradeLens is the result of a collaboration agreement between Maersk and IBM, a blockchain-enabled shipping solution designed to promote more efficient and secure global trade, bringing together various parties to support information sharing and transparency, and spur industry-wide innovation.

- As part of the TradeLens early adopter program, IBM and Maersk also announced that 94 organizations are actively involved or have agreed to participate on the TradeLens platform built on open standards.

- The TradeLens ecosystem currently includes:

    - More than 20 port and terminal operators across the globe, including PSA Singapore, International Container Terminal Services Inc, Patrick Terminals, Modern Terminals in Hong Kong, Port of Halifax, Port of Rotterdam, Port of Bilbao, PortConnect, PortBase, and terminal operators Holt Logistics at the Port of Philadelphia, join the global APM Terminals' network in piloting the solution. This accounts for approximately 234 marine gateways worldwide that have or will be actively participating on TradeLens.
    - Pacific International Lines (PIL) have joined Maersk Line and Hamburg Süd as global container carriers participating in the solution.
    - Customs authorities in the Netherlands, Saudi Arabia, Singapore, Australia and Peru are participating, along with customs brokers Ransa and Güler & Dinamik.
    - Participation among beneficial cargo owners (BCOs) has grown to include Torre Blanca / Camposol and Umit Bisiklet.

- TradeLens uses IBM Blockchain technology as the foundation for digital supply chains, empowering multiple trading partners to collaborate by establishing a single shared view of a transaction without compromising details, privacy or confidentiality.

- Shippers, shipping lines, freight forwarders, port and terminal operators, inland transportation and customs authorities can interact more efficiently through real-time access to shipping data ad shipping documents, including IoT and sensor data ranging from temperature control to container weight. Using blockchain smart contracts, TradeLens enables digital collaboration across the multiple parties involved in international trade.

- The trade document module, released under a beta program and called ClearWay, enables importers/exporters, customs brokers, trusted third parties such as Customs, other government agencies, and NGOs to collaborate in cross-organizational business processes and information exchanges, all backed by a secure, non-repudiable audit trail.

A summary of various work-in-progress blockchains is shown below.

Company	Focus	Whats the Problem?	Whats the Solution?
Blockfreight	Complete shipping blockchain	Fragmented IT systems with limited interoperability	A complete blockchain for shipping, with built in cryptocurrency token
Wave BL	Bill of Lading	A negotiable BL serves as receipt, contract of carriage and title of goods. Currently mainly analogue	Blockchain application allowing for sharing of BL data and anonymous trading of BL
Maersk; IBM	Documentation pipeline	Over 30 different documents are needed to process an export consignment across multiple supply chain steps	Shared blockchain based repository (i) making the needed documents only visible to the parties required to see them and (ii) tracking and time-stamping changes in the chain of custody of a shipment
Port of Rotterdam; ABN AMRO; Royal Flora Holland; TU Delft; and more	Trade finance	Cumbersome letter of credit process involving banks in both source and destination countries	Self-executing smart contracts triggering payment on proof of delivery
SKUchain	Trade finance	Cash flow issues related to the current trade finance process	Smart contracts. So-called 'brackets'; blockchain-based release of funds that are conditionally key-signed and triggered by signals
Everledger	Provenance and traceability	Origin of products is unknown for end user	Blockchain application for tracing diamonds
Provenance	Provenance and traceability	Because of obscure supply chain, many companies are unable to display the origin of their products to customers	Open blockchain-based traceability platform
SOLAS VGM/MTI	Verified gross mass of containers and data sharing	VGM data must be forwarded ahead of time to the carrier. Currently using EDIFACT	Application for recording container data upstream (load points and weighbridges) on a distributed ledger. Interoperable with EDIFACT and API