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Spatial Database Management in the Subsea Survey Service Industry: Database vs. Blockchain

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Abstract:

The subsea survey service industry is an industry which main jobs are acquiring survey data which mostly are the spatial data. These data are then compiled into a project database which contains all information about the projects from survey data, reports, deliverables, and other information regarding the projects. This information refers to various data that contains resources which can be to make decisions that will affect the current state of the project, as well as improving decision-making performance in the company. Spatial database in this form considered to be less effective in terms of data decentralization, immutability, security, and transparency. These aspects can be fulfilled by using blockchain technology. However, the suitability of blockchain technology towards spatial database is still questionable. This research will discuss various literature regarding blockchain, traditional or relational database, and GIS with the purpose comparing one technology to another and finding their strengths and weaknesses toward spatial database using aspects analyzed from previous literatures.

***Keywords:** Blockchain, spatial database, traditional database, literature analysis.*

I. INTRODUCTION

The subsea survey industry is an industrial sector excels in multi-disciplinary survey support, specialized in offshore, nearshore, also inshore for various purposes such as oil and gas, energy and renewable energy, and marine infrastructures. The services from companies in this industry offer wide-ranging services, from survey and positioning, geophysical and geotechnical survey, bathymetry survey, pipeline and inspection survey, and survey result charting. The objectives of those kind of surveys are varies, usually to fulfill client's request from the contract. Spatial data is the most common result of these surveys, since the survey, for many instances, is related to subsea geographical position. data comprise the relative geographic information about the earth and its features. A pair of latitude and longitude coordinates defines a specific location on Earth [22]. These data could be in vector format (point, line, area) or raster format (satellite imagery, georeferenced photo, etc.). Spatial data usually stored and visualized using Geographic Information System (GIS), a framework for gathering, managing, and analyzing data. It can visualize data into maps and 3D scenes. Not only that, but GIS can also help decision-maker by revealing in-depth insight into the data using algorithms which will show relationship and pattern between data.

Companies that focused on this industry most likely are working in a project-based work system as a service company for their clients. Therefore, the company should compile a project database which contains all information about the projects from survey data, reports, deliverables, and other information regarding the projects. These information refer to various data that contains resources which can be used by the project team and leader, project manager, and also consortium representative in order to gather information about projects, activities, or previous projects detail with to provide insights and sufficient background to make decisions that will affect the current state of the project, as well as improving decision-making performance in the company.

A spatial database is a database that is optimized for storing and querying data that represents objects defined in a geometric space. There are some ways to manage and utilize the spatial database. Generally, the spatial database is managed by using a relational database management system (RDBMS) or GIS at its finest, or it can be categorized as 'traditional' database management.

Another characteristic of this industry is similar with oil and gas industry, it has multi-party investment and cooperation, and the risk of fraud, error, and inefficiency in transactions are relatively high [23]. Therefore, the method to manage subsea survey database should be used to accommodate the conformity of database. Some other way to govern spatial database considering that characteristics is by using a slightly diverse technology: blockchain.

Nowadays, blockchain technology has gained much interest in the industry – said to replace traditional database management. Reasons are, the traditional database needs a central trusted party in sharing data and data that is distributed among nodes, which are inconvenience for a company in sharing their data with third parties. Data structure that keeps record of the transactions in the network is the core of blockchain itself. Some basic features that distinguish blockchain and traditional database are the immutability, decentralized, enhanced security, distributed ledger, consensus, and faster settlement.

However, the revolutionizing of database management using blockchain is still unclear, especially for geospatial data in the subsea services industry. Although the expectations are high, the real impact and benefit still need to be reviewed. In order to assess the correlation between spatial database, GIS, blockchain, and also the impacts in integrating blockchain for database management in the subsea service industry, analysis from literatures of these topics will be conducted, to develop better understanding the potential of blockchain technology, and also comparing suitability between these two methods with spatial database.

Structures for this paper will be separated in five sections; section 1 is the introduction which will describe some backgrounds of the research topics, section 2 will explained points of research objectives of this research, section 3 presents the methodological approach which conducts the literature analysis, section 4 will answer the research objectives based on scope review and preliminary assessment, lastly, section 5 will conclude the analysis by explaining the results and findings from the review regarding the topics, also explaining the limitations while conducting the research.

II. RESEARCH OBJECTIVE

This paper will analyze some literatures related to spatial database, GIS, RDBMS or traditional database, and blockchain as the platform for the database management, especially in the subsea survey services industry. Objectives of this research is to present general overview of the comparison of integration between blockchain and spatial database, and RDBMS with spatial database, by identifying characteristic suitability within the two methods in the existing literatures to propose a research agenda for future works.

III. METHODOLOGY

Methods used for this research is by identifying the research, select the studies, assess the quality, take notes and extract data, synthesis data, and report the results of the review. These steps are modified from [4] which already used in the previous research, also related to blockchain in [5]. Scoping review method taken from O'Malleys [14] and Arksey [11] is also used in this research to provide an initial indication of the topics systematically to ensure high level of accuracy, reliability, and trustworthiness. The scoping review conducted in this research lead to the understanding of how traditional database and blockchain is adopted and used to manage spatial database.

While RDBMS is a common method used to govern spatial database, blockchain is a rather new technology to integrate database management, especially for spatial database in the subsea services industry. Therefore, academic literatures, such as articles from journals and conference paper which discuss blockchain and spatial database is limited. In order to fully explore blockchain technology and its properties which can accommodate spatial database management, a structured and systematic literature review is conducted from thirty literatures related to blockchain and databases, but not limited to spatial database, GIS, and subsea survey industries.

IV. RESULTS AND FINDINGS

A systematic literature search was carried out using Google Scholar as search engine and University of Indonesia digital library which redirected to Scopus, ScienceDirect, Emerald Insight, and IEEE Xplore. Around 2,192 relevant articles found using the keyword *blockchain* from these sources. The result is

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then filtered with *data management* keyword to narrowed down the articles to the amount of 48. Additional search affected by snowball effect also conducted to search relevant articles. However, the automatic filters cannot find spatial database or GIS, so the search was performed manually using search engine. Less than ten articles found in the results, therefore "grey literatures" such as unpublished documents, reports, and articles from trusted sources were used to support the research.

A. Blockchain

Based on the search results, majority domains of blockchain-based applications were identified, those are business and industry, finance, governance, health, education, integrity verification, privacy and security, IoT, and data management. A year wise analysis of the selected paper relevant to data management can be seen in Figure 1.

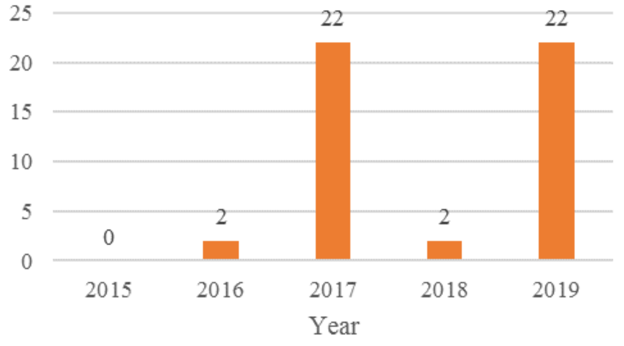

Figure 1. Blockchain for data management search result (2015-2019)

Blockchain can be described as a technology with peer-to-peer structure that could be used to solve the problem of maintaining the order of transactions and to avoid the double-spending problem [26]. It is introducing a kind of disruptions to the traditional data management process since the architecture and design of this technology provide properties like transparency, robustness, auditability, and security [5]. The basic nodes structure of blockchain is illustrated in Figure 2.

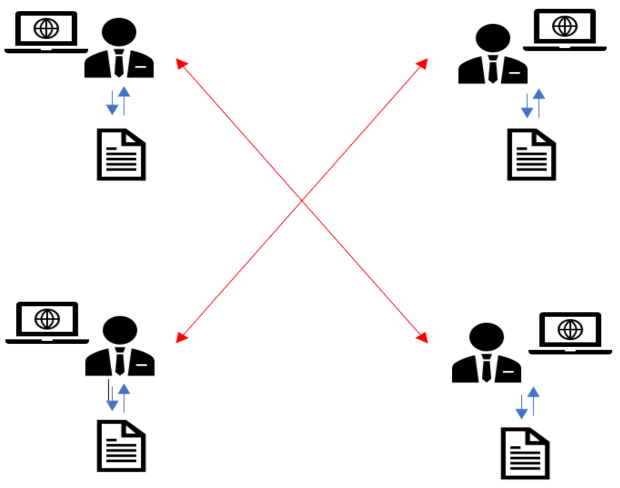

Figure 2. Blockchain ledger structure

Blockchain technology is known by its distributed ledger technology as shown in Figure 2. Blockchain databases consists of several decentralized nodes, each node is involved for data addition into the database, without changing the original data. Blockchain also should be considered as a distributed append-only timestamped data structure.

From previous research, the use of blockchain have been successfully adapted for some applications and industries. In the early age of blockchain, this technology is introduced with Bitcoin as its core underlying technology, but in several years blockchain has spread its potential to another some other applications beside financial system. For example, health-oriented application, governance, IoT, security, business, education, and data management. Each of the blockchain-enabled application has its own advantages and disadvantages that might be different for each other. To reap full benefit of blockchain technology, especially in managing spatial database, data elements in the subsea survey services industry should be breakdown in order to get the compatibility in adopting blockchain technology.

Blockchain also have some challenges in its application for database management. The main disadvantage of the blockchain technology are the high energy consumption to keep a real-time ledger, chain splitting that will resulted in large storage consumption, higher costs, and slow transaction [15].

Data management is one of the most arguable application of the blockchain technology. Although blockchain is considered to be the best option for data management, but this statement is still unclear

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due to some of blockchain limitations. Chowdury et al. (2018) did a critical analysis between blockchain and traditional database which resulted in decision tree analysis to determine which one is the best option for different cases [10]. This decision tree is considering some aspects from blockchain characteristics, which resulted in the database management compatibility. Figure 3 provides a simple decision of flow control diagram to decide whether blockchain should be used in spatial database management or not.

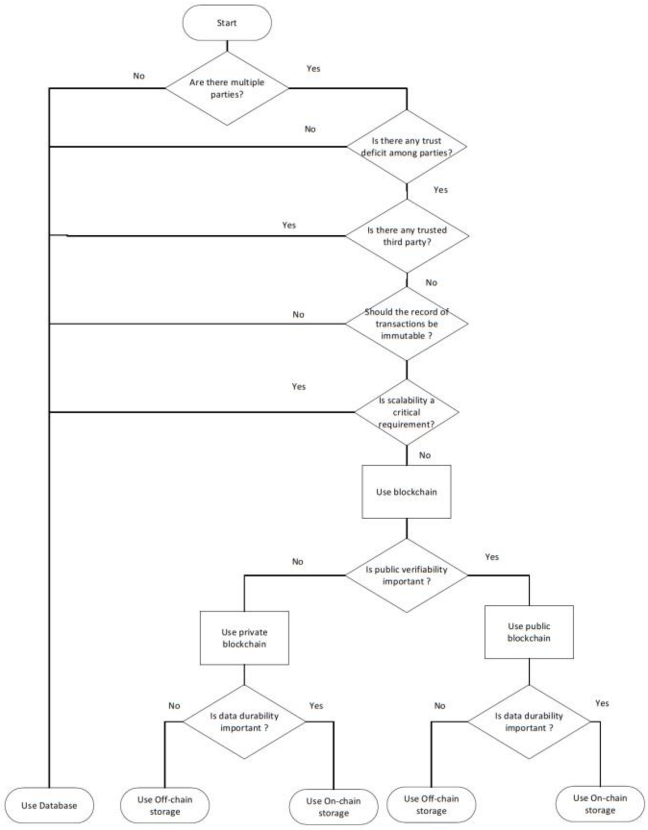

Figure 3. Decision Tree to determine the use of blockchain
(Chowdury et al., 2018)

From the diagram, it can be concluded that there are some properties in blockchain technology which should be considered while choosing the best option for database management. These are immutability, confidentiality of data, robustness/fault tolerance, performance, redundancy, and security. These elements are meant to be the advantages of blockchain usage. The used of blockchain is also considering the publicity and durability of data. Therefore, at the end of decision analysis tree, there are some option for blockchain usage. Two types of blockchain which generally used are public and private blockchain. Differences between public and private blockchain is summarized in Table I.

If the data are suitable with previous parameters mentioned in the diagram, users can choose between public and private blockchain, also off-chain and on-chain blockchain from the durability aspects. Besides, if all parameters are not suited with, in this case spatial database, users can just use traditional database instead.

Table I. Comparison between public and private blockchain

Public	**Private**
Anyone can join the network	Restricted, need permission
Anonymous	Identified
Each node can create new transaction	Only certain nodes can create new transaction
Need proof-of-work and proof-of-stake consensus protocols to add new block	Pre-approved participants to add new block
Long transaction approval frequency	Short transaction approval frequency
Low speed transaction	Comparatively faster
High cost, large energy use	Relatively cheaper and lower energy use

The comparison between public and private could also be the answer to some of the main disadvantages mentioned before. However, whether using private blockchain is better than public blockchain or not, there should be another consideration, particularly for managing spatial database.

B. Spatial Database

Data acquired from the survey are varies, it could be ranging from numbers to imagery, vector or raster data. The similarity between these various types of data is the spatial information within the data which shown where the data was obtained. Figure 4 shown the bathymetry data sample resulted from sea-mountain detection using multibeam echosounder in Hawaii.

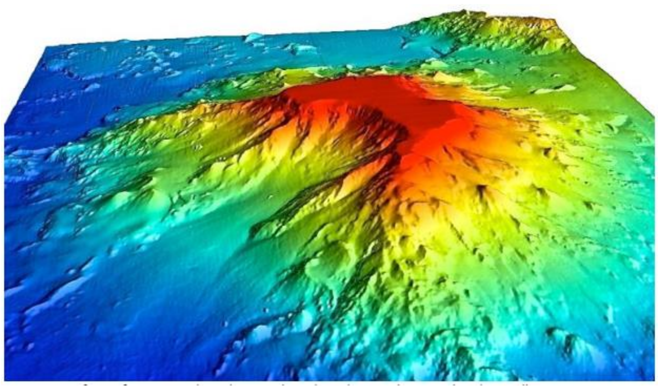

Figure 4. Bathymetric survey result
(Kaunana, 2014)

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Apparently, some people would see the image just as another ordinary image. But, one single image from the survey can have numerous information. As a matter of fact, it is only the final result from the survey. Bathymetry imagery is built by numerous points which have position and depth information each. The points are then gridded and processed to become a good image to be visualized. Therefore, the image color gradient represents the depth of the seabed, ranging from blue (deepest) to red (shallowest).

The data are then compiled as charts, 3D scene, or spatial database compilation in GIS. For managing spatial database, GIS is commonly used since there are already some software to accommodate common use of spatial data analysis. They also usually have dedicated sub-program to manage spatial database. For example, Esri ArcGIS have ArcMap to process and analyze spatial database and ArcCatalog to manage spatial database. Figure 5 summarize the process of spatial data compilation into GIS.

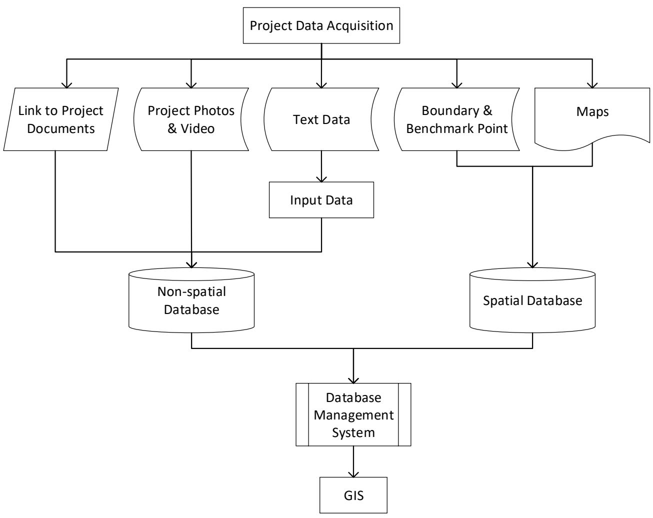

Figure 5. Spatial data compilation to GIS

Data obtained from the survey usually take many storage spaces, especially for raster/image data like the result on Figure 3, since it is containing much information in one data; position, depth and slope information for every measurement, and other data stored in the equipment used. However, it is all depending on how many days the survey taken and how large is the survey area.

Spatial data and deliverables from acquired data usually is a confidential data that should only be authorized by both client and contractor. Sometimes, the problem occurs when client do not trust the contractor to keep the data, or vice versa, contractor do not trust client as some irresponsible clients seems to alter the data without contractor consent, that in the future will resulted in disagreement between two or more parties. Spatial data managed with traditional or relational database have a difference with blockchain structures. If the blockchain use distributed ledger, relational database use centralized ledger as its structure. Figure 5 shows centralized ledger which commonly used in relational database. Client-server network architecture used to facilitate the designated authority to control database. Since the designated authority is responsible of the database control, if the security of this authority is violated, the data may be changed or even deleted. For example, a consortium of two companies, company X and company Y, share the same database for their survey result. Company X have some changes for the bathymetry survey result, but they amend the data without notice to company Y. This could lead to a big problem since they are supposed to have the same data, apparently, they do not since there was a change to the data. That could be the weakness in using RDBMS.

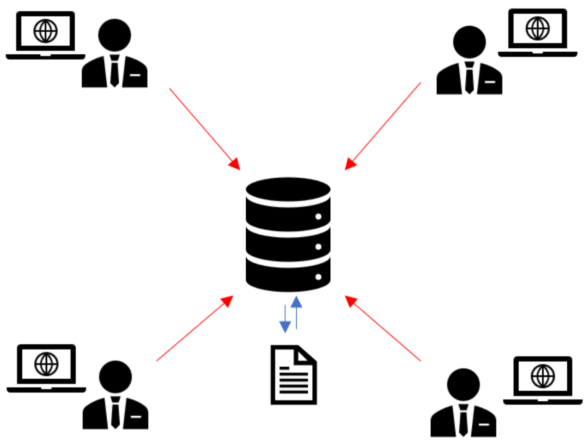

Figure 5. RDBMS ledger structure

C. *Spatial Database and Blockchain*

As mentioned before, blockchain have some benefits and challenges, depends on what kind of data that will be integrated with blockchain. In this research, spatial data is the type of data that will be discussed.

Some approaches from positive and negative points of blockchain will be the parameter of deciding whether spatial database is better be governed with traditional database or blockchain. Parameters of blockchain and database usage found in the literatures is then classified into nine main points. Comparison of different approaches between

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traditional database and blockchain is summarized in Table II.

1. Immutability

Immutability of managing spatial database in the subsea survey service industry is very much needed, since there are some parties involved in a project that will access the data in time. Blockchain can provide this feature using decentralized consensus mechanism. Every node in the system has the same level of access, thus will build and develop trust between parties. In traditional database only a single authorized person or division who can controls the database system. Again, there are several parties appertained to a project, therefore the immutability function of blockchain only valid if all parties are honest and trusted.

2. Confidentiality

Data in blockchain is encrypted with a digital signed system by transacting parties. Privacy is kept by using public key cryptography. Anybody can join and verify transaction in the network using open ledger system. This system will enable blockchain to reveal the transacting parties and the data in the transaction. However, some data in spatial database cannot be accessed by unauthorized parties to prevent any data leaks. Since data in the blockchain is not fully encrypted, this aspect could be considered further.

3. Fault Tolerance

Data in blockchain is stored distributedly. Therefore, each node that participating have a copy of the blockchain. The advantages of using blockchain, from this aspect, in spatial database management is the robustness. If a particular node like Distributed Denial of Service (DDoS) occurred, other nodes can still continue the process.

Table II. Comparison between traditional database and blockchain for spatial database (modified from Chowdury et al., 2018 and Golosova and Romanos, 2018)

Parameter	Database	Blockchain	Suitability
Immutability	Need a trusted party	Operate without any trusted party	Database & Blockchain
Data Confidentiality	Restrict access to authorized person	All nodes have visibility of the data	Database
Fault tolerance	Data is stored in central database	Data is distributed among nodes	Blockchain
Redundancy	Only the central party has copy	Each participating node has the latest copy	Blockchain
Security	Use traditional access control	Use cryptographic measure	Blockchain
Energy Consumption	Action on the data is depend on authorized person in control, energy is more controllable	Keep real-time ledger and solved a lot of solutions to validate transaction, drained high level of energy	Database
Storage	Data stored is controlled by authorized person	Data stored on the blockchain forever unchangeable and censorship-resistant, take up more storage	Database
Cost	Lower cost since database can be manage using simple coding or available software	Higher cost due to high initial capital cost and high level of energy consumption	Database
Performance (speed)	Immediate execution and update	Takes time to reach consensus	Database

4. Redundancy

Each node has a copy of the blockchain. Data stored in the blockchain will not be deleted nor overwrite. If there is any updates or changes towards the data, blockchain will 'create' new blocks that will lead to redundancy of the data. For some aspects, redundancy is not a good thing especially for storage efficiency, but for some aspects, redundancy can be good because the redundant data can be used as backup if DDoS occurred.

5. Security

Blockchain uses cryptographic measures to ensure the security of the data. In a blockchain protocol, blocks will be accepted and become valid transaction only if 51% of the mining nodes agree, besides, that will be an invalid transaction which distinct the mining nodes are controlled by malicious user. Spatial data that is stored in traditional database only maintained by central system. Therefore, any database management securities depend on the reliability of the system administrator.

6. Energy Consumption

The power consumption of blockchain system is high. It is needed to keep a real-time ledger. Network miner's in the blockchain attempt to solve a lot of solution per second to validate the transaction. Zero

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downtime to eliminates fault tolerance and unchangeable data in the blockchain also become the factor of high level of energy consumption. Traditional database tends to be lower in energy consumption since the data is stored centrally and there is no data redundancy system so there is only a little less 'work' than blockchain.

7. Storage

The storage problem of blockchain can be foresee from its system aspects mentioned in the previous points. Since blockchain takes up more space than traditional database, spatial data stored in the blockchain could not be big in size also to avert system failure and slow network. However, it cannot be avoided that the size of spatial data is rather large than simple data. However, if spatial data stored is only in number or listing form, storage would not be a big issue because of its relatively small.

8. Cost

The average cost of blockchain transaction is between 75 and 160 dollars and most of it covers by energy consumption [13]. Much high-tech system that blockchain provides also lead to higher cost. Also, the initial capital cost to build blockchain is also high.

9. Performance

For some data, blockchain can offer faster processing. However, if the case is to store spatial data, it will take more time because of the blockchain system process and huge size of data stored. To confirm a transaction in a network, will take up 10 to 60 minutes if there is any soft fork in the network. Eventually, traditional database can handle many transactions per seconds, and it can be customized by the engineer who is in control.

From the explanation of each aspects and suitability decision for spatial database it can be conclude that spatial database have some characteristics of data that will only effective to manage by using a particular database management system, whether it is using blockchain or traditional database. So far, considering the spatial database characteristics and current condition of blockchain technology, it is more suitable with traditional database or private blockchain, since blockchain problems occurred from some aspect like authority, energy consumption, and costs can be minimized if using private blockchain.

This consideration is coming from analyzing 48 papers which are related to these topics, then filtered to 25 paper that use blockchain and traditional database or RDBMS but not specifically used to manage spatial data or GIS in the subsea survey service industry. However, only 8 paper are specifically concern in geospatial or spatial data management using blockchain and comparing between these two methods of governing spatial database. Each of these researches also mentioned the advantage and disadvantages in using blockchain but not particularly suggesting of using one type of technology only.

Conclusion

Spatial database that is acquired from the survey in the subsea survey services industry can be managed and processed using two types of database management systems; traditional database or RDBMS and blockchain technology. Although blockchain technology is a system that has great expectations towards researchers and practitioners, the use of blockchain technology for spatial database should be developed especially in the storage space and speed performance. In the future, the integrating system between GIS which basically using RDBMS and private blockchain is very much awaited, since it will be very helpful to get quicker decision-making analysis.

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