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## Article

# Development of asset management model using real-time equipment monitoring (RTEM): case study of an industrial company

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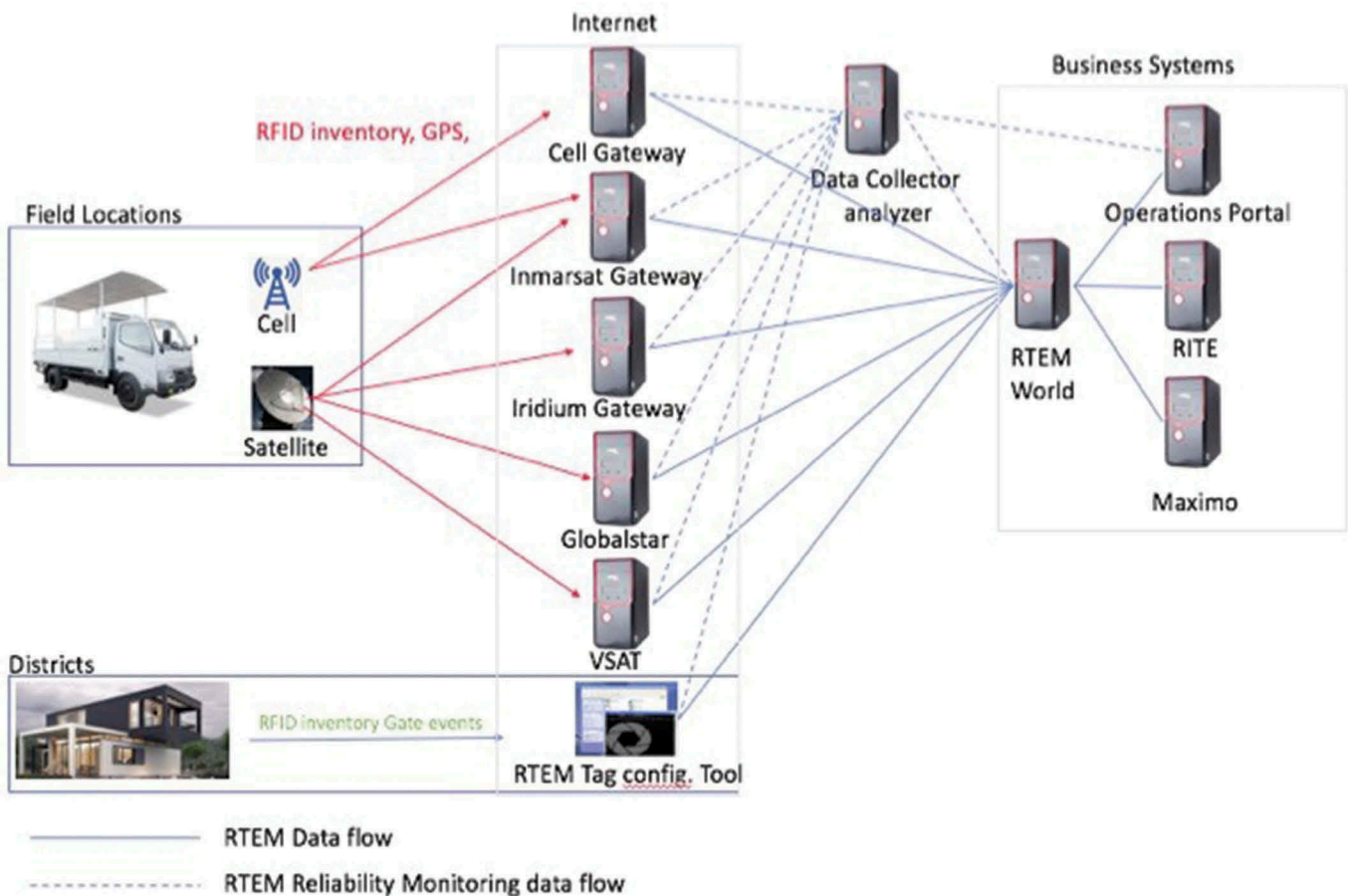
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## OPERATIONS, INFORMATION & TECHNOLOGY | RESEARCH ARTICLE

# Development of asset management model using real-time equipment monitoring (RTEM): case study of an industrial company

Oshios Earnest Iluore<sup>1</sup>, Angela Mamudu Onose<sup>2\*</sup> and Moses Emeterere<sup>3</sup>

**Abstract:** Globally, the issue of implementing efficient and effective asset management systems has been a challenge for most companies, especially those operating in the oil and gas industry due to the complex nature of their operations. In recent years, with the decline of oil prices, market conditions have become so competitive such that even a few minutes of downtime of equipment could lead to significant loss of revenue. A case study of an Industrial Company is presented, with the goal of assessing its current asset management system. Based on the evaluation of the current asset management system practiced by the Company, it was noted that there are significant gaps in the current practice, and the Company is yet to leverage advanced technological tools in managing its assets. Specifically, the Company does not currently have an appropriate system of tracking and monitoring its assets location, and utilization, despite the fact that the assets move from one location to another in fulfilling customer's needs. A Real-Time Equipment Monitoring system is developed for the industrial company using GPS, Barcodes and RFID



Oshios Earnest Iluore

### ABOUT THE AUTHOR

Earnest O. Iluore is a Distinguished Member of the Domtar Reliability Team. He holds the position of Reliability Supervisor Central Services at Domtar. Before joining the Domtar family, he worked for Axiom Equipment Group as a Lead (Maintenance and Services). Prior to that, he worked for Schlumberger as a key player in the Maintenance and Reliability team. He received his HND in Mechanical Engineering from Auchu Polytechnic Auchu, Nigeria, BEng in Mechanical and Manufacturing Engineering from the University of Portsmouth UK and MSc degrees in Reliability Engineering and Asset Management from the University of Manchester at Manchester UK. He is a Certified Maintenance and Reliability Professional (CMRP) and an active member of the Society for Maintenance and Reliability Professionals (SMRP). He is a Certified Vibration Analyst Level 2 (ISO 18436-2) and an active member of the Canadian Machinery Vibration Association (CMVA). He is a Lean Greenbelt Champion Certified by Canadian Association Manufacturer. The authors' practical approach to engineering and asset management makes the text in the journal an essential addition to the library of anyone practicing in these fields.

### PUBLIC INTEREST STATEMENT

Effective asset management systems remains a global concern as companies always seek an effective way to manage their assets to create value for both themselves and their shareholders. A privately owned company with over 15 years of experience in the oil and gas industry was selected as a case study with the goal of assessing its current asset management system. It was based on asset life cycle management process which has Equipment Reception, Maintenance Planning, Maintenance Scheduling, Maintenance Execution and Performance Testing as its highlight. The limitations of this approach include reactive maintenance being practised, unnecessary lag period recorded, poor optimization of asset mobilization, slow reaction to incidents and cases of asset loss. Real-Time Equipment Monitoring which includes the use of Radio Frequency Identification, Barcode and GPS was implemented. Aside from a record of 30.8% increase in asset utilization, specific benefits which include asset value retention, automated workflow, improved coordination and responsiveness were achieved.

technology to provide information relating to assets location, status, condition and maintenance history which led to 30.8% increase in assets utilization. Generally, a benefit analysis carried out shows that the new system will always provide real-time observation data and instrument parameters for maintenance engineers and ultimately company managers for effective decision-making at strategic levels.

**Keywords:** assets; barcodes; industrial company; maintenance; management and real time equipment monitoring

## 1. Introduction

### 1.1. Background knowledge

The issue of effective asset management systems is now becoming a global one as companies seek effective ways to manage their assets to create value for both themselves and their shareholders. (Jooste & Vlok, 2015). This raises more concern in the oil and gas industry due to their complex nature of their operations. Companies operating in the oil and gas industries in Nigeria have been facing challenging industrial conditions and declining markets in recent years, especially in 2015 and 2016 when the overall revenues generated in the oil and gas industry was subjected to decline (National Bureau of Statistics, 2016). Furthermore, there is increased pressure on Companies from stakeholders with respect to the social and environmental impact of their operations, thus, causing the need for improved efficiency in all aspects relating to company operations. Thus, it is not surprising that companies are even more concerned about their ability to manage and operate their complex offshore assets in a way that they can deliver functional services to the customer throughout the asset life cycle.

Asset management is concerned with the life cycle management of assets to achieve the business objectives of any organization that may own or manage assets. Asset management is not just a fancy word for maintenance, and is essential to all companies regardless of size, as poor asset management is often listed as one of the significant causes of an organization's failure. Generally, in the oil and gas industry, where pretty much most of the assets used are incredibly complex and expensive, asset management plays a significant role in ensuring that these assets are properly utilized, and maintained to ensure better reliability, keep their economic value, and do not get improperly disposed of due to lack of accessibility. One of the ways that companies can effectively manage their assets is through the implementation of an effective asset management system. However, it is almost impossible for companies to navigate through these complex terrains using traditional methods of asset management.

Existing literature has shown that organizations, both in the public and private sector face different challenges in managing their assets. In a research paper published by Irene et al. (2016), delegates to an industrial workshop which had different practitioners ranging from asset managers, consultants, designers, etc., in different industries, held at the University of Cambridge, UK, and at the Rutgers university, USA, were requested to provide input relating to the current challenges faced in terms of reducing asset life cycle costs and to identify innovative tools that can help in optimizing costs invested in assets. Amongst the input provided by the delegates, the most common responses are categorized into three broad categories – Asset Performance Monitoring and Prediction, Optimizing Capital Expenditure and Data Management.

In the oil and gas industry, for example, the priority on these physical assets over financial or current assets comes from the realization that it is the output of work performed with these physical assets that yield financial returns. Campbell et al. (2016) noted that there are a number of activities and roles that must be performed on the physical assets for there to be said that management has taken place. Some of these include the role of designing, constructing, operating, monitoring, repairing, replacing, and disposing of the physical assets (Maletič et al., 2017). With

these roles, it could be said that physical asset management actually encompasses all stages of the business life cycle, and is also a revolving rather than linear activity within the organization.

### **1.2. Discussion of benefits**

C. J. Li et al. (2016b) admonished that the selection and use of specific technologies for real-time asset monitoring must fit into a number of contexts, including the size of the firm, the industry of the firm, the functions of the assets, and personnel available to perform the monitoring. In the specific context of the oil and gas industry, there are static and rotating equipment that are used as part of the day-to-day running of oil blocs and operation of companies as a whole. Mhlaba and Masinde (2015) noted that most of these equipment are used at all verticals of the industry, including upstream, midstream and downstream. Some of these static and rotating equipment include, but not limited to, heat exchangers, pipelines, valves, turbines, furnaces, compressors, boilers, and pumps (C. J. Li et al., 2016b). Each of these types of equipment plays very instrumental roles, without which the work of refineries and oil and gas companies in general cannot be complete. While there are several methods of real-time asset monitoring, Ferdinandus and Setiawan (2016) observed that most of these overlap and so can be categorized into three main components. First of these involve the use of barcode labels in monitoring assets. Wang et al. (2015) posited that the use of barcode labels is very common for asset monitoring that relates to location identification. The instantaneous manner in which the information is given is what makes them real time (Yu et al., 2018). Many have also criticized the use of barcodes as being more manual rather than virtual and on-the-go Wahap et al. (2016). While this is admissible, several advancements are being made to improve the experience with barcode monitoring such as the ability to scan barcodes with smartphones (Al Mamun et al., 2016).

The second system or method of real-time asset monitoring involves the use of Global Positioning System (GPS). GPS tracking of physical assets is seen by many as the most perfect constitution of real-time monitoring. The reason for this is the manner in which GPS trackers give not only instantaneous information but also on-the-go information about assets (Thaduri et al., 2015). In a typical oil and gas company with several branches within the country, the GPS tracker can help the asset monitor to constantly tell the location and status of assets without making any special record for asset information to be sent (Shah et al., 2017).

While there are merits, Ferdinandus and Setiawan (2016) found that GPS asset tracking can have its own limitations. The major limitation comes when using this system for equipment that are moved or travel over longer distances. This is because across such distances, there are possibilities that tracking may fail with poor signal transmission across certain locations (Shah et al., 2017). To address this situation, Congress et al. (2018) observed that most modern GPS trackers have therefore been enhanced with advanced signal transmission technology to boost reception of signal strength from satellite systems to report over terrestrial networks.

Meanwhile, RFID tags have often been criticized as not constituting or ensuring real-time monitoring. The reason for this is the proximity limitation that comes with tracking via RFID. That is, when an equipment is tagged but is outside the receptive radius of the asset manager or whoever is responsible for monitoring, there could be total loss of communication with the equipment, thereby making it impossible to log information at a specifically needed time (Fang et al., 2016). There are however several researchers including Fang et al. (2016) who consider this as merely an excuse rather than a justification for claiming RFID tags not to constitute real-time monitoring. Adame et al. (2018) also posited that RFID tags are very good options for smaller firms, which cannot afford the more sophisticated and expensive GPS tracking systems. Because the equipment of such small companies are often within a smaller radius of space, it is always effective for their asset managers to know where an equipment is, and its status within 1.25 miles. This is a strong premise for classifying the RFID as examples of real-time monitoring components.

### 1.3. Problem statement

In an internal asset reconciliation report circulated by the management of this organization, the company noted that it made a loss in 2017 of 1.0 USD M in either overtime spent on repairing assets, or acquiring additional assets. Prior to this report, the company had issued a similar report where it indicated that it recorded loss related to missing asset and/or asset theft and under-utilization of assets costing approximately 3.2 USD M in the year. Consequently, the company needs to implement an improved system of managing its assets, as it currently has no appropriate system of tracking and monitoring its assets location, and utilization, despite the fact that the assets move from one location to another in fulfilling customer's needs. The aforementioned issues existed mainly because the current asset management system adopted by the company is largely manual; hence, asset data is largely prone to error, and there are no adequate controls for asset inventory management. Consequently, the current asset management system of this Company has been chosen as a case study, with the aim of evaluating its effectiveness, identifying peculiar problems, and developing an asset management system using Real-Time Monitoring (RTEM) to effectively manage the assets of the company, including tracking their location, collating data regarding their operation and maintenance status, with the aim of improving the overall utilization of the assets.

One of the major lines of argument in the body of literature relating to the use of real-time monitoring is the fact that it serves as a competitive advantage for the growth and expansion of companies, including those in the oil and gas industry (Rahimi et al., 2017). The competitive advantage is gained as the problems with asset management are eliminated as identified above. This is achieved by ensuring efficiency with assets (Roe et al., 2016), effectiveness with assets operation (Shah et al., 2017) and lastly having good corporate culture (Mamudu et al., 2019; Rødseth & Mo, 2016)

### 1.4. Methodology

- Gathering of relevant location data, existing and new, necessary to perform an analysis of the current asset management system at the organization. This information would include the organization's overall objectives, its asset management system, shortcomings, and specific data relating to its asset management. Gantt chart was incorporated to show how different milestones were achieved.
- Informal Interview of personnel responsible for using the system to obtain the required level of detail necessary to identify the current state of the asset management system.
- Identify the shortcomings with the current asset management system, after a thorough analysis. The analysis would be presented in the form of visual representations (Fishbone Diagram, T- Wheel) and qualitative analysis.
- Propose the implementation of a RTEM as a tool for an effective asset management system.
- Perform a benefit analysis of the system to ascertain that the proposed system is worth exploring further and deployed throughout the entire organization.

## 2. Company profile

The company in question is one of the world's leading oilfield service provider with over 15 years' experience in the upstream sector of Nigeria oil and gas industry. Its operations include drilling, production and well intervention service, spread across over 10 locations within Nigeria and three other African countries (Gabon, Ghana and Senegal). It offers services such as well services, directional drilling, oil testing, mud logging services, sales and rental of production equipment, amongst others to several exploration and production companies. Given the nature of its operations, the different functions are all decentralized, under the leadership of an asset manager who is responsible for the management of its own department's assets. However, the asset managers of each department follow already established asset management practice designed and implemented by the Company's general asset manager.

For the purpose of this study, the asset management practiced at the well servicing department has been selected as the case study, primarily because it is the largest operation at the organization, with the highest number of assets. The department manages approximately 2680 assets, which move from a central warehouse, and in some cases from the Company’s operational base in Port Harcourt, Rivers State to different sites, or locations specified by the customer in a year. In some instances, certain contracts span a period of more than 1 year, with the deployed asset remaining at the client’s site throughout the contract duration.

**2.1. The well services business segment**

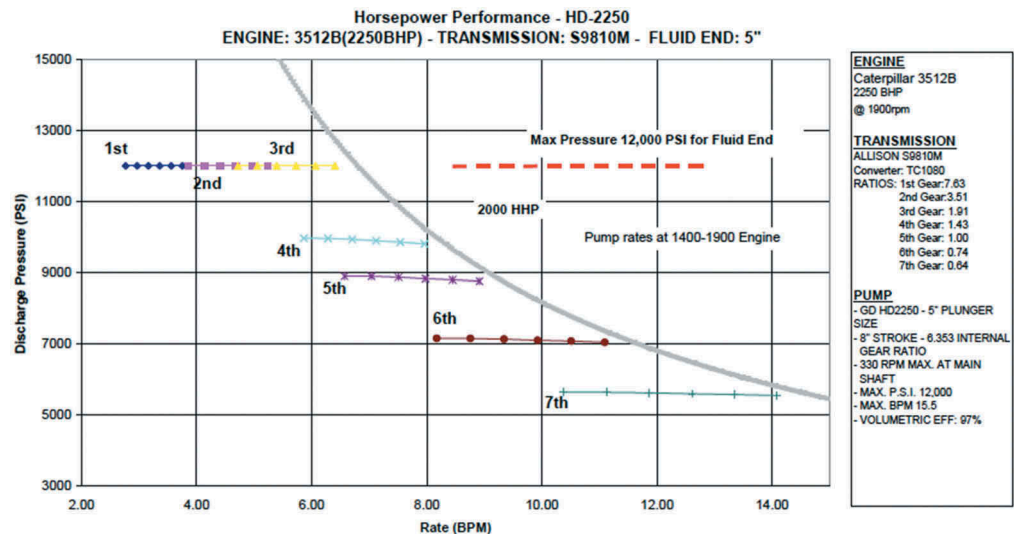
The Well Services segment is made up of three business units, namely; Well Intervention, Well Stimulation and Well integrity. The well intervention segment is responsible for maintaining or enhancing the well productivity after the well has been completed, and production has begun from the reservoir. In carrying its functions, the department employs the services of coiled tubing which are long, and often continuous length of pipes that are wound around a spool. The pipe diameter can range from 1 in. to 4.5 in, while the coil tubing can be from 2,00 ft to 15,00 ft, and longer lengths in some cases. The well stimulation processes involve fracturing, acidizing and water control treatments using a stimulation pump float or skid configuration at a high-horsepower in order to achieve an increase in the well productivity. One of the main equipment used in carrying out this operation is a Stimulation Pumper with Figure 1 showing the correlation between the pump discharge pressure and the pump rate.

The well integrity segment supports and protects well casing and also helps for zonal isolation. These services are very critical and common as their application cuts across many stages in the oil and gas production activities. This aspect of business uses a cement pumper to deliver a high-pressure service. Figure 2 shows the engine performance curve of the front and back, respectively.

**2.2. The current asset management system**

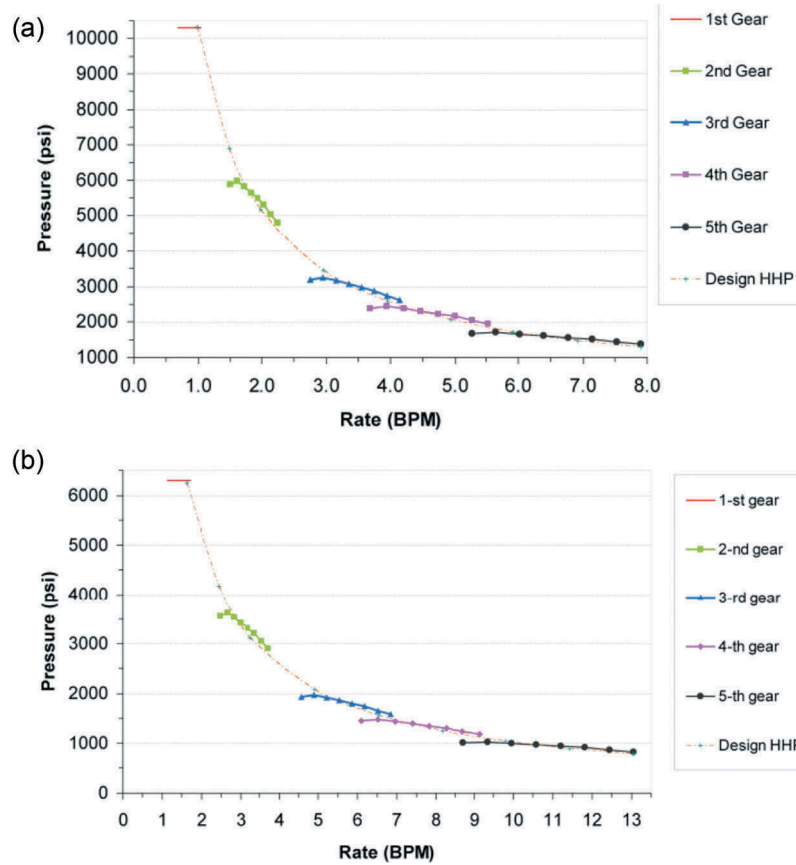
The well servicing division manages about 60% of the company’s drilling assets, with an annual capital investment of approximately 1 million US dollars, most of which is spent on materials, spares, and other asset purchases for use in both new and existing projects. Due to the nature of operations of the company, assets are typically moved from one client’s location to another, and the wide spread of clients can pose logistical challenges. Also, some of the assets and spares are typically imported into Nigeria from different countries, which means that in some cases, there would be a significant lead time between material order time and delivery time. To counter the

**Figure 1. Pump discharge pressure versus pump rate.**





**Figure 2. (a) Front engine performance curve. BPM – Beats per Minutes, HHP – High Horse Power. (b) Rear engine performance curve. BPM – Beats per Minutes, HHP – High Horse Power.**



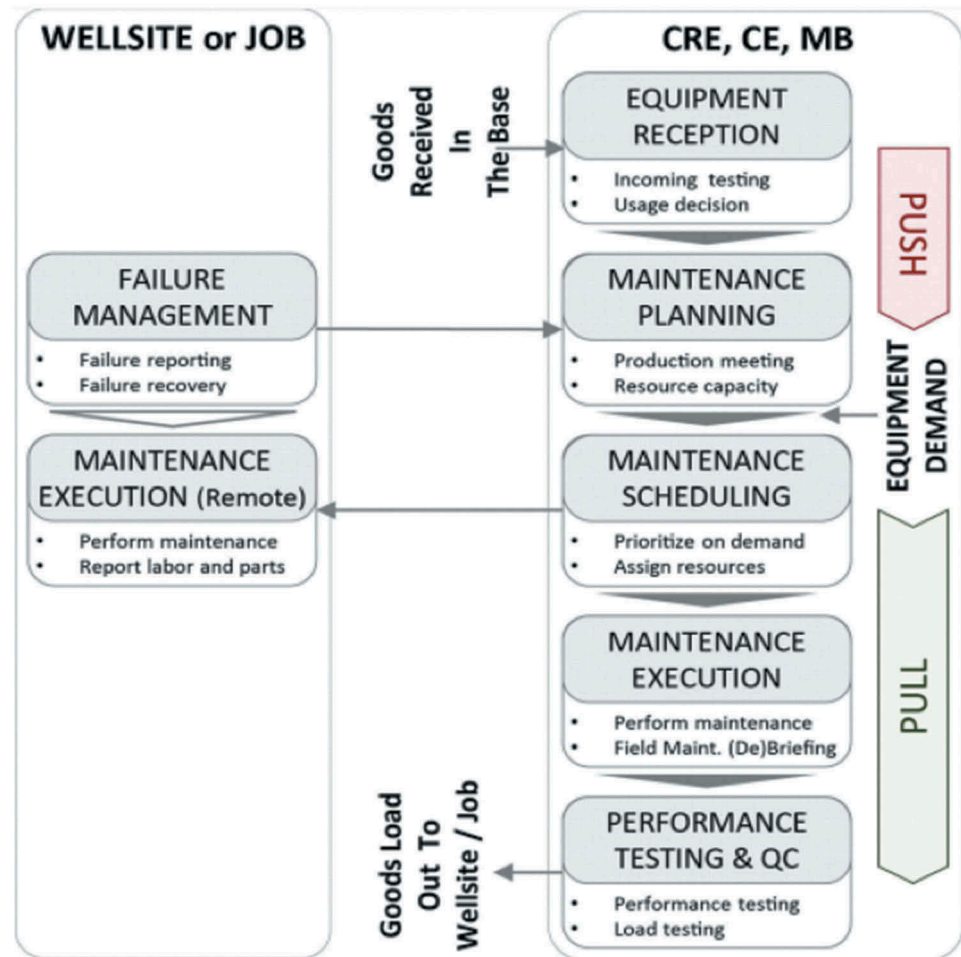
effect of the lead time, the company has established a warehouse system at various locations where required items can be ordered in advance, stored, and picked off when required.

The organization currently has a total of 53 designated warehouse and storage location in areas it operates across Africa. Of the 53 locations, 46 of them hold only equipment used for providing well services, as that is its largest operations. As at the time of carrying out this project work, the warehouse located at Takoradi holds about 373 pieces of drilling motors, 457 pieces of 3” drilling pipes, and varying other materials together valued at 3.28 USD m based on data obtained from the Maximo Asset management system. The general asset management is categorized into two, namely, material management department and the maintenance department. The material management department is responsible for procuring assets, and provides services to the different departments within the Company. It acts as a supermarket to the different departments within the Company. Once the department receives assets from suppliers, they are tagged with labels that contain an asset number, which are supplied to the Company by a third-party vendor.

The well service function responsible for asset management is known as the well service lifecycle management team (WSLM). The team is responsible for the total asset management from equipment reception to maintenance execution and planning. The asset life cycle management process performed by the WSLM is shown in Figure 3.

The **equipment reception** happens upon completion of work at a client site, when an equipment fails, or when maintenance is scheduled for an equipment. Equipment is received by the WSLM team into the base. The received equipment’s maintenance program is reviewed to identify any pending or due repair, and where there are any pending repairs, the equipment is washed, and

Figure 3. Asset maintenance/management processes overview (Industrial Company, 2019).



a work pack is created, and scope finalized depending on whether incoming test or preservation test is required. Once the work pack scope is finalized, the equipment is tagged and moved to the next phase of asset management process which is the maintenance planning. In the event that there are no pending or due repairs at the equipment reception stage, the equipment is washed, green tagged and moved to the green tag equipment area in the plant layout.

**Maintenance planning** involves confirming the availability of parts for repairs that require parts, and where there are shortages, a requisition is made to request for parts from the material management team. Also, at the maintenance planning stage, the resources including shop capacity, technicians’ competency, and estimated man-hours are evaluated, and where there are any gaps, it is escalated to the WSLM management team, and provision is made to cover relevant gaps; thereafter, the maintenance scheduling process commences. **The scheduling** involves three processes which are the initiation phase, the actual scheduling process, and the end. During the initiation phase, the job forecast is reviewed daily to capture recent work orders.

At the actual scheduling phase, the equipment mobilization dates, and workload and work pack list are reviewed by the WSLM team. Thereafter, the availability report is updated and tasks prioritized and organized, shop, tools, and technicians are assigned to the work pack and parts are reserved. The last phase which is the end is where the dates are reviewed to determine whether the mobilization dates are as expected, and depending on the outcome, the process moves to the maintenance execution

phase. At the **execution phase**, the work pack is assigned. Thereafter, the work scope is reviewed, relevant documentation, parts, hand tools, and diagnostic tools are collected. The maintenance tasks are performed, and the testing function is performed and completed if required. However, if performance testing is not required, the work pack is completed and green tagged.

The **equipment failure management** process occurs when equipment on the field is not fully operational. A deliberation is carried out to determine if a repair should be done on-site or whether back up is available. Once the equipment is ready for **performance testing**, the WSLM team reviews all the testing scenarios and pass or fail criteria. They collect relevant documentation, test kits and monitoring hand tools to execute the testing scenarios and record results and parameters. Once the tests are performed, they are reviewed to determine whether the results, parameters meet or pass the test criteria. If the parameters of the results meet the pass criteria, the work pack is completed and the equipment is green tagged; otherwise, the work pack is updated and further action is required on the equipment.

Generally, asset is actively managed in the Computerized Maintenance Management Systems (CMMS) by the asset line manager. The Operations Planning (OP) asset coordinator decides if an asset is needed or not. Following this decision, the Center of Efficiency (CE) manager request as asset status change based on the following decision tree (Figure 4).

### **2.3. Problems with the current asset management system**

From the asset management practiced at the well services of the industrial organization discussed above, it can be noted that the Company has a detailed process layout and flow for the maintenance of assets only from when they are received at the base. However, due to the nature of the operations where assets are constantly moved from location to the other, and in some cases, assets spending a significant amount of time at the client's location, or on the field, there is no real system of managing these assets, or knowing their status before they are sent to the WSLM team at the base. Some of the problems identified from this case study are enumerated below:

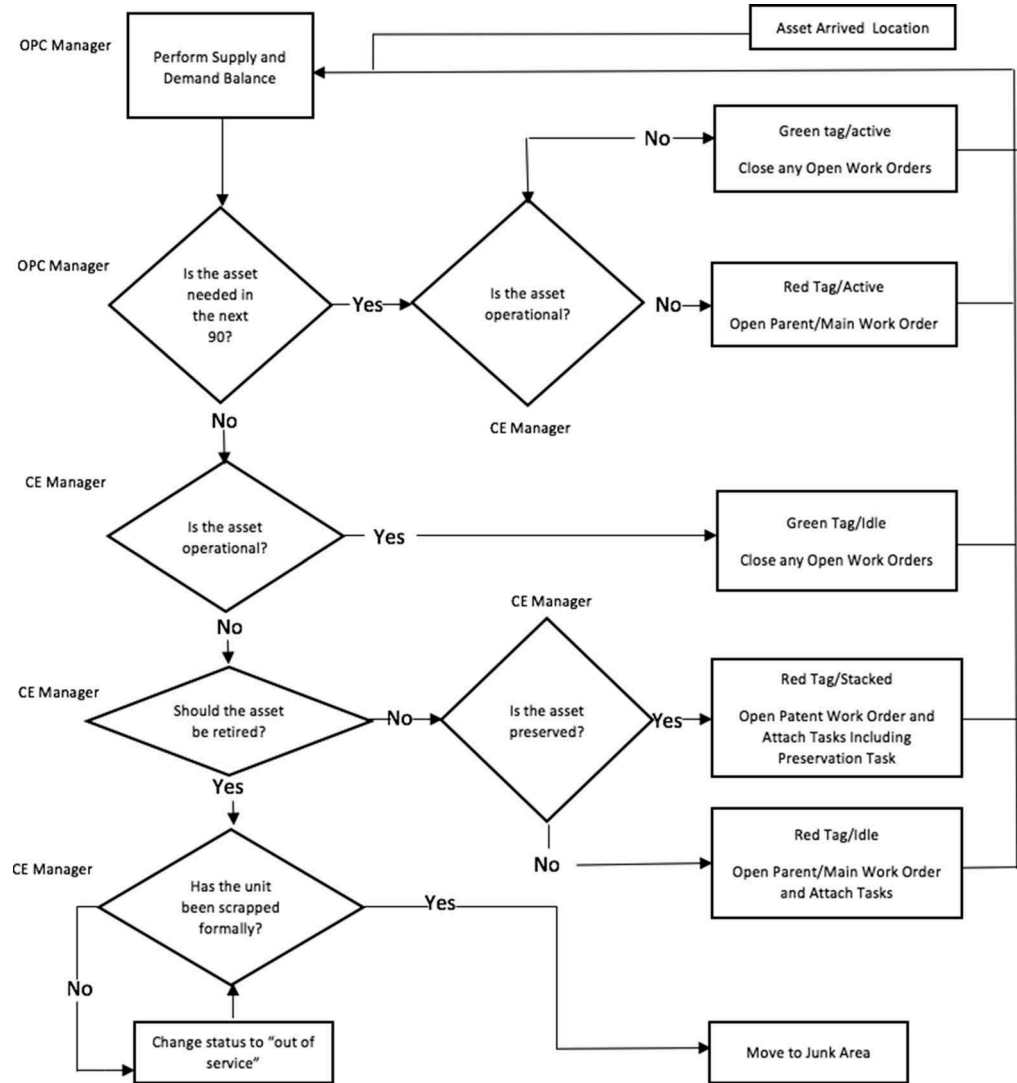
#### *2.3.1. Lack of or limited reliable data of asset location resulting in reactive maintenance planning (RMP) and a lot of idle time*

The first asset management challenge faced at the organization is the unavailability of data relating to its assets such as number, status of the assets and location. From the asset management practice described above, assets are typically sent to the WSLM for equipment reception and maintenance, only when a job is concluded at the field, thus reactive maintenance is mostly practiced. This also causes a time lag between when an event occurs and when it is documented in the appropriate channels. The information currently available is not enough to provide reasonable insight of the asset current location resulting in asset idle time and additional waiting period for an asset to be available for maintenance as shown in the T-wheel (Figure 5).

Also, over the years, the organization has expanded, establishing many subsidiaries in different locations, including outside Nigeria. During these changes, data was lost due to the use of different registration and tracking systems. Furthermore, the company currently uses a mix of manual approach to tracking its assets, i.e., the asset details are manually imputed on the Maximo asset management software. Manual recordkeeping cannot be accurate all the time. In addition to the above, there is no practical method available to identify the assets scheduled for preventive maintenance and to route them into the location for the maintenance technicians to access them for scheduled maintenance. This has led to a situation where assets that should be maintained continue to operate, sometimes beyond 100% design capacity until they breakdown, thus increasing the need for additional capital investment on the assets.

Based on the periodic audit carried out by the Company in 2018, the department noted that approximately 1.06 USD million was invested in excess of the budgeted Capital Expenditure. According to (International Monetary Fund, 2001), it should be noted that capital expenditure is

**Figure 4. Asset status management.**

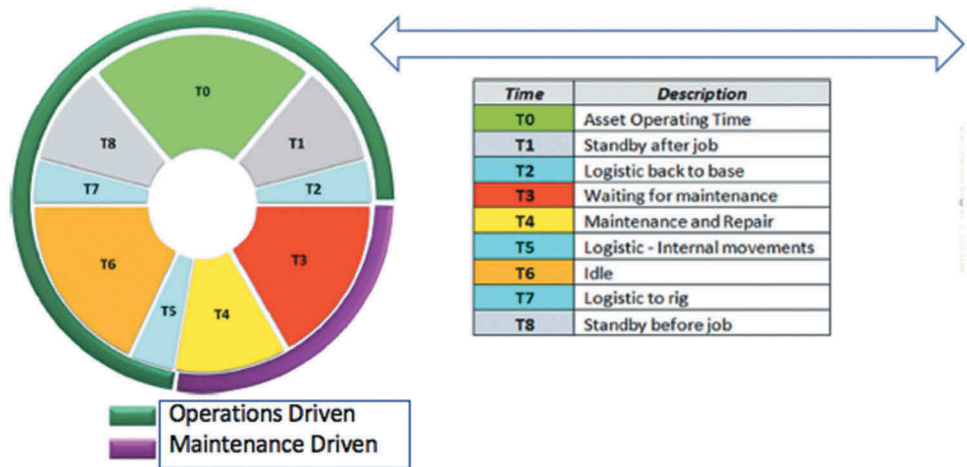


generally about physical assets with a useful life of more than 1 year. It also includes capital improvement or the rehabilitation of physical assets that enhance or extend the useful life of the asset (as distinct from repair or maintenance, which assures that the asset is functional for its planned life)

**2.3.2. Asset location and tracking**

The material management department currently uses labels containing asset numbers to tag its assets. Due to usage overtime, and sometimes in rugged locations, or deep waters, the tags become difficult to read after being subjected to environmental conditions like dirt, mud, etc. This increases the time required to locate assets, and in some instances, result in the company spending money to acquire assets that may already be available but difficult to locate/identify. Secondly, due to the inability to properly detect the location of assets, there is a possibility of incurring higher costs to ship an asset or spares from a different location (Kusumawardhani & Markeset, 2015). Figure 6 shows the asset disposal trend in the last 7 years while Table 1 highlights some recorded asset write-off between 2017 and March 2019.

**Figure 5. T-Wheel. T-Sections are derived from Maximo data (Author).**



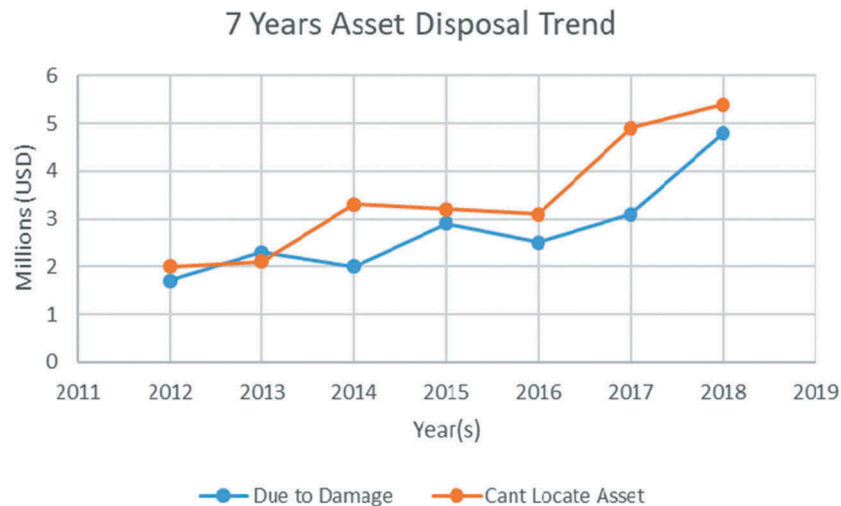
**2.3.3. Poor optimization of asset mobilization and planning**

The little information available is not available to the right person at the right time; therefore, the information is not always put to optimal use. One of the reasons for this issue is that information relating to assets is often documented by different WSLM team members on the Maximo software, and there may not be consistency in how this information is collated and recorded on the central system. As a result, it is often difficult to assess the quality of the asset holistically and this makes planning a challenging task. Also, in some cases, maintenance of certain assets is outsourced to third-party contractors that are external to the organization. The vendors are typically more concerned with carrying out the assigned task of repairs and maintenance, while paying very little attention to recording and documenting the job done which would be vital for the maintenance management team.

**2.3.4. Slow reaction to incidents and no real-time information on asset movement resulting in asset loss and inappropriate handling of radioactive sources**

Some of the equipment used for fracking operation have radioactive sources attached and when such an asset gets out of reach, it poses a huge risk to the environment and the entire populace.

**Figure 6. Data from the organization’s asset disposal report (Industrial Company, 2019).**



**Table 1. Recorded asset write-off between 2017 and March 2019**

Period	Reason for Asset Disposal	Cost
April 2018- March 2019	Due to Damage	\$ 4.8m
April 2018- March 2019	Not being able to locate asset	\$5.4m
April 2017 – March 2018	Due to Damage	\$3.1m
April 2017 – March 2018	Not being able to locate asset	\$2.2m

### 2.3.5. Asset loss and theft

This is especially common for rental equipment and spares. There are instances where an asset is moved from one client location to another without necessarily updating the information recorded by the warehouse attendant. Specifically, in 2017, the Company received a report from one of its clients reporting a case of frequent reordering due to loss of equipment on chaotic and hazardous drilling sites.

Considering the challenges faced, it was noted from the literature that these problems seem to be common problems and not peculiar to this organization when it comes to asset management. (Kusumawardhani et al., 2017; Kusumawardhani & Markeset, 2015; Elehinafe et al., 2019; Rahimi et al., 2017).

### 2.4. Root cause analysis

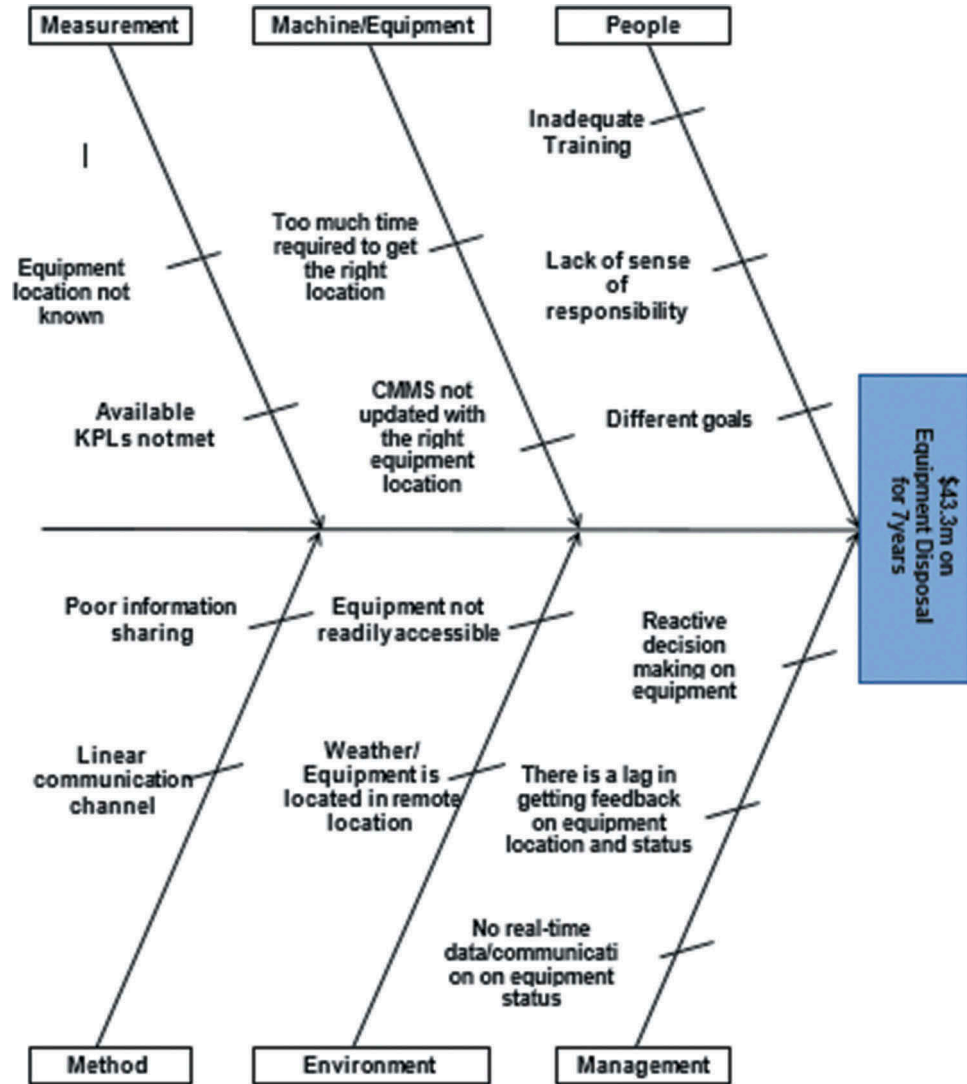
Root cause analysis with the aid of Fishbone tool (Figure 7) was used to group the above-highlighted problems into seven important groups for simplicity sake. These groups which include Measurement, Machine, People, Method, Environment and Management allow individuals to know their responsibilities.

### 3. Real-time asset monitoring and its systems

Asset monitoring is a physical asset management function that requires that all tangible assets or infrastructure of a firm be tracked to know their current state, location, and usage (H. Li et al., 2016). Manbachi et al. (2016) noted that asset monitoring has revolutionized and evolved over the years, changing from the most traditional form of tracking with the aid of manual processes. In the manual processes, several personnel were hired or employed to keep an eye on each asset and make a paper-and-pen report on their status (Zhong et al., 2017). This manual way of doing things is currently fading, as it has been found to be inefficient and ineffective in achieving the primary objective of asset management, which is to create value with the use of infrastructure (Mhlaba & Masinde, 2015).

As the manual approaches to asset monitoring are fading, it has been replaced by what has come to be known as real-time asset monitoring. As the name suggests, real-time asset monitoring basically requires that the practice of monitoring assets will be done on the go, whereby a report about the state, location and usage of the assets will be known at every particular moment in time (Yu et al., 2018). Manbachi et al. (2016) stressed that real-time asset monitoring

Figure 7. Fishbone diagram grouping highlighted issues.



has been made possible with advancements in technology that have come with the software and hardware that make it possible to connect physical assets to centralized information technology systems of the organization to keep track of each asset. Some of the common technologies associated with real-time asset monitoring are radio frequency identification (RFID), near field communication (NFC), Wi-Fi, Bluetooth, and GPS asset tracking (H. Li et al., 2016).

### 3.1. The real-time equipment monitoring (RTEM) based asset management model

Based on the challenges identified in the industrial company's asset management methods, the author has proposed the development of a RTEM for real-time tracking and monitoring of the department's equipment. The RTEM uses the RFID, Barcode and GPS technology which are considered very suitable for assets management as it can be used to track assets, store maintenance information, thus allowing the responsible personnel identify resources available easily and rapidly. The RTEM is linked with the Company's ERP system which is the CMMS. The various technologies utilized for developing the RTEM are discussed below:

### 3.2. Enterprise Resource Planning System (ERP) and Computerised Maintenance Management Software (CMMS)

ERP systems consist of “different functional modules which are integrated by software architecture and used by organization to enter, manipulate, and process, deliver data with the inbuilt business practices in real time across internal and external partners” (Felix et al., 2016). Integration of the system is one of the most important characteristics of such a system. The main purpose of an ERP system is to streamline and automate processes while ensuring regulatory compliance and gaining real-time insight into the overall performance. The goal of the CMMS is to make available quality data to assist maintenance in decision-making (Terry, 2014). CMMS help promote the standardization of equipment maintenance process and decision-making by providing the right information. In as much as the CMMS reduce the overall budget of the maintenance, it does not include enough feature of project management (Terry, 2014). Therefore, incorporating the ERP and CMMS will provide the required platform for the execution of the RTEM technology efficiently.

### 3.3. Barcode technology

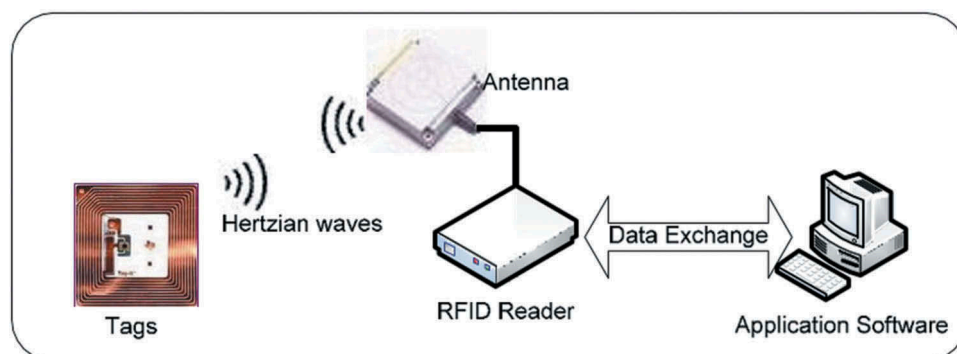
Barcodes are printed horizontal strips of vertical bars used for identifying specific items. Barcodes can be read by optical scanners called barcode readers or scanned from an image by special software (Wang et al., 2015). They are generally used in storing name, address, and other information. Barcodes are much quicker, more efficient entry of information and are inexpensive and easy to implement. As barcodes are printed and processed by machines, they are processed much faster than standard human data entry and with a much higher degree of accuracy. Barcodes have the potential of dramatically improving the productivity and reliability of nearly all applications (Wahap et al., 2016). For example, on an average, it takes 6 seconds for an operator to enter 12 characters of data, whereas scanning a 12-character barcode takes only 300 ms. The 12-error rate for typing is higher than scanning barcodes. A data entry error will translate into additional costs for a business that ranges from the cost of re-keying the data to sending the wrong asset to the wrong customer.

### 3.4. RFID technology

RFID is described as a technology that provides wireless, non-contact data communication among devices in a system. RFID was invented in October 1948 by Harry Stockman. It is an automatic system of identification that can process specific information regarding a targeted object using radio frequency, whose function can be carried out without manual intervention. When compared with bar code technology, RFID has better advantages, including being waterproof, long reading distance, antimagnetic, greater storage capacity, etc. (Robert, 2016).

As the RFID technology continues to grow, it has now been used worldwide in the field of asset management to perform activities such as tracking of assets, identification of assets, etc. (Fang et al., 2016). As shown in Figure 8, the RFID works using three main components, namely, the tag,

**Figure 8.** Illustration of RFID working mechanism (Adame et al., 2018).





the reader, and the antenna. The antenna works by emitting radio signals which then activates the tag, and read data to it. The RFID reader is often termed the main component of the system as it functions in data acquisition, interpretation, and communication. The antenna emits radio waves in ranges of 100 feet or more, subject to the power output. (Adame et al., 2018)

For asset management purposes, RFID tag is attached to both the equipment and the users. The RFID reader is then situated at the location of the assets to record the tags in the area. The location of the assets is equipped with a surveillance camera, and an alarm indicator to record and deal with unforeseen circumstances. The data recorded is stored in a central computer like the CMMS described above. The central computer is often connected to the intranet for effective flow and transmission of information to each asset location's computer. The main purpose of the data stored on the central computer is to enable management and personnel involved in the management of assets easy to identify and determine the condition of an asset.

The RFID tag consists of two parts, which are the integrated circuit (IC) for storing and processing the information, modulating or demodulating a radio frequency (RF) signal, and the specialized hardware for transmitting and receiving the signal. The tag makes it easy to identify and manage assets individually as they can be tracked and monitored through the sensor enhanced RFID technology. The historical data stored can be used in asset management activities like making investment decisions, tracking the assets which can all be done automatically.

### **3.5. GPS technology**

Global Positioning System (GPS) is a technology that is used for tracking and route planning. It is a satellite technology that uses a constellation of between 24 and 32 Medium Earth Orbit satellites to transmit accurate microwave signals that enable GPS receivers to determine the current location, velocity and time of the assets. The amazing system began as an application for the American military as a way to enhance the accuracy of booms and ensure the safety of the bomber pilot (Greg, 2016).

The GPS makes use of a tracking unit which makes it possible to identify the exact location of an object and to record the position of the object at regular intervals (Thaduri et al., 2015). The position of the object is typically stored regularly and, in some cases, transmitted to a central database location or sent via internet connection to computers using General packet radio service (GPRS). This information which is considered accurate can then be extracted by customized software or web services provided by different companies (Congress et al., 2018). Nearly 3 billion mobile apps clogging the world's phone and tablets use some sort of GPS-derived positioning information (Greg, 2016). More recently, tracking devices currently used are based on a GPS receiver chip embedded in them because this technology is the cheapest solution with a rapid growth among other ways.

The application of GPS devices in tracking and positioning objects has significantly increased in the past decades, and its application includes tracking, vehicle navigation, and mobile pattern recognitions (Zhao, 2015). GPS technology is still considered relatively new; hence, the potential of its use is still being investigated and researched. GPS Trackers (or GPS receiver) are of different types, and mainly designed for different purposes. The trackers contain data logger, data pusher, and data puller. The data logger keeps a record of the position of the device at regular intervals, which is either saved in the internal memory or internal flash memory.

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The data pusher is used to locate objects at regular intervals of time, and determine which server can analyze the data instantly. A GPS receiver is embedded in a system such as mobile phones, computers, and at regular intervals, the system sends messages with the information from the GPS receiver. Some organizations also provide data push technology that enables GPS tracking for asset management.

### 3.5.1. GPS devices employed

There are different GPS devices that have been developed by different manufacturers. Table 2 shows a summary of the GPS devices used in this work.

## 4. Proposed asset management strategy at the industrial company

It is important to develop an asset management strategy that aligns with the organization's overall strategic objectives. During the review phase prior to the development and implementation

**Table 2. Summary of GPS device specification (Author)**

Device picture	Device name	Operational environment	Satellite constellation	Expected power lifespan
	AssetLink AP3 3300 GPS Terminal	Land only-no offshore certification	Iridium	On-board battery with rechargeable solar cell (non-replaceable)
	SkyWave IDP-800 GPS Terminal	Land only-no offshore certification	Inmarsat	Replaceable lithium batteries
	Geoforce GT1 GPS Tracking Device	Offshore-ATEX, IECEx Zone 0 Certification	Globalstar	Integral, ported lithium battery (non-replaceable)

of the RTEM system, the current system was evaluated and the shortcomings identified. These were the basis upon which the asset management strategy was created. The strategy involves adopting a global traceability building block that uses standard barcode labels, RFID tags, and transponders on all of the company's technologies, products, materials and parts to enable the Company capture the data needed to:

- Identify equipment, parts and products,
- See their time and position throughout the value chain,
- Record their manufacturing and maintenance history,
- The goal is to vastly reduce the time spent locating assets and to increase the utilization of its assets globally.

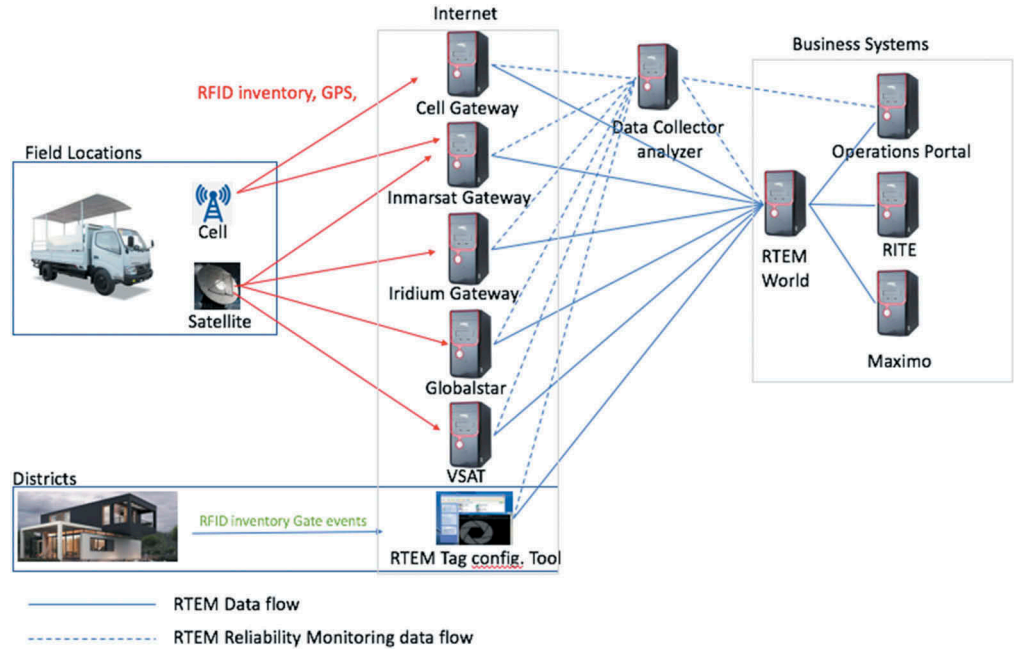
The overall asset management strategy adopted is expected to impact all functions and levels of the value chain within the organization and will impact certain transformational goals. The overall strategy is summarized in Figure 9.

Figure 10 also below depicts the RTEM Asset management model and its features: Connectivity, optimization, transparency, proactivity and agility. Each of these futures plays a great role in enabling more informed decisions, thereby shifting from linear, sequential asset management to an interconnected, open system asset management strategy. This model can lay the foundation for how asset management organizations compete in the future in line with the trending fourth industrial revolution. The RTEM Asset Management Model (AMM) represents a leap forward from the traditional asset management model to a fully connected and flexible system that integrates data from system-wide physical and human assets to drive asset management. Each department in the business system can access asset information when desire.

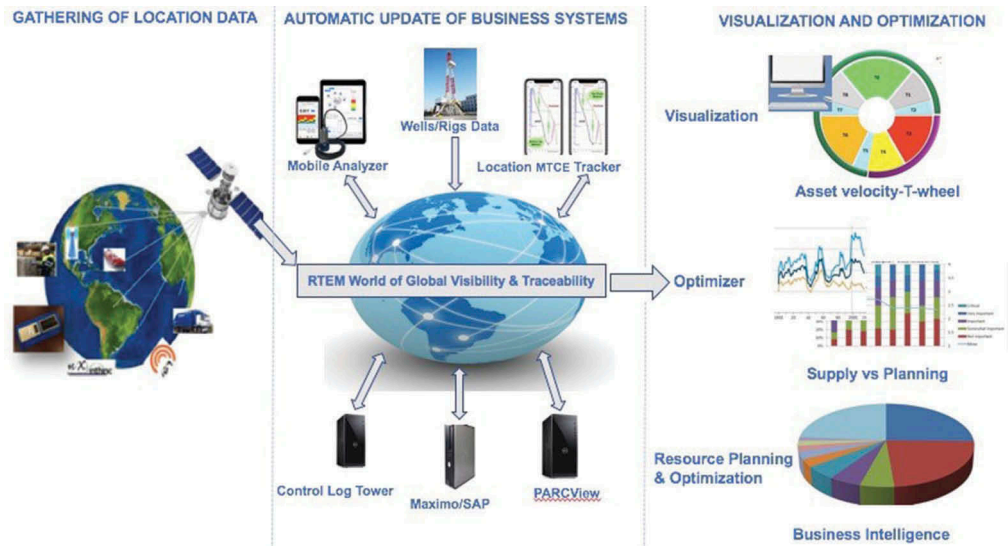
**Figure 9. Asset strategy overview.**



**Figure 10. Topological graph of the RTEM asset management model (Author).**



**Figure 11. Visual detail of the pilot phase of the RTEM-based asset management system (Author).**



**5. Implementation**

The steps adopted in implementing the RTEM system are enumerated below as:

- Gathering of all available location data
- Tagging the relevant assets at the location
- Updating the business systems, i.e., CMMS to reflect the new tag information
- Beta test

The process described above is presented in a pictorial image (Figure 11).

### 5.1. Data gathering

Existing available equipment data, including location, types, serial number, and maintenance history, were obtained from existing systems such as Maximo, Rite and the operations portal. The application of the equipment determines which of the GPS device will be installed as the Geoforce 1 was mounted on the offshore location assets and the land location asset had either the SkyWave, or Assetlink installed on them. The downhole tools had the barcode tags.

### 5.2. Mapping and installations

#### 5.2.1. GPS mapping and installation

The GPS devices were mapped to enable them to report data regarding the asset being attached to. The mapping was done automatically but, in some situations, it was not pragmatic to associate the GPS device to the asset while using the application. In such a situation, a manual mapping was done as shown in Figures 12, 13 and 14 below. The GPS devices were installed on the assets securely on mounts that are rigid to withstand weather checks and the weight of the device. The devices were placed in areas where they are not affecting the safe operation of the asset. For the fact that the GPS devices communicate with satellite networks (not cellular), special and deliberate care was considered during the installation of these devices for them to function and be able to transmit or receive data optimally. The following guideline has been put in place for a proper installation:

- The GPS device is installed as high as possible on the asset to minimize any blockage of the sky view.
- The device must be powered on and mounted horizontally facing the sky.
- Ensures the GPS device has 35 degrees of unobstructed visibility in all directions.
- The GPS device should be connected with the unit at all times unless undergoing a maintenance activity that requires remover of the device (Asset Manager's approval is required for any device removal).
- The device must be associated (i.e. mapped) using the RTEM application during the installation process.

**Figure 12. GPS devices mounted facing the sky, on top of the asset (Author).**

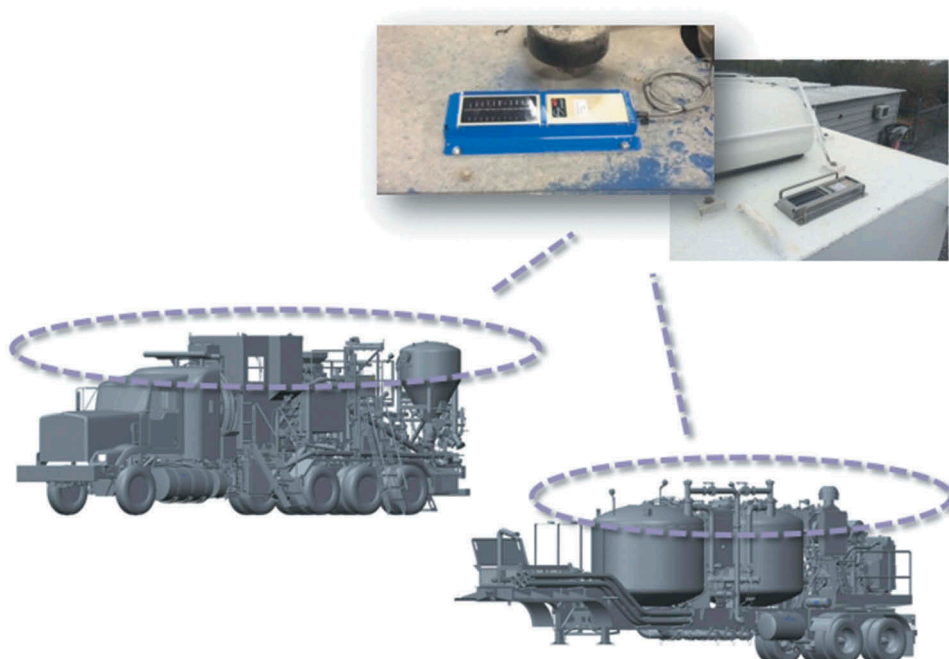


Figure 13. Geoforce GT1 Mount.



Figure 14. Pictures of the asset with SkyWave.



### 5.3. Barcode label installation

For proper installation of the barcode, the areas on the asset were cleaned thoroughly before attaching the barcode-printed labels as shown in Figures 15 and 16 below. At least four stickers are recommended to be installed on each asset and they were placed at eye level where possible on the front of the assets for easy identification, in order for technicians performing tasks to identify unit at ground level.

Figure 15. Sample Barcode on the asset at eye level and possible locations (Author).



Figure 16. Sample Barcode on the asset at eye level and possible locations (Author).



#### 5.4. BETA TEST

The BETA test is an acceptance test performed by the end-user of a product to validate its functionality, reliability, usability, and compatibility. Subsequent to the implementation phase of the RTEM, the system was tested for functionality and its fitness for purpose as well as assess whether the system meets the objectives intended in the asset management strategy.

##### 5.4.1. Email alert (Real time information)

Subsequent to gathering of data, tagging of the assets, mounting the GPS device, details of an asset logged in as arrival to the base, and it immediately sent an email alert to the registered recipient on the status of the asset as seen in Figure 17.

#### 6. Benefits of the RTEM Solution set for asset management at the industrial company

Based on the beta test carried out, the system appears to be able to achieve all that it was designed to achieve in relation to asset tracking and management. The system was able to provide the exact location, status, condition, and maintenance history on the asset leading to 30.8%

Figure 17. Screenshot from email alarm system showing information of a tagged asset entered on the database (Author).

From: Global Traceability <GT-noreply@ets.com>  
Sent: Wednesday, June 07, 2019 6:00 PM  
To: Undisclosed recipients <GT-NoReply@ets.com>  
Subject: MRCH-AA 310 entered Base-Takoradi - 2306

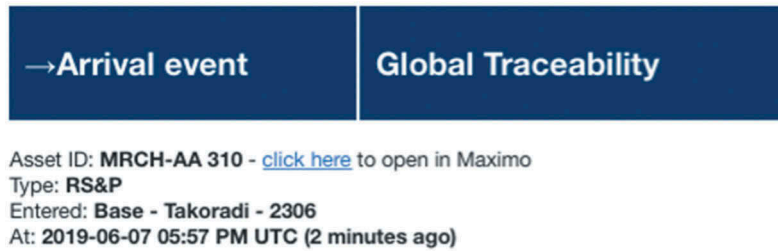
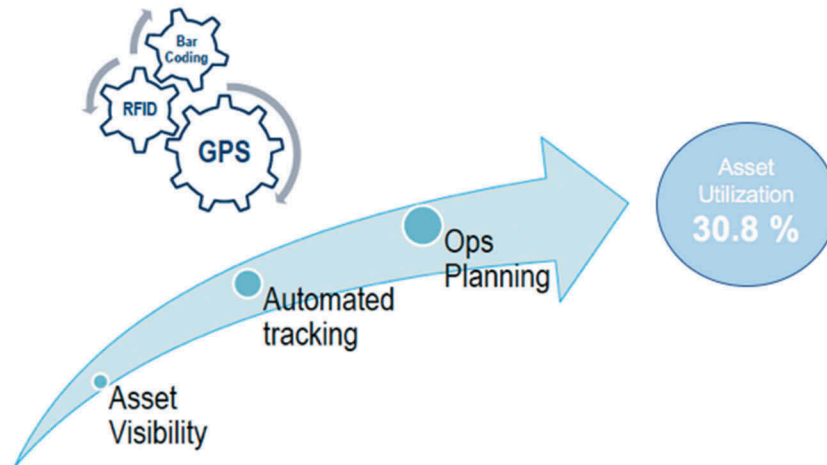


Figure 18. Benefits of RTEM.



increase in the asset utilization (Figure 18). The specific benefits identified from the model are highlighted below:

### 6.1. Automated workflows

The RTEM model significantly automated the Company's workflows from maintenance scheduling to spares ordering and asset tracking. The data related to activities of the assets can now be stored electronically, and retrieved easily. Based on the RTEM model, each time the maintenance personnel carries out maintenance on an equipment, they simply scan the code on the tag of the assets and complete a check box on a form in the portable computer device, which then sends data to the cloud, where it is saved on a master database. This would then update the record of the assets with the maintenance activity that has been performed on it. When the database is subsequently queried, the results generated would include the assets locations, all tasks completed and pending, as seen in the screenshots shown on the BETA test. It is also possible for the maintenance personnel to upload pictures that depict the condition of the asset if necessary. Also, if the database is queried and shows an asset in an unauthorized location, alerts can be issued to the general asset manager to commence the investigation immediately.

### 6.2. Saving time and potential errors

The RTEM model was also integrated to facilitate ordering of spares for certain assets, rather than the previous system of ordering spares when they are not required. With the RTEM, if personnel determine



that spares need replacing, they can take picture of it, include the part number of the spares that need replacing, and include it on the information of the asset that is stored on the database. This information can then be sent to the appropriate personnel that manages Company inventory (purchasing and warehousing), the finance department, and the relevant approval personnel. This significantly reduces communication errors and confusion, as the correct parts would be ordered, shipped.

### **6.3. Improved coordination**

The RTEM provides a web-based interface that displays real-time, and detailed view of all the activities (past and current) relating to the managed assets. Real-time information includes details like serial number, category, current location, warranty dates, and any other relevant information. Hence, asset information can easily be retrieved from the cloud storage, reviewed, printed, where necessary. Relevant personnel, e.g. general asset manager, the department's general managers and management team, can access the information securely from any location, and at any time. This helps management to evaluate the efficiency of processes against set benchmarks for asset management. Also, the ease with which information is retrieved on a real-time basis significantly reduced the time it takes to search or locate an asset thus significant time is saved during the periodic audit and asset count by external auditors of the Company, thereby saving money in external audit fees.

Other benefits include greater visibility, reporting and insights, improved responsiveness and skills utilization, accelerated workflows, asset value retention and better business opportunities.

### **7. Limitations**

It was initially challenging obtaining internal documents and technical documentation from the company; however, the author was later granted the individual user access to various applications needed. The extensive number of different applications and databases that needed to be accessed exemplify some of the challenges the industrial company face as an organization in relation to data and information management.

### **8. Conclusion**

This study set out to evaluate the asset management system at the industrial organisation, identify the challenges and propose a system of asset management using RFID. A contextualization of this theory has been made by looking into what current organisational experience in relation to this aspect, and this has led to the identification of several areas. Firstly, challenges related to identifying and location of assets for effective asset management were identified. It can be concluded that the extended application of RTEM and the utilization of the obtained data for implementing this model of asset management system hold the potential for significant improvements to asset utilization in the future.

By the implementation of an RTEM solution, which has the ability to perform advanced diagnostics and prognostics, managers overseeing various industrial companies can obtain benefits related to safer and more efficient operation of equipment, improved maintenance planning, reduced maintenance costs and so on. By taking on a holistic approach to the subject of asset management, the traditional organizational barriers can be removed, and thus the introduction of external expertise as well as the possibility of monitoring and operating equipment from remote locations can be achieved.

### **9. Recommendation for further studies**

The topic of asset management has become very relevant during the last few years, with several large organisation embracing the new ISO55000. The vast amount of data we are producing in the world today have now become so extensive that it is hard to comprehend. It is the author's opinion that those organizations that can develop and manage systems for the effective exploitation of this unprecedented amount of data to improve business performance and processes in the future

are the ones that will prevail and achieve excellence. Subjects like stock optimization based on predictive models for spare part consumption improved planning of operations based on the integration of weather forecasting or related activities should be looked into. In this study, only few equipment types were studied, it is, however, clear that several other equipment types may also prove to be both eligible and suitable for implementation.

In addition to the opportunities is the ability to make informed decisions that will help achieve a precision maintenance scale by utilizing real-time data from vibrations, pressure, flow rates and online oil condition monitoring.

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#### Cover Image

Source: Author

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#### References

- Adame, T., Bel, A., Carreras, A., Melià-Seguí, J., Oliver, M., & Pous, R. (2018). CUIDATS: An RFID-WSN hybrid monitoring system for smart health care environments. *Future Generation Computer Systems*, 78, 602–615. <https://doi.org/10.1016/j.future.2016.12.023>
- Al Mamun, M. A., Hannan, M. A., Hussain, A., & Basri, H. (2016). Theoretical model and implementation of a real time intelligent bin status monitoring system using rule based decision algorithms. *Expert Systems with Applications*, 48, 76–88. <https://doi.org/10.1016/j.eswa.2015.11.025>
- Campbell, J. D., Jardine, A. K., & McGlynn, J. (Eds.). (2016). *Asset management excellence: Optimizing equipment life-cycle decisions*. CRC Press.
- Congress, S. S., Puppala, A. J., & Lundberg, C. L. (2018). Total system error analysis of UAV-CRP technology for monitoring transportation infrastructure assets. *Engineering Geology*, 247, 104–116. <https://doi.org/10.1016/j.enggeo.2018.11.002>
- Elehinafe, F., Okonkwo, E., Okocha, S., Okoro, E., Mamudu, O. A., & Igwilo, K. (2019). The design of an integrated crude oil distillation column with submerged combustion technology. *The Open Chemical Engineering Journal*, 13(1), 7–22. <https://doi.org/10.2174/1874123101912010007>
- Fang, Y., Cho, Y. K., Zhang, S., & Perez, E. (2016). Case study of BIM and cloud-enabled real-time RFID indoor localization for construction management applications. *Journal of Construction Engineering and Management*, 142(7), 05016003. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0001125](https://doi.org/10.1061/(ASCE)CO.1943-7862.0001125)
- Felix, P., Verena, G., Lars, B., & Rainer, S., (2016) Innovations in Enterprise Information Systems Management and Engineering
- Ferdinandus, F. X., & Setiawan, E. I. (2016, December). GeoJSON Web Service based road assets management system for Surabaya city using mobile GPS. In *2016 international computer science and engineering conference (ICSEC)* (pp. 1–5). IEEE.
- Greg, M. (2016), Pinpoint How GPS is changing technology, culture, and our mind. pp. 18–54.
- Industrial Company. (2019). Company handbook. International Monetary Fund. (2001). Government Financial Statistics Manual.
- Irene, R, Kumar, P.A, Marco, M, & Marco, Garetti. 2016. A Framework for Implementing Value-based Approach in Asset Management. doi:10.1007/978-3-319-27064-7\_47
- Jooste, J. L., & Vlok, P. J. (2015). Identifying the critical success factors for engineering asset management services—an empirical study. In J. Amadi-Echendu, C. Hoohlo, & J. Mathew Eds., *Lecture notes in mechanical engineering* (Vol. 20). Springer International Publishing. [https://doi.org/10.1007/978-3-319-15536-4\\_32](https://doi.org/10.1007/978-3-319-15536-4_32)
- Kusumawardhani, M., Gundersen, S., & Tore, M. (2017). Mapping the research approach of asset management studies in the petroleum industry. *Journal of Quality in Maintenance Engineering*, 23(1), 57–70. <https://doi.org/10.1108/JQME-07-2015-0031>
- Kusumawardhani, M., & Markeset, T. (2015). Asset integrity knowledge management: A case study from the petroleum industry. *Operations and Supply Chain Management*, 8(3), 146–153. <https://doi.org/10.31387/oscm0210152>
- Li, C. J., ZHONG, H. H., FU, S. Q., FANG, S. J., & DAI, K. (2016b). Application of RFID technology in the intelligent asset management in colleges and universities. *Laboratory Science*, (5), 20. [http://en.cnki.com.cn/Article\\_en/CJFDTotol-YSKT201605020.htm](http://en.cnki.com.cn/Article_en/CJFDTotol-YSKT201605020.htm)
- Li, H., Chan, G., Wong, J. K. W., & Skitmore, M. (2016). Real-time locating systems applications in construction. *Automation in Construction*, 63, 37–47. ISSN 0926-5805. <https://doi.org/10.1016/j.autcon.2015.12.001>
- Maletič, D., Maletič, M., Al-Najjar, B., Gotzamani, K., Gianni, M., Kalinowski, T. B., & Gomišček, B. (2017). Contingency factors influencing implementation of

- physical asset management practices. *Organizacija*, 50(1), 3–16. <https://doi.org/10.1515/orga-2017-0003>
- Mamudu, O. A., Igwe, G. J., & Okonkwo, E. (2019). Process design evaluation of an optimum modular topping refinery for Nigeria crude oil using HYSYS aspen software. *Cogent Engineering*, 6(1), 1659123. <https://doi.org/10.1080/23311916.2019.1659123>
- Manbachi, M., Sadu, A., Farhangi, H., Monti, A., Palizban, A., Ponci, F., & Arzanpour, S. (2016). Impact of EV penetration on Volt-VAR Optimization of distribution networks using real-time co-simulation monitoring platform. *Applied Energy*, 169, 28–39. ISSN 0306-2619. <https://doi.org/10.1016/j.apenergy.2016.01.084>
- Mhlaba, A., & Masinde, M. (2015). A hardware based model for an asset monitoring and tracking system: Case of laptops. In *2015 international conference on emerging trends in networks and computer communications (ETNCC)* (pp. 155–161). IEEE, Windhoek, Namibia.
- National Bureau of Statistics. (2016). while the following should be added to the list of references. Nigerianstat.gov.ng. 2016. National Bureau of Statistics. [online] Available at <https://www.nigerianstat.gov.ng/> [Accessed 6 May 2020]
- Rahimi, F., Götze, J., & Møller, C. (2017). Enterprise architecture management: Toward a taxonomy of applications. *Communications of the Association for Information Systems*, 40(1), 120–166. <https://doi.org/10.17705/1CAIS.04007>
- Robert, D. (2016). An introduction to assets management. EA Technology Ltd. ISBN 978-0-9571508-3-6.
- Rødseth, H., & Mo, B. (2016). Integrated planning in autonomous shipping—application of maintenance management and KPIs. In *Proceedings of the 10th world congress on engineering asset management (WCEAM 2015)* (pp. 497–504). Cham: Springer.
- Roe, G. V., O'Banion, M. S., & Olsen, M. J. (2016). Mobile Lidar guidelines to support utility asset management along highways. In *Pipelines*, 2016, 922–932. DOI:10.1061/9780784479957.085
- Shah, A., Zhong, J., & Ly, J. (2017). Adopting smartphone technology to supplement road asset performance monitoring. In *AAPA international flexible pavements conference, 17th, 2017, Melbourne, Victoria, Australia*.
- Terry, W. (2014). Benchmarking Best Practices and Asset management: Updated for ISO 55000. Industrial Press, Inc.; Third edition (August 28, 2014)
- Thaduri, A., Galar, D., & Kumar, U. (2015). Railway assets: A potential domain for big data analytics. *Procedia Computer Science*, 53, 457–467. ISSN 1877-0509. <https://doi.org/10.1016/j.procs.2015.07.323>
- Wahap, N. A., Nor, N. M., Ahmad, N., Yusoff, N. M., Noor, M. Z. M., & Ismail, N. M. (2016). Geospatial embedded technology for on-site tracking and monitoring. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*, 8(4), 81–85. <https://journal.utm.edu.my/index.php/jtec/article/view/1177>
- Wang, M., Tan, J., & Li, Y. (2015). Design and implementation of enterprise asset management system based on IOT technology. In *2015 IEEE international conference on communication software and networks (ICCSN)* (pp. 384–388). IEEE, Chengdu, China.
- Yu, Z., Yuan, C., & Zheng, K. (2018). A university fixed asset database information management system based on internet of things. In *2018 2nd IEEE advanced information management, communicates, electronic and automation control conference (IMCEC)* (pp. 2488–2491). IEEE, Xian, China.
- Zhao, X. (2015). On processing GPS tracking data of spatiotemporal car-movements: A case study. *Journal of Location Based Services*, 9(4), 1–19.
- Zhong, R. Y., Wang, L., & Xu, X. (2017). An IoT-enabled real-time machine status monitoring approach for cloud manufacturing. *Procedia CIRP*, 63, 709–714. ISSN 2212-8271. <https://doi.org/10.1016/j.procir.2017.03.349>



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