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An Overview of RFID Technology in Field Material Transfer Management

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Abstract - **This paper aims to evaluate applicability of Automatic Identification and Data Capture technologies, Radio Frequency Identification (RFID) technology, for Field Material Transfer (FMT) and Materials Management processes (MMP) of an Oilfield Services Company with problems identified in accuracy, timeliness, and reliability of data in the company's inventory management. This study will examine some of the key challenges and risks on adoption of RFID technology for the company, through evaluating return on investment (ROI), technical systematic integration processes, and partial or phase implementation strategy to achieve benefits while addressing gaps for FMT and materials management process. The research examines at the current process flows and gap areas, reviews the existing RFID tools and applications via current research and established physical supply chain theories, and proposes possible solutions with applicable RFID techniques and structures for the company, as well as potential risks and challenges that the company may face in application of the RFID technology.**

Keywords – **RFID Technology, Inventory Management, Field Material Transfer Management (FMT), Physical Supply Chain Management**

I. INTRODUCTION

During recent years, many research studies have been conducted to ensure the reliability and timeliness of material supplies for production and delivery of products within supply chain management environments. Through this, businesses aim to achieve their goals of maximising profits while providing return on investment and value proposition to shareholders [1]. In recent business environment where supply bases are widening across broader regions internationally, it has become increasingly challenging to accurately estimate and monitor delivery lead times and reliability in quality and quantity of materials in transit [2], directly impacting reliability of inventory planning and stock management processes which often result in excess or shortage of inventories and inconsistent inventory turnover. Excess inventories will impact financial performance of a firm significantly, by freezing the company's working capital which could be used for other value adding activities such as R&D investments, imposing unnecessary inventory carrying cost which can cost approximately 25% of the total inventory value in general, as well as potential write-offs or discount sales of the inventories which directly impacts the company's profitability [3]. Also, any lack of material supplies will lead to inefficiency in manufacturing processes resulting in operational and production cost increase, impact in production speed and continuity hence reduction in profit margin of the company. The continuing development of connectivity technologies such as RFID can present sound opportunities for the firms to overcome the challenges and improve their efficiency and effectiveness of material supply and transportation managements as well as enabling digital integration of their supply value chain. This paper aims to assess the existing RFID applications and industry examples and propose applicability of the RFID solutions to an Oilfield Service Company's inter-company materials transfer system as a case study, to improve the inventory materials data accuracy to achieve the efficiency and effectiveness of the company's warehouse and materials management system with optimizing the materials data flow and update frequency hence minimizing lags and data input mistakes and errors.

II. LITERATURE REVIEW

The literature review to evaluate the applicability of RFID, automatic identification, and data capture technologies for field material transfer within manufacturing and oil and gas sectors. The paper aims to examine the current and existing studies within this field to further develop the understanding of the key challenges and risks towards adoption of these technologies and the potential benefits on the application and integration within firms. Through these studies, the researchers will be able to examine and analyse the linkages and thus provide a conceptual framework to categorise this important research dimension.

A. Radio-Frequency Identification (RFID) and Current Applications

Radio-frequency identification (RFID) is commonly implemented Automatic Identification and Data Capture (AIDC) technologies currently available [4]. It has been used across number of institutions and sectors, especially within global supply chain, logistics and warehouse management environments. It is a technology with wireless automatic identification mechanism which transmits data between RFID tags and readers via radio frequency waves [5]. Each RFID Tag can carry uniquely

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identifiable information of a product such as product identification number, date of production, producer, shipping information, expiry date, etc. depending on purpose of the use. A tag can store up to 100 time more data than barcodes and a reader can identify up to 200 tags at once, providing superior recognition efficiency over other wireless identification technologies [6]. The collected data then is communicated to and processed by a RFID middleware and used by business systems and applications.

With RFID technology in logistics, together with Electronic Product Code application, such automatic target recognition mechanism allows users to access relevant data via real-time logistics tracking and monitoring where the entire logistics chain process being completely transparent for all stakeholders in the supply chain [7]. For example, Eastern Logistics Limited, a 3PL SME (small and medium enterprise) adopted RFID technology in envisaging the logistics operation of the company [8]. The application improved visibility of shipping movements and accuracy of lead times of all the related logistics lags, resulting in enhanced performance of its supply chain partners in inventory level reduction, avoidance of stock shortages and improved stock delivery efficiency. Earlier studies examined a manufacturing company who introduced RFID technology in one of the company's production line for tracing components [9]. As a result, the production cycle time, machine utilisation rate and penalty cost by late deliveries were significantly improved in comparison to the company's traditional production scheduling model. RFID technology has also been used in the pull-based inventory replenishment operations of materials management in physical supply chain. Research case study examined the impact of RFID-enabled pull-based *"inventory replenishment system"* of the Thin-film-transistor liquid-crystal display (TFT-LCD) industry, where it was observed that with the application of RFID technology, there was reduction of 6.19% on the inventory cost [26]. Joint systematic approach of RFID and the Global Positioning System (GPS) has also been actively explored and implemented in various industries. The combined model of RFID and GPS enabled the real-time location of resources regardless of if they are located indoor or outdoor [10].

B. Digital Integrated Warehousing and Inventory Management

In the sector of materials and warehouse management of physical supply chain, accuracy of inventory and stock count data is crucial especially for the stock keeping, unit planning, inventory management, monitoring, and control of in/out-flow of materials [11]. With the global phenomenon of digitalisation and recent focus on maximising supply value chain, many businesses are aiming to achieve higher efficiency and effective methods of selection, storage, sorting, and transferring products and services. Together with increasing adoption of centralized distribution models, automation and integration of warehousing systems is unavoidable [11]. Fundamentally, warehouses are used to store products, and it is essential for a warehouse to be effectively organized and operate so that its users can always be aware of the storage status as in capacity rate, product details, qualities, and quantities, and to locate any product at any time efficiently. However, companies commonly face challenges in warehouse management with growingly complicated variety of materials, and recent trend of focusing on operational and cost efficiencies leading the firms move from having bulk inventories to continuous inflow of small but enough quantities [12].
Such challenge could be overcome by implementing RFID-enabled warehouse inventory management system. The system automatically maintains detailed product information and advice its users the exact location of items and their status. Researchers demonstrated the use of warehouse inventory management system with RFID and Internet of Things (IoT) communication technologies in their research [13]. In their model, the RFID tagged information is transmitted to open-source hardware via a wireless platform through the internet. The developed system, with a web-based analytical platform, results in system that offers significantly lower cost with much more dynamic performance over the traditional warehouse inventory management systems [13]. GENCO, a multinational logistics company, is another good example of RFID-enabled technology application in warehousing. GENCO adopted a RFID-based resource management system (RFID-RMS) for their warehouse management practices. The RFID-RMS enables users to find the most appropriate resource management packages for their warehouse operations by having various solutions from a case-based data warehouse, which are integrated with RFID and case-based reasoning technologies, providing the users opportunities to improve in both time efficiency and cost effectiveness of their warehouse operations [14]. By applying the RFID-RMS, GENCO successfully improved picking process efficiency of its forklift operation by up-to 20%, increased pallet shipping accuracy from 92% to 99%, which also is believed to reduce its operation cost drastically by saving cover of re-shipping, cost of re-stocking and reduction in human resources in manual task handling such as dock checkers [14]. RFID technology can also be paired up with IoT sensors which then can provide more detailed information to the users such as temperature and humidity, and by further enhancing the analytics capability with Machine Learning (ML), the technology can greatly improve especially the long-distance logistics and materials management of perishable items and dangerous goods that are sensitive to external environments. Another research tested the proposed system in the consumable food supply chains and proved huge reimbursements that the system brought especially by having real-time visibility on the product information with status and conditions history for the proactive stock condition control, hence minimizing risk of having damaged stocks in storage and transit [15].

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C. Digital Supply Chain Integration

There have been rapid changes in the supply chain management in the past decade especially with the increasing trend of globalization led by fast evolution of technological development, and digitalization has been the key focus area, which all businesses and functions have been highlighting as the most important competitive advantage. Such development posed greater importance on firm's capability to anticipate and manage its supply chain partners and lack of such ability will result in supply chain risks [16]. Such risks can be mitigated the best via Supply Chain Integration (SCI) which aims to achieve efficient and effective integration of physical, informational, and financial flows [17]. Integration of cross-functional borders with high degree of information share, mutual dependence and joint development activities among suppliers and customers is a critical success factor to achieve competitive advantage [18]. Therefore, to realise and obtain the maximum benefit of the SCI, firms must ensure that they integrate information flows, business processes, networks, and infrastructure. This is where a digital supply chain (DSC) plays a significant role and generates greater value for the SCI. A digital supply chain in simplest form is a digitalised supply chain model that offers competent, smart, value-driven processes aiming to create new forms of business value and revenue that is leveraged by innovative technological and analytical methods [19]. DSC is about how supply chain processes are driven with innovative digital technologies, tools and solutions, and the digital communication technologies such as RFID, IoT and cloud computing have always been highlighted as a key enabler.

D. Supply Chain Risk Management (SCRM)

As stated earlier, the concerned Oilfield Service Company faces challenges in its inter-company inventory transfer system due to validity and reliability of the records which are caused by delay in movement records and manual inputs and locating the excess inventory items together with classification and logistics provisions. To overcome the challenges, adoption, and implementation of RFID and IoT technologies are suggested as per the earlier reviewed research cases and examples. In application of the RFID technology, the company's standard warehouse management policies and procedures must be fully reviewed and updated accordingly to the new process with RFID application, as well as the physical implementation of RFID tag and readers and arrangements of the warehouses and store fitouts to fully accommodate the RFID tagging system in consideration of movements of the items. This is where the above-mentioned various RFID-enabled warehouse management systems can be applied. By adopting IoT sensors with the RFID technology, the company aims to achieve more comprehensive real-time data and information about the stored items, i.e., temperature, humidity, expiry duration, etc. [15], which when paired up with advanced analytics technology will provide greater insights to the stored items hence improve efficiency of the traceability system as well as minimise loss of stocks by mistreatments of environmentally sensitive items such as chemicals. Another important aspect of potential improvement of inventory management and tracking is from the Supply Chain Information System Integration with the suppliers and 3PLs. As stated earlier, the application of sound SCI and DSC itself provides significant competitive advantage to the company by having continuous flow of information, processes, and strategies as well as physical and financial flows [17, 18, 19]. However, in addition of the SCI, application of the RFID infrastructure or radio-frequency integration, the company will be able to obtain greater visibilities in both up and downstream flows of the inventory items in real-time, which will be the basis of true end-to-end digitally automated procurement and distribution systems and process.

As well as the physical warehouse application, the company must ensure that the RFID tools and infrastructures are synchronized with its MRP system with application of unique identification codes by using Supplier Part Number (SPN) and Buyer Part Number (BPN), which also are critical inputs of the SCI model with the company's suppliers and 3PLs. By having a strong integration between the physical warehouse management system and the MRP as Distribution Operating System, the company aims to have complete information, visibility, and traceability of its inventories. With application of the suggested technologies, the system will support addressing the issues the company is facing in the FMT and Inventory Management system by enabling it to;

- trace and track movements of individual ordered inventory items from the company's internal Manufacturing Centres and 3rd party suppliers real-time, ensuring greater accuracy in the supply lead time of the ordered items;
- effectively and efficiently manage inventories in the warehouse with ability to monitor the location, status, and movement of the items, generating cost and efficiency savings as well as being able to minimize excess inventories and optimize inventory level;
- obtain maximum accuracy of the inventory stocks and movements in real-time, enabling the inter-company materials transfer system and process accurate thus minimize risk of having faulty transfer order placements, and;
- improve visibility on inventory consumption and order forecasts per job and location which minimize risk of inventory shortages and able to mitigate gaps in materials planning.

III. CASE STUDY BACKGROUND

XYZ is an International Oilfield Services Company applies materials management system (MRP) which works based on a computerized electronic system. The MRP not only engages with the company's purchasing

systems to place orders to its internal Manufacturing Centres and approved 3rd party suppliers, but also functions as key database and Operating System for the company's inter-company Field Material Transfers (FMT). The MRP holds information of all inventory requests, purchases, and on-hand stock counts, and FMT essentially is transfer of excess or unused inventories and materials of a location, whether it being a field location, local warehouse, or central distribution centre, to another location who need the stocks. Locations in need of materials will place an order via the MRP, which the requirement will be communicated to the central Distribution Service Centre (DSC) of the region who will first search for inventory status of other locations in MRP to assess availability of excess or unused materials in other locations. If available, the DSC will arrange transportation via the company's Transportation Management System (TMS) in liaison with the regional Logistics Control Tower (LCT). If no excess materials are available in any of the locations, the DSC will place an order via the company's Procurement System to its Manufacturing Centres or approved 3rd party suppliers. In the scenario of inter-company material transfer, FMT, required materials can be various type of inventories from chemicals, specialty MROs (Materials, Repair and Operations), replenishment parts, etc. and there are over 120 countries where the company operates with multiple job locations in each country in addition to the company's bases and warehouses. By just looking at these simple statistics, one can easily see the complexity and frequency of the FMT requirements of the company and of course the criticality of the efficiency and accuracy of the systems supporting the processes and operations. The procedure and process of the inter-company FMT has been set to maximize the company's inventory utilization and optimize the turnover, hence minimize cost of the overall inventory management. And the reliability of the data and information is critical for the success of the system because regardless of materials planning and forecasting quality, the system is opted to fail causing losses in both time and money if the data and information provided by the MRP are not timely and reliable.

Inaccuracy of the data and information from the MRP often lead to significant waste of time and resources in obtaining required inventory materials of a location for a job. For example, if the MRP over-states inventory count status of location A, which is flagged as excess inventory, hence inter-company transfer is arranged without any new purchase order placement, it already creates wastes in time and money by arranging material transfer between the ordering location and the location A. It will be days after the team realizes the faulty information, and the delay in supply as a result can cause a catastrophic event if the material required is a critical piece of part that is required to run a well operation hence can cause stoppage with cost of millions of dollars per day of loss time. In such scenario the event will cost the company opportunity for negotiation with the supplier, delivery lead time, reputation and future bargaining power with the supplier, large logistics cost for urgent shipping (hot shot), as well as potential loss of reputation and trust from the effected client as well as penalties and loss of revenue possibly.

IV. RISKS AND CHALLENGES

There are several benefits that the application of RFID connectivity technology can bring to the company, however also there are various risks and challenges that the company must ensure to understand and anticipate. Firstly, the company must carefully analyse Return on Investment (ROI) of the RFID technology implementation, where the main uncertainty of the technology comes from the high initial investment cost as well as continuous expense on the tags [20]. Proper evaluation of ROI will point to the company's expectation on quantifiable benefits [21]. The company may also consider partial or categorized application, i.e., applying the system only for operations-critical inventory items. Also, the company must evaluate complexity, capability, and capacity of systematic integration with its existing legacy systems [22] to minimise any potential risk in technical implementation failure. The company operates with quality MRP, ERP and Supply Operating Systems, and if they cannot digest the RFID-generated data, it will create additional cost by bringing a layer interface translating the data between the two systems or complete failure of RFID technology adoption. Industrial readiness of the technology adoption is also a challenge in implementing the RFID technology for the company, especially when considering RFID connectivity integration with 3rd party supply chain partners for concerns particularly on the complexity of system integration with various operating systems and lack of standards [23]. DoD and Wal-Mart are good examples of difference in RFID application scale with their suppliers. While DoD enforced its RFID mandate to its top suppliers, Wal-Mart reduced it by lower penalties for failure to apply tags for its 600 supplier who experienced significant challenges in execution of the technology [24]. Also, with the rapid increase in use of wireless Auto-ID technologies such as RFID in a wide variation of different industries, variety of objects scanned has also been increasing concurrently, and an increasing problems of RFID application coexistence has been identified [25]. Hence the company must ensure to have clear mechanism of handling the different correlation of sensitivity and the radio-frequency signal ranges, and application of unique identification number mechanism, such as BPN or Manufacturing Part Number to create unique-key when integrated with the radiofrequency mechanism.

V. CONCLUSIONS AND FUTURE RESEARCH

The RFID technology is the most recognised and widely accepted wireless Automatic Identification and Data Capture technologies currently accessible within the market. By having been able to contain uniquely identifiable data and information of individual items and wirelessly communicate them real-time via the RFID tags

and readers, the technology offers significant benefits especially in physical supply chain sectors of logistics and warehousing where seamless flow of accurate and reliable data with traceability is required. Prompting such RFID technology to the Oilfield Services Company, this research studies aims to convey huge benefits to the company's Field Material Transfer (FMT) processes as well as its warehouse management, MRP system and logistics operations. The problems that the current systems and processes are often facing would be addressed with the key benefits that the RFID technology offers, especially by having been able to uniquely identify individual project or item tagged, automatically and digitally share the information, monitor the status of each item, improve traceability of the items at any transportation stage, improve accuracy in data and visibility, etc. [22]. Furthermore, the efficiency and accuracy gains in inventory management processes and systems, and the FMT processes, RFID-enabled information and materials management system could also enable the company with an opportunity of gaining stronger competitive advantages by being able to obtain platforms for end-to-end digital supply chain integration which will drive further enhancement of its internal and external supply chain value chain and operations with greater efficiency and cost reduction gains. In summary, although there are several challenges and risks in adopting the RFID technology for the company at a larger scale, with thorough evaluation of ROI, technical systematic integration planning and consideration of partial or by-phase implementation strategy, the company would gain significant benefits and address the problems it is facing in the FMT and Materials Management processes.

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