Warehouse Management Systems:
Comparison of Two Pittsburgh-Based Manufacturing Firms

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INTRODUCTION

Warehouse Management Systems and Supply Chain Management Technologies

A warehouse management system (WMS) is an integral part of supply chain management. It enables a warehousing operation to gather data about items as they are received, monitor inventory, and facilitate picking, packing, and shipping processes. A WMS should be able to support information visibility between the warehouse and procurement and logistics operations. This improves accuracy, quality, and productivity for the entire supply chain (Chaturvedi & Chakrabarti, 2018; Clarke & Clarke, 2014; Constantinos & Oyon, 2010; Shah, et al., 2008). Beginning with automatic identification and data capture (AIDC), the need for paperwork and manual processes is reduced; WMS makes possible the automation of warehouse operations, reducing time and effort of staff (Biswas & Sarker, 2008; Browning & Heath, 2009). Vendor-managed inventory (VMI) can optimize inventory levels in the warehouse, while approaches such as just-in-time (JIT), digital twins, and or cross-docking can almost eliminate costly storage of warehouse inventory entirely. A number of these applications and/or technologies are discussed in the next sections.

AIDC

Automatic information and data capture (AIDC) can be defined as a systematic data capture that more traditionally was manual inputted by notation or keyboard. AIDC inherently reduces input error by reducing human interaction with the data (Baxter & Hirschhauser, 2004; Beldona & Tsatsoulis, 2010; Bergé, 2016; Blanchard, 2014; Smith & Offodile, 2008). Digital twins couples with AIC and blockchain technologies (Bhurjee, et al., 2018; Casino, et al., 2019; Tseng, et al., 2018; Wang, et al., 2019; Weking, et al., 2020), provide a very promising future in logistics and supply chain technologies in terms of enhanced efficiencies and economies of scale in the short-term future. The purpose is obtaining accurate and reliable identification of physical objects in real time and in meaningful detail. Its simplest form might involve affixing a barcode to an item and then scanning that barcode to enter its number and corresponding data into an information system. More advanced than traditional barcodes are RFID (radio frequency identification) tags, which can contain more data and can transmit that data with no direct line-of-sight between tag and reader (Brandon-Jones, 2017; Casadesus & de Castro, 2005). AIDC technologies are an essential first step for a modern warehouse management system (WMS) (Basu & Nair, 2012; Smith, 2005; Yang & Park, 2011).

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VMI

Vendor-managed inventory (VMI) is a partnering between firms to improve efficiency in the supply chain. The supplier takes on the role of inventory planner and controls materials at a client or customer's location until they are used. Before partnerships such as this, suppliers would have to rely on demand forecasting based on previous orders from buyers to determine their production and delivery scheduling. There would often be extended periods of time between orders from buyers in which demand would accumulate and then surge. This order batching, and uncertainty and fluctuations in demand forecasts, can result in amplified order variabilities that move up the supply chain, referred to as the bullwhip effect (Lee, 1997; Yazdi, & Esfeden, 2018). In a VMI system, information is more visible between the supplier and buyer; the supplier knows the actual demand for and usage of materials and this mitigates the inefficiencies of the bullwhip effect. Using blockchain technologies to keep essential information about items in transit and related changes in documentation are important facets if VMI-managed systems are going to be efficient and productive (Tan, et al., 2018; Tapscott & Tapscott, 2017). For the usage and movement of materials to be accurately documented in a timely manner, however, relies on AIDC. For this captured data to be transferred, relies on information systems to be integrated between the vendor and the client (Gonzálvez-Gallego, et al., 2015).

Digital Twins

Conceptually, a digital twin is a current icon, schematic representation, or a model of an actual physical asset that can be identified in the operations cycle. As noted by Lim, et al. (2021), traditional approaches to performance and measurement models (i.e., model and train) leads to hysteretic and isolated model building that results in low efficiency and low utilization of data-mining potentials. For example, simulation based on theoretical and static models are quite common and extensively used in commercial and industrial applications as the accepted tool for the verification, validation, and optimization of a system, especially in the earliest planning stage. However, as suggested by Lim, et al. (2021), very little attention is centered on the optimization characteristics of the simulation model during real-time, run-time of the systems as data is being collected.

There are associated information tags associated with it that helps management understand the asset's condition, tracking information, and historical data about the asset. Digital twins are far more than a representation of an asset for tracking and informational purposes, it can be used in predictive and descriptive analytics to create models of future behavior to can, in turn, be used for managerial control for optimizing its operation in logistical and supply chain management (SCM). The Internet of Things (IoT) accessibility is essential to make digital twins work (Crum, 2014). A digital twin can be a model of a component, a system of components, or a combination of systems that are integrated in some way (Jones, et al., 2020; Yang & Lirn, 2017). From the micro-level (a physical part or component of a system) to the macro-level (series of systems working together to mine, manufacture, and deliver assets).

Typical applications of digital twins include operations optimization techniques, predictive maintenance, anomaly detection, to fault detection and/or isolation (Liu, et al., 2021). Machine learning (both low level or shallow learning to higher-level learning such as deep or multi-level model building of learning algorithms are used. In such applications, a multitude of input variables are used in designing, manufacture, and delivery of products (i.e., pumps, engines, power plants, manufacturing lines of assembly, optimizing best use of a fleet of vehicles. Digital-twin models use physical performance

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