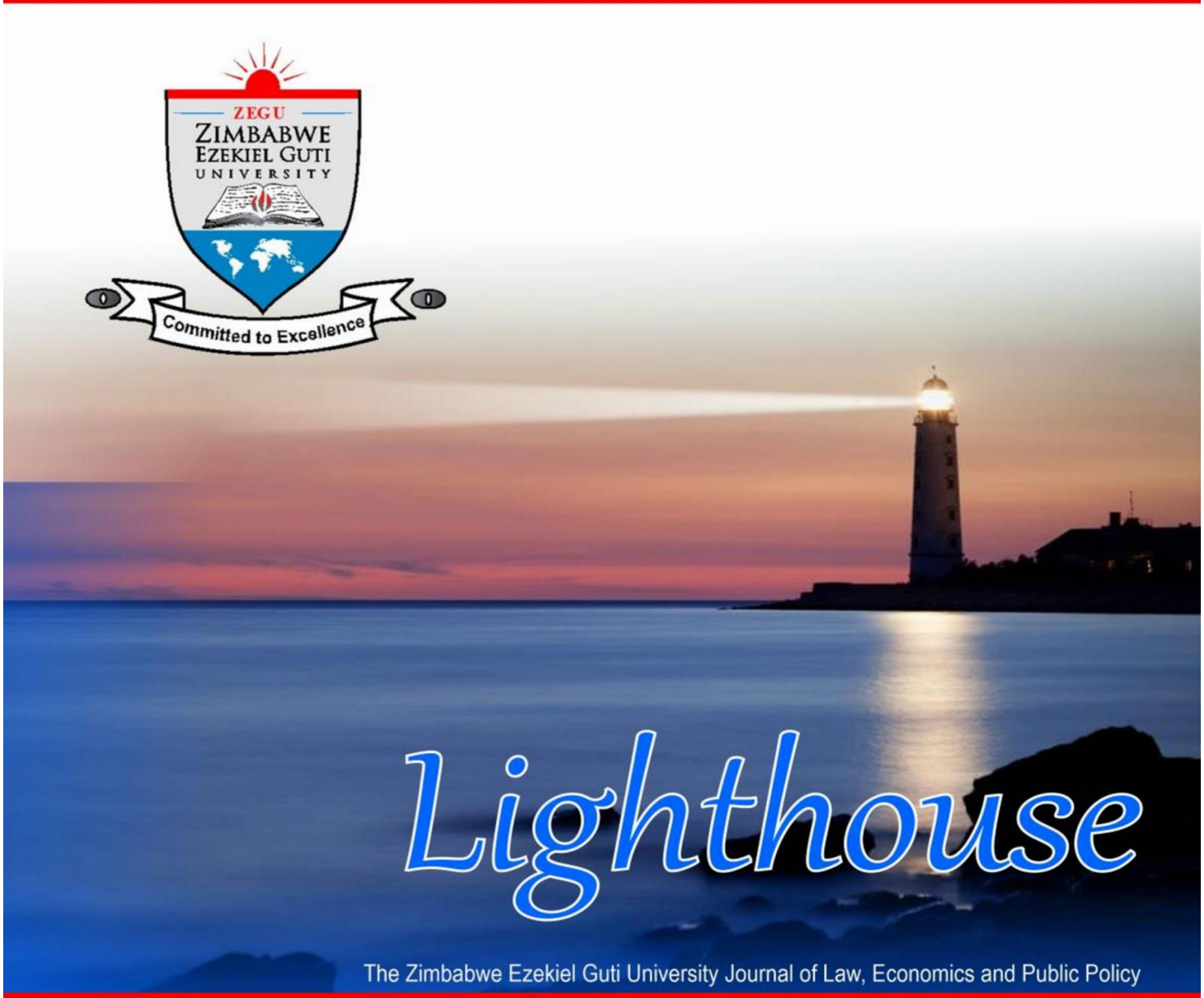

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CRITICAL ELEMENTS IN DEFINING AN INTELLIGENT SUPPLY CHAIN MODEL FOR WAREHOUSE INFRASTRUCTURE

MUTUMWAWASHE DUBE[1]

ABSTRACT

Smart supply chains and warehouses aim to increase quality, productivity and efficiency with the notion of environmental justice in mind. Since the year 2015, the use of smart and intelligent supply chains gained traction with the use of the Internet of Things (IoT) taking centre stage in the discussion of the development of smart supply chains. The study evaluates the defining elements of an intelligent supply chain and their usefulness in the implementation of smart warehouse infrastructure. The study used the qualitative methodology and in-depth interviews. The study found that the use of digitalised warehouse infrastructures can position the manufacturing industry in Zimbabwe as the breadbasket globally and jewel crown of Africa. The study found that a smart supply chain can be defined by a tracking and tracing system that uses technology and the use of the IoT. There is need to move away from manufacturing that relies on fossil fuels and move towards

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sustainable manufacturing based on smart warehousing and inventory management. The study used qualitative methodology and in-depth interviews.

Keywords: efficiency, environment, traction, sustainability, fossil, intervention

INTRODUCTION

Supply chains play a crucial role in manufacturing and services operations (Zhang, Yang and Yang, 2022). The supply chain consists of all the processes, transformations and flows involved in the making of a product from raw material to the finished product (Hamdy, Mostafa and Alawady,
2020). The supply chain consists of all the parties involved directly and indirectly in the fulfilment of a customer request. It includes not only manufacturers and suppliers but also warehouses, retailers and even the customers (*ibid.*). Warehousing is an integral part of supply chain management. Traditionally, it is a place to store and hold inventory before being shipped to customers or distributed to retailers for sale (Affia and Aamer, 2020). However, nowadays they do not function as storage facilities only, but also as critical places where supply and demand are matched through inventory management to meet the demands of the customer (*ibid.*). Automation and digitalisation are the driving forces of Industrial Revolution 4.0 (4IR) as the revolution led to the mass production of goods, which increased the need for modern warehouses (Jarasuniene, Ciziuniene and Cereska, 2023). The extensive production of goods launched by the 4IR intensifies the necessity for modern warehouses (*ibid.*). In recent years, which is at the turn of the year 2010, the functioning of warehousing has gotten unpredictable with the increasing number of goods handled in a warehouse, thus customary and manual strategies for warehouse management can no longer deal with such volumes of activities (*ibid.*). This intensity of production has prompted the use of modern innovation to manage these challenges
(*ibid.*).

The article explores the integral elements in defining an intelligent supply chain model for warehouse infrastructure. An intelligent supply chain has become an important part of manufacturing across the world and with this globalisation, there

is need for the adoption of intelligent supply chains in African manufacturing industries if they are to survive the global markets and put a mark on modern supply chains. There is great need for intelligent supply chains in the Zimbabwean manufacturing industry as these can help reduce climate change by reducing the emission of greenhouse gases that are released by the old model of buildings, the industrial model before the 4IR. Environmental justice is the missing link in the creation of intelligent supply chains if Zimbabwe is to create a supply chain that does not harm the environment.

CONCEPTUAL FRAMEWORK

The conceptual framework that guides the article is the public goods standpoint propounded by Samuelson (1954) (). The public goods standpoint postulates that efforts of private businesses are likely to lead to inadequate standard infrastructures for at least two reasons (*ibid.*).

The first reason for the failure arises from the public goods nature of the standards inevitably leads to a free rider problem and the result is underinvestment in the provision of infrastructures (*ibid.)*. This problem of free-riders is what the African manufacturing sector is facing currently with special reference to Zimbabwe the market and the players within the market are operating based on a neo-liberal standpoint without any investment into smart and sustainable infrastructure jeopardising the future due to the need to have a free market.

Old models of warehouses are said to produce 30% of the greenhouse gas emissions (Raza and Malik, 2019). Under-investment in smart infrastructure can lead to the failure of public goods and this is what Zimbabwe is currently experiencing due to the lack of investment in smart infrastructure. The manufacturing industry is lagging behind and failing to produce goods for public consumption. Zimbabwe is one of the countries that import much of what is consumed in the country due to the failure of the industry to produce public goods. Zimbabwe produces what it does not consume and consumes what it does not produce, meaning there is a failure in the manufacturing industry to produce public goods on a mass scale.

The second reason is coordination failure through wrong investments that are suboptimal (Samuelson 1954). There is need for the digitalisation of the supply

chain so that it can track and monitor the investments that are pursued by manufacturing companies so that they do not go off track and pursue wrong investments.

Resolving these public goods and coordination failures requires intervention from another industry, which is the merging of the information and communications technology (ICT) and the manufacturing industries. The merging of the two industries leads to the creation of smart manufacturing and warehousing infrastructure development that allows African manufacturing industries to reposition themselves on the global map as major players, not as mere spectators and extractors of raw materials and buyers of value-added products. The creation of intelligent supply chains can solve the shortage of public goods in Zimbabwe as these bring with them warehousing infrastructures that allow for the smart tracking and movement of goods. Zimbabwe has gone through phases whereby the manufacturing industry has been revived and protected by the government without reaching full production potential in the manufacturing sector. Intelligent supply chains can help through the creation of warehouse infrastructures that are also smart using the IoT. The creation of smart warehouses helps because nowadays warehouses do not function as storage facilities only, but also as a critical place where supply and demand are matched through inventory management to meet the demands of the customer (Affia and Aamer, 2020).

LITERATURE REVIEW

The literature to be reviewed focuses on the supply chain, an intelligent supply chain and the warehouse infrastructure.

SUPPLY CHAIN

Supply chains encompass companies and business activities needed to design, make, deliver and use a product or service (Khan *et al*., 2010). Businesses depend on their supply chain to provide them with what they need to survive and thrive (Ganeshan and Harrison, 1995). The supply chain involves many flows, that is, information flow, financial flow and material flow (*ibid.*). Third-party logistics is also involved in the supply chain, and this is a situation whereby a company uses its logistics resources on behalf of another company in handling the inbound and

outbound logistics of the company that owns the commodities (*ibid.*). The term ―supply chain management‖ arose in the late 1980s and came into widespread use in the 1990s (Chopra and Meindl, 2001). Before that time, businesses used terms such as logistics and operations management (Khan *et al*., 2016). A supply chain can, therefore, be described as the alignment of firms that bring products or services to the market (Lambert, Stock and Ellram 1998).

Thus, supply chain management is a set of approaches used to efficiently integrate suppliers, manufacturers, warehouses and customers so that merchandise is produced and distributed in right quantities, to the right locations and at the right time to minimise system-wise cost while satisfying service level requirements (*ibid.*). Supply chain management is the task that moves in a process from supplier to manufacturer, to wholesaler, to retailer to consumer (Khan *et al*., 2016). The supply chain formerly involved production of goods, storage and transportation of goods to the final user. However, now with the involvement of technology, the supply chain has evolved to become smart. The smart supply chain now involves the internet and other technologies.

INTELLIGENT SUPPLY CHAIN

The wide disruptions due to the COVID-19 pandemic demonstrated the importance of supply chain flexibility and resilience (Zhang *et al*., 2022). An intelligent or smart supply chain is a supply chain that integrates the partners to self-organise and automatically adapt to environmental changes and makes intelligent decisions to best achieve business goals (*ibid.*). The main features of a smart or intelligent supply chain include being integrated, intelligent, adaptive, and self-optimising (*bid.*).

The supply chain is a dynamic evolving process that extends vertically and horizontally in terms of integration, along with technology development and business innovation. With the development and integration of ICT and artificial intelligence (AI), supply chains evolve from single partner/flow intelligence to multi-partner or whole supply network intelligence and, ultimately, to promote and realise the digitalisation and intelligentisation of different businesses/systems (Liu *et al*., 2018). Thus, developing a resilient and smart supply chain is an

indispensable yet challenging task for manufacturers and other stakeholders (Zhang *et al*., 2022). The emergence of new (ICT) technologies, such as big data analysis, the Internet of IoT and blockchain, makes it possible to develop a smart supply chain (SaucedoMartinez *et al*., 2018).

Driven by new technologies and the need for adapting to constantly changing markets, the 4IR provides a new platform for smart manufacturing, bringing manufacturers close to customers (Lasi *et al*.,
2014). Industry 4.0 can provide cyber-physical systems to integrate customer needs into the different stages of manufacturing (Zhang *et al*., 2022). The implication of the 4IR technology has transformed the manufacturing industry and created economies of value creation during the past four years (Ching *et al*., 2022). This entire value-creation network is typically coincident with the supply chain (Zhang *et al*., 2022). Thus, supply chain management is an important factor that impacts the performance of smart manufacturing under the 4IR. Supply chains should keep pace with the revolution (Zhang *et al*., 2022). Zhang (2015) has indicated that smart manufacturing needs smart or even smarter supply chains for support since the supply chains affect the availability of the input for manufacturing, the interaction of multiple functions of production, the efficiency of the delivery of the finished goods to customers and responsiveness of the network.

The smart supply chain is to use advanced technologies, especially ICT, to link the processes in different partners of a supply chain to form an intelligent connected system (Wu *et al*., 2016). Industry 4.0 has a more positive impact on manufacturing industries in German companies (Sarbu *et al*., 2021). Duman and Akdemir (2021) opined that the benefits of smart supply chains in business yield profitability, improvement in sales and production speed, and increase in productivity, quality and efficiency in firms. New emerging technologies from the 4IR, such as ICT, show promise in improving the supply chain in various ways (Colin *et al*., 2015). Supply chain management aims to meet customer demands on time with the highest quality and lowest cost that can be obtained by improving the process and achieving the linkage between them, removing the non-value-added activities across the supply chain and making it more agile (Kovacs and Kot, 2016). The IoT has a significant role to play in improving and enhancing the performance of all the functions of supply chain management which are production, location and

marketing (Mostafa and Eltawil, 2016). All the functions can benefit supply chain management by saving time and cutting costs, while bringing customer satisfaction.

INTELLIGENT WAREHOUSE INFRASTRUCTURE

Intelligent supply chain management can have an impact on the modelling of a smart warehouse management system. Industrial buildings produce nearly 30% of all greenhouse gas (GHG) emissions (Malik *et al*., 2019). This includes indirect emissions from increasing energy consumption and packaging waste production (Rupp *et al*., 2022). In the United States of America (USA), Environmental Protection Agency (EPA) data showed that nearly 23% of GHG comes directly from industrial sources like warehousing, logistics processes, manufacturing and construction (Stolaroff *et al*., 2018). The direct emission created during various warehousing processes such as storage, goods consolidation, distribution and transporting cargo has been on the increase in recent times (Chuah *et al*., 2022).

Seaborne cargo, which is 90% of globally traded commodities, is processed in warehouses and transported via existing road infrastructure to and from various ports (Oloruntobi *et al*., 2023). This made warehouses and logistics inevitable and now need to be intelligent and sustainable for the safety of the environment. The implications to the environment continue to be of utmost concern, necessitating several global calls to embrace environmental, social and governance standards (*ibid.*). This means leaser energy usage for heating and energising operations in warehouses and logistics centres will minimise the dependence on fossil fuels (*ibid.*). Shemi *et al*. (2018) observe that one industry that mounted the utmost pressure on the centrally generated electricity is the storage and warehouse sector, prompting the release of indirect emissions. Adopting a warehouse management system can have a positive impact on the supply chain performance. That is because using Management Information System and wireless barcodes can achieve cost reduction, flexibility, inventory reduction and delivery in time reduction, thus achieving customer satisfaction (Hamdy and Mostafa, 2020). The introduction of barcode-enabled real-time warehouse management systems and automation with the addition of technologies like near-field communication (NFC), radio-frequency identification, global positioning systems (GPSs), wireless sensor network, WiFi

and robotics, has changed the warehousing system by reducing manpower costs (van Geest *et al*., 2022).

Intelligent supply chain management must have an IoT that allows one to track work-in-progress, and inventory, and improve the picking and receiving of goods in the wool yarn industry (Hamdy and Mostafa 2020). Wei *et al*. (2015) found the use of barcodes by supply chains to be helping in the warehouse management system by helping in the management of inventory, supporting decision making and decreasing the workforce costs, thus it achieves improved overall performance. The use of intelligent supply chains is critical in achieving inventory control, increasing efficiency of the operations, enhancing warehouse utilisation, reducing manpower, reducing loading time and increasing inventory accuracy (Hamdy and Mostafa, 2020). With the help of the adoption of new technologies such as the IoT, block chain, big data analytics, artificial intelligence, machine learning, deep learning and robotics, the operations of warehouses may be radically transformed (van Geest *et al*., 2022).

The main advantages of smart warehouses are that they provide realtime information which is not possible in traditional warehouse systems, manual tasks are minimised, and automation of tasks is maximised so that high-value tasks are performed by the employees (*ibid.*). Smart warehousing allows for improved operational scalability because updating infrastructure is easier than the update of human capital within the organisation. In smart warehouses, automated decisions are made using different prediction models and the use of sensors to monitor expensive equipment and, therefore, downtime is minimised (*ibid.*). Warehouses are no longer a storage places only, but rather a place where valueadded services take place in that some warehouses are starting to assemble and pack (De Koster *et al*., 2017). The manual warehouse operations involved errors during the inventory control and picking process and to ensure quality and safety in the smart supply chain, warehousing has technical systems that reduce the margin for human error (Skerlic, 2017).

Warehouse inventory management plays a crucial role in supply chain management, leveraging 4IR technologies, the smart automated warehouse

becoming popular, especially for e-commerce companies (Liu *et al*., 2018). The warehouse and distribution centre with 4IR technologies become a supporting part of smart manufacturing processes (Mohammed, 2017). Smart warehouse management uses the IoT and Big

Data to make the monitoring, tracking and location of various materials and products in the warehouse environment (Aviles-Sacoto *et al*., 2019). Therefore, technological advancement through automation of the warehousing system in the intelligent supply chain defines the smart supply chain and can be used for the modelling of smart warehousing, a model that involves less human handling of goods using machines.

METHODOLOGY

The study used a qualitative methodology, leaning towards case study research design. To craft the discourse forming this article, the study engaged purposive sampling to sample eight respondents that have worked in the manufacturing sector in Zimbabwe with experience on the supply chain. The study also engaged literature and document review to understand the state of the supply chain and warehouse infrastructure in Zimbabwe. Snyder (2019) states that a literature review-based study can direct the researcher on the gaps within the study area and how others have addressed the pitfalls within a certain research area. The data was analysed using narrative data analysis. The study focused on TechFarm, a Zimbabwean telecommunication company that supplies electronic gadgets.

THE USE OF THE INTERNET

The study showed that there is use of smart technology at the TechFarm warehouses to track and trace inventory and reduce the time spent in the supply chain and make deliveries of products to the consumers in time. The findings indicated that there is the use of the Internet of Things in the warehousing system at TechFarm. One participant said:

> What we do here is we use the internet to track and trace our inventory so that the time spent tracing and searching for inventory boxes is less, as everything is computerised, making the smart supply chain time effective in Zimbabwe.

The study also revealed that the use of the IoT in the supply chain is critical in defining a smart supply as it indicates that a supply has to selfoptimise. One participant indicated that:

> The Internet of Things defines a smart supply chain as it gives the supply chain the ability to self-optimise and self-organise as it can help cut human interference and reduce delays.

The IoT has been shown in the findings to define a smart supply chain that can operate with minimum human intervention. One participant said:

> One aspect that defines an intelligent smart supply chain is the ability to use the Internet of Things and reduce human interference so that the machines can operate and locate inventory. The basis of smart supply chain is to reduce human work as the population is ageing.

The IoT can define a smart supply chain as it can reduce the human interference as the population is ageing in most of the countries, including Zimbabwe.

MODEL OF AUTOMATION

The study showed that a smart supply chain can be defined by a model of automation that can reduce the loss of goods. The findings revealed that the traditional model of supply chain lost goods through breaking as the picking and handing of goods by humans led to errors. One participant indicated that:

> What defines a smart supply chain is a model of automation that can work to reduce the loss of goods in the warehouse so that the company makes profits rather than losses. This is because the traditional supply chain involved packing and picking by humans and this led to loses due to the breaking of inventory.

The study revealed that the automation model is what defines a smart supply chain as it can use better ways to track and transport the goods to the pick-up counter. One participant stated that:

> One thing that can define a smart supply chain is the creation of an automation model for the supply chain that can reduce breakages and loss of goods in the picking and packing due to human error. A smart supply

chain can be defined by automation through the use of RFID (radio frequency identification) to track and trace the inventory.

These findings showed that for a smart supply chain to be defined there is need for an automation model that allows for the automation of services such as the packing and picking of orders, as well as the tracking and tracing.

TRACKING SYSTEM

The findings revealed that for a supply chain to be defined as a smart supply chain, there is need for tracking and tracing system of goods and services to avoid the loss of inventory in transit or the loss of time in tracing for a box in the warehouse. One participant indicated that:

> For a supply chain to be defined as a smart supply chain, there need for a tracking and tracing system that can help in the tracking of inventory in transit through the use of GPS and TechFarm has the best tracking system for goods in transit.

The findings revealed that there a need for a good tracing and tracking system in the supply chain to reduce the issue of time lost during the tracing of boxes. One participant said:

> Much of the time in the traditional supply chain was lost in the tracing and tracking of goods in the warehouse as there was no system to track the loads of boxes stacked in the warehouse. Now with the use of smart supply chains tracing and tracking of boxes in the warehouse is now easy as there is now the use of barcode tracking in the supply chain and the bar code tracing can define a smart supply chain.

The study showed that for the supply chain to be defined as a smart supply chain, there is a need for the automation of tracking system using robots that are computerised to trace and track the inventory. One participant said:

> For a supply chain to be intelligent, it needs to include automation of the tracking and tracing system and this is done through the use of robots that are computerised to know where to find the goods and services. This also helps the supply chain against industrial action induced delays. As TechFarm we are

striving to create a robot-based supply chain tracking and tracing system in the near future.

The study revealed that for a supply chain to be defined as a smart supply chain, there is need for an intelligent tracking system that can track inventory and minimise time lost in the process of tracing for the goods.

DISCUSSION

The use of smart supply chain management comes with the use of IoT and this can be used to define intelligent supply chain management as everything within this supply chain is connected to the Internet. This model of supply chain is intelligent and can be implemented in the manufacturing sector in Zimbabwe as it is time effective in locating and picking the inventory. In support of these findings are Oner *et al*. (2017), who observed that a warehouse framework based on RFID can track workin-progress and inventory, and improve picking and receiving goods. The findings indicated that an intelligent supply chain is defined by the automation of processes using robotics and other machines to minimise loss of products through human error in the handling of goods in the warehouse.

This model of automation can be adopted for the modelling of warehouse infrastructure in the Zimbabwean manufacturing industry to avoid the loss of products due to human error in the inventory handling process. In agreement with these findings, Skerlic (2017) observed that manual warehouse operations involved errors during the inventory control and picking process and there was need to ensure that quality and safety in the smart supply chain warehousing has technical systems that reduce the margin of human error. There is need to avoid these errors in the manufacturing sector in Zimbabwe if the manufacturing industry is to be revitalised and take centre stage again in the region and the continent of Africa. The findings indicated that a smart supply chain can be defined by mechanisation and automation of the processes which can also be said of the model of warehouse systems that develop based on automation to reduce the cost of labour.

The manufacturing sector in Zimbabwe can adopt a warehouse infrastructure that is intelligent. With automated machines like robots to reduce the cost of labour, this can also reduce downtime due to industrial strikes and breaks. These findings

are in line with Hamdy and Mostafa (2020), who observed that the use of intelligent supply chains is critical in achieving inventory control, increasing efficiency of the operations, enhancing warehouse utilisation, reducing manpower, reducing loading time and increasing inventory accuracy. These intelligent supply chains and warehousing can also be dangerous for developing countries with high unemployment rates as the adoption of these smart machines signifies loss of jobs for individuals within the manufacturing industry due to the reduction of dependence on manpower.

The development of an intelligent warehouse can be a step in the right direction for the manufacturing industry in Zimbabwe as it reduces the loading time and increases inventory accuracy. The findings indicated that the adoption of a smart supply chain can lead to the use of warehouse infrastructure as areas of value-added services. This can be a step in the right direction for the manufacturing industry in Zimbabwe as beneficiation has remained the missing piece on Zimbabwean products.

There is need for smart warehouse infrastructures that are allow value addition processes. These findings are again supported by Hamdy and Mostafa (*bid.*) who observed that the use of intelligent supply chains is critical in achieving, increasing efficiency of operations, enhancing warehouse utilisation in value-added services allowing firms to produce customised and finished goods. The findings indicated that the traditional warehouse infrastructure is responsible for 30% of GHG emissions Malik *et al*. (2019). Therefore, the development of smart sustainable warehouse infrastructure becomes important in Zimbabwe as the country is part of the global effort to reduce climate change. The direct emission created during various warehousing processes such as storage, goods consolidation, distribution and transporting cargo, has been ion the increase in recent times (Chuah *et al*., 2022).

There is need to reduce the rise in the emission of GHGs hence the development of smart and sustainable warehouse infrastructure models. The findings indicated that the smart warehouse models must have barcode tracking systems and technologies that allow for the location of goods with ease. This can be useful in the manufacturing industry in Zimbabwe as it allows the location of inventory in no

time, especially for those dealing in e-commerce. Consistent with the findings are van Geest *et al*. (2022), who postulated that the introduction of the barcode enables real-time warehouse management systems and automation, with the addition of technologies like near-field communication (NFC), radiofrequency identification, global positioning systems (GPS), wireless sensor network, WiFi and robotics, has changed the warehousing system in reducing manpower costs. These technology-based models of warehouse infrastructure are cost-effective as they reduce manpower due to the use of automated machines.

CONCLUSION AND RECOMMENDATIONS

In conclusion, Industrial Revolution 4.0 has become an eminent revolution sweeping across the world, spurred on by the need to reduce climate change and practise sustainable development. There is need for the development of intelligent and sustainable warehouse infrastructure models. This article summarises the definition of an intelligent supply chain as a supply chain that is based on the Internet of Things and the automation of services to reduce waste and the impacts of manufacturing on the environment.

RECOMMENDATIONS

- There is need for the development of smart models of warehousing to achieve environmental justice using sustainable infrastructures.
- There is need for the government to lead the development of the models of smart warehouse infrastructures in Zimbabwe.
- There is need for models of smart technologies that will be compatible with the current employment indices and protects people‘s jobs as unemployment is already high.
- There is need to prioritise environmental justice by creating smart models of warehouses that do not emit greenhouse gases.
- There is need for the creation of a smart supply chain first to see the feasibility of smart warehousing.

REFERENCES

Avilés-Sacoto, S.V., Avilés-González, J.F., Garcia-Reyes, H., BermeoSamaniego, M.C., Cañizares-Jaramillo, A.K. and Izquierdo-Flores, S.N. (2019). A Glance of Industry 4.0 at Supply Chain and Inventory Management. *International Journal of Industrial Engineering, 26*(4).

Ching, N.T., Ghobakhloo, M., Iranmanesh, M., Maroufkhani, P. and Asadi, S. (2022). Industry 4.0 Applications for Sustainable Manufacturing: A Systematic Literature Review and a Roadmap to Sustainable Development. *Journal of Cleaner Production, 334*, 130133.

Chopra, S. and Meindl, P. (2001). Supply Chain Management: Strategy. *Planning and Operation*, *15*(5), 71-85.

Chuah, L.F., Mokhtar, K., Bakar, A.A., Othman, M.R., Osman, N.H., Bokhari, A., Mubashir, M., Abdullah, M.A. and Hasan, M. (2022). Marine Environment and Maritime Safety Assessment Using Port State Control Database. *Chemosphere*, *304*, 135245.

Colin, M., Galindo, R. and Hernández, O. (2015). Information and Communication Technology as a Key Strategy for Efficient Supply Chain Management in Manufacturing SMEs. *Procedia Computer Science*, *55*, 833-842.

De Koster, R.B., Johnson, A.L. and Roy, D. (2017). Warehouse Design and Management. *International Journal of Production Research*, *55*(21), 6327-6330.

Duman, M.C. and Akdemir, B. (2021). A Study to Determine the Effects of Industry 4.0 Technology Components on Organisational Performance. *Technological Forecasting and Social Change,* 167, 120615.

Ganeshan, R. and Harrison, T.P. (1995). An Introduction to Supply Chain Management. Pennsylvania: Penn State University.

Hamdy, W., Mostafa, N. and Elawady, H. (2020). An Intelligent Warehouse Management System Using the Internet of Things.*The Egyptian International Journal of Engineering Sciences and Technology,32(Mechanical Engineering)*, 59-65.

Jarašūnienė, A., Čižiūnienė, K. and Čereška, A.(2023). Research on the Impact of IoT on Warehouse Management. *Sensors*, *23*(4), 2213.

Khan, M., Hussain, M. and Saber, H.M. (2016). Information Sharing in a Sustainable Supply Chain. *International Journal of Production Economics*, *181*, 208-214.

Kovács, G. and Kot, S. (2016). New Logistics and Production Trends as the Effect of the Global Economy Changes. *Polish Journal of Management Studies*, *14*(2), 115-126.

Lamballais, T., Roy, D. and De Koster, M.B.M. (2017). Estimating Performance in a Robotic Mobile Fulfilment System. *European Journal of Operational Research, 256*(3), 976-990.

Lambert, D., Stock, J.R. and Ellram, L.M. (1998). *Fundamentals of Logistics Management*. London: McGraw-Hill/Irwin.

Lasi, H., Fettke, P., Kemper, H.G., Feld, T. and Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, *6*,*239242*.

Liu, L., De Vel, O., Han, Q.L., Zhang, J. and Xiang, Y. (2018). Detecting and Preventing Cyber Insider Threats: A Survey. *IEEE Communications Surveys & Tutorials*, *20*(2), 1397-1417.

Malik, A., Yuningtias, U.A., Mulhayatiah, D., Chusni, M.M., Sutarno, S., Ismail, A. and Hermita, N. (2019). Enhancing Problem-Solving Skills of Students through Problem Solving Laboratory Model Related to Dynamic Fluid. In *Journal of Physics: Conference Series, 1157*(3), 032010.

Mohamed, M. (2018). Challenges and Benefits of Industry 4.0: An Overview. *International Journal of Supply and Operations Management*, *5*(3), 256-265.

Mostafa, N. and Eltawil, A. (2016*).* Vertical Supply Chain Integrated Decisions: A Critical Review of Recent Literature and a Future Research Perspective. Supply Chain Management: Applications for Manufacturing and Service Industries. In: Habib, M. (ed,), Management Science-Theory and Applications Series. New York, NY: Nova Science Publishers,.

Oloruntobi, O., Mokhtar, K., Rozar, N.M., Gohari, A., Asif, S. and Chuah, L.F. (2023). Effective Technologies and Practices for Reducing Pollution in Warehouses - A Review. *Cleaner Engineering and Technology*, *13*, 100622.

Oner, M., Ustundag, A. and Budak, A. (2017). An RFID-based Tracking System for Denim Production Processes. *The International Journal of Advanced Manufacturing Technology, 90*(1-4), 591604.

Raza, A. and Malik, T.N. (2019). Energy Management In Commercial Building Microgrids. *Journal of Renewable and Sustainable Energy, 11*(1), 015502.

Rupp, M., Buck, M., Klink, R., Merkel, M. and Harrison, D.K. (2022). Additive Manufacturing of Steel for Digital Spare Parts – A Perspective on Carbon Emissions for Decentral Production. *Cleaner Environmental Systems,4*, 100069.

Samuelson, P.A. (1954). The *Pure Theory of Public Expenditure. The Review of Economics and Statistics, 34*(4), 387-389.

Saucedo-Martínez, J.A., Pérez-Lara, M., Marmolejo-Saucedo, J.A., SalaisFierro, T.E. and Vasant, P. (2018). Industry 4.0 Framework for Management and Operations: A Review. *Journal of Ambient Intelligence and Humanized Computing, 9*, 789-801.

Sarbu, R., Alpopi, C., Burlacu, S. and Diaconu, S. (2021). Sustainable Urban Development in the Context of Globalization and the Health Crisis Caused by the Covid-19 Pandemic. In *SHS Web of Conferences* (Vol. 92, p. 01043). Bucharest Romania: EDP Sciences.

Shemi, A., Magumise, A., Ndlovu, S. and Sacks, N. (2018). Recycling of Tungsten Carbide Scrap Metal: A Review of Recycling Methods and Future Prospects. *Minerals Engineering, 122*, 195-205.

Škerlič, S. and Muha, R. (2017). Reducing Errors in the Company‘s Warehouse Process. *Transport Problems, 12*(1),83-92.

Snyder, H. (2019). Literature Review as a Research Methodology: An Overview and Guidelines. *Journal of Business Research, 104*, 333339.

Stolaroff, J.K., Samaras, C., O‘Neill, E.R., Lubers, A., Mitchell, A.S. and Ceperley, D. (2018). Energy Use and Life Cycle Greenhouse Gas Emissions of Drones for Commercial Package Delivery. *Nature Communica*tions, *9*(1), 409.

van Geest, M., Tekinerdogan, B. and Catal, C. (2022). Smart Warehouses: Rationale, Challenges and Solution Directions. *Applied Sciences*, 12(1), 219.

Wei, Y.L., Han, A., Glanville, J., Fang, F., Zuniga, L.A., Lee, J.S., Cua, D.J. and Chien, Y.H. (2015). A Highly Focused Antigen Receptor Repertoire Characterizes γδ T Cells that are Poised to Make IL-17 Rapidly in Naive Animals. *Frontiers in Immunology*, *6*, 118.

Wu, L., Yue, X., Jin, A. and Yen, D.C. (2016). Smart Supply Chain Management: A Review and Implications for Future Research. *The International Journal of Logistics Management*, *27*(2), 395-417.

Zhang, L., Yang, X., Li, T., Gan, R., Wang, Z., Peng, J., Hu, J., Guo, J., Zhang, Y., Li, Q. and Yang, Q. (2022). Plant Factory Technology Lights up Urban Horticulture in the Post-Coronavirus World. *Horticulture Research*, *9*, uhac018.

Zhang, G., Yang, Y. and Yang, G. (2023). Smart Supply Chain Management in Industry 4.0: The Review, Research Agenda and Strategies in North America. *Annals of Operations Research, 322*(2), 1075-1117.

Zhang, J. *et al.* (2015). Coordinating a Supply Chain for Deteriorating Items with a Revenue-sharing and Cooperative Investment Contract. *Omega*, *56*, 37-49.