Markov Chain and Inventory Management of Manufacturing Companies in Nigeria

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ABSTRACT: *The inability to adapt and accept the deployment of new technologies in solving inventory-related problems have been some of the challenges manufacturing companies face in Nigeria. Some studies have suggested that the use of the Markov chain is capable of improving inventory management, however, the capabilities and effectiveness of the Markov chain in enhancing inventory management in manufacturing companies remain quite unclear. This study reviewed the Markov chain and inventory management of manufacturing companies as used in prior studies. The study adopted an exploratory research design in reviewing prior studies using relevant materials from journals, periodicals and relevant documented materials. The study through the review observed that the Markov chain has the ability to improve inventory management in manufacturing companies. The study also recommended that managers in manufacturing companies should improve their inventory management and manufacturing operations by adopting quantitative and scientifically aided decision-making modelling for their inventory management systems, such as linear programming, stochastic programming, mixed integer programming, genetic algorithms and the Markov chain decision-making processes.*

KEYWORDS: inventory management; Markov chain; mathematical estimations; stochastic process; supply-chain; warehousing**.**

INTRODUCTION

Effective inventory management has become one significant and key element of supply chain management that enhances organizational performance and manufacturing companies are no exception. In the world of digitalization of businesses and increasing volume of transactions, traditional methods in decisions making based on the instinct of managers are increasingly becoming inadequate in the contemporary business competitive environment. Manufacturing companies now tend to align their operations in line with the volume of transactions that require more innovation and effective inventory management (Lotfi, Kargar & Hoseini, 2021). In the new technological age, the relevance of the mathematical application and use of the Markov chain stochastic statistical model in solving sequential events.

The Markov chain stochastic model like many other systems and sequential processes can be involved in solving inventory management in manufacturing firms characterized by dynamic or static (e.g. random or fixed) variables. Also the stationary (time-invariant) or non-stationary (time-variant), linear or non-linear, discrete-state or continuous-state or time, event-driven or time driven, stochastic or deterministic (Huang, Meng, Liu, Liu & Li, 2022; Xu, Hou, Zhu, Li, Liu, Lei, & Wu, 2021; Yang, Lin, Liu, Chou, 2021). Besides studies have shown that the Markov chain model can be applied in sequence events like supply chain, computer systems, telecommunication systems, software systems, traffic systems, transportation systems, queuing systems and energy distribution modelling systems that involve mathematical sequences, time-variant and time-invariant procedures.

Inventory management of manufacturing companies is concerned with the methodological and systematic procedure of the management of ordering, storing, maintaining and usage of corporate organizations' inventories (Afrinaldi, 2020). In a manufacturing industry setting, inventory management also entails the control of the supply chain cycle of products from the raw materials ordering stage down to the warehouse of the raw materials, issuing of raw materials up to production components and work-in-progress management, finished goods warehousing and storage and delivery to the financial consumers (Kamran, Zhao & Ambreen, 2017).

In addition, Nwuba, Omankhanlen, Chimezie and Okoye (2020), posited that inventory management is the strategic process of monitoring and controlling inventory aimed at adequate replenishment as and when due, towards meeting customers' demands at all times. The ability to determine the appropriate and right inventory level in the manufacturing companies is significant to the successful performance of the organization (Amah, 2016). Ahmed, Hasan, Hoque and Alam (2018) contended that higher and excessive inventory is detrimental to the working capital of an organization as it tends to tie down funds and ultimately affects the financial performance of the company. In the same manner, inappropriately lowered inventory could as well be harmful to efficient inventory management. Therefore, inventory management requires that the manufacturing companies maintain a balanced and optimal inventory level in line with the requirements for the raw materials and in line with the storage space and production demands and inventory for the finished goods in line with the customers' requests and demands (Akinleye, Odunayo & Fajuyagbe, 2018; Nalubowa, Namango, Ochola & Mubiru, 2021). Inventory management would require striking a balance and keeping inventory costs to the least cost savings possibilities.

In most instances, inventory management reflects on the quality decisions in relation to when to re-order, the quantity the company should maintain as the re-order levels and the quantity to order from the clients at each time (Chatys, 2020). Several alternative possibilities tend to conflict and compete with each other, requiring accurate decisions in selecting the best option (Papadopoulos & Keily, 2018). The effective decision is important because the level of uncertainty and the possible resulting effect have a great effect on the performance of the manufacturing companies involved for the now and for the future.

Statement of the Problem: Managers have great challenges meeting effective and optimal inventory management requirements in manufacturing companies due to the complexities caused by the volume of transactions and demands from customers from diverse locations. Tochukwu and Hyacinth (2015) noted that inventory management is problematic and potent high risk capable of disrupting production and customer satisfaction. Some of the problems of inventory management include inconsistent tracking of products, inventory warehousing inefficiencies, inaccurate data management, inability to meet changing and increasing demand fluctuations, poor documentation, product stocking challenges and complexity in the supply chain management (Akinleye et al., 2018). Others include inefficient inventory processing and poor inventory control (Ahmed et al., 2018).

The hesitations in making inventory management decisions are significant because of (i) limitations in the capability to an accurate method of all the parameters and the variables connected with the problem (ii) lack of accurate predicting human behaviour (iii) limitations in accurate prediction of possible outcome based on uncertainties in future events. In making better corporate investment and inventory management decisions, modern technologies and prior researchers have provided different decision support and models to assist in making accurate decisions to maximize inventory management opportunities as well as minimize uncertainties towards improving corporate efficiency and performance. In resolving the problem of inventory management in manufacturing companies, new innovations in optimizing inventory management can be qualitative or quantitative in attempting the problems. While the qualitative involves rational and intuitive decision-making methods like Just-in-time, another is quantitative which includes the use of mathematical approaches like decision trees, linear programming methods, and the introduction of Markov Decision Models (MDM) (Karim & Nalkade, 2020; Lotfi, Mardani & Weber, 2021)

The main objective of this study is to examine the Markov chain and inventory management of manufacturing companies in Nigeria. In addressing the problem of inventory management and the possible influence of the Markov chain in resolving the problem and challenges of inventory management of manufacturing companies in Nigeria, the study proposes to employ an explanatory approach and non-empirical approach, aimed and directed at reviewing prior literature on the Markov chain and inventory management. The rest of the study is fashioned in this manner:

In section 2, the study considers the literature review and theoretical framework. In section 3, the methodology is presented. The conclusion and recommendations will be considered in section 4 of the study.

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Markov Chain: The Markov chain is a mathematical process that involves defining the possibility of future action based on the given current states of certain known variables, such that when the probability of future actions at each point or state is determined, a decision tree can be drawn and then the likelihood of result can be calculated. Markov chain is a mathematical model that involves a stochastic procedure where current events tend to rely on prior events and only depend on that moment. Interestingly, in the Markov chain, stochastic processes provide an interesting property of the finite Markov chain (Lotfi, Mardani & Weber (2021). Markov chain is a globally used model in diverse areas of theoretical and applied mathematics and science, including statistics, operations research, industrial engineering, linguistics, artificial intelligence, demographics, and genomics.
Consistently, according to Akhlaghi and Malkhalifeh (2019), the Markov chain is one of the mathematical quantitative models that researchers had found useful in inventory management. Akumu (2014) reported that the Markov chain had a significant impact on inventory management and is closely linked to improving and enhancing efficiency in inventory management. The Markov chain has been researched by various studies. Markov chain has been employed in various ways, in inventory market analysis, manpower planning, energy supply rationing, and many other ways in making effective forecasting and predicting as well as inventory management. Grossman, Pinto and Ramaswamy (2019) noted that the Markov chain is also a continuous-time procedure referred to as continuous-time Markov chain (CTMC), a statistical model for general simulation model for problem-solving. The Markov chain is generally characterized by its g-steps transition probability and integration of differential equation: $(1+x^2)dy/dx = n(1+y^2)$.

According to Vafadar, Tolousi-rad and Hayward (2017) since inventory management is quite encompassing and involves the entire manufacturing supply chain processes of managing inventories from the raw materials to finished goods, the Markov chain becomes convenient in this regard. Also, Sharma and Viswakarma (2014) documented that in an effort to ensure efficient inventory management, the management of companies intends to avoid excessiveness as well as shortages of products using orthodox approaches, the just-in-time (JIT), material requirement planning (MRP) that are qualitative or using mathematical and more sophistication of Markov chain processes (MCP) that is quantitative in nature.

Markov chain otherwise called the Markov process is a model that requires a sequential and structural process of events by which the possibility of each incident largely depends only on the particular attainment of action in the previous incident. According to Ambreen and Altab (2016), it can be likened to saying that what will happen tomorrow depends on the outcome of today's events. Markov chain was developed by the renowned Markov Andrey, a Russian mathematical in the year 1906. Markov chain is one of the prominent analytical tools that was developed to handle complex problems as well as predict inventory management. It is an inventory forecasting model that assists in solving complex issues in relation to inventory management efficiency.

Isik, Unal and Una (2017) reported that the Markov chain is closely connected with effective inventory management, while Kamran, Zhao and Ambreen (2017) opined that the Markov chain had a significant influence on inventory management. Afrinaldi (2020) employed the Markov chain in determining the number quantity of supplies required, re-order level or safety inventory level. Karim and Nakade (2020) also used the Markov chain to ensure equitable and effective distribution of inventory management and supplies. Lotfi, Mardani and Weber (2021) noted that determining the optimal quantity of supplies needed, reorder levels and safety inventory level are significant in inventory management by using a stochastic optimization model to lend support in inventory management decision-making and effective inventory management to prevent disruptions in the supply chain cycles.

According to Grossman et al., (2019), the Markov chain model signifies a chain of stochastic events, where the possibility of one event transition is subject to the state reached in the prior events. Hence there is no memory beyond the prior event. Lotfi *et al.*, (2021) further posited that the chain successive of events is generally referred to as Markov procedures which tend to be continuous if the transition can occur at any time or discrete if the transition can possibly occur at fixed times. Markov chain is a special tool for the case of stochastic process, used in estimating matrix of transitive from the observing states of a known system. Markov Decision Process (MPC) is a chronological and sequence decision-making stochastic method that is employed to study complex systems using about 21 generally categorized into 5 elements comprising of (i) Decision epochs (ii) States (iii) Actions, (iv) transition probabilities and (v) rewards. Based on this, the primary objective of the decision taker here is to optimize, hence the environment is categorized into different states.

Afrinaldi (2020) noted that the inventory decisions could be modelled at the points in time (decision epochs) which could be fixed or not (discrete or continuous). The ultimate goal is to select a course of action that optimizes actions based on rules that will move the desired goal effective choice and these decisions will translate to corporate policies aimed at enhancing adequate inventory management efficiency and in turn ensuring financial performance and profit maximization. Nwuba *et al.*, (2020) carried out research using the Markov chain stochastic inventory management for a single product with irregular demands to establish the optimal order level at the same time as the reorder level during long-term customers' demands. The Markov chain model employed *(X, r)* inventory policy that allows two different order sizes *(X1, X2)* and two different reorder levels (r1, r2). *X1* was placed when the reorder level reached r1, a normal re-supply option. *X2* was the order when the reorder level reached *r2*, assisting in accelerated re-supply requirements.

Furthermore, Nalubowa *et al.*, (2021) noted that the Markov chain has two perspectives, discrete-time (countable space) and continuous time (continuous space). While Chatys (2020) submitted that Markov revealed that a stochastic process is a series of indexed collections of arbitrary or random variables $\{X_t\} = (X_0, X_1, X_2, X_3$, describing the behaviour of a system operating over a time period. For instance, in the application of inventory management in a typical instance: X_t represents the demand for phones during a week t, X_t has a Poisson distribution with a mean of 1.

Studies have suggested that various Markov chain models can be deployed in solving inventory management. For instance, Akhlaghi and Malkhalifeh (2019) stated that the Spatio-temporal Markov chain model (STMCM) has the capacity to combine with probability chain adjustment to predict states of inventory variations and has the mathematical ability to estimate inventory variation propagation in a multistage factory and production procedures.

Processes: According to Ahiska, Appaji, Russell, King and Warsing (2013), in a typical situation, the Markov chain can be estimated in this process:

i. Establishment of the mathematical expression of the condition of transition probability matrices is established based on both spatial and temporal dimensions.
ii. Defining the probability chains and probabilities of joint states required to improve the prediction accuracy of the (STEMCM)
iii. Evolution algorithm with self-adaptive mutation strategies to optimize the weights pf the probabilities in STEMCM.

The result of the procedure based on the factory data provided can assist inventory managers with better inventory plans to maintain optimal inventory management. The use of the Markov chain in inventory management is involved processes and procedures for an inventory variation prediction problem been to investigate in a real inventory system with possibilities of multiple production stages in a factory of manufacturing companies.

Inventory Management

According to Haung, Meng, Liu, Liu and Huang (2022), inventory management has become necessary considering the extent of uncertainties of the inventory process could be quite challenging when making inventory orders decisions of what and when to order, the time factors and many others are carefully put into perspective to ensure satisfactory inventory management. Costantino, Gravio, Shaban and Tronci (2015) stressed that uncertainty could be witnessed in term of inventory quantity, quality or delivery time for orders delivery resulting from several unforeseen circumstances. Also according to Karim and Nakade (2020), In addition, issues could arise in inventory management likely internal factors random equipment breakdowns, procedures in fixing and adjustments, unexpected workload, shortages and disappointments in supplies due to labour strikes, transportation disruptions possible from vehicle breakdowns, accidents, bad weather, or natural disasters, market conditions or cases of price adjustments, inflationary causing change in price, insufficiency of goods when they are needed.

Ahiska et al., (2013) posited that inventory management is significant to incorporate all these factors in every step in making successful inventory management. Inventory management is critical and can be complicated for multistage and effective smoothing manufacturing processes and multitasking production in factory production since reasonable inventory management is essentially a key driver that will facilitate continuous factory production and online order delivery to customers for finished goods as well as finished goods in each case. Owing to diverse transactional uncertainties and delays in inventory ordering and delivery inherent in the supply chain processes, manual and physical-based models may not accurately and effectively estimate and approximate inventory management, the need for a new innovation using the Markov chain as a better alternative in resolving the problem of inventory management in manufacturing companies.

Silbermayr and Minner (2014) documented that there are other inventory management software packages that have the capacity to track and control the manufacturing companies' inventory as they are bought, manufactured, stored and used in case of raw materials that will enhance effective manufacturing operations without hitches. For effective inventory management and seamless production processes for the manufacturing companies, it is required that companies ensure effective inventory management that will enhance corporate profitability, scaling and systematic approach to product and raw materials sourcing, warehousing, delivery both of raw material or components as well as finished goods sales when they are required (Sharma & Vishwakarma, 2014). Grossmann, Ye, Pinto and Ramaswamy (2020) further stated that the software like Invex inventory management software can be useful, other include Quick Book, Zoho inventory management, Inflow inventory, and Ordoro inventory management systems.

Markov Chain and Inventory Management

Studies have researched the relationship and interconnectivity between the Markov chain and inventory management in companies sensitive to inventory management as well as supply chain challenges. Huang, Meng, Liu, Liu and Huang (2022) reported that the Markov chain is one of the simple mathematical models that could be employed in solving inventory-related problems, suggesting that the Markov chain has several practical abilities and applications in the corporate world in predicting the possible number of defectives pieces that will come off a production assembly line when operating status of the equipment on the line. Also, the study of Lotfi, Kargar, Hoseini, Nazari, Safavi and Weber (2021) reported that the Markov chain had a positive effect on inventory management, situating that helped in predicting the proportion of corporate receivables that are likely turning to bad debts. According to Myers, Wallin and Wikstrom (2017), the Markov chain exerted a positive impact on inventory management, positing that the Markov chain facilitated the forecasting of future brand loyalty of current customers from the pool of current customers as well as the ability to predict stock price and options price using the Markov chain analysis.

On the contrary, some studies have different opinions on the relevance of the Markov chain analysis as well as the found contradictory reports. For instance, Akhlaghi and Malkhalifeh (2019); Huang *et al.*, (2022) studied the predicting ability of the Spatio-temporary Markov model in Modelling and predicting inventory management in manufacturing processes in multistate steel production, where inventory variation and analysis of variants were considered in companies producing steel. The study observed that in the use of the Markov chain, the Spatio-temporal Markov model was better than the steel-adaptive mutation strategies as the former was found more stable Silbermayr and Minner (2014) and came up with the position Markov chain has a negative effect. The study further stated that though the Markov chain analysis is a useful tool in making predictions and forecasting events, however, that the Markov chain does not have the ability to provide explanations for some of its predictions. Consistent with the views of Silbermayr and Manner (2014), in a study, Ahiska *et al.*, (2013) found some flaws in the Markov chain, the study revealed that the Markov chain is not a good and useful tool in explaining reasons for the underlying situation in most predicted events.

Relevance of Markov Chain in Inventory Management

i. It simplifies inventory management processes
ii. It ensures out-of-sample forecasting accuracy
iii. It is a simple model for companies that have adopted and mastered the Markov chain
iv. It is a mathematical tool that aids the management in predictions more than other complicated mathematical models.
v. It has the advantage of speed and accuracy due to its analytical method which means that the dependability parameters for the system are calculated in effect by a formula.

Markov Chain Models: A spectrum of Markov chain models are available as reported in the literature.

i. The Markov process model or estimate Markov chain
ii. Queuing net model
iii. Generalize semi-Markov process
iv. Stochastic automata networks model
v. Timed-Petri net model
vi. Colour Petri models
vii. Stochastic Petri model
viii. Queueing Petri net
ix. Performance evaluation model
x. Process Algebra and Mini-Max Algebra

Challenges of the Markov Chain

i. Performance estimation problems through data analysis and behaviour of the data during the analysis, reliability of the analysis, sensitivity and issues of lead time analysis.
ii. Problem-solving designing challenges such as topical network designs, buffer allocations and workload allocations.
iii. The concern of optimization problems associated with replacement policies if the companies are incompatible with the existing Markov model, and quality optimization
iv. Production planning and control problems in relation to multistage and multi0allocations of inventory problems, capacity planning, control and monitoring strategies as well as quality control.
v. Production job sequencing and scheduling problems. The problem of routing mix challenges, fleet sizing and quality of maintenance schedule

Theoretical Framework.

The Markov Chain Theory: The Markov chain theory was developed by Russian University Mathematician Andrey Andeeryevich Markov in the year 1922 (Abellan-Nebot, Liu, Subiron and Shi (2012). The Markov chain theory is concerned with a mathematical system that experiences a transition from one step to another according to certain probability rules. The Markov chain theory stated that, given an arbitrary initial value, the chain will converge to the equilibrium point provided that the chain is run for a sufficiently long period of time (Abell'an and Liu (2013). Markov chain was named after Andrey Markov, who suggested a kind of model used for keeping track of systems that change according to given probabilities. With this theory, one can give predictions of future events based on the events. But not farther into the future, for instance, predictions of the stock market or weather (Akumu, 2014; Ambreen & Aftab, 2016). Markov chain has many applications as statistical models of real-world processes for example animal population dynamics, queues or lines of customers arriving at an airport and current exchange rates.

Markov chain theory is concerned with the process of a stochastic model describing a sequence of probable events in which the probability of each event depends only on the outcome of the previous event (Babai, Boylan, Syntetos & Ali, 2016). A Markov chain or Markov process is a stochastic model explaining a sequence of likely events in which the probability of each event relies only on the state achieved in the previous event. Informally, this may be thought of as 'What happens next is determined by the current state of affairs. Markov chain has many applications as statistical models of real-world processes for example animal population dynamics, queues or lines of customers arriving at an airport and current exchange rates. Markov chain also appears in many areas: Physics, Genetics, Mathematics, Finance, and of course Data Science and Machine Learning (Chaipradabgiat, Jin & Shi, 2009; Chatys, 2020).

Information Foraging Theory: The information Foraging theory was attributed to Peter Pirolli and Stuart Cardin in early 1990. The theory of information foraging is concerned with human behaviours as likened to the manner animals hunt for food in the same manner human beings seek new information and new ideas in solving immediate problems. According to Ching, Fung and Ng (2002), information foraging theory suggested that human beings are too inquisitive and ever searching for new things and this is because human beings use built-in foraging mechanisms that evolve to assist animals in search for food. Ahmed, Hasan, Hoque and Alam (2018) submitted that information foraging theory considers various information technologies and methods resulting from research to solve human needs and problems. The nexus between the Markov chain and inventory management can be associated with the desire of mathematicians to search for possible solutions to the problem related to inventory problems (Isik, Unal & Una, 2017). The information foraging theory seeks to relate the manner and how animals predict forage its environment searching for food as the same manner human being search for information and predict how this ending searching for knowledge led to explain the relevance of Markov chain analysis as a product of information in simplifying the predictive abilities of information to forecast future events like bad debts forecast and future stock price predictions.

Optimal Inventory Theory: The optimal inventory theory was developed by Harris in the year 1913 when it became necessary to put into perspective the practice of most of the needs of retailers needed to be predicted at the time, to avoid customer disappointment resulting from lack of products. Harris was concerned with the huge amount of money tied down in inventory, yet periodically, the customer demands would not be met, and at some period, the goods would get deteriorated because they are bought in excess without a good storage mechanism in mind (Qiu, Tan & Xu, 2017). The optimal inventory theory suggested that there is a need to seek an optimal inventory that will ensure the availability of products as well as not overstocking the goods to avoid wastage and loss to the management. According to Lang, Stulz and Walkling (1991) optimal inventory theory seek to ensure inventory management practice in place and a method that will assist in determining what the customers may likely need, the storage and replenishes on a regular basis that will not tie down capital as well as not running out of inventory, by estimating the amount that would be required to maintain an optimal inventory, the re-order period and quantity and storage management.

Empirical Review

Haung, Meng, Liu, Liu and Huang (2022) studied the predicting ability of the Spatio-temporary Markov model in Modelling and predicting inventory management in manufacturing processes in multistate steel production, where inventory variation and analysis of variants were considered in companies producing steel. The study reviewed various stages involved in the application of the Markov chain in solving inventory-related problems. The study observed that in the use of the Markov chain, the Spatio-temporal Markov model was better than the steel-adaptive mutation strategies as the former was found more stable. The study recommended that the Spatio-temporary be adopted by managers in manufacturing companies as it could assist managers since it could assist them in better production plans to maintain optimal inventory management

Papadopoulos, Li and Kelly (2018) investigated the problems in formulating an appropriate Markov chain in solving the problem in manufacturing companies. The study adopted an exploratory research approach, as it reviewed and classifies time models of manufacturing systems using the Markov chain. The study provided the benefits associated with the application of the Markov chain mathematical systems. The study concluded and stated that some challenges and limitations were encountered in course of the study review.

Silbermayr and Minner (2014) investigated the effect of the Markov chain on the inventory system with buyers facing Poisson demand. The study employed an exploratory research approach where information on the buyers who procured from a set of potential suppliers and who were not perfectly reliable. It was observed from the review that each supplier was seen to be actually available for a certain amount of time (on-time) and then breaks down for a certain amount of time during which it can supply nothing at all (off-time). The state of the system was defined as inventory level. The Markov chain model was applied and this had a positive effect in minimizing the buyers' long-run average cost and at the same time maximising cash flow optimization.

Ahiska, Appaji, Russell, King and Warsing (2013) investigated the effect of the application of the Markov chain in single product inventory management decisions. The study employed an exploratory research design reviewing a series of studies in the Markov chain analysis. The study consideration of the Markov chain adopted in various areas like orders to ensure a perfect and reliable supplier to avoid suppliers' disappointment and at a good price. The study observed from the review that there were changes in the cost of the order, either as a fixed cost or in unit cost, reordering costs as well as suppliers' reliability level improved.

METHODOLOGY

The study carried out a review of the Markov chain and inventory management of manufacturing companies in Nigeria. The study employed an exploratory researcher design, using relevant resources sourced from journals, periodicals and useful Markov and inventory-related materials were found to be useful to the study. In attempting the relevance of the Markov chain, the study observed that the Markov as one economic and engineering mathematical tool is useful in many stochastic processes like inventory management. From the theoretical perspective, the study underpinned the study using the Markov chain theory in support of the Markov chain and optimal inventory theory to reinforce inventory management.

CONCLUSION, RECOMMENDATIONS AND CONTRIBUTION TO KNOWLEDGE

Conclusions

The study took reviews of the Markov chain and inventory management of manufacturing companies in Nigeria. In addressing the study, exploratory research was adopted, using sourced materials from prior studies on the Markov chain, journals, and periodicals relevant to the Markov chain. In the review process, the study considered some previous studies, the application of the Markov chain as a mathematical stochastic process in solving sequential related problems in corporate organizations. While the Markov chain had been used in diverse ways in solving problems, our study concentrated on the events consequential to inventory management of manufacturing companies. Our approach and the contextual observation from our review showed the high uncertainty of the application of the Markov chain in any of the manufacturing companies in Nigeria. While the application and use of the Markov chain in the manufacturing companies in Nigeria remains unpredictable, the study observed that the Markov chain has the capability to estimate and evaluate the expected efficiency management and optimization of supply chain procedure and inventory management of manufacturing companies in Nigeria.

In our review, we observed that the Markov chain can be applied using a mathematical stochastic process to estimate the number of visits that can be made byproducts to lifecycle stages in the receiving of raw materials and supply of finished products, the anticipated quantity of products that visits a lifecycle stage, as well as products, mean durations of stay in a lifecycle stage. Our review in relation to the Markov chain and inventory management showed that the Markov chain could provide probabilities of absorption used in predicting the possible number of products that could be discarded and incinerated and the possible receivables that could likely result in bad debts in the near future.

Recommendations

The study recommended that considering the benefits and significance of the Markov chain as reviewed, managers of manufacturing companies should apply any of the Markov chain models in tackling inventory management and other supply chain issues in manufacturing companies. The study also recommended that managers in manufacturing companies should improve their inventory management and manufacturing operations by adopting quantitative and scientific aided decision-making modelling for their inventory management systems, such as linear programming, stochastic programming, mixed integer programming, genetic algorithms and the Markov chain decision-making processes.

Limitations and contribution to Knowledge

This study reviewed the nexus between the Markov chain and inventory management of manufacturing companies in Nigeria. The review provided insight and an integral understanding of the Markov chain as novel research and a contribution to the existing Markov chain studies in Nigeria. In the process, the study had some limitations, as the study adopted exploratory research design quantitative research using data sourced from the manufacturing companies in Nigeria as fewer manufacturing companies employ the Markov chain in their inventory management in Nigeria.

References

Abell´an, J. V., & Liu, J. (2013). Variation propagation modelling for multi-station machining processes with fixtures based on locating surfaces. *International Journal of Production Research, 51*(15), 4667–4681.

Abellan-Nebot, J. V., Liu, J., Subiron, F. R., & Shi, J. (2012). State space modeling of variation propagation in multistation machining processes considering machining-induced variations. *Journal of Manufacturing Science and Engineering, 134*(2),

Afrinaldi, F. (2020). Exploring product lifecycle using Markov chain. *Procedia Manufacturing, 43*, 391–398.

Ahmed, U.W., Hasan M., Hoque A. & Alam, M.J. (2018). Impact of free cash flow on profitability: An empirical study on pharmaceutical company. *Journal of Jessore University of Science and Technology, 3*(0), 2521-5493.

Akinleye, G.,Odunayo M. & Fajuyagbe, K. (2018). Free cash flow and firms' growth: An empirical investigation of Nigerian quoted non-financial firms. *Journal of Economics and Behavioral Studies. 10*(3), 258-267.

Akumu, O. (2014). Effect of free cash flow on profitability of firms listed on the Nairobi securities exchange.

Akhlaghi, R., & Malkhalifeh,R. M. (2019). A linear programming DEA model for selecting a single efficient unit. *International Journal of Industrial Engineering Operational Research, 1*(1), 1-21.

Ambreen, S., & Aftab, J. (2016). Impact of free cash flow on profitability of firms listed in Karachi Stock Exchange. *Euro-Asian Journal of Economics and Finance, 4*(4), 113–122

Ahiska, S. S., Appaji, S. R., Russell, E., King, B. N., & Warsing, D. (2013). Markov decision process-based policy characteristics approach for a stochastic inventory control problem with unreliable sourcing. *International Journal of Production Economics 14*(4), 485–496.

[Babai, M. Z., Boylan, J. E., Syntetos, A. A., & Ali, M. M. (2016). Reduction of the value of information sharing as demand becomes strongly auto-correlated. *Journal of Production Economics, 18(*1), 130–135.

Chaipradabgiat, T., Jin, J., & Shi, J. (2009). Optimal fixture locator adjustment strategies for multi-station assembly processes. *IIE Transactions, 41(*9), 843–852.

Chatys, R. (2020). Application of the Markov Chain theory in estimating the strength of fiber layered composite structures with regard to manufacturing aspects. *Advance Science. Technology Research Journal 14(4), 148–155*.

Ching, W. K., Fung, E. S., & Ng, M. K. (2002). A multivariate Markovv chain model for categorical data sequences and its applications in demand predictions. *IMA Journal of Management Mathematics, 13*(3), 187–199.

Costantino, F., Gravio, G. D., Shaban, A., & Tronci, M. (2015). SPC forecasting system to mitigate the bullwhip effect and inventory variance in supply chains. Expert Systems

Grossmann, I. E., Ye., I. E., Pinto, J. M., & Ramaswamy, S. (2020). Modeling for reliability optimization of system design and maintenance based on Markov chain theory, *Computer and Chemical Engineering, 124*(5), 381-404.

Huang, J., Meng, Y., Liu, F., Liu, C., & Huang, L. (2022). Modeling and predicting inventory variation for multistage steel production processes based on a new Spatio-temporal Markov model. *Computer Engineering, 164*(5), 1-21.

Isik, O., Unal, E.A. & Una, Y. (2017). The effect of firm size on profitability: evidence from Turkish manufacturing sector. *Journal of Business, Economics and Finance, 6*(4), 301-308

Kamran, M., Zhao, Z., & Ambreen, S. (2017). Free cash flow impact on firm's profitability : An empirical indication of firms listed in KSE , Pakistan. *European Online Journal of Natural and Social Sciences, 6*(1), 146–157

Karim, R., & Nakade, K., (2020). A Markovian production-inventory system with consideration of random quality disruption. *Journal Advance Mechanic System Manufacturing, 14*(5). 1–18,

Lang, L., Stulz, R. &Walkling, R. (1991). A test of the free cash flow hypothesis: The case of bidder returns. *Journal of Financial Economics, 29*(2), 315-335. [25]

Lotfi, R., Kargar, B., Hoseini, S. H., Nazari, S. Safavi, S., & Weber, G. W. (2021). Resilience and sustainable supply chain network design by considering renewable energy," *International Journal Energy Researcher, 45*(12), 17749–17766.

Myers, D. S., Wallin, L., & Wikström, P. (2017). An introduction to Markov chains and their applications within finance. *MVE220 Finance. Risk Read. Project, 45*(4), 1-21.

Nwuba, E. B., Omankhanlen, A. E., Chimezie,P. O., & Okoye, L. U. (2020). Financial control systems and financial systems theory: free cash flow and profitability nexus: a comparative study of manufacturing firms in Nigeria and Ghana. Wseas transactions on systems and control.

Papadopoulos, C. T., & Li, M., & Kelly, M. E. J. (2018). A classification and review of timed Markov models of manufacturing systems. *Computer Industrial Engineer, 128*(4), 219–244,

Qiu, X., Tan, K., & Xu, J. (2017). Multiple exponential recombinations for differential evolution. *IEEE Transactions on Cybernetics, 47*(4), 995–1006.

Rout, M., Majhi, B., Majhi, R., & Panda, G. (2014). Forecasting of currency exchange rates using an adaptive ARMA model with differential evolution based training. *Journal of King Saud University-Computer and Information Sciences, 26*(1), 7–18.

Shaban, A., & Shalaby, M. A. (2018). Modelling and optimizing of variance amplification in supply chain using response surface methodology. *Computers & Industrial Engineering, 12(1*0), 392–400.

Sharma, S. P., & Vishwakarma, Y. (2014). Application of Markov process in performance analysis of feeding system

Silbermayr, L. and Minner, S. (2014). A multiple sourcing inventory model under disruption risk. *International Journal of Production Economics*, *149*(0), 37-46.

Tang, L., & Meng, Y. (2021). Data analytics and optimization for smart industry. *Frontier of Engineering Management*, *8*(2), 157–171.

Tochukwu, C., & Hyacinth, I. (2015). Agent based markov chain for job shop scheduling and control: review of the modeling technigue. [Online]. Available: www.ijiset.coma

Wang, K., Li, G., Du, S., Xi, L., & Xia, T. (2021). State space modelling of variation of the sugar industry. *Journal of Industrial Mathematical. 1*–9,

Wang, L., He, J., Wu, D., & Zeng, Y. (2012). A novel differential evolution algorithm for joint replenishment problem under interdependence and its application. *International Journal of Production Economics, 135*(1), 190–198.

Vafadar, V., Tolouei-Rad, M., & Hayward, K. (2017). Evaluation of the effect of product demand uncertainty on manufacturing system selection. *Procedia Manufacturing, 11*(1), 1735–1743,

Xu, L., Hou, L., Zhu, Z., Li, Y., Liu, J., Lei, T., & Wu, X. (2021). Mid-term prediction of electrical energy consumption for crude oil pipelines using a hybrid algorithm of support vector machine and genetic algorithm. *Energy, 222*, 119955.

Yang, F., Jin, S., & Li, Z. (2017). A modification of DMVs based state-space model
of variation propagation for multistage machining processes. *Assembly Automation*, *37*(4), 381–390.

Yang, Y., Lin, J., Liu, G., & Zhou, L. (2021). The behavioural causes of bullwhip effect in supply chains: A systematic literature review. *International Journal of Production Economics,* 236, 108120

Yue, X., & Shi, J. (2018). Surrogate model-based optimal feed-forward control for dimensional variation reduction in composites parts' assembly processes. *Journal of Quality Technology, 50*(3), 279–289.

Yue, X., Wen, Y., Hunt, J. H., & Shi, J. (2018). Surrogate model-based control considering uncertainties for composite fuselage assembly. *Journal of Manufacturing Science and Engineering, 140*(4), Article 041017.

Zhang, F., & Butt, S. I. (2016). A systematic approach to quality oriented product sequencing for multistage manufacturing systems. *Mathematical Problems in Engineering, 20(*6), 1–9.

Zhang, L., & Wong, T. N. (2015). An object-coding genetic algorithm for integrated process planning and scheduling. *European Journal of Operational Research, 244*(2), 434–444.

Zhang, T., & Shi, J. (2016). Stream of variation modeling and analysis for compliant composite part assembly-Part I: Single-station processes. Journal of Manufacturing Science and Engineering, 138(12), Article 121003.

Zhou, S., Liu, M., Chen, H., & Li, X. (2016). An effective discrete differential evolution algorithm for scheduling uniform parallel batch processing machines with non-identical capacities and arbitrary job sizes. *International Journal of Production Economics, 17(9)*, 1–11.