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Assessment of operations research models and performance of small and medium scale enterprises in Nigeria

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Abstract

Purpose – This study examines how the adoption of operations research models (ORMs) affects the performance of small and medium enterprises (SMEs) in Lagos State. It explores the combined impact of various ORMs on both financial and non-financial performance in a dynamic economic environment.

Design/methodology/approach – Using a descriptive survey design, data were collected from 382 SME owners across 20 local government areas in Lagos through stratified random sampling. structural equation modeling analyzed the relationships between ORM adoption and SME performance.

Findings – SMEs in Lagos State show strong adoption of ORMs, significantly improving financial ($R^2 = 0.838$) and non-financial ($R^2 = 0.839$) performance. Decision theory, inventory and probabilistic programming yield the highest impact. Forecasting, linear and network models also contribute positively. ORM adoption enhances productivity, efficiency, customer satisfaction and strategic alignment. However, integer programming, queuing and goal programming show no significant effect.

Originality/value – This study integrates multiple ORMs within dynamic capability theory to provide empirical evidence of how SMEs can leverage operational capabilities to remain competitive and adaptable. The findings offer practical insights for policymakers, SME owners and support agencies to foster environments that encourage ORM adoption.

Keywords Operations research, Operations research models, Financial performance, Non-financial performance, SMEs, Inventory management, Network analysis

Paper type Research article

1. Introduction

Generally, it is unarguable that small and medium scale enterprises (SMEs) are key to economic growth, innovation and employment creation as they contribute towards economic development in both developing and developed societies. The latter is the foundation of industrialization and adds significant value to the national gross domestic product (GDP) and employment generation (Etuk *et al*., 2014; Zafar and Mustafa, 2017; NBS, 2019). It is estimated that SMEs contribute to about 48% of GDP, constitute 96% of the total number of registered businesses and create about 84% of jobs in Nigeria (NBS, 2019). Regardless of their importance, a large percentage of the Nigerian SMEs die after five years in business mainly because of the multidimensional inefficiencies in their operations, low access to finance, shortage of managerial skills and poor infrastructure (Adedipe, 2023). The level of failure measured at this high failure rate supports the necessity of practical, scientific interventions to improve the performance, resilience and sustainability of SMEs.

Operations research (OR) provides a powerful procedural and scientific model that is suitable for addressing complicated decisions and problems in operations. It uses a variety of quantitative and qualitative modeling instruments-linear programming, dynamic programming (DP), queuing theory, simulation, network models, forecasting, etc. to maximize resource applications, simplify the process of production planning, better manage

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the inventory and optimize the supply chain in organizations (Idolor, 2017; Rodríguez-Espíndola *et al*., 2022). The essence of the OR process refers to its five-step recursive phases of individual tasks that include identification of the problem, the formulation of a model, derivation of solutions, solution validation/testing and implementation of the best decisions. Using this structured methodology, operations research models (ORMs) model operational complexities in the real world into manageable systems that enable decision-making to enhance operational results in an informed, data-driven decision.

Worldwide, ORMs have returned immense improvements in terms of performance in SMEs in different sectors and locations. As another example, mixed-integer programming has resulted in significant benefits to production scheduling and order fulfillment in manufacturing SMEs (Perez-Rave and Jaramillo-Álvarez, 2011). Similarly, the emerging markets in Asia have seen the strong optimization approaches enhance the competence of SMEs to uncertainty and lack of resources in the markets (Asian Productivity Organization, 2015), and ORMs approach in the supply chain has enabled Indian SMEs to reduce costs and enhance relations with the stores (Chopra and Meindl, 2016). In Latin America, linear programming (LP) has proved useful in allocating resources optimally in low-income contexts (Medeiros *et al*., 2009) and, in the Middle East, ORMs have been used to make supply chains resilient, making it adapted and quick to respond to a volatile business environment (Alshahrani and Salam, 2022). Also, mixed integer programming (IP) that was implemented in Indonesia has yielded a 20% increase in production scheduling (Riskadayanti *et al*., 2020), reflecting the practical effects of OR strategies within the new developing markets.

Nevertheless, Nigerian SMEs are not capitalizing on the full potential of ORMs because of a few contextual factors, such as inadequate technology, skill shortages and limitations in the infrastructure (Adedipe, 2023). The current literature is more inclined to discuss single usage of ORMs, such as inventory management or supply chain optimization and fails to provide a combined framework that would describe the impact of using several ORMs in concert as a solution to the various and interconnected nature of issues Nigerian SMEs may have to face (Idolor, 2017). In addition, the existing body of findings does not usually pay attention to the specifics of the Nigerian socio-economic environment (cultural diversity, heterogeneity of economy, resource limitations).

Addressing these gaps, the present study introduces the operations research synergy framework (ORSF), grounded in dynamic capability theory (Teece *et al*., 1997) and the resource-based view (Barney, 1991). The ORSF assumes that the synergistic effect of simultaneous usage of various ORMs can develop a considerable increase in SME adoption ability, business performance and consistency. This framework utilizes the five-step OR process, which is the identification of a problem, model development, calculation of a solution, testing and implementation, to streamline key performance indicators (KPIs) such as profitability, cost-effectiveness and the quality of services Asian Productivity Organization (2015). The framework moves the SMEs to think in a holistic manner to tackle their complex problems, enhancing resource distribution, quality of decision making, service delivery and competitiveness of various industries and socioeconomic settings that are common in Nigeria.

In empirical terms, the research surveys 400 SMEs within the six states in Southwestern Nigeria: Lagos, Ogun, Oyo, Osun, Onsen and Ondo, making these states economic behemoths with various SME ecosystems. The study extensively tests the combined effect of ORMs on SME performance using partial least squares structural equation modeling (PLS-SEM). The selection of Lagos State, Nigeria (the economic center), was in response to its cosmopolitan status, high density of SMEs and exposure of its people to modern management practices, thus making it representational in the exploration of the study.

This study makes great contributions to the theory and practice by developing an integrated and multi-model approach. It brings the ORMs literature beyond ad hoc applications to a holistic, application specific to emerging economies and those with challenging operational conditions. The results will be used by policymakers and SME practitioners offering evidence-based approaches to address the high failure rates of Nigerian SMEs and make their sustainability and

competitiveness effective on the basis of the National Development Plan 2021–2025 of Nigeria to diversify the economy (Dataphyte, 2021). Finally, the research provides informative findings that can be adaptable to other developing scenarios facing the same SME problems, hence enhancing sustainable regional economic development as well as the globe at large.

2. Literature review

2.1 History of operations research

McClosky and Trefthen were the first to coin the term OR in a small town in the United Kingdom called Bowdsey in 1940. The term OR originated in a military context. Military authorities invited and grouped various scientists during Second World War to assist them in proffering solutions to strategic, logistics and tactical problems that stemmed from scarce resources. The authorities, through this adventure, wanted specific plans and proposals as well as implementation roadmaps that would ensure optimal utilization of scarce resources, which would eventually give them victory. The adventure paid off and was described as winning a war without going to war fronts. It was equally termed as research into military operations.

2.2 Conceptualizing operations research

OR is an interdisciplinary, data-based field created during the Second World War with the focus of assisting decision-making under complexity by modeling the situation through the application of qualitative and quantitative analyses (McClure and Miller, 1979; White, 1990). Practitioners describe OR as a well-organized, scientific practice that provides executives with unbiased, analytical grounds on which to solve operation-related issues within their reach (Akingbade, 1991; Idolor, 2017). Its main assumption is the abstraction of real-world problems into structured schemes (mathematical, statistical, or simulation) that are true to important system variables and constraints. OR empirically informs management by finding solutions to its problems, creating generalized models, inferring and testing optimal arrangements and transferring them to practice through iterations (Rodríguez-Espíndola *et al*., 2022).

2.3 Taxonomy of operations research models

The literature has distinguished a rich repertoire of twelve canonical ORMs (Ighomereho, 2006a, b; Idolor, 2012, 2017): inventory models (e.g. economic order quantity (EOQ), just-in-time (JIT), ABC analysis), LP, non-linear programming (NLP), IP, DP, goal programming (GP), queuing theory, network models (Program Evaluation and Review Technique (PERT) and critical path method (CPM)), probabilistic programming (PP), simulation, forecasting and decision theory (DT). Whereas the inventory models allow SMEs to maintain a balance between the stock, reduce the holding costs and enhance cash flow (Akinola and Odesola, 2018; Odesola and Akinola, 2018). Linear and non-linear programming are used to forecast the allocation and format of resources with linear and complex relations, respectively. IP supports discrete variables such as the size of each batch, whereas DP divides the multi-staged problems into separate sub problems. The method of GP is a generalization of linear methods to multiple-objective problems resolving trade-offs between cost, quality and delivery. Queuing (QU) theory and network models break down service flows and supply chains in order to minimize wait times and transportation expenses. PP systems ultimately treat uncertainty as modeling input, i.e. they incorporate variations in demand or supply shock in formal model formulation. The process of simulation is a copy of the real thing so that a kind of experimentation can be carried out in terms of the process of what-if scenarios without jeopardizing operations. Forecasting is the use of past data and statistical methods to predict demand and market trends. Lastly, DT includes prescriptive, rational decision-making with uncertainty. In combination, these ORMs offer SMEs a complete set of tools to organize production, regulate inventories, distribution channels and operate in the volatile environment (Akingbade, 1991; Idolor, 2017).

2.4 Defining and measuring SME performance

Performance includes the capacity of an enterprise to attain strategic goals on either financial or non-financial levels such as cost effectiveness, profitability, quality, delivery, innovation and stakeholder contentment (Khurram and Attaullah, 2011; Lebas, 1995; Odesola, 2025; Odesola *et al*., 2025). KPIs are measurable values, which are utilized to track the progress towards achievement of these goals within given durations. According to Garvin (1993), it is stated that what cannot be measured cannot be managed and this therefore demonstrates that strong systems of measurement are required. As of Kaplan and Norton (1992), balanced scorecard (BSC) can strategically be considered as an integrated framework that measures performance in four different ways: financial, customer, internal process and learning and growth, helps organizations align daily operations to strategic purposes. The BSC promotes organizational agility and sustainability by including non-financial performance (NFP) metrics, including customer satisfaction, capabilities in the process of efficiency and innovation capacity. Such holistic approaches are especially helpful to SMEs, since they offer a structured, but relatively flexible frameworks to monitor performance along a number of dimensions, as well as quickly respond to market changes.

2.5 Operations research models and performance

Empirical evidence confers the beneficial effect of ORMs on the performance of SME. Otokiti *et al*. (2022) presented a concept of a resilient business model framework based on the ORMs of the Nigerian SMEs. Riskadayanti *et al*. (2020) applied mixed IP in order to improve production scheduling in Indonesian SMEs. Rodríguez-Espíndola *et al*. (2022) used robust optimization to make decisions in an uncertain environment. Other studies (McClure and Miller, 1979; White, 1990) have also confirmed the positive influence of ORMs. In spite of the progress made, research gaps exist regarding ORM among the SMEs in Nigeria. The theoretical gaps are that cultural factors have not been well included in theoretical features. Empirical gaps entail a tight regional scope (Idolor, 2017) and incomplete ORM models of holistic approach. Policy gaps do not factor in ORMs in national plans. This paper fulfills them by suggesting the framework of the operations research synergy, which considers Southwestern Nigeria with possible multi-ORM in the SSA.

2.6 Strategic application of operations research models in SMEs

ORMs have traditionally been viewed as essential for decision-making and operational efficiency in large firms by providing quantitative frameworks for complex and uncertain environments. Historically, ORMs were considered too resource-intensive and complicated for small and medium-sized enterprises (SMEs), which often lack extensive data and technical skills. However, recent studies demonstrate growing efforts to customize ORMs for SMEs, recognizing their critical role in enhancing SME performance amid turbulent supply chains, rapid digitalization and increasing competition (Riesener *et al*., 2023). Adapting ORMs to the SME context involves addressing unique challenges, including limited financial and technical resources, smaller datasets and the need for agile, timely decision-making. For example, supply chain and inventory optimization techniques help SMEs reduce costs while meeting rising environmental standards (Govindan *et al*., 2017). Similarly, Baki (2022) developed a multi-criteria decision-making method that integrates quantitative data and qualitative factors to improve supplier selection within SMEs. ORMs also support resilience and agility in production and financial planning. Research by Dura *et al*. (2025) highlights how digital OR methods enhance manufacturing SME resilience to disruptions, while Wang *et al*. (2023) apply fuzzy multi-criteria models to assess financial risk under uncertainty. Additionally, the democratization of decision support systems enables SME managers without specialized skills to monitor performance and make informed decisions (Gar engo *et al*., 2005). Historically, adaptations of ORMs in SMEs, especially in Africa, address special management needs (Zongo, 2024; Tesfayohannes, 2012). Meta-analyses confirm significant improvements in

SME manufacturing, service and technology sectors worldwide (Ahmad and Qiu, 2009; Battistoni *et al*., 2013; Susanty *et al*., 2022). Advanced tools such as simulation and machine learning now drive operational efficiency and strategic decisions in European and Asian SMEs.

2.7 Theoretical justification

Dynamic capabilities theory (DCT), introduced by Teece *et al*. (1997), emphasizes a firm's ability to integrate, reconfigure and renew resources to adapt to changing market conditions. This framework is relevant in understanding how SMEs enhance performance through the adoption of ORMs. DCT offers insights into key SME operations. Sensing changes enables SMEs to leverage ORMs to identify shifts in market dynamics, technology, or regulations, helping them anticipate opportunities and challenges. Seizing opportunities through ORMs equips SMEs with analytical tools for informed decision-making and resource optimization, improving efficiency and competitiveness. Reconfiguring resources allows SMEs to realign capabilities, adapt to challenges and enhance processes–ensuring continuous renewal essential for long-term relevance. DCT also illustrates how these interconnected capabilities create a cycle of innovation and growth. Applying DCT, this study shows how ORMs foster adaptability, resilience and competitiveness in Nigeria's dynamic business landscape. This highlights the need for SMEs to cultivate agility and responsiveness, enhancing sustainability and positioning them for long-term success. DCT provides a robust theoretical lens to understand the strategic impact of ORM adoption on SME performance.

3. Hypotheses' development

This section establishes the hypotheses for the current study.

3.1 Operations research models and non-financial performance

The relationship between ORMs and performance is critically important for SMEs navigating complex, competitive environments. ORMs such as inventory management, simulation, forecasting and DT provide SMEs with sophisticated tools to streamline operations, optimize resource allocation and minimize costs (Ighomereho, 2006a, b; Idolor, 2017; White, 1990). By enabling data-driven decision-making and risk management, these models facilitate resilient growth and operational excellence, essentially marrying high-level analytics with entrepreneurial agility (Akingbade, 1991; McClure and Miller, 1979). While the foundational value of ORMs is well-established in the literature, contemporary performance measurement emphasizes a balanced view beyond pure financial metrics. The balanced scorecard framework (Kaplan and Norton, 1992) highlights that non-financial indicators such as customer satisfaction, operational efficiency, market share and innovation are essential precursors to long-term business success. However, the empirical evidence linking ORM adoption directly to these critical NFP dimensions remains underdeveloped, particularly within the unique context of Nigerian SMEs. Previous studies have focused largely on operational efficiencies or general performance, leaving a gap in understanding the holistic impact of ORMs on the factors that drive sustainable competitive advantage. This study seeks to fill this gap by proposing that:

H1. Application of ORMs has a positive and significant influence on the non-financial performance of small and medium-scale enterprises in Lagos state, Nigeria.

3.2 Operations research models and financial performance

ORMs are widely recognized as vital tools for enhancing the FP of firms. For SMEs, ORMs offer systematic, analytical methodologies for improving essential processes such as production scheduling, inventory control, supply chain management and workforce

planning (Idolor, 2012; McClure and Miller, 1979). By identifying inefficiencies, optimizing operations and enabling data-driven strategic decisions, ORMs help SMEs increase productivity, reduce costs and enhance their competitiveness in the marketplace, ultimately leading to improved financial sustainability (Akingbade, 1991; Ighomereho, 2013). FP, encompassing metrics like profitability, return on investment and sales growth, remains a primary indicator of business success (Kaplan and Norton, 1992). While the theoretical link between ORMs and financial outcomes is strong, there is a distinct lack of robust empirical evidence quantifying this relationship within the specific socio-economic environment of Nigeria. The challenging business landscape of Lagos State, characterized by infrastructure deficits and market volatility, presents a unique context in which to test the efficacy of ORMs. This study aims to provide this needed empirical validation, hypothesizing that the application of ORMs directly translates to superior financial results for SMEs in this setting.

H2. Application of ORMs has a positive and significant effect on the financial performance of small and medium-scale enterprises in Lagos state, Nigeria.

4. Methodology

4.1 Small and medium-scale enterprises

Because of their firm-level and individual-level characteristics, SMEs were chosen to attain the objectives and test the hypotheses designed for this study. SMEs are performing and have continued to perform a significant role in developing economies of both developed and developing nations as they contribute to creating jobs, economic growth and innovative ideas, products, services, or techniques (NBS, 2019). From the World Bank (2020) report, SMEs account for close to 90% of all world businesses and well over 50% of all world employment. In terms of GDP, formal SMEs account for up to 40% of GDP in emerging or developing economies.

4.2 Research design

This study used a quantitative research design via survey methodology. This design helps to test hypotheses and examine the relationships between religiosity dimensions and innovation among SMEs in Southwest Nigeria. SEM was used for data analysis to assess the structural relationships between the measured variables and latent constructs. According to Creswell (2014), a quantitative research design is suitable for studies that use statistical methods to establish patterns and relationships among variables.

4.3 Study area

The study was conducted in Lagos State, Nigeria. Lagos state has been adjudged to be one of the fastest-growing cities in the world (Agency Report, 2021). The State was also regarded as the commercial base of Nigeria. The population of Lagos state, as predicted by the National Bureau of Statistics in its Demographic Statistics Bulletin (2020), was 12,772,884. The State has a lot of natural resources that include oil, gold, bitumen and natural gas reserves.

4.4 Population and sampling

The population for the study consisted of SMEs in Lagos State in Southwestern Nigeria. According to the National Bureau of Statistics (NBS, 2019), the number of SMEs in the State is 8,395, as reported in the 2019 survey. Slovin's formula was used to determine the sample size for the study, with the aid of

$$n = \frac{N}{(1+Ne^2)}$$

where N is the population of the study, e is the error margin and *n* is the sample size. For this study, the value of N is 8,395, while the commonly used confidence level of 95% (0.05) is employed. Therefore, the sample size for this research study is calculated as follows

8,395/1+ (8,395) (0.05)2 = 381.80 = 382 small and medium scale enterprises. A random sampling technique was used to select 382 enterprises. In contrast, the stratified sampling proportional to size technique was used to administer copies of a structured questionnaire to the enterprises across the 20 Local Government Areas (LGA) in the State.

4.5 Data collection instrument

This study utilized the research instrument on the basis of previous empirical studies by Idolor (2017), McClure and Miller (1979) and White (1990). The information was gathered using a structured questionnaire based on five sections: Section A contained the respondents socio-demographic data; Section B dealt with the different types of ORMs, Section C handled the constructs pertaining to overall business performance, Section D concerned FP issues affecting the SMEs with the Lagos state of Nigeria and Section E covered the problems facing the adoption of ORMs by these SMEs. The expert review was conducted, which served as the way to maintain content validity, according to the recommendation by DeVellis (2016) on scale development. The assessment of reliability through Cronbach's alpha was carried out prior to data collection by checking the consistency of the construct. The reliability scores of all constructs satisfied the reliability above 0.70. Analysis was done using SEM, which is used to investigate the connections between the variables in the study rigorously.

4.6 Procedure

The survey consisted of a validated questionnaire that was applied to the SMEs that were randomly selected in all the LGA in the Lagos State, southwestern Nigeria. Stratified random sampling was employed with LGAs chosen as the strata designed to increase the representativeness of the samples. The questions contained in the questionnaires focused on constructs that are critical in determining employee well-being, including retention and performance, which were operationalized into twelve ORMs that were linked to SME performance measures. Scales, especially multi-item scales that were adapted from previous literature (e.g. Gerhardt *et al*., 2019), were able to warrant content validity. Items were rated using a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). Face to face administering of the questionnaires by our trained research assistants based in each of the LGA was done to maximize their response rates and quality of data received. Before the central survey, reliability was tested during pilot testing (Cronbach's alpha >0.70) as well as testing internal consistency. The items that used Likert-scale were combined to form composite scores concerning the construct by averaging the item responses. Such composite scores were used as observed variables in SEM analyses to check the hypothesized relationships. This is a systematic way of measuring and collecting data, which lends value to the rigorousness, validity and reliability of the study.

4.7 Data analysis

SEM was employed for data analysis. SEM is a comprehensive statistical technique to assess structural relationships between measured variables and latent constructs. According to Kline (2009), SEM is appropriate for complex models and hypothesis testing regarding relationships among multiple variables.

4.8 Justification for the choice of analytical technique

The current research adopts PLS-SEM applied through SmartPLS 4, which is appropriate in prediction-based studies to determine the noteworthy drivers of SME performance and test the effectiveness of ORMs. The orientation towards the maximized explained variance (R') by

PLS-SEM improves the validity and accuracy of causal inferences and predictions (Hair *et al*., 2019). It is perfect due to its capacity in managing complex models consisting of more than one latent construct and indicators, and it does not have difficulties with identification of the models, as can be found in covariance-based SEM. Also, the non-parametric feature of PLS-SEM can deal with Likert-scale survey response data, which enhances the reliability of analysis.

4.9 Constructs measurement

Multi-item scales adapted and based on valid research studies measured constructs, and they were operationalized along a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The constructs entail: Adoption of ORMs: As a reflective construct with items copied and modified based on Alshahrani and Salam (2022), Medeiros *et al*. (2009) and Asian Productivity Organization (2015). SME Performance: It is a multidimensional construct and includes both financial (profitability, sales growth and return on investment) and non-financial (operational efficiency, product/services quality and customer satisfaction) dimensions with scale items being drawn from Kaplan and Norton (1992) and Odesola (2025).

5. Data presentation and analysis

5.1 Analysis of objective one: the prominent ORMs being adopted by SMEs' owners in Lagos state, Nigeria

The highest rates of adoption of ORMs by SMEs in Lagos State, Nigeria are always above 96% and 97.2% with LP having the highest adoption rate at 97.2%. Activation rates also register high with the DP, having recorded the highest rate of 95.1%. The awareness and interest levels, however, remain low, with the interest raising between the figures of 47.9% and 51.7%, as well as the awareness shifting between 29.4% and 32.6%. The trend (shown in Table 1) indicates that a good number of SMEs are still ignorant of knowing in detail these analytical tools, hence inhibiting wider uptake. LP is a tool that is being used across various levels at all times and it is quite critical to the operating strategy of SMEs. Based on the findings, it is noticeable that SMEs exhibit a high level of receptiveness to ORMs after their adoption, but the upstream components may need a restructuring approach to enhance the overall penetration rates and efficient utilization rates, which implies the necessity of policy-making efforts and educational campaigns to raise awareness and interest rates.

5.2 Measurement quality assessment

The measurement quality assessment focuses on the reliability and validity of constructs with the help of the reliability analysis, convergent validity, discriminant validity and model fit levels. The value of composite reliability (CR) and Cronbach's alpha coefficient (shown in Table 2) confirm the satisfactory reliability of the constructs and their internal consistency, where the value of the CR varies between 0.837 and 0.921, and the value of Cronbach's alpha is above 0.70. Nevertheless, most constructs have low average variance extracted (AVE) values, which are just below the recommended standard of 0.50, with a few constructs such as forecasting, queuing and NFP. There are also differences in indicator loadings, with some constructs, more especially in adoption loading, it is less than 0.70 across the constructs, which signifies that there is potential place for refinement as a way forward to enhance convergent validity.

One possible explanation for the low loadings (<0.5) of adoption (Table 2) for LP and DT is contextual variability in Nigerian SMEs. Specifically, firms may express interest in adopting these OR techniques without fully integrating them into their decision-making processes due to resource constraints or other organizational limitations, resulting in weak empirical associations.

Table 1. Distribution of ORMs adoption among SMEs' owners in Lagos state, Nigeria

Operational research models		Scores	Percentage (%)
Inventory	Adoption	1,708	96.5
	Activation	1,662	93.9
	Trial	1,517	85.7
	Evaluation	1,231	69.5
	Interest	869	49.1
	Awareness	529	29.9
Linear programming	Adoption	1,720	97.2
	Activation	1,672	94.5
	Trial	1,548	87.5
	Evaluation	1,308	73.9
	Interest	911	51.5
	Awareness	544	30.7
Queuing	Adoption	1,710	96.6
	Activation	1,654	93.4
	Trial	1,526	86.2
	Evaluation	1,247	70.5
	Interest	870	49.2
	Awareness	538	30.4
Network	Adoption	1,717	97.0
	Activation	1,666	94.1
	Trial	1,505	85.0
	Evaluation	1,232	69.6
	Interest	848	47.9
	Awareness	549	31.0
Decision theory	Adoption	1,714	96.8
	Activation	1,674	94.6
	Trial	1,531	86.5
	Evaluation	1,234	69.7
	Interest	889	50.2
	Awareness	535	30.2
Dynamic programming	Adoption	1,705	96.3
	Activation	1,683	95.1
	Trial	1,554	87.8
	Evaluation	1,285	72.6
	Interest	915	51.7
	Awareness	577	32.6
Probabilistic programming	Adoption	1,712	96.7
	Activation	1,664	94.0
	Trial	1,529	86.4
	Evaluation	1,233	69.7
	Interest	871	49.2
	Awareness	549	31.0
Simulation	Adoption	1,713	96.8
	Activation	1,678	94.8
	Trial	1,529	86.4
	Evaluation	1,248	70.5
	Interest	860	48.6
	Awareness	533	30.1
Forecasting	Adoption	1,710	96.6
	Activation	1,662	93.9
	Trial	1,513	85.5
	Evaluation	1,233	69.7
	Interest	857	48.4
	Awareness	554	31.3

(*continued*)

Table 1. Continued

Operational research models		Scores	Percentage (%)
Non-linear programming	Adoption	1,710	96.6
	Activation	1,669	94.3
	Trial	1,533	86.6
	Evaluation	1,263	71.4
	Interest	894	50.5
	Awareness	546	30.8
Goal programming	Adoption	1,705	96.3
	Activation	1,670	94.4
	Trial	1,512	85.4
	Evaluation	1,247	70.5
	Interest	862	48.7
	Awareness	520	29.4
Integer programming	Adoption	1,711	96.7
	Activation	1,678	94.8
	Trial	1,522	86.0
	Evaluation	1,255	70.9
	Interest	891	50.3
	Awareness	547	30.9

Source(s): SPSS output

5.3 Discriminant validity (HTMT criterion)

Discriminant validity was assessed using the HTMT, with a conservative threshold of 0.85, as recommended by Henseler *et al.* (2015). Values below this threshold indicate adequate discriminant validity between constructions. The HTMT analysis (see Table 4) shows that several inter-construct relationships remain within acceptable limits. For example, the HTMT values between DP and GP (0.804) and between dynamic programming and network (0.833) are below the 0.85 threshold. However, some values are marginally close to or slightly above this threshold, such as dynamic programming and forecasting (0.853), inventory and goal programming (0.883) and queuing and goal programming (0.887). Although these higher values suggest conceptual proximity between some constructs, the HTMT values still conform to the discriminant validity assessment criteria within acceptable tolerance levels (Table 3).

5.4 Model fit indices

Model fit was evaluated using the standardized root mean square residual (SRMR), d_ULS, d_G, Chi-square and Normed Fit Index (NFI), as recommended by Henseler *et al.* (2016). The SRMR is considered acceptable if below 0.08, and NFI values closer to 1 indicate a better fit.

The SRMR value reported is 0.132 for both the saturated and estimated models, which exceeds the commonly accepted threshold, indicating a less-than-ideal model fit (Table 5). The d_ULS values are 70.189 (saturated model) and 70.202 (estimated model), while the d_G values are 15.625 and 15.628, respectively. The Chi-square statistics are also substantial, with values of 20,804.874 (saturated model) and 20,810.968 (estimated model). The NFI value is 0.395, which is below the conventional cut-off for a good model fit. Although these indices indicate room for improvement in model specification, they are reported here for completeness and transparency (Table 4).

5.5 The association between application of ORMs and the financial performance of SMEs in Lagos State, Nigeria

The analysis of the relationship between ORMs and FP of SMEs in Lagos State revealed several statistically significant associations. DP ($\beta = 0.109$, $t = 3.328$, $p = 0.001$), DT

Table 2. Reliability and convergent validity results of constructs (loadings, Cronbach's alpha, CR and AVE)

Constructs	Indicators	Loadings	Cronbach's alpha	CR	AVE
Dynamic programming	Activation	0.622	0.789	0.849	0.491
	Adoption	0.508			
	Awareness	0.608			
	Evaluation	0.842			
	Interest	0.792			
	Trial	0.77			
Decision theory	Activation	0.587	0.771	0.837	0.478
	Adoption	0.358			
	Awareness	0.594			
	Evaluation	0.874			
	Interest	0.815			
	Trial	0.783			
Forecasting	Activation	0.64	0.793	0.854	0.501
	Adoption	0.498			
	Awareness	0.600			
	Evaluation	0.85			
	Interest	0.785			
	Trial	0.804			
Financial performance	FP1	0.677	0.787	0.846	0.441
	FP2	0.618			
	FP3	0.693			
	FP4	0.61			
	FP5	0.605			
	FP6	0.709			
	FP7	0.723			
Goal programming	Activation	0.652	0.79	0.851	0.497
	Adoption	0.493			
	Awareness	0.572			
	Evaluation	0.848			
	Interest	0.783			
	Trial	0.809			
Integer programming	Activation	0.616	0.783	0.847	0.49
	Adoption	0.448			
	Awareness	0.592			
	Evaluation	0.861			
	Interest	0.793			
	Trial	0.798			
Inventory	Activation	0.64	0.792	0.852	0.500
	Adoption	0.479			
	Awareness	0.581			
	Evaluation	0.86			
	Interest	0.795			
	Trial	0.807			
Linear programming	Activation	0.639	0.766	0.838	0.479
	Adoption	0.343			
	Awareness	0.583			
	Evaluation	0.857			
	Interest	0.798			
	Trial	0.800			

(*continued*)

Table 2. Continued

Constructs	Indicators	Loadings	Cronbach's alpha	CR	AVE
Non-financial programming	NFP1	0.707	0.905	0.921	0.539
	NFP2	0.694			
	NFP3	0.724			
	NFP4	0.762			
	NFP5	0.772			
	NFP6	0.73			
	NFP7	0.777			
	NFP8	0.71			
	NFP9	0.737			
	NFP10	0.721			
Non-linear programming	Activation	0.641	0.787	0.849	0.494
	Adoption	0.461			
	Awareness	0.586			
	Evaluation	0.856			
	Interest	0.789			
	Trial	0.802			
Network	Activation	0.605	0.769	0.84	0.481
	Adoption	0.36			
	Awareness	0.61			
	Evaluation	0.857			
	Interest	0.798			
	Trial	0.807			
Probabilistic programming	Activation	0.65	0.781	0.846	0.489
	Adoption	0.419			
	Awareness	0.597			
	Evaluation	0.854			
	Interest	0.792			
	Trial	0.792			
Queuing	Activation	0.691	0.792	0.853	0.502
	Adoption	0.454			
	Awareness	0.575			
	Evaluation	0.854			
	Interest	0.775			
	Trial	0.815			
Simulation	Activation	0.616	0.77	0.839	0.478
	Adoption	0.416			
	Awareness	0.574			
	Evaluation	0.855			
	Interest	0.792			
	Trial	0.793			

Source(s): SmartPLS output

($\beta = 0.149$, $t = 4.580$, $p < 0.001$), forecasting ($\beta = 0.068$, $t = 2.206$, $p = 0.027$), GP ($\beta = 0.103$, $t = 3.285$, $p = 0.001$), inventory ($\beta = 0.127$, $t = 4.307$, $p < 0.001$), LP ($\beta = 0.082$, $t = 2.714$, $p = 0.007$), network models ($\beta = 0.087$, $t = 2.520$, $p = 0.012$), PP ($\beta = 0.126$, $t = 3.514$, $p < 0.001$) and simulation ($\beta = 0.100$, $t = 3.026$, $p = 0.002$) all demonstrate significant positive relationships with FP (see Table 5 and Figure 1). Conversely, IP, NLP and queuing did not yield significant path coefficients. The model's explanatory power is strong, with an R-square value of 0.838 and an adjusted R-square of 0.832, indicating that approximately 83.8% of the variance in FP can be explained by the application of ORMs. However, the model fit indices suggest a suboptimal fit, with SRMR at 0.146 and NFI of 0.387.

Table 3. Discriminant validity assessment using HTMT criterion

	DP	DT	FC	FP	GP	IP	IV	LP	NFP	NLP	NW	PP	QU	SM
DP														
DT	0.806													
FC	0.853	0.883												
FP	0.888	0.885	0.882											
GP	0.804	0.863	0.821	0.868										
IP	0.836	0.885	0.848	0.876	0.835									
IV	0.888	0.830	0.801	0.821	0.883	0.853								
LP	0.813	0.858	0.848	0.878	0.817	0.800	0.821							
NFP	0.812	0.803	0.831	0.728	0.852	0.887	0.836	0.822						
NLP	0.886	0.836	0.853	0.848	0.873	0.832	0.827	0.838	0.813					
NW	0.833	0.885	0.848	0.886	0.857	0.830	0.824	0.850	0.831	0.824				
PP	0.883	0.832	0.858	0.886	0.880	0.856	0.830	0.830	0.820	0.812	0.885			
QU	0.846	0.824	0.838	0.875	0.887	0.834	0.858	0.828	0.822	0.848	0.858	0.823		
SM	0.846	0.804	0.842	0.880	0.872	0.882	0.806	0.826	0.803	0.834	0.860	0.887	0.814	

Source(s): SMART PLS output

Table 4. Model fit indices for the measurement model (SRMR, d_ULS, d_G, Chi-Square, NFI)

	Saturated model	Estimated model
SRMR	0.132	0.132
d_ULS (RSMEA)	70.189	70.202
d_G (Goodness-of-Fi	15.625	15.628
Chi-square	20804.874	20810.968
NFI	0.395	0.395

Source(s): SmartPLS output

Table 5. PLS-SEM analysis output

Paths	Path coefficients	standard deviation (STDEV)	*t*-statistics	*p*-values	Decision
DP → FP	0.109	0.033	3.328	0.001**	Significant
DT → FP	0.149	0.032	4.580	0.000**	Significant
FC → FP	0.068	0.031	2.206	0.027*	Significant
GP → FP	0.103	0.031	3.285	0.001**	Significant
IP → FP	0.019	0.030	0.641	0.521	Not significant
IV → FP	0.127	0.029	4.307	0.000**	Significant
LP → FP	0.082	0.030	2.714	0.007**	Significant
NLP → FP	0.037	0.031	1.190	0.234	Not significant
NW → FP	0.087	0.034	2.520	0.012*	Significant
PP → FP	0.126	0.036	3.514	0.000**	Significant
QU → FP	0.052	0.033	1.580	0.114	Not significant
SM → FP	0.100	0.033	3.026	0.002**	Significant
R-square	0.838				
R-square adjusted	0.832				
SRMR	0.146				
d_ULS	67.064				
d_G	13.378				
Chi-square	18180.464				
NFI	0.387				

Note(s): ** sig. at 1%; * sig. at 5%; DP = dynamic programming; DT = decision theory; FC = forecasting; FP = financial performance; GP = goal programming; IP = integer programming; IV = inventory; LP = linear programming; NLP = Non-linear programming; NW = network; PP = probabilistic programming; QU = queuing; and SM = simulation

Source(s): SmartPLS output

5.6 Investigate the association between the application of ORMs and the non-financial performance of SMEs in Lagos state, Nigeria

The correlation among ORMs and NFP of SMEs in Lagos State indicates that there are numerous relationships that have been proved to be statistically significant (see Table 6 and Figure 2). The DT (0.140, $t = 3.009$, $p = 0.003$), the Forecasting (0.124, $t = 2.785$, $p = 0.005$), the Inventory (0.164, $t = 3.357$, $p = 0.001$), the LP (0.099, $t = 2.573$, $p = 0.010$), the NLP (0.1 On the other hand, the statistically significant relations are not shown in DP, GP, IP, queuing and simulation. The explanatory power of the model is quite high and its *R*-square value includes 0.839, whereas the adjusted R-square value includes 0.833, which represents 83.9% of the NFP variance is explained by the ORM applications. Nevertheless, the fit model indicates that the model does not fit perfectly with SRMR of 0.142 and NFI of 0.390.

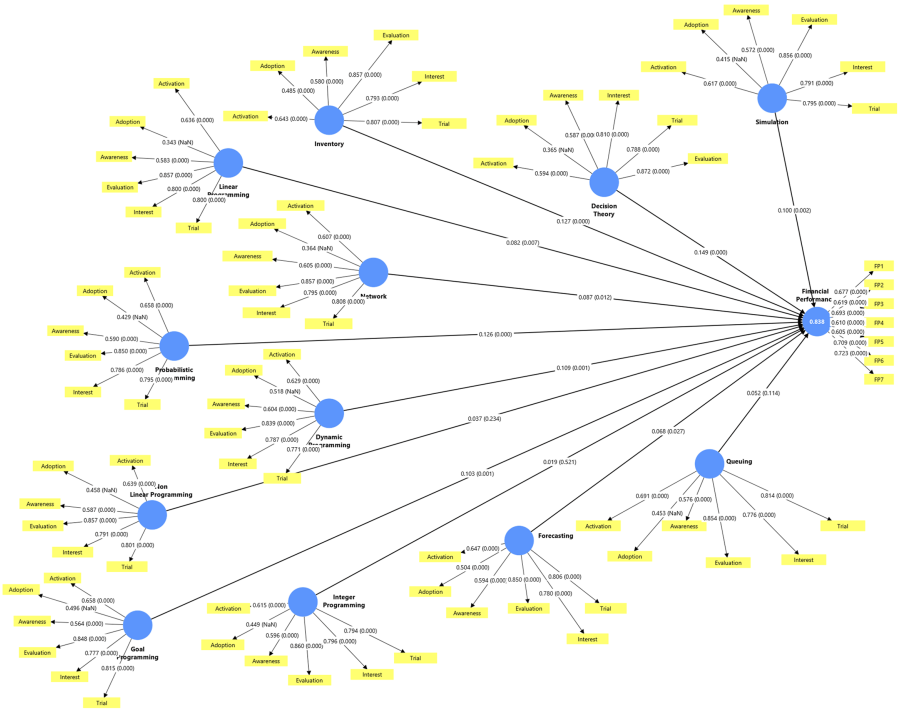

Figure 1. Path analysis coefficient between the ORM application and FP. Source: Smart PLS output

6. Discussion of findings

The results of studying the impact of the various ORMs on the financial and NFP of SMEs in Lagos State (the economic hub of Nigeria) hold vital lessons for businesses that perform in a volatile and rapidly-changing environment (Agency Report, 2021).

6.1 Financial performance

The majority of the ORMs are closely linked to positive FP, highlighting their usefulness to SME in terms of profitability and effectiveness. The strongest influence (2019a) with the highest value of the coefficient (2019a) is DT: The latter sustains the importance of structure in dynamic capability theory to make decisions based on uncertainty (Teece *et al*., 1997). Semi-dynamic programming (DP), inventory (IV), GP, PP, LP, network models (NW), simulation (SM) and forecasting (FC) are the other methods that have significant benefits to increasing revenue, cash flow and profit margins as well as optimizing allocation of resources, risk management and operational planning (Garvin, 1993; Kaplan and Norton, 1992). FP has the model explaining the variance of 83.8 s ($R^2 = 0.838$), which means that ORMs have strategic significance in terms of managing SME (Lebas, 1995; Khurram and Attaullah, 2011). Meanwhile, IP, NLP and queuing (QU) have no notable influence, and probably, those practices are not within the data capability or the sizes of operation of many SMEs (Idolor and Okolie, 2015).

6.2 Non-financial performance

Switching to non-financial criteria, the study observes that all the companies, DT, IV, FC, LP, NLP, NW and PP, achieve great successes in the sphere of customer satisfaction, efficiency of

Table 6. PLS-SEM analysis output

Paths	Path coefficients	STDEV	*t*-statistics	*p*-values	Decision
DP → FP	0.111	0.063	1.759	0.079	Not significant
DT → FP	0.140	0.047	3.009	0.003*	Significant
FC → FP	0.124	0.044	2.785	0.005*	Significant
GP → FP	−0.030	0.039	0.773	0.440	Not significant
IP → FP	−0.033	0.044	0.745	0.456	Not significant
IV → FP	0.164	0.049	3.357	0.001*	Significant
LP → FP	0.099	0.039	2.573	0.010*	Significant
NLP → FP	0.111	0.038	2.897	0.004**	Significant
NW → FP	0.112	0.044	2.535	0.011**	Significant
PP → FP	0.132	0.047	2.814	0.005***	Significant
QU → FP	0.066	0.047	1.428	0.153	Not significant
SM → FP	0.056	0.046	1.207	0.228	Not significant
R-square	0.839				
R-square adjusted	0.833				
SRMR	0.142				
d_ULS	68.738				
d_G	14.682				
Chi-square	19646.015				
NFI	0.390				

Note(s): *** sig. a 0.1%; ** sig. at 1%; * sig. at 5%; DP = dynamic programming; DT = decision theory; FC = forecasting; GP = goal programming; IP = integer programming; IV = inventory; LP = linear programming; NFP = non-financial performance; NLP = non-linear programming; NW = network; PP = probabilistic programming; QU = queuing; and SM = simulation

Source(s): Smart PLS output

operations, innovation and social responsibility. This is also what BSC anticipates such indicators to be tied up with a long-term sustainability and the ability to win a competitive advantage (Kaplan and Norton, 1992). The lack of substantive effects of DP, GP, IP, QU and SM indicates that not all ORMs are apparently sea-worthy operationally robust, but will always need an added organizational capacity-culture, leadership commitment and change management in order to transform into the benefit of the customer (Kline, 2009; Teece, 2001). The non-financial model gives 83.9% of the variance-83.9% performance variance demonstrates that ORMs have a holistic impact on the success of SME (Lebas, 1995; Khurram and Attaullah, 2011).

6.3 Applicability and generalizability of findings

The findings from this study on Nigerian SMEs hold significant implications for broader applicability, though generalizability is contingent on contextual factors. The core principles of ORM optimization, modeling and data-driven decision-making are inherently transferable across sectors (Akingbade, 1991; Ighomereho, 2006a, b). The efficacy of inventory models, LP for resource allocation and network models for project management suggests that the benefits observed in the Nigerian context could extend to agriculture, construction and services in other regions, provided the models are adapted to sector-specific constraints and objectives. Geographically, the results are particularly relevant for other developing and emerging economies that share characteristics with Nigeria, such as resource constraints and economic volatility. The demonstrated success of ORMs in this complex environment suggests they could be effectively applied in other African nations (Tesfayohannes, 2012; Zongo, 2024), as well as in larger emerging economies like India or Brazil, where studies have also noted the positive impact of operational improvements on

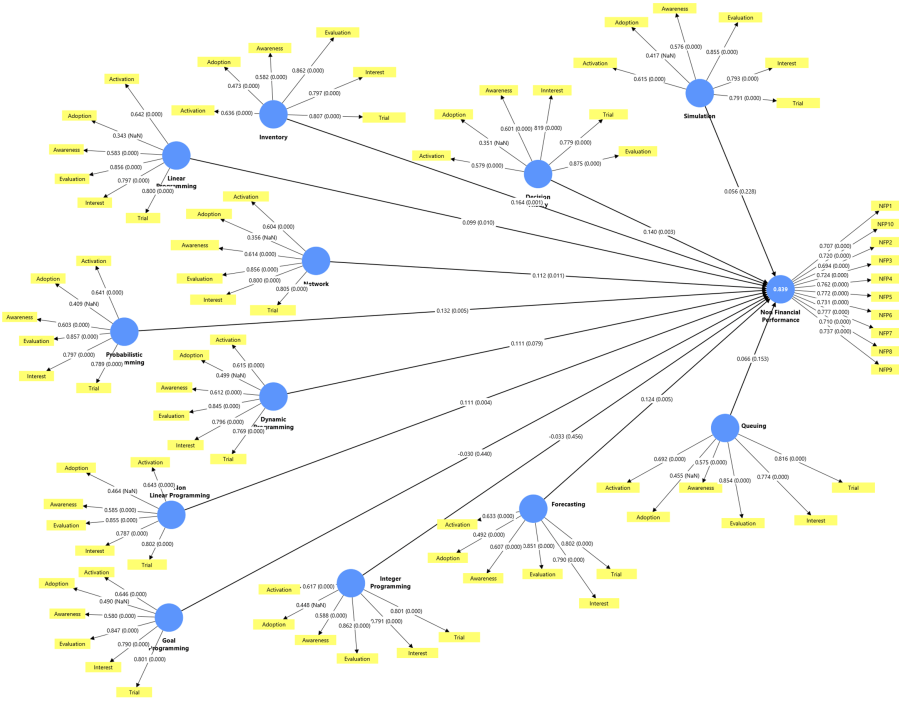

Figure 2. Path analysis coefficient between the ORM application and NFP. Source: Smart PLS output

SME performance (Ahmad and Qiu, 2009; Susanty *et al.*, 2022). The level of digital maturity is a key moderating factor; in contexts with more advanced infrastructure, the impact of ORMs could be even greater. Therefore, while the magnitude of the effects may vary, the fundamental positive relationship between ORM adoption and SME performance is a transferable principle, offering a valuable blueprint for fostering resilience and growth in diverse developing economies.

6.4 The convergence of operations research and artificial intelligence

The future of operational decision-making lies in the powerful convergence of traditional OR and modern AI, a synergy that represents a natural evolution in business analytics (Petropoulos *et al.*, 2023). OR provides the structured framework for defining and solving optimization problems, while AI and machine learning excel at identifying complex, non-linear patterns and generating predictions from large datasets. This creates a symbiotic relationship where AI enhances OR by providing superior, data-driven forecasts and insights and OR provides the rigorous methodology to embed those insights into actionable, optimal decisions. For SMEs, this convergence is increasingly accessible. An SME might now use an inventory system where a machine learning algorithm predicts demand, which is then fed into an OR model to calculate the optimal order quantity, or a logistics platform that uses real-time AI-processed data to dynamically solve vehicle routing problems (Rodríguez-Espíndola *et al.*, 2022). Thus, the journey of OR adoption documented in this study represents a critical first step toward a future where AI-powered OR models become a standard tool for SMEs, transforming data from a simple record of past performance into the most critical asset for predictive planning and achieving sustainable competitive advantage.

7. Theoretical implications, practical implications

The results of the study confirm the primary theoretical frameworks such as the resource-based theory and dynamic capabilities, that focus on the significance of the acquisition and the use of capabilities such as the ORMs aimed at creating competitive advantage and flexibility within a volatile market such as Lagos. Research also contributes to the literature of performance measurement by indicating the importance of having a well-balanced scorecard approach in measuring both financial and non-financial measures in determining the effectiveness of the organization. Managers of SMEs should apply a few chosen ORMs, including DT, Inventory control and Forecasting, in order to achieve the optimal financial results with minimal service drops. Moreover, capacity-building activities and specific training may enable SMEs to avoid typical hazards, namely the shortage of resources and rapid market changes. Development agencies and policymakers must assist in the diffusion of ORMs by offering support in technical assistance, affordable software packages and education courses, furthering resilience and valued participation of SMEs in the development of the economy amidst infrastructural and institutional hindrances.

8. Limitations and future studies

There are a number of limitations that make this study offer opportunities for future research. The cross-sectional design limits the possibility of causal inference, and longitudinal studies should be advocated to prove causality. Also, the method based on single respondents per SME can create common method bias and the approach based on perceptual identification of the performance may bring subjectivity, indicating the necessity to triangulate with the objective data. Additionally, the geographic and contextual specificity of the study precludes its application in other environments, indicating that upcoming studies should concentrate on replicating and generalizing the same results in other environments.

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