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Dual Sourcing for Critical Energy Equipment under Exchange-Rate and Fuel-Price Volatility

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Abstract
This paper develops a risk-based procurement decision model for utilities and independent power producers in import-dependent economies facing currency depreciation, fuel-price volatility, shipping disruptions, and uncertain supplier lead times. It links five risk drivers—exchange-rate volatility, fuel-price volatility, foreign lead-time uncertainty, shipment disruption, and domestic capacity uncertainty—to supplier allocation and four outcomes: expected cost, tail cost, service level, and supplier concentration. A single-period stochastic program combines expected cost and Conditional Value-at-Risk (CVaR), models correlated exchange-rate and fuel-price shocks, accounts for freight costs and replacement demand, and excludes foreign units arriving after the nine-month planning horizon. The model is solved using sample average approximation with 20,000 Monte Carlo scenarios calibrated to 2021 conditions, followed by sensitivity analysis.
The base-case results indicate that fully utilising domestic capacity (34 units) and ordering 20 foreign units, representing a 37% foreign share, reduces expected cost by 25% and CVaR by 55% compared with sole foreign sourcing, while increasing the fill rate from 84.2% to 96.7%. Higher foreign lead-time variability reduces the optimal foreign order from 25 to 16 units as lead-time standard deviation increases from one to four months, lowering the fill rate from 99.0% to 94.0%. Exchange-rate volatility primarily increases expected and tail costs, while fuel-price volatility has a limited effect. Greater disruption probability increases tail risk, whereas risk aversion modestly increases foreign orders for insurance. Rigid equal-split procurement raises expected cost by nearly 10 million local currency units without improving tail risk. Domestic supply remains fully utilised even when its price doubles, while expanding qualified domestic capacity from 24 to 44 units nearly halves CVaR at almost unchanged expected cost. The findings emphasise prioritising supplier reliability over price, sizing foreign orders according to timely usable arrivals, managing currency risk through contracts and treasury instruments, and using concentration limits as safeguards rather than equal-split rules. Supporting domestic and regional manufacturing capacity and ensuring reliable foreign-exchange access can further reduce procurement risks.

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1. Introduction

Critical energy equipment is characterised by high unit value, long manufacturing cycles, a small number of qualified suppliers and severe consequences of non-availability. A failed generator step-up transformer or an unavailable set of turbine blades can idle hundreds of megawatts for months, and the cost of that idle capacity (lost energy sales, contractual penalties, emergency rental generation and reputational damage) typically dwarfs the purchase price of the missing part. Procurement teams therefore face a problem that is not well captured by price-focused tendering: they must trade off purchase cost against the reliability and timing of supply.

Studies of energy facilities in emerging markets link spare-parts availability directly to plant uptime (Okonkwo *et al*., 2018b; Okonkwo, Agbabiaka, *et al*., 2021) [198, 201], and reliability and maintenance research on power infrastructure shows that failures of high-value assets are frequent enough to make spare provisioning a recurring decision rather than a rare event (Adaramola *et al*., 2018; Gideon *et al*., 2019) [2, 102]. The year 2021 made this trade-off unusually sharp for buyers in emerging and import-dependent markets. Several currencies depreciated against the US dollar, raising the local-currency cost of imported equipment that is invoiced in dollars. Oil prices recovered from their 2020 lows to an average of roughly 70 US dollars per barrel, which raised freight and bunker surcharges and, for thermal-heavy power systems, increased dispatch hours and wear on rotating equipment. At the same time, the pandemic-era disruption of container shipping lengthened and destabilised lead times from overseas manufacturers. Buyers that had consolidated purchases with a single low-cost foreign supplier discovered that the lowest quoted price could be the most expensive choice once delays, currency moves and shortages were counted. Port congestion and demurrage were already a recognised cost driver for importers in West Africa before the pandemic (Okonkwo *et al*., 2020) [197], and import procedures, documentation and access to foreign exchange add further delay and uncertainty (Jones & Ominyi, 2020) [124]. Reviews of post-disruption supply chains and of force majeure practice in energy supply contracts show how quickly such shocks reach buyers (Anene, 2021; Uchechi *et al*., 2020) [37, 260].

Dual sourcing is the natural response, but it raises a quantitative question that practitioners often settle by rule of thumb: *how much* should be allocated to each source? A 50/50 split is easy to defend but rarely optimal. Procurement frameworks developed for the energy sector emphasise strategic sourcing, vendor evaluation and bid selection (Okonkwo *et al*., 2018a; Ahiaeke Patrick *et al*., 2021) [14, 200], but they seldom quantify how volume should be split when prices, lead times and supplier reliability are all uncertain. This paper develops a decision model to answer that question. The model is a single-period, two-supplier procurement problem that jointly captures currency-denominated purchase prices with partial indexation of the domestic supplier, fuel-price pass-through into freight and into demand for replacement units, stochastic lead times evaluated against a hard planning window, random domestic capacity, foreign shipment disruptions and an explicit supplier-concentration constraint. The buyer minimises a mean-CVaR objective, which expresses aversion to rare but very costly outcomes, and the analysis yields an interpretable first-order condition linking the foreign order to an *effective yield* that combines disruption and lateness. To our knowledge, these sources of risk have not previously been combined in a single allocation model for critical energy equipment. We illustrate the model with a numerical study calibrated to 2021 conditions, with sensitivity analysis on exchange-rate volatility, fuel-price volatility, their correlation, disruption probability, lead-time mean and variability, the domestic price premium and domestic capacity, and we translate the results into procurement guidance.

The remainder of the paper is organised as follows. Section 2 synthesises the related literature. Section 3 presents the conceptual model. Section 4 sets out the methodology, including the formal model, its structural properties, the solution approach and the calibration. Section 5 reports the results. Section 6 discusses the findings in light of prior work, Section 7 draws out theoretical, managerial and policy implications, Section 8 states the limitations, Section 9 outlines directions for future research and Section 10 concludes.

2. Literature Synthesis

2.1. Multiple Sourcing, Lead Times and Supply Uncertainty

The value of using more than one supplier has been studied extensively. Minner (2003) [158] surveys multiple-supplier inventory models and distinguishes between price-driven, lead-time-driven and reliability-driven reasons for diversification. Random-yield models, reviewed by Yano and Lee (1995) [277], treat supplier unreliability as a random fraction of the order that is delivered. Dada *et al*. (2007) [72] analyse a newsvendor who chooses among unreliable suppliers and show that cost is the order qualifier while reliability determines how much is ordered from each supplier beyond the cheapest. Federgruen and Yang (2008) [96] study supplier portfolio selection under demand and supply risk. Our model inherits the newsvendor structure of this stream but makes reliability depend on two distinct mechanisms, capacity shortfall and late arrival, which behave differently in the analysis.

Early analytical studies showed that, under random yield, spreading orders across suppliers can lower expected cost even when one supplier is cheaper (Anupindi & Akella, 1993; Gerchak & Parlar, 1990; Henig & Gerchak, 1990; Parlar & Wang, 1993) [40, 100, 110, 215]. Agrawal and Nahmias (1997) [12] examine how many suppliers to keep when yields are uncertain, and Swaminathan and Shanthikumar (1999) [246] show that the benefit of diversification depends on the shape of the demand distribution. Babich *et al*. (2007) [54] add competition and supplier default risk, and Ahiska *et al*. (2013) [15] characterise optimal policies under unreliable sourcing with a Markov decision process. Surveys of multiple-supplier inventory control by Svoboda *et al*. (2021) [245] and of newsvendor extensions by Khouja (1999) [130] and Qin *et al*. (2011) [218] confirm that single-period models remain the standard tool for one-off procurement of high-value items, which is the setting adopted here.

A second stream studies dual sourcing between a fast, expensive source and a slow, cheap one. Classic results go back to Fukuda (1964) [98] and Whittemore and Saunders (1977) [272], who analyse two supply options with different lead times. Veeraraghavan and Scheller-Wolf (2008) [268] propose a simple dual-index policy for capacitated systems, Allon and Van Mieghem (2010) [30] introduce tailored base-surge allocation between offshore and near-shore production, and Xin and Goldberg (2018) [275] prove its asymptotic optimality, while Sun and Van Mieghem (2019) [241] extend the analysis to robust capped dual-index policies. Tomlin and Wang (2005) [253] and Wang *et al*. (2010) [270] compare dual sourcing with mix flexibility and with process improvement, Tomlin (2009) [252] considers learning about supplier reliability, and Yang *et al*. (2009) [276] study backup production under asymmetric information. Disruption-oriented dual-sourcing models are developed by (Hu *et al*., 2013; Silbermayr & Minner, 2014; Xanthopoulos *et al*., 2012; Yu *et al*., 2009) [113, 237, 274, 279]. The domestic-foreign structure

of the present model mirrors the base-surge logic with the roles reversed: the near source carries the base load because it is reliable, and the distant source supplies the surge.

Stochastic lead times have their own literature. Kaplan (1970) [127] and Zipkin (1986) [280] derive optimal policies when lead times are random, and Song (1994) [240] shows that greater lead-time variability does not always raise costs or stock levels, a result that anticipates the effective-yield finding of Section 4.4. Order splitting across suppliers to pool lead-time risk is examined by Sculli and Wu (1981) [229] and Ramasesh *et al.* (1991) [219] and reviewed critically by Thomas and Tyworth (2006) [250]. Capacity uncertainty, which we use to model the domestic supplier, is treated by Ciarallo *et al.* (1994) [70]. Textbook treatments of these models appear in (Arrow *et al.*, 1951; Chopra & Meindl, 2016; Porteus, 2002; Silver *et al.*, 2017; Zipkin, 2000) [43, 65, 217, 238, 281].

2.2. Disruption Risk and Supply Chain Resilience

Tomlin (2006) [251] compares mitigation strategies (inventory, sourcing) and contingency strategies (rerouting, volume flexibility) for a firm exposed to supplier disruptions, and shows that the preferred strategy depends on disruption frequency and duration and on the firm's risk attitude. Kleindorfer and Saad (2005) [132] propose a broader framework for disruption risk, and Sheffi and Rice (2005) [233] emphasise redundancy and flexibility as sources of resilience. Snyder *et al.* (2016) [239] review operations research models of supply chain disruption. Most of this work treats prices as known; the present paper adds price risk from currency and fuel markets.

Empirical evidence shows why disruptions deserve explicit modelling: announcements of supply chain glitches are followed by significant falls in shareholder value and by lasting increases in equity risk (Hendricks & Singhal, 2003, 2005) [108, 109]. Conceptual frameworks for supply risk and resilience were developed by (Chopra & Sodhi, 2004; Christopher & Peck, 2004; Craighead *et al.*, 2007; Ponomarov & Holcomb, 2009; Tang, 2006a, 2006b) [67, 69, 71, 216, 247, 248], and Chopra *et al.* (2007) [66] argue that recurrent and disruption risks call for different responses. Ho *et al.* (2015) [112] organise the supply chain risk management literature, and the COVID-19 pandemic renewed interest in ripple effects and in the viability of intertwined supply networks (Ivanov & Dolgui, 2020; Ivanov *et al.*, 2019) [121, 122].

For imported equipment, lead-time variability largely reflects maritime schedule reliability. Liner services frequently miss their scheduled arrival times, and these delays propagate into hinterland supply chains (Notteboom, 2006; Vernimmen *et al.*, 2007) [160, 269]; the pandemic magnified the effect through port congestion and capacity withdrawals (Notteboom *et al.*, 2021) [161]. Import compliance and customs interdiction regimes add further variability (Aneke & Adesemoye, 2021) [36], while integrated procurement information systems and chain-of-custody frameworks improve the planning and traceability of inbound orders (Ahiaeke Patrick *et al.*, 2020; Aneke & Adesemoye, 2019) [13, 34].

2.3. Price Risk and Risk-Averse Procurement

Kazaz *et al.* (2005) [128] show how exchange-rate uncertainty shapes global production and allocation decisions, and Ding *et al.* (2007) [81] integrate operational decisions with financial hedging in global markets. These papers establish that operational flexibility, including the ability to switch supply sources, acts as a real option against currency movements. Our setting differs in that the buyer is in a weak-currency economy procuring capital equipment, the domestic price is itself partially indexed to the exchange rate, and there is no assumption that financial hedges are available or cheap, which is realistic for many emerging-market utilities.

Exchange-rate exposure in global sourcing has often been framed as a real option. Kogut and Kulatilaka (1994) [134] value the flexibility of a multinational production network, Huchzermeier and Cohen (1996) [114] quantify the value of switching production under currency risk, Dasu and Li (1997) [80] derive optimal operating policies under exchange-rate variability, and Lowe *et al.* (2002) [149] screen location strategies for currency risk. Kouvelis (1999) [138] reviews global sourcing under exchange-rate uncertainty, and Van Mieghem (2003) [267] links capacity investment to operational and financial hedging. The real-options perspective of (Dixit & Pindyck, 1994; Trigeorgis, 1996) [82, 256] provides the conceptual basis for treating a second supplier as an option on supply.

Commodity and input-price risk has been studied in procurement with spot markets (Haksöz & Seshadri, 2007; Seifert *et al.*, 2004) [106, 230], portfolio and option contracts (Fu *et al.*, 2010; Martínez-de-Albéniz & Simchi-Levi, 2005) [97, 151], stochastic purchase prices (Berling & Martínez-de-Albéniz, 2011; Goel & Gutierrez, 2011) [57, 104] and joint inventory and financial hedging (Caldentey & Haugh, 2006; Gaur & Seshadri, 2005; Kouvelis *et al.*, 2013) [61, 99, 139]. Oil price shocks have long been shown to affect macroeconomic activity, with effects that differ according to whether they originate in supply or demand (Hamilton, 1983; Kilian, 2009) [107, 131], and energy prices are among the most volatile of all commodity prices (Regnier, 2007) [220]. Fuel prices also shape shipping operations, because carriers adjust vessel speed and fleet size when bunker costs rise (Ronen, 2011) [225]. These links motivate the joint modelling of fuel and exchange-rate shocks in Section 4.

We measure tail risk with Conditional Value-at-Risk, introduced for optimisation by Rockafellar and Uryasev (2000, 2002) [223, 224]. CVaR is coherent, easy to communicate (the average cost in the worst 5 percent of scenarios) and admits a linear-programming representation under sampled scenarios, which makes it attractive for procurement committees that must justify decisions to boards and regulators.

CVaR satisfies the axioms of coherent risk measures (Artzner *et al.*, 1999) [44] and is often preferred to Value-at-Risk because it accounts for the size of losses beyond the quantile (Jorion, 2007; Sarykalin *et al.*, 2008) [126, 228]. Its optimisation properties are summarised by Rockafellar (2007) [222] and applied to portfolio selection by Krokhmal *et al.* (2002) [140], building on the mean-variance tradition of Markowitz (1952) [150]. In inventory theory, risk aversion has been introduced through expected utility (Eeckhoudt *et al.*, 1995) [88], mean-variance criteria (Choi *et al.*, 2008) [64], Value-at-Risk (Tapiero, 2005) [249] and CVaR (Chen *et al.*, 2009; Gotoh & Takano, 2007; Wu *et al.*, 2013) [63, 105, 273], and Chen *et al.* (2007) [62] characterise risk-averse policies in a multi-period setting. Our formulation follows the CVaR newsvendor of Chen *et al.* (2009) [63] and the random-capacity extension of Wu *et al.* (2013) [273], adding currency, fuel and lead-time uncertainty.

2.4. Procurement of Critical Equipment in Emerging Energy Markets

A growing applied literature addresses procurement and supply risk for energy and infrastructure operators in emerging economies. Agbabiaka *et al*. (2019) [7] propose a supply chain risk management model for engineering, procurement and construction (EPC) and gas processing projects, and Ogunwole *et al*. (2021) [193] develop a resilience framework for critical infrastructure and gas processing plants. Okonkwo *et al*. (2018a) [200] set out a framework for strategic procurement optimisation in oil and gas operations, while Okonkwo *et al*. (2018b) [201] and Okonkwo, Agbabiaka, *et al*. (2021) connect inventory availability and materials readiness to plant uptime and maintenance performance. Contract and vendor governance are treated by Okonkwo *et al*. (2019) [202], regulatory compliance in high-risk energy procurement by Okonkwo, Ogunwole, *et al*. (2021), and data-driven vendor evaluation by Ahiaeke Patrick *et al*. (2021) [14]. On the logistics side, Okonkwo *et al*. (2020) [197] model demurrage and port efficiency in emerging economies, and Nnabueze *et al*. (2021) [159] and Ike *et al*. (2021) [116] examine end-to-end visibility and supplier relationship management as sources of resilience. Contractual risk allocation for high-value energy services and the role of force majeure clauses are reviewed by Uchechi and Ominyi (2019) [259] and Uchechi *et al*. (2020) [260]. Currency risk from the buyer's perspective is addressed in work on tiered treasury architecture and foreign-exchange control (Dada *et al*., 2021a) [73] and on cross-border strategic finance (Isiekwu *et al*., 2021) [120]. These contributions are largely conceptual or framework-based; they identify the relevant risks and governance levers but do not provide a quantitative rule for splitting volume between suppliers. The present model is intended to supply that rule.

Related applied work examines capital project delivery and programme management for high-risk infrastructure (Aminu-Ibrahim *et al*., 2019, 2021; Nwafor *et al*., 2019b; Ogbete *et al*., 2021) [32, 33, 162, 191], capital budgeting in upstream energy (Nwangwu *et al*., 2021) [163], and statutory and regulatory compliance in energy licensing and bidding (Ominyi *et al*., 2020; Uchechi & Ominyi, 2020; Uchechi *et al*., 2019) [204, 259, 260]. Studies of contractor governance and operational integrity in high-risk energy operations (Arumosoye & Obriki, 2020; Nwangwu *et al*., 2018; Obogo, Uduokhai, *et al*., 2021) [47, 164, 181] and of agile supply chain digital transformation with embedded IT risk controls (Mbonu *et al*., 2020a) [155] complete the picture of the operating environment in which critical equipment is procured.

Supplier selection has been studied for decades, and Weber *et al*. (1991) [271] summarise the criteria and methods used in early work. Multi-criteria methods such as the analytic hierarchy process combined with linear programming remain popular (Ghodsypour & O'Brien, 1998) [101], and reviews by Ho *et al*. (2010) [111] and Aissaoui *et al*. (2007) [21] document the shift from pure selection towards joint selection and order-quantity allocation. Applied work in emerging markets has examined procurement process automation and transparency (Akinleye & Adeyoyin, 2021) [24], analytics for procurement profitability (Akin-Oluyomi *et al*., 2020) [23], data-driven operations management (Efobi *et al*., 2021) [89], ESG-integrated and circular-economy procurement decisions (Okojie & Abioye, 2020; Okojie *et al*., 2020) [195], and supply chain talent and capability building (Falemi *et al*., 2020) [95]. Supplier concentration is commonly measured with the Herfindahl-Hirschman Index (Rhoades, 1993) [221], which we adopt as a governance constraint.

Power systems in Sub-Saharan Africa have long been constrained by under-investment, weak utility finances and unreliable supply (Eberhard *et al*., 2008, 2016; Trimble *et al*., 2016) [86, 87, 257], and the Nigerian sector in particular has suffered from low availability of installed capacity (Emodi & Boo, 2015; Oseni, 2011; Oyedepo, 2012) [90, 211, 213]. The International Energy Agency (2019) [117] outlook highlights the region's growing equipment needs, and global analyses point to rising demand for grid equipment and the materials it requires as energy transitions accelerate (International Energy Agency, 2021a, 2021b) [118, 119]. Within utilities, spare-transformer provisioning has been modelled probabilistically (Chowdhury & Koval, 2005; Li *et al*., 1999) [68, 148] and set within transformer asset management practice (Abu-Elanien & Salama, 2010) [1] and power system reliability evaluation (Billinton & Allan, 1996) [58]. Spare-parts inventory theory provides further foundations, from the multi-echelon METRIC model (Sherbrooke, 1968) [234] to reviews of the special characteristics of maintenance spares and of system-oriented models (Basten & van Houtum, 2014; Huiskonen, 2001; Kennedy *et al*., 2002) [56, 115, 129]. Local studies of grounding design, voltage control, solar integration and microgrids show how equipment requirements evolve with the network (Adeniji *et al*., 2020; Komi & Adeniji, 2020; Oshevire *et al*., 2017; Sunday & Omoegun, 2018, 2019; Yeboah & Ike, 2020) [4, 137, 212, 242, 243, 278], supported by solar-resource and wind-power forecasting models (Komi, 2021; Odejobi & Ahmed, 2018a) [135, 188], peer-to-peer energy trading (Shittu *et al*., 2021) [236] and hydrogen integration (Shittu *et al*., 2019) [235].

Read together, these strands lead to three observations. First, operational models of multiple sourcing treat yield, lead-time and disruption risk in depth but usually take purchase prices as known. Second, models of currency and commodity risk treat prices as stochastic but rarely consider supply that is unreliable or late. Third, the applied literature on energy procurement in emerging economies identifies the full set of risks and the governance levers available to buyers, yet remains largely conceptual and offers no quantitative rule for splitting volume between suppliers.

The gap that this paper addresses is therefore the joint treatment of currency, fuel, lead-time and disruption risks in a supplier-allocation model for critical energy equipment, together with an explicit concentration constraint that mirrors governance rules many utilities adopted after 2020.

3. Conceptual Model

Figure 1 summarises the conceptual model that guides the analysis. Five exogenous risk drivers act on the attributes of the two supply sources: exchange-rate volatility, fuel-price volatility and its correlation with the exchange rate, foreign lead-time uncertainty, shipment disruption and domestic capacity uncertainty. The exchange rate acts on landed cost, fully for the foreign supplier and partially, through the indexed share of its cost base, for the domestic supplier. Fuel prices act on freight costs and, through higher dispatch and asset stress, on demand for replacement units. Lead-time uncertainty and disruption combine into the foreign effective yield, the share of each ordered unit that arrives usable within the planning window, while capacity uncertainty limits what the domestic supplier can deliver.

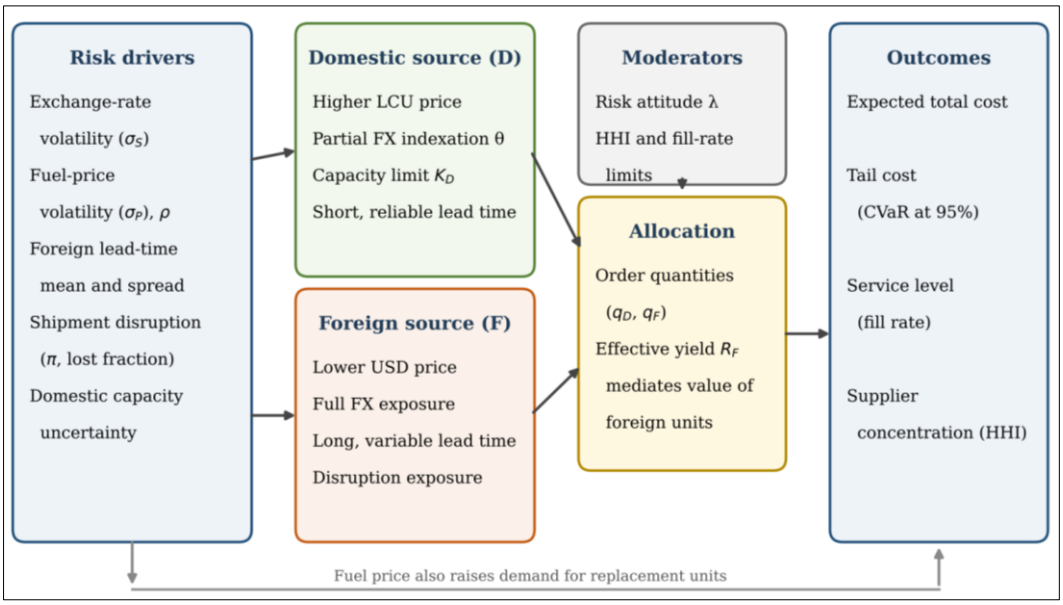


Fig 1: Conceptual model linking risk drivers, supplier attributes, moderators, the allocation decision and procurement outcomes.

These supplier attributes determine the value of each unit ordered from each source, and the allocation decision is moderated by the buyer's risk attitude and by governance limits on supplier concentration and service level. The decision in turn produces four outcomes: expected total cost, tail cost measured by CVaR, service level measured by the fill rate, and supplier concentration measured by the HHI. The structure draws on the random-yield view of supplier unreliability (Dada *et al*., 2007; Yano & Lee, 1995) [72, 277], the real-options view of sourcing flexibility under currency risk (Kogut & Kulatilaka, 1994; Kouvelis, 1999) [134, 138] and the resilience perspective in which assured supply has value beyond its price (Sheffi & Rice, 2005; Tomlin, 2006) [233, 251]. The conceptual model implies three expected relationships that the formal analysis examines. First, the foreign order should fall as the foreign effective yield falls, whether because lead times become longer or more variable or because disruption becomes more likely. Second, currency volatility should raise tail cost more than it changes the allocation, because it alters the dispersion of the foreign landed cost rather than its mean. Third, reliable domestic capacity should be used first, and expanding it should reduce tail cost more than any reallocation of a fixed capacity.

4. Methodology

The study follows a quantitative decision-modelling design in four steps. First, the decision setting implied by the conceptual model is specified (Section 4.1). Second, it is formalised as a single-period stochastic program with a mean-CVaR objective (Sections 4.2 and 4.3), and its structural properties are derived analytically (Section 4.4). Third, the program is solved by sample average approximation over Monte Carlo scenarios (Section 4.5). Fourth, the model is calibrated to stylised 2021 conditions and examined through one-factor-at-a-time sensitivity analysis (Section 4.6), with the results reported in Section 5.

4.1. Problem Setting

Consider a power utility (the buyer) that must secure a stock of a critical, standardised equipment item, for example distribution and generator step-up transformers of a given rating, or a family of turbine hot-gas-path components, for a 12-month planning horizon. Orders are placed at the start of the year. Units that arrive within a planning window of $T = 9$ months can be installed or held as strategic spares in time to protect against the year's failures and planned replacements; units arriving later cannot cover this year's needs and are carried at no value to the current period.

Items of this kind are usually governed by asset integrity and reliability programmes that determine when replacements are needed (Atta *et al*., 2020, 2021; Obetta, 2018, 2019, 2020) [51, 52, 166, 167, 168], and their failure rates rise with operating intensity and harsh service conditions (Obetta & Ninduwezuor-Ehiobu, 2018, 2019; Obetta *et al*., 2020, 2021) [168, 169, 170, 172].

Two qualified suppliers are available. The first is a domestic or regional supplier (D), a local or near-shore assembler with a short lead time (mean 3 months). Its price is quoted in local currency units (LCU), but a fraction θ of its cost base consists of imported components, so its price is partially indexed to the exchange rate. Its nominal annual allocation to the buyer is K_D units, and realised capacity is random because of component shortages and competing orders. The buyer pays only for units delivered.

The second is a foreign original equipment manufacturer (F), an established firm with a lower dollar price but a long and variable lead time (mean 6 months, standard deviation 2 months) and exposure to shipment disruption (port congestion, vessel incidents, export delays) that destroys or indefinitely delays part of the consignment. Following common practice under letters of credit, the buyer commits to the full dollar payment for the ordered quantity, converted at the spot rate prevailing at payment. This payment structure is typical of import transactions where access to foreign exchange is administratively controlled (Jones & Ominyi, 2020) [124].

Demand for the item over the horizon is uncertain. It is driven by failures, planned replacements and network expansion, and it rises with fuel prices because high fuel prices in 2021 coincided with higher dispatch of thermal units and greater stress on assets. Failure-prediction work on energy assets supports treating demand for replacements as a function of

operating intensity (Komi & Adamolekun, 2021) [136]. A shortfall triggers a large penalty per unit representing downtime, emergency procurement at spot premiums and rental generation. Excess units incur a holding cost covering storage, insurance and capital.

The buyer's governance policy may also impose a maximum supplier concentration, measured by the HHI of quantity shares, to avoid dependence on any single source. The decision is the pair of order quantities (q_D, q_F).

4.2. Notation and Uncertainty

Table 1: Notation

Symbol	Meaning
q_D, q_F	Order quantities from domestic and foreign suppliers (decision variables, units)
S, S_0	Exchange rate at payment (LCU per USD) and its reference value
P, P_0	Fuel price at shipment (USD per barrel) and its reference value
D	Demand for units within the planning window
L_D, L_F	Random lead times of the two suppliers (months)
T	Planning window within which units are usable (months)
$\tilde{K}_D$	Realised domestic capacity available to the buyer (random)
δ, ℓ	Foreign disruption indicator and fraction of shipment lost if disrupted
p_D, θ	Domestic base price (LCU) and its share indexed to the exchange rate
p_F	Foreign unit price (USD)
f_D, f_F	Freight cost per unit at reference fuel price (LCU, USD)
h, b	Holding cost and shortage (downtime) penalty per unit (LCU)
λ, α	Weight on CVaR and CVaR confidence level
H_{max}	Maximum allowed supplier concentration (HHI)

Let Z_1 and Z_2 be standard normal variables with correlation ρ. The exchange rate and fuel price are lognormal with unit mean multipliers:

$$S = S_0 \exp(-\sigma_S^2/2 + \sigma_S Z_1),\ P = P_0 \exp(-\sigma_P^2/2 + \sigma_P Z_2) \quad (1)$$

A positive ρ reflects the tendency, observed for oil importers, of currency weakness to coincide with higher dollar fuel costs; for oil exporters ρ can be negative. Demand responds to fuel prices with elasticity η:

$$D = \max\{0,\ \mu_D[1 + \eta \ln(P/P_0)] + \sigma_D \varepsilon\},\ \varepsilon \sim N(0,\ 1) \quad (2)$$

Lead times L_D and L_F are lognormal with given means and standard deviations. The foreign disruption indicator δ is Bernoulli with probability π, and the lost fraction ℓ is uniform on [0.3, 0.9]. Realised domestic capacity is $\tilde{K}_D = K_D \cdot \kappa$, where κ is a truncated normal multiplier with mean 1 and coefficient of variation 0.15.

4.3. Costs, Objective and Constraints

The landed unit costs, in LCU, are

$$c_D = p_D[(1 - \theta) + \theta\, S/S_0] + f_D\, P/P_0,\ c_F = (p_F + f_F\, P/P_0)\, S \quad (3)$$

Usable quantities arriving within the window are

$$Y_D = \min(q_D, \tilde{K}_D) \cdot 1\{L_D \le T\},\ Y_F = q_F(1 - \delta\ell) \cdot 1\{L_F \le T\} \quad (4)$$

and total usable supply is $Y = Y_D + Y_F$. The total cost in a scenario ξ is

$$C(q, \xi) = c_D \min(q_D, \tilde{K}_D) + c_F\, q_F + h(Y - D)^+ + b(D - Y)^+ \quad (5)$$

The first two terms are purchase costs, with the foreign order paid in full irrespective of disruption or lateness. The last two terms are the holding and shortage costs. Because c_F is the product of a dollar price and a random exchange rate, foreign purchasing carries direct currency exposure; the domestic price carries a smaller, indexed exposure θ.

The buyer solves

$$\min_q\ \Phi(q) = (1 - \lambda)\ E[C(q, \xi)] + \lambda\ CVaR_\alpha[C(q, \xi)] \quad (6)$$

subject to

$$0 \le q_D \le K_D,\ q_F \ge 0,\ s_D^2 + s_F^2 \le H_{max},\ FR(q) \ge FR_{min} \quad (7)$$

where $s_i = q_i / (q_D + q_F)$ are quantity shares, the HHI constraint limits concentration ($H_{max} = 1$ means no restriction and $H_{max} = 0.5$ forces an equal split), and $FR(q) = 1 - E[(D - Y)^+]/E[D]$ is an optional fill-rate service constraint. Using the representation of Rockafellar and Uryasev (2000) [223],

The HHI is the standard concentration measure in competition analysis (Rhoades, 1993) [221]; applied here to quantity shares, it records how dependent the buyer is on its largest supplier.

$$CVaR_\alpha[C] = \min_\tau \{\ \tau + E[(C - \tau)^+] / (1 - \alpha)\ \} \quad (8)$$

so that, with N sampled scenarios, problem (6) to (7) becomes a mixed-integer program with auxiliary variables $u_n \ge C_n - \tau$, $u_n \ge 0$.

4.4. Structural Properties

Define the foreign *effective yield* $R_F = (1 - \delta\ell) \cdot 1\{L_F \le T\}$, the fraction of each ordered foreign unit that is usable within the window. Then $Y_F = q_F R_F$.

Proposition 1 (Risk-Neutral Optimality Condition): Let $\lambda = 0$ and suppose demand has a continuous distribution. At an interior optimum the foreign order satisfies

$$E[c_F] = b \cdot E[R_F \, 1\{D > Y\}] - h \cdot E[R_F \, 1\{Y > D\}] \quad (9)$$

Argument. Differentiating (5) with respect to q_F gives $\partial C/\partial q_F = c_F + R_F[h \cdot 1\{Y > D\} - b \cdot 1\{D > Y\}]$, which is non-decreasing in q_F because Y increases in q_F. Hence E[C] is convex in q_F; setting its derivative to zero gives (9).

Condition (9) is a generalised critical-fractile rule: the marginal landed cost of a foreign unit must equal the expected shortage cost it avoids minus the expected holding cost it creates, both scaled by the probability that the unit actually arrives usable. It has three implications.

First, lead-time risk acts as a loss of yield rather than as a reason to over-order. Raising the variability of L_F increases Pr($L_F > T$) and lowers E[R_F], which shrinks the right-hand side of (9). Because the buyer pays for late units in full, the optimal foreign order falls rather than rises. This contrasts with classical safety-stock logic, where lead-time variability increases stock levels.

Second, exchange-rate volatility enters mostly through the tail of the cost distribution. With the mean-preserving specification in (1), E[c_F] is unchanged by σ_S, so the risk-neutral allocation is nearly insensitive to currency volatility. It matters for $\lambda > 0$, because CVaR penalises scenarios where a weak currency coincides with high demand or disruption.

Third, fuel prices act on both sides of the trade-off. A higher P raises c_F and c_D through freight but also raises D through (2), increasing the shortage term. With freight a small share of landed cost, the demand channel dominates and the net effect on the allocation is small.

Proposition 2 (Preference for The Reliable Source): If the domestic supplier's expected landed cost per *usable* unit, E[c_D]/Pr($L_D \le T$), is below the shortage penalty b and the domestic supply is less correlated with the shortage event than foreign supply, then under $\lambda \ge 0$ the domestic order is at its upper bound K_D whenever the foreign order is positive.

Sketch. Exchanging one foreign unit for one domestic unit reduces the probability of a usable-supply shortfall by more than the price premium in penalty-weighted terms, so the objective decreases until the capacity bound binds. The numerical results in Section 5 are consistent with this property: in every case with K_D of 44 units or less, the domestic order equals K_D; only at 54 units, when domestic capacity alone exceeds expected demand, does the bound stop binding.

4.5. Solution Approach: Sample Average Approximation

Because equipment is ordered in whole units and the feasible region is small, we solve the sample average approximation (SAA) of (6) to (7) by exhaustive enumeration over integer pairs (q_D, q_F) with $q_D \in \{0,.., K_D\}$, $q_F \in \{0,.., 60\}$ and $q_D + q_F \ge 30$. For each candidate we evaluate the empirical mean and the empirical CVaR at $\alpha = 0.95$ over $N = 20{,}000$ scenarios drawn with common random numbers, so that differences between candidates are not driven by sampling noise. Enumeration guarantees a global optimum of the SAA problem despite the non-convexity introduced by the capacity minimum in (4); for larger instances (more suppliers or multiple items) the mixed-integer formulation based on (8) can be solved with a commercial solver.

Sample average approximation is an established method for stochastic discrete optimisation with known convergence properties (Kleywegt *et al*., 2002) [133], and its foundations are set out in standard texts on stochastic programming (Birge & Louveaux, 2011; Shapiro *et al*., 2009) [59, 232]. It has been applied to supply chain design under uncertainty by Santoso *et al*. (2005) [227]. Scenario generation uses standard Monte Carlo techniques for correlated lognormal variables (Glasserman, 2004) [103]. For larger instances, heuristic and approximation methods developed for cloud and network resource allocation offer scalable alternatives to full enumeration (Ahmed & Odejobi, 2018b; Ahmed *et al*., 2019, 2020; Odejobi *et al*., 2019) [16, 17, 18, 189].

4.6. Parameter Calibration

The instance is stylised, representing a standardised distribution-class equipment item bought in volume, but anchored to conditions faced by an import-dependent utility in 2021. The reference exchange rate is 410 LCU per USD and the reference fuel price is 70 USD per barrel, which are close to the official naira rate and the average Brent price in that year. Prices are expressed in millions of LCU per unit. Table 2 lists the base-case parameters.

Table 2: Base-case parameters

Parameter	Value	Interpretation
S_0, σ_S	410 LCU/USD; 0.25	Reference rate; annual FX volatility
P_0, σ_P, ρ	70 USD/bbl; 0.40; 0.35	Fuel reference, volatility and correlation with FX
μ_D, σ_D, η	40; 8; 0.15	Mean and SD of demand; fuel elasticity of demand
p_D, θ, f_D	0.95; 0.35; 0.010	Domestic price (LCU m), FX-indexed share, freight
p_F, f_F	USD 1,850; USD 100	Foreign price and freight per unit (see note)
K_D, CV of capacity	34 units; 0.15	Domestic allocation and its reliability
L_D (mean, SD)	3; 0.8 months	Domestic lead time
L_F (mean, SD)	6; 2.0 months	Foreign lead time
T	9 months	Usable planning window
π, ℓ	0.10; U[0.3, 0.9]	Disruption probability; fraction lost
h, b	0.10; 6.0	Holding cost and downtime penalty (LCU m per unit)
λ, α	0.5; 0.95	CVaR weight and confidence level

Note to Table 2: the instance represents a standardised distribution-class transformer and protection package. The foreign price of USD 1,850 per unit (0.00185 USD million in model units) and freight of USD 100 per unit at the reference fuel price give a landed foreign cost of about 0.80 LCU million per unit at the reference exchange rate, roughly 17 percent below the domestic price. Only relative magnitudes matter for the allocation. With these values about 8.3 percent of foreign shipments arrive after the window, versus essentially none of the domestic deliveries.

5. Results

5.1. Optimal Allocation Versus Sole Sourcing

Table 3 compares the optimal risk-averse policy with the two sole-sourcing benchmarks and with the risk-neutral optimum. Sole domestic sourcing is capped by capacity, so it leaves a large expected shortfall and the lowest fill rate. Sole foreign sourcing is optimised over the order size; it achieves the lowest purchase cost per unit but has the highest volatility and by far the worst tail, because a single disruption or a late vessel exposes the buyer to large shortage penalties at the same time that it has already paid in full in dollars.

Table 3: Policy comparison (costs in LCU million; 20,000 scenarios)

Policy	q_D / q_F	Foreign share %	E[C]	SD[C]	$CVaR_{0.95}$	Fill rate %	P(no shortage) %
Sole domestic	34 / 0	0.0	81.6	43.9	184.9	78.6	19.6
Sole foreign	0 / 45	100.0	74.2	76.0	310.3	84.2	61.9
Risk-neutral dual ($\lambda = 0$)	34 / 16	32.0	54.8	25.5	142.0	95.6	74.8
Risk-averse dual ($\lambda = 0.5$)	34 / 20	37.0	55.5	23.5	139.7	96.7	82.3

The risk-averse dual-sourcing policy orders the full domestic allocation of 34 units plus 20 foreign units. Relative to sole foreign sourcing, expected cost falls from 74.2 to 55.5 LCU million (−25 percent) and CVaR falls from 310.3 to 139.7 (−55 percent). The fill rate rises to 96.7 percent. Moving from the risk-neutral to the risk-averse policy adds four foreign units as insurance: expected cost rises by only 0.74 LCU million while CVaR falls by 2.37 and the probability of no shortage rises from 74.8 to 82.3 percent.

The cost decomposition of the optimal policy is instructive: purchase costs account for 46.7 LCU million, expected shortage penalties for 7.7 and holding costs for 1.1. The dollar-denominated share of purchase spending is 16.0 LCU million, about 34 percent, which defines the buyer's residual currency exposure.

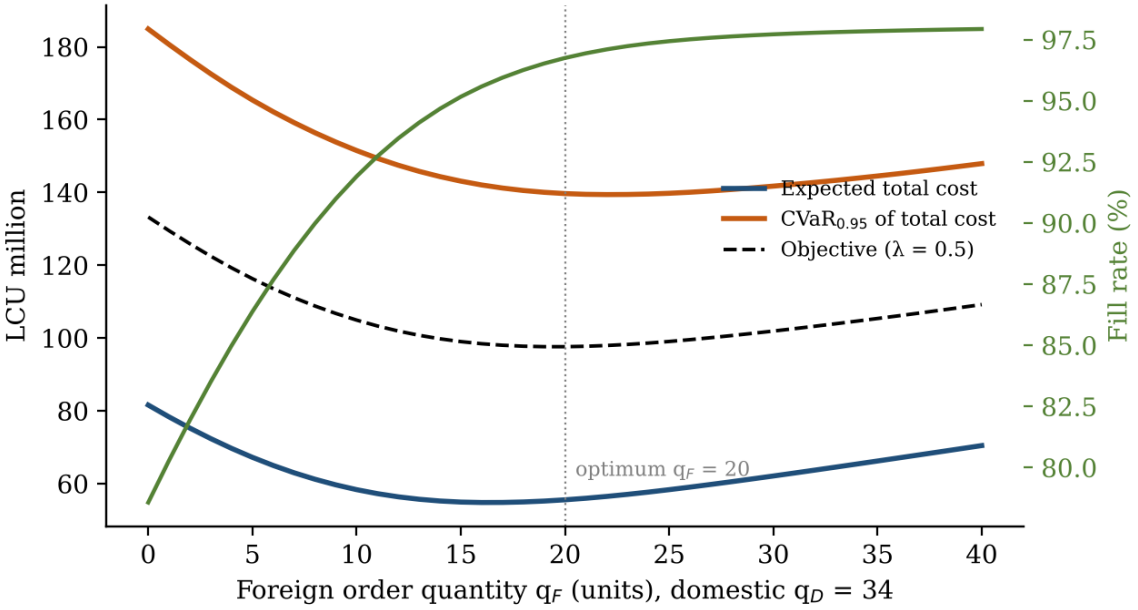


Fig 2: Expected cost, CVaR, objective and fill rate as functions of the foreign order, with the domestic order at capacity.

Figure 2 shows why the optimum is interior. The first foreign units are extremely valuable because they cover demand that domestic capacity cannot; expected cost and CVaR fall steeply. Beyond roughly 16 units the expected-cost curve turns up because additional foreign units are increasingly likely to be surplus. CVaR keeps falling a little longer because extra units still protect against joint domestic shortfall and foreign disruption scenarios, which places the mean-CVaR optimum at 20 units. Fill rate saturates near 98 percent, showing that the remaining shortages stem from disruptions and late arrivals that additional ordering cannot fix cheaply.

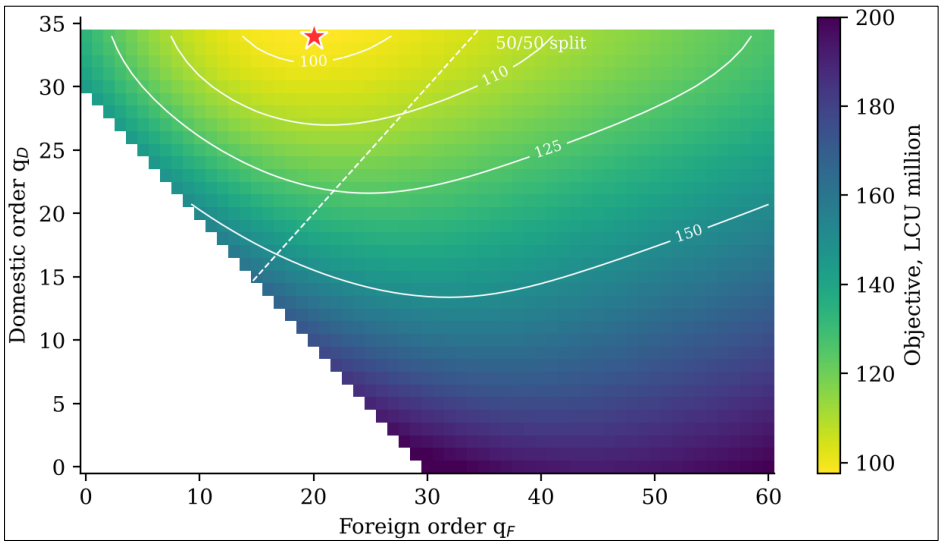


Fig 3: Objective surface $\Phi(q_D, q_F)$ for $\lambda = 0.5$. The star marks the optimum; the dashed line marks an equal 50/50 split.

Figure 3 maps the full objective surface. The basin around the optimum is relatively flat along the q_F axis but steep along the q_D axis: under-ordering from the reliable domestic source is far more costly than mis-sizing the foreign order by a few units. The 50/50 line passes well away from the optimum except at very high total quantities, which illustrates the cost of equal-split heuristics.

5.2. Risk Attitude and Concentration Limits

Table 4: Effect of risk aversion λ and concentration cap H_{max}

Setting	q_D / q_F	HHI	E[C]	$CVaR_{0.95}$	Fill rate %
$\lambda = 0$	34 / 16	0.56	54.80	142.04	95.6
$\lambda = 0.25$	34 / 18	0.55	54.95	140.53	96.3
$\lambda = 0.5$	34 / 20	0.53	55.54	139.67	96.7
$\lambda = 0.75$	34 / 21	0.53	55.97	139.47	96.9
$\lambda = 1$	34 / 22	0.52	56.47	139.40	97.1
$H_{max} = 0.62$ ($\lambda = 0.5$)	34 / 20	0.53	55.54	139.67	96.7
$H_{max} = 0.55$ ($\lambda = 0.5$)	34 / 20	0.53	55.54	139.67	96.7
$H_{max} = 0.5$ ($\lambda = 0.5$)	34 / 34	0.50	65.36	143.90	97.8

Greater risk aversion monotonically increases the foreign order (16 to 22 units), trading small increases in expected cost for reductions in CVaR. Concentration caps of 0.62 and 0.55 are not binding because the unconstrained optimum already has an HHI of 0.53. A strict equal-split rule ($H_{max} = 0.5$) forces 34 foreign units, raising expected cost by 9.8 LCU million and the objective by 7.0, while CVaR actually worsens slightly because surplus dollar purchases add currency-driven cost in bad scenarios. A concentration constraint is therefore valuable as a guardrail against single sourcing but costly if written as a rigid equal split.

5.3. Exchange-Rate, Fuel-Price and Disruption Sensitivity

Table 5: Sensitivity of the optimal policy to market and disruption risks ($\lambda = 0.5$)

Parameter	q_D / q_F	E[C]	$CVaR_{0.95}$	Objective	Fill rate %
$\sigma_S = 0.10$	34 / 20	55.52	138.66	97.09	96.7
$\sigma_S = 0.25$	34 / 20	55.54	139.67	97.61	96.7
$\sigma_S = 0.40$	34 / 19	55.22	141.71	98.46	96.5
$\sigma_S = 0.55$	34 / 18	54.99	145.99	100.49	96.3
$\sigma_P = 0.20$	34 / 19	55.26	139.67	97.46	96.5
$\sigma_P = 0.40$	34 / 20	55.54	139.67	97.61	96.7
$\sigma_P = 0.60$	34 / 20	55.41	139.96	97.69	96.8
$\rho = -0.30$	34 / 20	55.46	138.04	96.75	96.8
$\rho = 0.00$	34 / 20	55.49	138.76	97.13	96.8
$\rho = 0.35$	34 / 20	55.54	139.67	97.61	96.7
$\rho = 0.70$	34 / 19	55.24	140.91	98.07	96.5
$\pi = 0.00$	34 / 20	53.89	131.29	92.59	97.5
$\pi = 0.10$	34 / 20	55.54	139.67	97.61	96.7
$\pi = 0.20$	34 / 19	57.02	146.70	101.86	95.7
$\pi = 0.30$	34 / 19	58.74	151.58	105.16	95.0

Exchange-rate volatility: Raising σ_S from 0.10 to 0.55 increases CVaR from 138.7 to 146.0 LCU million but changes the foreign order only from 20 to 18 units. Consistent with Proposition 1, currency risk raises the price of the foreign hedge in bad states without changing its expected cost, so the response is a modest shift toward the domestic source, which in the base case is already at capacity. The practical message is that currency volatility should be managed mainly through contract terms (local-currency pricing, indexation caps, staged payments) and financial instruments where available, rather than by large changes in sourcing shares.

Fuel-price volatility and correlation: Fuel-price volatility and its correlation with the exchange rate have almost no effect on the allocation. Freight is a small fraction of landed cost, and the demand channel raises shortage risk for both suppliers alike. Fuel risk therefore matters more for budgeting than for allocation.

Disruption probability: As π rises from 0 to 0.30, CVaR rises from 131.3 to 151.6 and the fill rate falls from 97.5 to 95.0 percent, yet the foreign order barely changes (20 to 19). Since the disruption hits the foreign consignment as a block, extra units ordered from the same source are lost together with the rest; the cure for higher disruption risk is not to order more from the same supplier but to add independent capacity.

5.4. Lead-Time Uncertainty

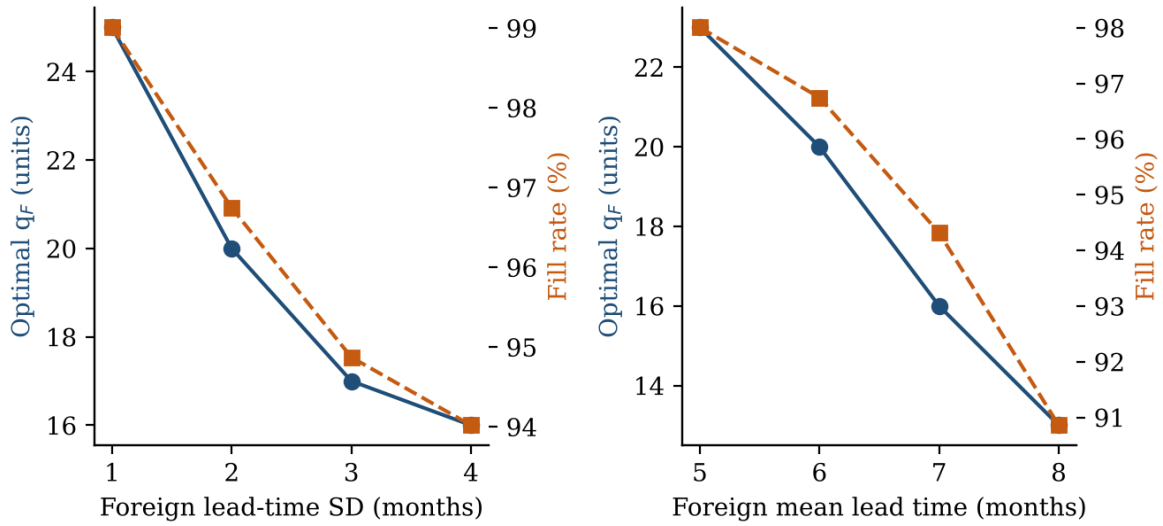


Fig 4: Optimal foreign order and resulting fill rate as functions of foreign lead-time variability (left) and mean (right).

Lead-time parameters have the largest effect on the allocation. When the standard deviation of the foreign lead time increases from 1 to 4 months, the optimal foreign order drops from 25 to 16 units, CVaR rises from 100.0 to 156.8 and the fill rate falls from 99.0 to 94.0 percent. A one-month increase in the mean lead time, from 6 to 7 months, lowers the optimal foreign order from 20 to 16 units; at 8 months it falls to 13. This is the effective-yield mechanism of Proposition 1: units that are likely to miss the window are paid for but provide no protection, so the buyer rationally buys fewer of them. The flip side is a falling fill rate, which shows that in 2021-type conditions buyers could not order their way out of shipping delays; the value of a shorter or more predictable lead time is substantial. Comparing the 1-month and 2-month SD cases, reducing foreign lead-time variability by one month lowers the objective by 20.2 LCU million, which is a benchmark for what the buyer could rationally pay for expedited or guaranteed delivery terms.

5.5. Domestic Price Premium and Capacity

Table 6: Effect of the domestic price and of domestic capacity

Setting	q_D / q_F	Foreign share %	E[C]	$CVaR_{0.95}$	Fill rate %
p_D = 0.95	34 / 20	37.0	55.54	139.67	96.7
p_D = 1.10	34 / 19	35.8	59.99	144.77	96.5
p_D = 1.25	34 / 19	35.8	64.79	149.53	96.5
p_D = 1.40	34 / 19	35.8	69.59	154.30	96.5
p_D = 1.60	34 / 19	35.8	75.98	160.68	96.5
K_D = 24	24 / 24	50.0	59.48	185.66	92.4
K_D = 34	34 / 20	37.0	55.54	139.67	96.7
K_D = 44	44 / 15	25.4	55.94	99.77	98.9
K_D = 54	50 / 8	13.8	55.72	82.37	99.5

Raising the domestic base price from 0.95 to 1.60 LCU million, so that the domestic unit costs roughly double the landed foreign cost, does not change the allocation: domestic capacity remains fully used. With a downtime penalty of 6 LCU million per unit, the reliability advantage of the domestic source outweighs even large price premiums, in line with Proposition 2. The premium is simply passed through to cost.

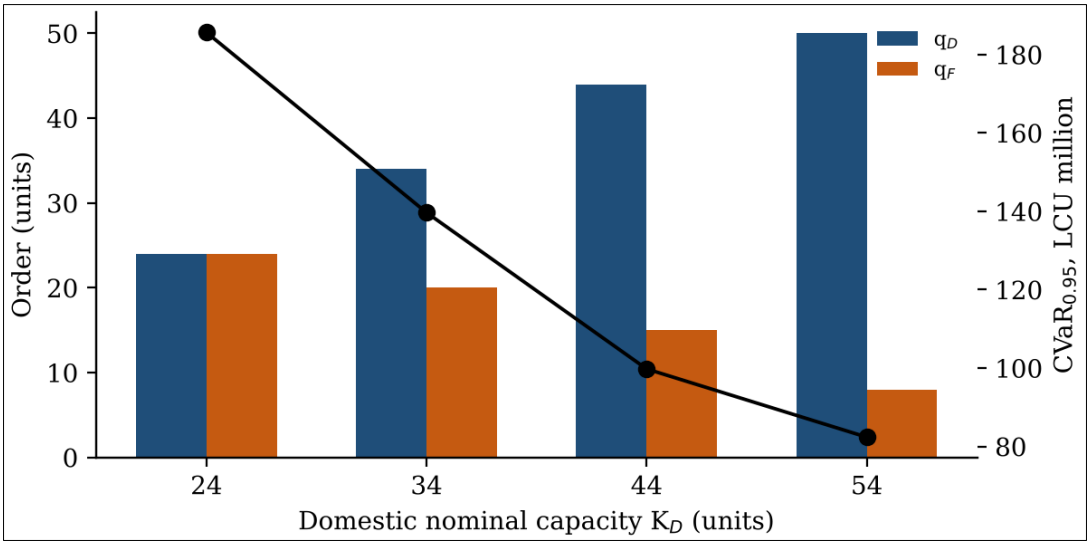


Fig 5: Optimal orders and CVaR as domestic qualified capacity expands.

Capacity, by contrast, is decisive (Figure 5). With only 24 units of domestic capacity the buyer must split evenly and CVaR reaches 185.7. Expanding domestic capacity to 44 units cuts the foreign share to 25.4 percent and CVaR to 99.8, almost halving tail cost relative to the 24-unit case, at nearly constant expected cost. At 54 units the buyer does not use all available capacity (it orders 50), yet still keeps 8 foreign units, because foreign supply hedges against the domestic capacity shortfall. Dual sourcing therefore remains optimal even when one source could in principle cover all demand.

6. Discussion

The results align with, and in places qualify, findings in the literature. The finding that the reliable source is filled to capacity despite a sizeable price premium is consistent with Dada *et al*. (2007) [72], who show that cost determines which suppliers qualify while reliability determines how much each supplies, and with Yu *et al*. (2009) [279] and Silbermayr and Minner (2014) [237], who find dual sourcing valuable when disruption risk is material. The allocation also resembles the tailored base-surge structure of Allon and Van Mieghem (2010) [30], with the difference that here the near source provides the base volume because it is reliable rather than because it is cheap.

The lead-time result qualifies standard inventory intuition. In continuous-review settings more variable lead times usually call for more safety stock, although Song (1994) [240] showed that the relationship is not always monotone. In the present setting the hard planning window and full prepayment turn lateness into a loss of yield, so more variable foreign lead times make each foreign unit less valuable and the optimal order falls. This mechanism differs from the order-splitting benefit discussed by Thomas and Tyworth (2006) [250], which relies on independent lead times reducing the variability of the effective replenishment time.

The weak allocation response to exchange-rate volatility is consistent with the real-options literature (Huchzermeier & Cohen, 1996; Kouvelis, 1999) [114, 138], in which volatility raises the value of flexibility mainly when production or sourcing can be switched after the uncertainty is resolved. Here the order is committed before the exchange rate is known, so volatility shifts the cost distribution rather than the optimal split. The risk-averse response, a modest increase in foreign units as insurance against joint domestic shortfall and disruption, differs from the order reduction typically found for risk-averse newsvendors with reliable supply (Chen *et al*., 2009) [63]; the difference arises because supply itself is uncertain, as in the random-capacity setting studied by Wu *et al*. (2013) [273].

Finally, the strong effect of domestic capacity supports the emphasis on supplier development and resilience in applied work on energy infrastructure in emerging markets (Agbabiaka *et al*., 2019; Ogunwole *et al*., 2021) [7, 193] and gives it a quantitative basis: in the calibrated instance, moving from 24 to 44 units of qualified domestic capacity nearly halves tail cost at almost unchanged expected cost. All three expected relationships of the conceptual model in Section 3 are therefore borne out by the numerical analysis.

7. Implications

7.1. Theoretical Implications

For research on supplier allocation, the analysis shows that lead-time risk and disruption risk can be represented jointly through an effective yield whenever a hard usage window applies, which connects stochastic lead-time models with the random-yield literature. It also shows that, when the order is committed once, exchange-rate volatility acts as a driver of tail risk rather than of allocation. Models that combine operational and financial hedging should therefore be evaluated with risk measures that capture the tail of the cost distribution rather than with expected cost alone.

7.2. Managerial Implications

The results suggest several guidelines for procuring critical equipment under conditions like those of 2021. The first is to allocate for reliability before price. When downtime penalties are large relative to price gaps, the reliable short-lead-time source should be filled to its qualified capacity before the

cheaper distant source is used. Price differences of the size typically observed between regional assemblers and global OEMs do not overturn this. This is consistent with resilience frameworks for critical gas and power infrastructure that place assured supply ahead of unit price (Agbabiaka *et al*., 2019; Ogunwole *et al*., 2021) [7, 193]. The second is to size the foreign order with an effective-yield rule. The foreign order should be set using the probability that a unit arrives usable within the window, not the nominal quantity. Ordering extra foreign units to compensate for lateness is counterproductive when late units are paid for in full. Shipment-level visibility of the kind described by Nnabueze *et al*. (2021) [159] provides the data needed to estimate this probability.

Third, investment in capacity and lead-time reliability is worth more than buffer volume. Qualifying additional domestic or regional capacity and negotiating firm delivery windows (with liquidated damages or staged payments tied to delivery) reduce tail risk far more than adjusting order quantities. The lead-time sensitivity provides a willingness-to-pay benchmark for such terms. Supplier development and relationship management (Ike *et al*., 2021) [116] and contract structures that allocate delay risk and liability clearly (Okonkwo *et al*., 2019; Uchechi & Ominyi, 2019) [202, 259] are the practical routes to these gains. Fourth, concentration limits work best as guardrails. An HHI cap in the region of 0.6 prevents single sourcing without forcing costly equal splits. Rigid 50/50 rules raised cost without improving tail risk in our calibration. Such caps fit naturally into compliance-based procurement governance for high-risk energy environments (Okonkwo, Ogunwole, *et al*., 2021) [198].

Fifth, currency risk is better handled through contracts and finance than through volume. Because exchange-rate volatility shifts cost distributions more than optimal shares, local-currency pricing, indexation formulas with caps and floors, and where possible forward cover are better tools than reallocating volume. Tiered treasury structures and CFO-led cross-border finance provide the organisational means to apply them (Dada *et al*., 2021a; Isiekwu *et al*., 2021) [73, 120]. Finally, fuel risk should be budgeted mainly through its effect on demand. Fuel prices affect equipment requirements via higher dispatch and asset stress more than via freight. Planning scenarios should link fuel price assumptions to failure and replacement forecasts. Predictive demand and maintenance analytics can supply these linked forecasts (Adaramola *et al*., 2018; Aifuwa *et al*., 2020) [2, 20].

7.3. Implementation and Policy Implications

Applying the model requires reliable inputs. Failure and demand forecasts can draw on predictive maintenance and condition monitoring (Mayo *et al*., 2021; Sunday *et al*., 2020) [152, 244], on inspection data from unmanned aerial vehicles, LiDAR and geographic information systems for grid and corridor assets (Dagodzo, 2018a, 2018b; Dagodzo & Ahiaeke Patrick, 2020, 2021a, 2021b) [75, 76, 77, 78, 79], and on machine-learning forecasting methods developed for revenue, cash flow, customers and markets (Basnet *et al*., 2021; Dada *et al*., 2021b; Oziri *et al*., 2020; Sanni *et al*., 2020a; Seyi-Lande *et al*., 2020; Tonoyan *et al*., 2021a, 2021b) [55, 74, 214, 226, 231, 254, 255], including comparative reviews of predictive forecasting for operational resource allocation (Unamma *et al*., 2018) [264]. The quality of these inputs depends in turn on data-quality and single-source-of-truth frameworks for reporting across organisational units, on the analytics capacity of the institutions that use them (Unamma *et al*., 2019, 2021) [265, 266], and on methods for extracting usable information from unstructured maintenance, procurement and financial records (Iziduh *et al*., 2020) [123]. Forecasting and risk-stratification techniques from reservoir engineering, public health and environmental risk modelling offer transferable methods for estimating rare-event probabilities (Azeez & Badmus, 2018; Lamidi & Olamide, 2018; Nwangwu *et al*., 2020; Oparah *et al*., 2021) [53, 141, 165, 210], as do data-driven policy and value-chain models in agricultural economics (Jones & Ominyi, 2021; Michael & Ogunsola, 2021c) [125, 157].

The data and decision tools must run on secure, well-governed information systems. Utilities face specific operational technology risks (Adegbite *et al*., 2020; Ahmed *et al*., 2021) [3, 19], and enterprise frameworks address security audit, intrusion detection, incident response, insider threat and data availability (Akeju *et al*., 2018; Dosunmu & Ogundele, 2019, 2020, 2021; Fadayomi *et al*., 2019; Mbonu *et al*., 2019) [22, 83, 84, 85, 94, 156]. Data protection governance, risk-based business intelligence and continuous performance visualisation support transparent procurement decisions (Mbonu *et al*., 2018, 2021a; Ogbole *et al*., 2021) [153, 154, 192], and IT support models determine whether such tools stay available across dispersed sites (Anyanwu, 2019, 2020) [41, 42].

On the financial side, procurement allocations interact with budgeting, accounting controls and treasury. Frameworks for strategic accounting, financial analytics, executive decision systems and cost management (Bola-Sadipe *et al*., 2019; Lawal & Oduleye, 2018a, 2019b, 2021b; Oduleye & Medon, 2021) [60, 142, 145, 147, 190] and for tax governance and transfer pricing in cross-border operations (Lawal & Oduleye, 2018b, 2019a) [143, 144] help translate the expected-cost and CVaR outputs into budgets. Treating the cost of poor quality as a governance metric offers a practical way to express the shortage and downtime penalty in terms that boards and regulators already monitor (Ashore-Onisemo *et al*., 2021) [49]. Internal audit and risk-based control models (Akomolafe & Agu, 2018, 2019a, 2019b, 2019c) [26, 27, 28, 29], ethics and compliance training and tamper-proof regulatory recordkeeping (Anichukwueze *et al*., 2020, 2021) [38, 39], and trade finance, transaction banking and relationship banking arrangements (Agboada *et al*., 2018b, 2020; Ezeako *et al*., 2019; Okafor *et al*., 2021) [8, 9, 93, 194] govern how letters of credit and foreign-exchange purchases are executed. Scenario analysis of fiscal measures such as finance bills can inform assumptions about import duties and currency policy (Akinola *et al*., 2020) [25].

Contracting and compliance also shape which allocations are feasible. Frameworks for cross-border mergers, post-merger compliance integration, privacy by design in corporate restructuring and multi-jurisdictional supply chain governance (Ominyi, 2020, 2021; Ominyi & Anichukwueze, 2020; Ominyi *et al*., 2021) [204, 205, 206], anti-money laundering, anti-bribery and financial crime controls (Atakpa, 2021; Ominyi & Anichukwueze, 2021) [50, 207], stamp duty and contract-review standardisation (Uchechi, 2018; Uchechi *et al*., 2021) [258, 263], and risk-based decision-making, traceability and lean distribution in regulated supply chains (Aneke & Adesemoye, 2020; Obukadata *et al*., 2021a, 2021b) [35, 186, 187] all bear on how foreign and domestic suppliers are qualified and paid.

Finally, critical equipment is installed and maintained in high-hazard environments, so procurement timing must be

coordinated with safety management. Research on heat stress, near-miss reporting, hazard recognition, safety culture, contractor governance, management walkthroughs, human error and incident prevention in industrial and construction settings (Arumosoye & Obriki, 2018, 2019, 2021; Obogo *et al*., 2020a, 2020b, 2020c; Obogo, Arumosoye, & Obriki, 2021; Obogo, Obriki, & Arumosoye, 2021; Obogo, Ozobu, *et al*., 2019a, 2019b; Obogo, Uduokhai, *et al*., 2019; Obriki & Arumosoye, 2018, 2019, 2020, 2021) [45, 46, 48, 173, 174, 175, 176, 178, 179, 182, 183, 184, 185], together with work on adaptive safety management and predictive compliance monitoring in aviation (Adeyelu, 2018, 2019) [5, 6], shows that late equipment deliveries often translate into compressed and riskier installation schedules. When supply failures do occur, root-cause and thematic analysis of major incidents provides a structured way to learn from them and to update the lead-time and disruption parameters used in the model (Okwesa *et al*., 2021) [203]. Standard operating procedures, lean methods, digital operations, joint-venture governance and compliance workflows (Agboada *et al*., 2018a, 2019; Ambali *et al*., 2021; Eyetsemitan *et al*., 2020, 2021) [10, 11, 31, 91, 92] provide the organisational routines through which the allocation policy proposed here can be institutionalised.

For policy makers, regulators and development finance institutions, the capacity result suggests that support for qualifying local and regional manufacturers of grid equipment can reduce utilities' exposure to currency and shipping shocks more effectively than measures that act only on prices, and that access to foreign exchange for letters of credit is itself a source of supply risk that public policy can reduce.

8. Limitations

The study has several limitations. The model is single-period and treats the order decision as made once, so it ignores rolling re-orders, the carry-over of late units and emergency purchases on the spot market, all of which would add flexibility and partly offset the penalty on late foreign units. Financial hedging is not modelled, so the buyer's only response to currency risk is operational. Supplier disruption is assumed independent of the exchange rate, whereas currency crises can coincide with import restrictions or foreign-exchange rationing. The demand response to fuel prices is captured by a single elasticity. Finally, the calibration is stylised: the parameters approximate 2021 conditions for an import-dependent utility but are not estimated from a particular firm's data, so the numerical results should be read as illustrative of the mechanisms rather than as forecasts.

9. Future Research

Several extensions would be valuable. A multi-period version with carry-over of late units, rolling re-orders and an emergency spot-purchase option would show how much of the penalty on late foreign units can be recovered through dynamic decisions. Adding forward contracts as decision variables would allow joint operational and financial optimisation in the spirit of Ding *et al*. (2007) [81]. Modelling dependence between currency crises and import disruption would test whether the case for domestic capacity strengthens further. Empirical calibration using utility maintenance records, failure data and supplier delivery histories would allow the model to be validated and used for actual tenders. Embedding the allocation in a wider capital-allocation process would let procurement risk be weighed against other uses of scarce foreign exchange (Lawal & Oduleye, 2021a) [146]. Finally, extending the model to several suppliers and several equipment classes, using the mixed-integer formulation based on (8), would make it applicable to full procurement portfolios.

10. Conclusion

This paper has developed a mean-CVaR decision model for dual sourcing of critical energy equipment that integrates exchange-rate risk, fuel-price risk, stochastic lead times, domestic capacity uncertainty, foreign shipment disruptions and supplier-concentration constraints. A newsvendor-type optimality condition shows that lead-time uncertainty enters as a loss of effective yield, which leads to the counterintuitive but practically important result that more variable foreign lead times call for smaller, not larger, foreign orders. In a calibrated 2021 setting, the optimal policy fills domestic capacity and sources about 37 percent of volume abroad, reducing expected cost by a quarter and tail cost by more than half relative to sole sourcing from the cheapest-landed supplier. Exchange-rate volatility mainly raises cost and tail risk, fuel volatility has a second-order effect on allocation, and the largest gains come from expanding reliable capacity and securing predictable delivery. The framework can be implemented with standard simulation and optimisation tools and offers procurement committees a transparent basis for balancing cost, concentration and reliability.

Appendix a. Simulation Procedure

For each scenario $n = 1,.., 20{,}000$: (i) draw correlated normals (Z_1, Z_2) and compute S and P by (1); (ii) draw demand by (2), truncated at zero; (iii) draw lognormal lead times with the stated means and standard deviations by moment matching; (iv) draw the disruption indicator, lost fraction and domestic capacity multiplier (truncated to [0.3, 1.2]); (v) for each candidate (q_D, q_F) compute (3) to (5). The same scenario set is used for all candidates within a run (common random numbers, fixed seed). Empirical CVaR is the mean of costs at or above the empirical 95th percentile. Sensitivity runs regenerate scenarios with the altered parameter and the same seed. Monte Carlo standard errors of expected cost at the optimum are below 0.2 LCU million, small relative to the differences reported.

References

1. Abu-Elanien AEB, Salama MMA. Asset management techniques for transformers. Electric Power Systems Research. 2010;80(4):456-464. doi:10.1016/j.epsr.2009.10.008
2. Adaramola TS, Fadero S, Gideon EN. Predictive maintenance and condition monitoring in critical power and energy infrastructure. Iconic Research and Engineering Journals. 2018;2(5):454-477. doi:10.64388/IREV2I5-1722489
3. Adegbite MP, Adebayo A, Ahmed MO. Securing operational technology networks in electric utilities: A systematic review of NERC CIP compliance and architectural threat mitigation. International Journal of Engineering and Modern Technology. 2020;6(3):103-146. doi:10.56201/ijemt.vol.6.no3.2020.pg103.146
4. Adeniji IO, Shittu H, Opara IS, Shittu MA. Grounding system design optimization for medium-voltage distribution networks in emerging power markets. Iconic

Research and Engineering Journals. 2020;3(11):547-565. doi:10.64388/IREV3I11-1714040
5. Adeyelu OO. A predictive compliance monitoring framework for detecting systemic safety risks through aviation consumer complaint data. Iconic Research and Engineering Journals. 2018;1(8):250-276. doi:10.64388/IREV1I8-1718478
6. Adeyelu OO. An adaptive safety management system implementation model for aerodromes in developing economy contexts. Iconic Research and Engineering Journals. 2019;3(4):628-654. doi:10.64388/IREV3I4-1718479
7. Agbabiaka J, Okonkwo CS, Ogunwole O, Mayo W, Okeke OT. Supply chain risk management model for EPC and gas processing projects. Iconic Research and Engineering Journals. 2019;3(2):968-980. doi:10.64388/IREV3I2-1713124
8. Agboada P, Anene UN, Ezeako R, Okoli IE. Partnership ecosystems in private banking: A review of advances in non-financial value-proposition design. International Journal of Engineering Technology Research & Management. 2020;4(11):96-115.
9. Agboada P, Ezeako R, Okoli IE, Ibeh AV. Distributorship and trade finance product design: A conceptual framework for new-to-bank growth in emerging markets. Iconic Research and Engineering Journals. 2018b;2(5):552-578. doi:10.64388/IREV2I5-1723312
10. Agboada P, Ezeako R, Okoli IE, Uzondu CS. Digital transformation in operations management: A review of advances in automation, analytics, and process redesign. International Journal of Engineering Technology Research & Management. 2018a;2(11):109-134.
11. Agboada P, Ezeako R, Okoli IE, Uzondu CS. Standard operating procedures as change infrastructure: A conceptual framework for sustaining operational improvement. Iconic Research and Engineering Journals. 2019;3(6):706-730. doi:10.64388/IREV3I6-1723313
12. Agrawal N, Nahmias S. Rationalization of the supplier base in the presence of yield uncertainty. Production and Operations Management. 1997;6(3):291-308. doi:10.1111/j.1937-5956.1997.tb00432.x
13. Ahiaeke Patrick MC, Okonkwo CS, Mayo W, Okeke OT. A GIS enabled framework for modern ERP procurement processes. International Journal of Multidisciplinary Research and Growth Evaluation. 2020;1(5):499-508. doi:10.54660/IJMRGE.2020.1.5.499-508
14. Ahiaeke Patrick, M. C., Okonkwo, C. S., Mayo, W., & Okeke, O. T. (2021). Model for data driven vendor evaluation and bid selection using geospatial intelligence. *Shodhshauryam, International Scientific Refereed Research Journal*, 4(4), 426-443. https://doi.org/10.32628/SHISRRJ214461
15. Ahiska SS, Appaji SR, King RE, Warsing DP. A Markov decision process-based policy characterization approach for a stochastic inventory control problem with unreliable sourcing. International Journal of Production Economics. 2013;144(2):485-496. doi:10.1016/j.ijpe.2013.03.021
16. Ahmed KS, Odejobi OD. Resource allocation model for energy-efficient virtual machine placement in data centers. IRE Journals. 2018b;2(3):1-10.
17. Ahmed KS, Odejobi OD, Oshoba TO. Algorithmic model for constraint satisfaction in cloud network resource allocation. IRE Journals. 2019;2(12):516-532.
18. Ahmed KS, Odejobi OD, Oshoba TO. Predictive model for cloud resource scaling using machine learning techniques. Journal of Frontiers in Multidisciplinary Research. 2020;1(1):173-183.
19. Ahmed MO, Adegbite MP, Adebayo A. Zero trust architecture for operational technology in North American critical infrastructure: A framework for implementation and resilience optimization. International Journal of Engineering and Modern Technology. 2021;7(1):66-113. doi:10.56201/ijemt.vol.7.no1.2021.pg66.113
20. Aifuwa SE, Oshoba TO, Ogbuefi E, Ike PN, Nnabueze SB, Olatunde-Thorpe J. Predictive analytics models enhancing supply chain demand forecasting accuracy and reducing inventory management inefficiencies. International Journal of Multidisciplinary Research and Growth Evaluation. 2020;1(3):171-181. doi:10.54660/.IJMRGE.2020.1.3.171-181
21. Aissaoui N, Haouari M, Hassini E. Supplier selection and order lot sizing modeling: A review. Computers & Operations Research. 2007;34(12):3516-3540. doi:10.1016/j.cor.2006.01.016
22. Akeju B, Edivri J, Ogbole JI, Okoruwa PO, Fadayomi O, Abolaji TO. Conceptual model for insider threat classification and risk modeling in complex digital systems. Iconic Research and Engineering Journals. 2018;1(9):476-492. doi:10.64388/IREV1I9-1713778
23. Akin-Oluyomi OT, Atima ME, Akinleye OK, Akokodaripon DA. Using Tableau and Excel for comprehensive profitability analysis in retail procurement operations. International Journal of Multidisciplinary Research and Growth Evaluation. 2020;1(5):385-393.
24. Akinleye, O. K., & Adeyoyin, O. (2021). Process automation framework for enhancing procurement efficiency and transparency. *Shodhshauryam, International Scientific Refereed Research Journal*, 4(4), 356-387.
25. Akinola AS, Farounbi BO, Onyelucheya OP, Okafor CM. Translating finance bills into strategy: Sectoral impact mapping and regulatory scenario analysis. Journal of Frontiers in Multidisciplinary Research. 2020;1(1):102-111.
26. Akomolafe O, Agu MU. A conceptual model for enhancing internal audit quality through technology-enabled risk assessment frameworks. Iconic Research and Engineering Journals. 2018;1(9):458-475.
27. Akomolafe O, Agu MU. A conceptual framework for developing risk-based internal control models in the insurance and banking sectors. Iconic Research and Engineering Journals. 2019a;2(8):335-354.
28. Akomolafe O, Agu MU. A review of data-driven risk evaluation models for emerging market financial institutions. Iconic Research and Engineering Journals. 2019b;3(6):433-448.
29. Akomolafe O, Agu MU. Advances in financial resilience through integrated governance and compliance strategies. Iconic Research and Engineering Journals. 2019c;2(10):607-620.
30. Allon G, Van Mieghem JA. Global dual sourcing: Tailored base-surge allocation to near- and offshore

production. Management Science. 2010;56(1):110-124. doi:10.1287/mnsc.1090.1099
31. Ambali KB, Eyetsemitan RA, Oyeleye AO, Fadayomi O. Lean Six Sigma for small enterprises: A systematic review and Lite-DMAIC adaptation framework for resource-constrained organizations. Iconic Research and Engineering Journals. 2021;5(5):562-583. doi:10.64388/IREV5I5-1716957
32. Aminu-Ibrahim AY, Ogbete JC, Ambali KB. Capital project delivery models for high risk healthcare infrastructure in developing national health systems. Iconic Research and Engineering Journals. 2019;2(10):626-649. doi:10.64388/IREV2I10-1713588
33. Aminu-Ibrahim AY, Ogbete JC, Ambali KB. Program management models for coordinated multi-site healthcare infrastructure expansion projects. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(6):661-678.
34. Aneke OB, Adesemoye AC. Toward an integrated conceptual framework for traceability and chain-of-custody integrity in pharmaceutical distribution. Iconic Research and Engineering Journals. 2019;3(4):655-672.
35. Aneke OB, Adesemoye AC. A conceptual framework for risk-based decision-making in good manufacturing practice environments. Iconic Research and Engineering Journals. 2020;4(6):325-341.
36. Aneke OB, Adesemoye AC. Reframing trade and import compliance: A conceptual model for risk-based interdiction of illicit medical products. International Journal of Scientific Research in Science and Technology. 2021;8(6):1226-1248.
37. Anene UN. Supply chain resilience and risk management in global distribution networks: A review of advances post-disruption. International Journal of Engineering Technology Research & Management. 2021;5(11):137-161.
38. Anichukwueze CC, Osuji VC, Oguntegbe EE. Designing ethics and compliance training frameworks to drive measurable cultural and behavioral change. International Journal of Multidisciplinary Research and Growth Evaluation. 2020;1(3):205-220.
39. Anichukwueze CC, Osuji VC, Oguntegbe EE. Blockchain-based architectures for tamper-proof regulatory recordkeeping and real-time audit readiness. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(6):485-504.
40. Anupindi R, Akella R. Diversification under supply uncertainty. Management Science. 1993;39(8):944-963. doi:10.1287/mnsc.39.8.944
41. Anyanwu, K. C. E. (2019). *Developing a maturity model for standardizing IT support operations across geographically distributed multi-office organizations.* Iconic Research and Engineering Journals, 3(5)., 580-598.
42. Anyanwu KCE. Balancing cost and operational continuity in hybrid remote and on-site IT support for multi-branch SMEs. International Journal of Economics and Financial Management. 2020;5(2):132-148. doi:10.56201/ijefm.v5.no2.2020.pg132.148
43. Arrow KJ, Harris T, Marschak J. Optimal inventory policy. Econometrica. 1951;19(3):250-272. doi:10.2307/1906813
44. Artzner P, Delbaen F, Eber JM, Heath D. Coherent measures of risk. Mathematical Finance. 1999;9(3):203-228. doi:10.1111/1467-9965.00068
45. Arumosoye OM, Obriki OD. Development of an integrated heat stress risk conceptual model for industrial operations in extreme environments. Iconic Research and Engineering Journals. 2018;1(12):141-160. doi:10.64388/IREV1I12-1714415
46. Arumosoye OM, Obriki OD. Systematic review of near-miss and hazard observation data utilization in industrial safety management. Iconic Research and Engineering Journals. 2019;3(2):981-999. doi:10.64388/IREV3I2-1714417
47. Arumosoye OM, Obriki OD. A governance-oriented conceptual model for contractor safety performance in multi-contract industrial projects. International Journal of Multidisciplinary Research and Growth Evaluation. 2020;1(5):728-740. doi:10.54660/.IJMRGE.2020.1.5.728-740
48. Arumosoye OM, Obriki OD. Organizational learning-based conceptual maturity model for continuous safety performance improvement. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(1):970-980. doi:10.54660/.IJMRGE.2021.2.1.970-980
49. Ashore-Onisemo, Funmilayo, Unamma, Uchechi Mary-Linda, Iziduh, Ebehiremen Faith. Reconceptualizing cost of poor quality as a cross-sector governance metric. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(6):1119-1136. doi:10.54660/.IJMRGE.2021.2.6.1119-1136
50. Atakpa, M. I. (2021). A review of predictive analytics models for anti-money laundering detection in commercial banking systems. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, 7(2), 778-804. https://doi.org/10.32628/CSEIT2064813
51. Atta S, Tofah P, Adenuga OM. Advances in non-destructive testing methods for weld integrity evaluation in high-capacity power infrastructure. International Journal of Engineering and Modern Technology. 2021;7(1):20-47. doi:10.56201/ijemt.vol.7.no1.2021.pg20.47
52. Atta S, Tofah P, Kankam MA, Adenuga OM. A critical review of NDT-based integrity management and corrosion risk assessment strategies for refinery process equipment. International Journal of Engineering and Modern Technology. 2020;6(2):19-46. doi:10.56201/ijemt.vol.6.no2.2020.pg19.46
53. Azeez LO, Badmus OB. Data-driven framework for predicting subsurface contamination pathways in complex remediation projects. Iconic Research and Engineering Journals. 2018;2(5):312-335.
54. Babich V, Burnetas AN, Ritchken PH. Competition and diversification effects in supply chains with supplier default risk. Manufacturing & Service Operations Management. 2007;9(2):123-146. doi:10.1287/msom.1060.0122
55. Basnet, A., Oghenemaiga, E., & Anene, U. N. (2021). Audience segmentation and forecasting models for enhancing targeted digital marketing effectiveness.

Shodhshauryam, International Scientific Refereed Research Journal, 4(5), 279-305.
56. Basten RJI, van Houtum GJ. System-oriented inventory models for spare parts. Surveys in Operations Research and Management Science. 2014;19(1):34-55. doi:10.1016/j.sorms.2014.05.002
57. Berling P, Martínez-de-Albéniz V. Optimal inventory policies when purchase price and demand are stochastic. Operations Research. 2011;59(1):109-124. doi:10.1287/opre.1100.0862
58. Billinton R, Allan RN. Reliability evaluation of power systems (2nd ed.). Plenum Press; 1996. doi:10.1007/978-1-4899-1860-4
59. Birge JR, Louveaux F. Introduction to stochastic programming (2nd ed.). Springer; 2011.
60. Bola-Sadipe D, Aliliele C, Eboh EE. Conceptual model for strategic accounting systems strengthening financial transparency and regulatory compliance. IRE Journals. 2019;3(6):535-564. doi:10.64388/IREV3I6-1715327
61. Caldentey R, Haugh M. Optimal control and hedging of operations in the presence of financial markets. Mathematics of Operations Research. 2006;31(2):285-304. doi:10.1287/moor.1050.0179
62. Chen X, Sim M, Simchi-Levi D, Sun P. Risk aversion in inventory management. Operations Research. 2007;55(5):828-842. doi:10.1287/opre.1070.0429
63. Chen, Y., Xu, M., & Zhang, Z. G. (2009). A risk-averse newsvendor model under the CVaR criterion. *Operations Research*, 57(4), 1040-1044. https://doi.org/10.1287/opre.1080.0603
64. Choi, T.-M., Li, D., & Yan, H. (2008). Mean-variance analysis for the newsvendor problem. *IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans*, 38(5), 1169-1180. https://doi.org/10.1109/TSMCA.2008.2001057
65. Chopra S, Meindl P. Supply chain management: Strategy, planning, and operation (6th ed.). Pearson; 2016.
66. Chopra S, Reinhardt G, Mohan U. The importance of decoupling recurrent and disruption risks in a supply chain. Naval Research Logistics. 2007;54(5):544-555. doi:10.1002/nav.20228
67. Chopra S, Sodhi MS. Managing risk to avoid supply-chain breakdown. MIT Sloan Management Review. 2004;46(1):53-61.
68. Chowdhury AA, Koval DO. Development of probabilistic models for computing optimal distribution substation spare transformers. IEEE Transactions on Industry Applications. 2005;41(6):1493-1498. doi:10.1109/TIA.2005.858310
69. Christopher M, Peck H. Building the resilient supply chain. The International Journal of Logistics Management. 2004;15(2):1-14. doi:10.1108/09574090410700275
70. Ciarallo FW, Akella R, Morton TE. A periodic review, production planning model with uncertain capacity and uncertain demand: Optimality of extended myopic policies. Management Science. 1994;40(3):320-332. doi:10.1287/mnsc.40.3.320
71. Craighead CW, Blackhurst J, Rungtusanatham MJ, Handfield RB. The severity of supply chain disruptions: Design characteristics and mitigation capabilities. Decision Sciences. 2007;38(1):131-156. doi:10.1111/j.1540-5915.2007.00151.x
72. Dada M, Petruzzi NC, Schwarz LB. A newsvendor's procurement problem when suppliers are unreliable. Manufacturing & Service Operations Management. 2007;9(1):9-32.
73. Dada T, Isiekwu CP, Oluwo K. Advances in multinational cash flow consolidation and FX risk control using tiered treasury architecture. Iconic Research and Engineering Journals. 2021a;4(11):601-620. doi:10.64388/IREV4I11-1714351
74. Dada T, Isiekwu CP, Oluwo K. Designing CRM-based sales forecasting models for multichannel lending institutions. Iconic Research and Engineering Journals. 2021b;5(3):451-466. doi:10.64388/IREV5I3-1714352
75. Dagodzo D. A conceptual framework for UAV integration into national power grid inspection programs. Iconic Research and Engineering Journals. 2018a;2(5):391-412. doi:10.64388/IREV2I5-1716082
76. Dagodzo D. A review of UAV applications in electrical transmission line inspection: Methods, technologies, and challenges. Iconic Research and Engineering Journals. 2018b;2(6):234-254. doi:10.64388/IREV2I6-1716083
77. Dagodzo D, Ahiaeke Patrick MC. UAV-based pipeline and corridor monitoring: A review of current practices and emerging technologies. Iconic Research and Engineering Journals. 2020;3(10):574-597. doi:10.64388/IREV3I10-1716084
78. Dagodzo D, Ahiaeke Patrick MC. A review of GIS applications in utility asset management and infrastructure planning. Iconic Research and Engineering Journals. 2021a;5(3):468-492. doi:10.64388/IREV5I3-1716085
79. Dagodzo, D., & Ahiaeke Patrick, M. C. (2021b). An integrated framework for UAV, LiDAR, and GIS in infrastructure corridor management. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, 7(5), 497-524. https://doi.org/10.32628/CSEIT217566
80. Dasu, S., & Li, L. (1997). Optimal operating policies in the presence of exchange rate variability. *Management Science*, 43(5), 705-722. https://doi.org/10.1287/mnsc.43.5.705
81. Ding Q, Dong L, Kouvelis P. On the integration of production and financial hedging decisions in global markets. Operations Research. 2007;55(3):470-489.
82. Dixit AK, Pindyck RS. Investment under uncertainty. Princeton University Press; 1994.
83. Dosunmu AA, Ogundele PO. Security audit and enterprise risk assessment frameworks for resilient information systems. Iconic Research and Engineering Journals. 2019;3(5):434-447. doi:10.64388/IREV3I5-1713225
84. Dosunmu AA, Ogundele PO. Intrusion detection and prevention models for enhancing organizational cyber defense effectiveness. Iconic Research and Engineering Journals. 2020;4(6):310-324. doi:10.64388/IREV4I6-1713226
85. Dosunmu, A. A., & Ogundele, P. O. (2021). Incident response and digital forensics strategies for rapid cyber attack containment. *Gyanshauryam, International Scientific Refereed Research Journal*, 4(4), 239-258.
86. Eberhard A, Foster V, Briceño-Garmendia C, Ouedraogo F, Camos D, Shkaratan M. Underpowered: The state of the power sector in Sub-Saharan Africa (Africa Infrastructure Country Diagnostic Background

Paper 6). World Bank; 2008. Available from: http://hdl.handle.net/10986/7833
87. Eberhard A, Gratwick K, Morella E, Antmann P. Independent power projects in Sub-Saharan Africa: Lessons from five key countries (Directions in Development: Energy and Mining). World Bank; 2016. doi:10.1596/978-1-4648-0800-5
88. Eeckhoudt L, Gollier C, Schlesinger H. The risk-averse (and prudent) newsboy. Management Science. 1995;41(5):786-794. doi:10.1287/mnsc.41.5.786
89. Efobi, O. Z., Akinleye, O. K., & Fasawe, O. (2021). Framework for data-driven operations management and performance improvement in educational institutions. *Gyanshauryam, International Scientific Refereed Research Journal*, 4(6), 127-158.
90. Emodi NV, Boo KJ. Sustainable energy development in Nigeria: Current status and policy options. Renewable and Sustainable Energy Reviews. 2015;51:356-381. doi:10.1016/j.rser.2015.06.016
91. Eyetsemitan RA, Ambali KB, Oyeleye AO, Fadayomi O. Multi-stakeholder governance alignment in joint venture operations: A conceptual framework for coordinating business processes in highly regulated environments. Iconic Research and Engineering Journals. 2020;4(4):418-441. doi:10.64388/IREV4I4-1716955
92. Eyetsemitan RA, Ambali KB, Oyeleye AO, Fadayomi O. Translating tax and regulatory requirements into SME compliance workflows: A conceptual framework for implementing IAS 12, VAT, PAYE, and withholding tax. Iconic Research and Engineering Journals. 2021;4(11):621-641. doi:10.64388/IREV4I11-1716956
93. Ezeako R, Okoli IE, Uzondu CS, Ibeh AV. Relationship banking performance: A conceptual framework for portfolio growth and profitability acceleration. International Journal of Engineering Technology Research & Management. 2019;3(11):132-151.
94. Fadayomi O, Abolaji TO, Edivri J, Ogbole JI, Okoruwa PO, Akeju B. Risk-based cybersecurity assurance and data availability: Limitations, advances and future research opportunities. Iconic Research and Engineering Journals. 2019;2(12):602-617. doi:10.64388/IREV2I12-1713779
95. Falemi A, Akhigbe R, Akin-Oluyomi OT. A conceptual supply chain talent development model for capability building across distributed operations. International Journal of Multidisciplinary Research and Growth Evaluation. 2020;1(5):439-456. doi:10.54660/.ijmrge.2020.1.5.439-456
96. Federgruen A, Yang N. Selecting a portfolio of suppliers under demand and supply risks. Operations Research. 2008;56(4):916-936.
97. Fu, Q., Lee, C.-Y., & Teo, C.-P. (2010). Procurement management using option contracts: Random spot price and the portfolio effect. *IIE Transactions*, 42(11), 793-811. https://doi.org/10.1080/07408171003670983
98. Fukuda Y. Optimal policies for the inventory problem with negotiable leadtime. Management Science. 1964;10(4):690-708. doi:10.1287/mnsc.10.4.690
99. Gaur V, Seshadri S. Hedging inventory risk through market instruments. Manufacturing & Service Operations Management. 2005;7(2):103-120. doi:10.1287/msom.1040.0061
100. Gerchak Y, Parlar M. Yield randomness, cost tradeoffs, and diversification in the EOQ model. Naval Research Logistics. 1990;37(3):341-354. doi:10.1002/nav.3800370301
101. Ghodsypour, S. H., & O'Brien, C. (1998). *A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming.* International Journal of Production Economics, 56-57, 199-212. https://doi.org/10.1016/S0925-5273(97)00009-1
102. Gideon EN, Adaramola TS, Fadero S. Reliability engineering and failure analysis in complex engineering systems. Iconic Research and Engineering Journals. 2019;2(11):703-727. doi:10.64388/IREV2I11-1722490
103. Glasserman P. Monte Carlo methods in financial engineering. Springer; 2004.
104. Goel A, Gutierrez GJ. Multiechelon procurement and distribution policies for traded commodities. Management Science. 2011;57(12):2228-2244.
105. Gotoh J, Takano Y. Newsvendor solutions via conditional value-at-risk minimization. European Journal of Operational Research. 2007;179(1):80-96. doi:10.1016/j.ejor.2006.03.022
106. Haksöz, Ç., Seshadri S. Supply chain operations in the presence of a spot market: A review with discussion. Journal of the Operational Research Society. 2007;58(11):1412-1429. doi:10.1057/palgrave.jors.2602401
107. Hamilton JD. Oil and the macroeconomy since World War II. Journal of Political Economy, 91(2), 228-248. 1983. doi:10.1086/261140
108. Hendricks KB, Singhal VR. The effect of supply chain glitches on shareholder wealth. Journal of Operations Management. 2003;21(5):501-522. doi:10.1016/j.jom.2003.02.003
109. Hendricks KB, Singhal VR. An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm. Production and Operations Management. 2005;14(1):35-52.
110. Henig M, Gerchak Y. The structure of periodic review policies in the presence of random yield. Operations Research. 1990;38(4):634-643. doi:10.1287/opre.38.4.634
111. Ho, W., Xu, X., & Dey, P. K. (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *European Journal of Operational Research*, 202(1), 16-24. https://doi.org/10.1016/j.ejor.2009.05.009
112. Ho, W., Zheng, T., Yildiz, H., & Talluri, S. (2015). Supply chain risk management: A literature review. *International Journal of Production Research*, 53(16), 5031-5069. https://doi.org/10.1080/00207543.2015.1030467
113. Hu, X., Gurnani, H., & Wang, L. (2013). Managing risk of supply disruptions: Incentives for capacity restoration. *Production and Operations Management*, 22(1), 137-150. https://doi.org/10.1111/j.1937-5956.2012.01342.x
114. Huchzermeier A, Cohen MA. Valuing operational flexibility under exchange rate risk. Operations Research. 1996;44(1):100-113. doi:10.1287/opre.44.1.100
115. Huiskonen J. Maintenance spare parts logistics: Special characteristics and strategic choices. International

Journal of Production Economics. 2001;71(1-3):125-133. doi:10.1016/S0925-5273(00)00112-2
116. Ike PN, Ogbuefi E, Nnabueze SB, Olatunde-Thorpe J, Aifuwa SE, Oshoba TO, *et al*. Supplier relationship management strategies fostering innovation, collaboration, and resilience in global supply chain ecosystems. International Journal of Multidisciplinary Evolutionary Research. 2021;2(2):52-62. doi:10.54660/IJMER.2021.2.2.52-62
117. International Energy Agency. Africa energy outlook 2019. IEA; 2019. Available from: https://www.iea.org/reports/africa-energy-outlook-2019
118. International Energy Agency. Net zero by 2050: A roadmap for the global energy sector. IEA; 2021a. Available from: https://www.iea.org/reports/net-zero-by-2050
119. International Energy Agency. The role of critical minerals in clean energy transitions. IEA; 2021b. Available from: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions
120. Isiekwu CP, Oluwo K, Dada T. A conceptual model for CFO-led strategic finance in joint venture and cross-border partnerships. Iconic Research and Engineering Journals. 2021;4(7):383-400. doi:10.64388/IREV4I7-1714350
121. Ivanov D, Dolgui A. Viability of intertwined supply networks: Extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak. International Journal of Production Research. 2020;58(10):2904-2915. doi:10.1080/00207543.2020.1750727
122. Ivanov D, Dolgui A, Sokolov B. The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics. International Journal of Production Research. 2019;57(3):829-846. doi:10.1080/00207543.2018.1488086
123. Iziduh, Ebehiremen Faith, Ashore-Onisemo, Funmilayo, Unamma, Uchechi Mary-Linda. Natural language processing for unstructured records in finance and public services: A review. International Journal of Multidisciplinary Research and Growth Evaluation. 2020;1(5):1215-1229. doi:10.54660/.IJMRGE.2020.1.5.1215-1229
124. Jones BC, Ominyi M. A review of legal barriers to import-export participation for Nigerian entrepreneurs. IIARD International Journal of Economics and Business Management. 2020;6(4):51-70. doi:10.56201/ijebm.vol.6.no4.2020.pg51.70
125. Jones BC, Ominyi M. Developing a conceptual framework linking West African agricultural value chains to household economic stability. International Journal of Economics and Financial Management. 2021;6(2):89-114. doi:10.56201/ijefm.v6.no2.2021.pg89.114
126. Jorion P. Value at risk: The new benchmark for managing financial risk (3rd ed.). McGraw-Hill; 2007.
127. Kaplan RS. A dynamic inventory model with stochastic lead times. Management Science. 1970;16(7):491-507. doi:10.1287/mnsc.16.7.491
128. Kazaz B, Dada M, Moskowitz H. Global production planning under exchange-rate uncertainty. Management Science. 2005;51(7):1101-1119.
129. Kennedy WJ, Patterson JW, Fredendall LD. An overview of recent literature on spare parts inventories. International Journal of Production Economics. 2002;76(2):201-215. doi:10.1016/S0925-5273(01)00174-8
130. Khouja M. The single-period (news-vendor) problem: Literature review and suggestions for future research. Omega. 1999;27(5):537-553. doi:10.1016/S0305-0483(99)00017-1
131. Kilian L. Not all oil price shocks are alike: Disentangling demand and supply shocks in the crude oil market. American Economic Review. 2009;99(3):1053-1069. doi:10.1257/aer.99.3.1053
132. Kleindorfer PR, Saad GH. Managing disruption risks in supply chains. Production and Operations Management. 2005;14(1):53-68.
133. Kleywegt AJ, Shapiro A, Homem-de-Mello T. The sample average approximation method for stochastic discrete optimization. SIAM Journal on Optimization. 2002;12(2):479-502. doi:10.1137/S1052623499363220
134. Kogut B, Kulatilaka N. Operating flexibility, global manufacturing, and the option value of a multinational network. Management Science. 1994;40(1):123-139. doi:10.1287/mnsc.40.1.123
135. Komi NM. Hybrid deep learning for wind power forecasting: From grid stability to market equity for small generators. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(6):989-1014. doi:10.54660/.IJMRGE.2021.2.6.989-1014
136. Komi NM, Adamolekun A. Interpretable machine learning for early failure prediction in distributed renewable energy assets. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(6):1015-1038. doi:10.54660/.IJMRGE.2021.2.6.1015-1038
137. Komi NM, Adeniji IO. Co-optimizing technical performance and community affordability in smart solar microgrids for underserved regions. International Journal of Engineering and Modern Technology. 2020;6(3):173-212. doi:10.56201/ijemt.vol.6.no3.2020.pg173.212
138. Kouvelis, P. (1999). Global sourcing strategies under exchange rate uncertainty. In S. Tayur, R. Ganeshan, & M. Magazine (Eds.), Quantitative models for supply chain management (pp. 625-667). Springer. https://doi.org/10.1007/978-1-4615-4949-9_20
139. Kouvelis, P., Li, R., & Ding, Q. (2013). Managing storable commodity risks: The role of inventory and financial hedge. *Manufacturing & Service Operations Management*, 15(3), 507-521. https://doi.org/10.1287/msom.2013.0433
140. Krokhmal P, Palmquist J, Uryasev S. Portfolio optimization with conditional value-at-risk objective and constraints. Journal of Risk. 2002;4(2):43-68. doi:10.21314/JOR.2002.057
141. Lamidi OBA, Olamide A. Spatially explicit risk modeling framework for tracking subsurface contaminant migration in data-limited remediation sites. Iconic Research and Engineering Journals. 2018;2(6):178-198.
142. Lawal OA, Oduleye TE. A conceptual model for financial analytics driven enterprise value creation in technology firms. Iconic Research and Engineering Journals. 2018a;2(2).

143. Lawal OA, Oduleye TE. A review and conceptual framework for tax governance and cross-border compliance analytics. Iconic Research and Engineering Journals. 2018b;2(5).
144. Lawal OA, Oduleye TE. A conceptual risk assessment model for transfer pricing in multinational corporations. Iconic Research and Engineering Journals. 2019a;2(12).
145. Lawal OA, Oduleye TE. Conceptualizing data driven executive decision systems for strategic financial planning. Iconic Research and Engineering Journals. 2019b;3(3).
146. Lawal, O. A., & Oduleye, T. E. (2021a). A conceptual decision model for capital allocation using financial analytics. *Gyanshauryam, International Scientific Refereed Research Journal*, 4(2), 269-295.
147. Lawal, O. A., & Oduleye, T. E. (2021b). Aligning financial planning analytics with corporate strategy: A conceptual integration model. *Shodhshauryam, International Scientific Refereed Research Journal*, 4(3), 319-346.
148. Li, W., Vaahedi, E., & Mansour, Y. (1999). Determining number and timing of substation spare transformers using a probabilistic cost analysis approach. *IEEE Transactions on Power Delivery*, 14(3), 934-939. https://doi.org/10.1109/61.772337
149. Lowe, T. J., Wendell, R. E., & Hu, G. (2002). Screening location strategies to reduce exchange rate risk. *European Journal of Operational Research*, 136(3), 573-590. https://doi.org/10.1016/S0377-2217(01)00065-0
150. Markowitz H. Portfolio selection. Journal of Finance. 1952;7(1):77-91.
151. Martínez-de-Albéniz V, Simchi-Levi D. A portfolio approach to procurement contracts. Production and Operations Management. 2005;14(1):90-114.
152. Mayo, W., Ogbole, J. I., Okoruwa, P. O., & Babatope, O. M. (2021). Designing an AI-predictive maintenance model for e-commerce systems using machine learning and cloud analytics. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, 7(5), 416-440. https://doi.org/10.32628/IJSRCSEIT
153. Mbonu IS, Aliliele C, Iwuanyanwu U, Oluoha OM. A conceptual framework for legal and ethical risk modeling in enterprise data protection governance systems. Iconic Research and Engineering Journals. 2018;2(2):207-226. doi:10.64388/IREV2I2-1714911
154. Mbonu IS, Aliliele C, Iwuanyanwu U, Uzoka E. A conceptual framework for risk based business intelligence architecture in financial technology platforms. International Journal of Multidisciplinary Research and Growth Evaluation. 2021a;2(6):731-746. doi:10.54660/.IJMRGE.2021.2.6.731-746
155. Mbonu IS, Iwuanyanwu U, Aliliele C, Uzoka E. A conceptual framework for agile supply chain digital transformation with embedded IT risk and ISO compliance controls. Iconic Research and Engineering Journals. 2020a;3(11):566-593. doi:10.64388/IREV3I11-1714916
156. Mbonu IS, Iwuanyanwu U, Uzoka E, Oluoha OM. Advances in enterprise log analytics and automated incident response architectures using Python and SIEM platforms. Iconic Research and Engineering Journals. 2019;3(2):1000-1019. doi:10.64388/IREV3I2-1714915
157. Michael, O. N., & Ogunsola, O. E. (2021c). Impact of data-driven agricultural policy models on food production efficiency and resource optimization. *Gyanshauryam, International Scientific Refereed Research Journal*, 4(4), 182-208.
158. Minner, S. (2003). Multiple-supplier inventory models in supply chain management: A review. *International Journal of Production Economics*, 81-82, 265-279.
159. Nnabueze SB, Ike PN, Olatunde-Thorpe J, Aifuwa SE, Oshoba TO, Ogbuefi E, *et al*. End-to-end visibility frameworks improving transparency, compliance, and traceability across complex global supply chain operations. International Journal of Multidisciplinary Futuristic Development. 2021;2(2):50-60. doi:10.54660/IJMFD.2021.2.2.50-60
160. Notteboom TE. The time factor in liner shipping services. Maritime Economics & Logistics. 2006;8(1):19-39. doi:10.1057/palgrave.mel.9100148
161. Notteboom T, Pallis T, Rodrigue JP. Disruptions and resilience in global container shipping and ports: The COVID-19 pandemic versus the 2008-2009 financial crisis. Maritime Economics & Logistics. 2021;23(2):179-210. doi:10.1057/s41278-020-00180-5
162. Nwafor MI, Uduokhai DO, Ifechukwu GO, Stephen D, Aransi AN. Developing an analytical framework for enhancing efficiency in public infrastructure delivery systems. Iconic Research and Engineering Journals. 2019b;2(11):657-670.
163. Nwangwu, C. V., Duvbiama-Owasanoye, O. A., & Akano, O. A. (2021). Aligning capital budgeting with field development execution in the upstream petroleum sector. *Gyanshauryam, International Scientific Refereed Research Journal*, 4(4), 259-282.
164. Nwangwu CV, Duvbiama-Owasanoye OA, Onwumere A. A framework for operational integrity in high-risk drilling: Balancing productivity and safety compliance. Iconic Research and Engineering Journals. 2018;2(5):436-453.
165. Nwangwu CV, Duvbiama-Owasanoye OA, Onwumere A. High-fidelity reservoir forecasting: A technical review of multimodal modeling for long-term production estimates. Iconic Research and Engineering Journals. 2020;4(5):390-409.
166. Obetta PC. A risk-based inspection concept for fitness-for-service assessment of ageing pressure vessels on offshore joint venture facilities. Iconic Research and Engineering Journals. 2018;2(5):497-520. doi:10.64388/IREV2I5-1722578
167. Obetta PC. Reliability and integrity management of fired heaters, boilers and furnaces in upstream oil and gas: A review. Iconic Research and Engineering Journals. 2019;3(5):599-626. doi:10.64388/IREV3I5-1722580
168. Obetta PC. A reliability-centered maintenance (RCM) concept for static mechanical equipment in offshore oil and gas operations. International Journal of Multidisciplinary Futuristic Development. 2020;1(1):74-91. doi:10.54660/IJMFD.2020.1.1.74-91
169. Obetta PC, Ninduwezuor-Ehiobu N. A condition-based maintenance concept for CALM buoy bearings and swivels to improve offshore crude export availability. Iconic Research and Engineering Journals. 2018;2(6):385-410. doi:10.64388/IREV2I6-1722579
170. Obetta PC, Ninduwezuor-Ehiobu N. Integrity assurance of FSO turret mooring systems: A review of inspection,

monitoring and life-extension strategies. Iconic Research and Engineering Journals. 2019;3(6):599-629. doi:10.64388/IREV3I6-1722581
171. Obetta PC, Ninduwezuor-Ehiobu N, Olisakwe HC. Corrosion management and material selection for crude oil export equipment in marine environments: A review. International Journal of Multidisciplinary Futuristic Development. 2020;1(1):92-110. doi:10.54660/IJMFD.2020.1.1.92-110
172. Obetta PC, Ninduwezuor-Ehiobu N, Olisakwe HC. Advances in non-intrusive inspection of pressure vessels: Reducing shutdown frequency and OPEX in oil and gas operations. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(6):1137-1153. doi:10.54660/.IJMRGE.2021.2.6.1137-1153
173. Obogo SF, Arumosoye OM, Obriki OD. Advances in internal QHSE audit systems for industrial engineering operations. Iconic Research and Engineering Journals. 2020a;4(4):399-417. doi:10.64388/IREV4I4-1715499
174. Obogo, S. F., Arumosoye, O. M., & Obriki, O. D. (2020b). Conceptual risk management model for heavy lifting and crane installation engineering operations. *Shodhshauryam, International Scientific Refereed Research Journal*, 3(4), 122-144. https://doi.org/10.32628/SHISRRJ214441
175. Obogo, S. F., Arumosoye, O. M., & Obriki, O. D. (2020c). Critical review of occupational safety management systems in oil and gas maintenance projects. *Shodhshauryam, International Scientific Refereed Research Journal*, 3(4), 145-166. https://doi.org/10.32628/SHISRRJ214442
176. Obogo SF, Arumosoye OM, Obriki OD. Advances in proactive hazard recognition and near miss reporting systems. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(6):835-846. doi:10.54660/IJMRGE.2021.2.6.835-846
177. Obogo SF, Obriki OD, Arumosoye OM. Conceptual model for incident prevention in industrial maintenance engineering environments. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(6):847-858. doi:10.54660/IJMRGE.2021.2.6.847-858
178. Obogo SF, Ozobu CO, Uduokhai DO. Advances in leadership driven safety culture transformation in large construction workforces. Iconic Research and Engineering Journals. 2019a;3(5):507-523. doi:10.64388/IREV3I5-1715497
179. Obogo SF, Ozobu CO, Uduokhai DO. Development of a construction safety risk governance model for multi contractor high rise projects. Iconic Research and Engineering Journals. 2019b;2(9):502-522. doi:10.64388/IREV2I9-1715495
180. Obogo SF, Uduokhai DO, Ozobu CO. Systematic review of hazard identification and risk control practices in urban construction projects. Iconic Research and Engineering Journals. 2019;2(12):666-681. doi:10.64388/IREV2I12-1715496
181. Obogo SF, Uduokhai DO, Ozobu CO. Review of contractor safety compliance systems in infrastructure engineering projects. International Journal of Scientific Research in Civil Engineering. 2021;5(4):76-100. doi:10.32628/IJSRCE215412
182. Obriki OD, Arumosoye OM. Conceptual modeling of data-driven occupational safety risk control in large-scale energy infrastructure projects. Iconic Research and Engineering Journals. 2018;1(7):169-189. doi:10.64388/IREV1I7-1714414
183. Obriki OD, Arumosoye OM. A conceptual framework linking management safety walkthrough frequency and coverage to safety culture outcomes in mega projects. Iconic Research and Engineering Journals. 2019;2(8):355-374. doi:10.64388/IREV2I8-1714416
184. Obriki OD, Arumosoye OM. Conceptual framework for human error causation in high-risk construction and industrial activities. International Journal of Multidisciplinary Research and Growth Evaluation. 2020;1(5):715-727. doi:10.54660/.IJMRGE.2020.1.5.715-727
185. Obriki OD, Arumosoye OM. Conceptual model for institutionalizing life-preserving safety practices across project-based organizations. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(1):961-969. doi:10.54660/.IJMRGE.2021.2.1.961-969
186. Obukadata VO, Awulu I, Williams I. Digital transformation, data analytics, and automation driving operational performance in pharmaceutical manufacturing. International Journal of Multidisciplinary Research and Growth Evaluation. 2021a;2(6):1173-1194. doi:10.54660/.IJMRGE.2021.2.6.1173-1194
187. Obukadata VO, Awulu I, Williams I. A Lean Six Sigma approach to mitigating pharmacy distribution bottlenecks in developing healthcare settings. International Journal of Multidisciplinary Research and Growth Evaluation. 2021b;2(6):1195-1211. doi:10.54660/.IJMRGE.2021.2.6.1195-1211
188. Odejobi OD, Ahmed KS. Statistical model for estimating daily solar radiation for renewable energy planning. IRE Journals. 2018a;2(5):1-12.
189. Odejobi OD, Hammed NI, Ahmed KS. Approximation complexity model for cloud-based database optimization problems. IRE Journals. 2019;2(9):1-10.
190. Oduleye TE, Medon JJ. A data-driven cost management model for improving strategic financial planning and performance evaluation. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(6):524-537.
191. Ogbete, J. C., Aminu-Ibrahim, A. Y., & Ambali, K. B. (2021). Risk managed construction strategies for complex and highly regulated healthcare facility developments. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, 7(5), 362-392. https://doi.org/10.32628/CSEIT217561
192. Ogbole, J. I., Okoruwa, P. O., Babatope, O. M., & Oyewole, T. (2021). Developing an integrated data visualization model for continuous business performance monitoring and optimization. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, 7(5), 441-467. https://doi.org/10.32628/IJSRCSEIT
193. Ogunwole, O., Okonkwo, C. S., Agbabiaka, J., Mayo, W., & Okeke, O. T. (2021). Supply chain resilience framework for critical infrastructure and gas processing plants. *Shodhshauryam, International Scientific*

Refereed Research Journal, 4(4), 444-461. https://doi.org/10.32628/SHISRRJ214462
194. Okafor CM, Osuji VC, Dako OF. Fintech-enabled transformation of transaction banking and digital lending as a catalyst for SME growth and financial inclusion. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(6):485-504.
195. Okojie JS, Abioye RF. Reconciling chemical safety with circular-economy targets: A decision framework for post-consumer recycled polymers in consumer-goods packaging balancing REACH compliance, lifecycle GHG footprint, and regulatory risk. International Journal of Multidisciplinary Research and Growth Evaluation. 2020;1(5):992-1006.
196. Okojie JS, Filani OM, Ihwughwavwe SI, Sakyi JK. Sustainable procurement practices: ESG-integrated supply chain models for corporate responsibility and environmental performance. IRE Journals. 2020;4(2).
197. Okonkwo CS, Agbabiaka J, Ogunwole O, Mayo W, Okeke OT. Model for demurrage elimination and port logistics efficiency in emerging economies. International Journal of Multidisciplinary Research and Growth Evaluation. 2020;1(5):552-562. doi:10.54660/IJMRGE.2020.1.5.552-562
198. Okonkwo CS, Agbabiaka J, Ogunwole O, Mayo W, Okeke OT. Conceptual model for materials readiness and maintenance-driven supply chain performance. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(6):584-594. doi:10.54660/IJMRGE.2021.2.6.584-594
199. Okonkwo CS, Ogunwole O, Mayo W, Okeke OT. Framework for regulatory-compliant procurement in high-risk energy environments. International Journal of Multidisciplinary Research and Growth Evaluation. 2021;2(6):595-605. doi:10.54660/IJMRGE.2021.2.6.595-605
200. Okonkwo CS, Ogunwole O, Okeke OT. Framework for strategic procurement optimization in oil and gas operations. Iconic Research and Engineering Journals. 2018a;1(7):153-168. doi:10.64388/IREV1I7-1713119
201. Okonkwo CS, Ogunwole O, Okeke OT. Model for inventory availability and plant uptime improvement in energy facilities. Iconic Research and Engineering Journals. 2018b;2(4):160-172. doi:10.64388/IREV2I4-1713120
202. Okonkwo CS, Ogunwole O, Okeke OT, Mayo W. Conceptual framework for cost reduction through contract negotiation and vendor governance. Iconic Research and Engineering Journals. 2019;2(9):468-482. doi:10.64388/IREV2I9-1713121
203. Okwesa, Ifeanyichukwu Jeffrey, Unamma, Uchechi Mary-Linda, Iwuanyanwu, Uzoamaka. Root-cause and thematic analysis for major incident management: A review. International Journal of Social Sciences and Management Research. 2021;7(4):100-131. doi:10.56201/ijssmr.v7.no4.2021.pg100.131
204. Ominyi M. Developing a conceptual framework for post-merger compliance integration in multi-jurisdictional banking transaction. IIARD International Journal of Banking and Finance Research. 2020;6(3):78-95. doi:10.56201/ijbfr.vol.6.no3.2020.pg78.95
205. Ominyi M. Toward a conceptual framework for embedding privacy by design in corporate restructuring and transaction structuring. Journal of Accounting and Financial Management. 2021;7(5):152-173. doi:10.56201/jafm.vol.7.no5.2021.p152.173
206. Ominyi M, Anichukwueze CC. A review of regulatory clearance frameworks for cross-border mergers and acquisitions in African financial markets. Journal of Accounting and Financial Management. 2020;6(4):73-99. doi:10.56201/jafm.vol.6.no4.2020.pg73.99
207. Ominyi M, Anichukwueze CC. A systematic review of anti-money laundering and anti-bribery compliance regimes across emerging and developed markets. International Journal of Economics and Financial Management. 2021;6(2):89-118. doi:10.56201/ijefm.v6.no2.2021.pg89.118
208. Ominyi M, Uchechi N, Anichukwueze CC, Jones BC. Navigating high-value statutory compliance: Strategic frameworks for upstream licensing and public bidding. International Journal of Multidisciplinary Research and Growth Evaluation. 2020;1(5):1230-1246. doi:10.54660/.IJMRGE.2020.1.5.1230-1246
209. Ominyi M, Uchechi N, Anichukwueze CC, Jones BC. Shared responsibility and multi-jurisdictional alignment in global supply chain governance. International Journal of Multidisciplinary Evolutionary Research. 2021;2(2):131-147. doi:10.54660/IJMER.2021.2.2.131-147
210. Oparah, O. S., Ezeh, F. E., Olatunji, G. I., & Ajayi, O. O. (2021). AI-based risk stratification framework for large-scale public health emergency preparedness and response planning. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, 7(1), 332-366.
211. Oseni MO. An analysis of the power sector performance in Nigeria. Renewable and Sustainable Energy Reviews. 2011;15(9):4765-4774. doi:10.1016/j.rser.2011.07.075
212. Oshevire, P., Eyenubo, O. J., & Amayo, B. (2017). Voltage control in the presence of distributed generation. *ATBU Journal of Science, Technology and Education*, 5(2), 165-173.
213. Oyedepo, S. O. (2012). Energy and sustainable development in Nigeria: The way forward. *Energy, Sustainability and Society*, 2(1), 15. https://doi.org/10.1186/2192-0567-2-15
214. Oziri ST, Arowogbadamu AAG, Seyi-Lande OB. Predictive analytics applications in reducing customer churn and enhancing lifecycle value in telecommunications markets. International Journal of Multidisciplinary Futuristic Development. 2020;1(2):40-49.
215. Parlar M, Wang D. Diversification under yield randomness in inventory models. European Journal of Operational Research. 1993;66(1):52-64. doi:10.1016/0377-2217(93)90205-2
216. Ponomarov SY, Holcomb MC. Understanding the concept of supply chain resilience. The International Journal of Logistics Management. 2009;20(1):124-143. doi:10.1108/09574090910954873
217. Porteus EL. Foundations of stochastic inventory theory. Stanford University Press; 2002.

218. Qin Y, Wang R, Vakharia AJ, Chen Y, Seref MMH. The newsvendor problem: Review and directions for future research. European Journal of Operational Research. 2011;213(2):361-374. doi:10.1016/j.ejor.2010.11.024
219. Ramasesh RV, Ord JK, Hayya JC, Pan A. Sole versus dual sourcing in stochastic lead-time (s, Q) inventory models. Management Science. 1991;37(4):428-443. doi:10.1287/mnsc.37.4.428
220. Regnier E. Oil and energy price volatility. Energy Economics. 2007;29(3):405-427.
221. Rhoades SA. The Herfindahl-Hirschman index. Federal Reserve Bulletin. 1993;79(3):188-189.
222. Rockafellar, R. T. (2007). Coherent approaches to risk in optimization under uncertainty. In Tutorials in Operations Research (pp. 38-61). INFORMS. https://doi.org/10.1287/educ.1073.0032
223. Rockafellar RT, Uryasev S. Optimization of conditional value-at-risk. Journal of Risk. 2000;2(3):21-41.
224. Rockafellar RT, Uryasev S. Conditional value-at-risk for general loss distributions. Journal of Banking & Finance. 2002;26(7):1443-1471.
225. Ronen D. The effect of oil price on containership speed and fleet size. Journal of the Operational Research Society. 2011;62(1):211-216. doi:10.1057/jors.2009.169
226. Sanni JO, Ajiga D, Atima ME. Analytical models addressing measurement challenges of marketing return on investment in regulated services. International Journal of Multidisciplinary Research and Growth Evaluation. 2020a;1(5):636-648. doi:10.54660/IJMRGE.2020.1.5.636-648
227. Santoso T, Ahmed S, Goetschalckx M, Shapiro A. A stochastic programming approach for supply chain network design under uncertainty. European Journal of Operational Research. 2005;167(1):96-115.
228. Sarykalin, S., Serraino, G., & Uryasev, S. (2008). *Value-at-risk vs.* conditional value-at-risk in risk management and optimization. In Tutorials in Operations Research (pp. 270-294). INFORMS. https://doi.org/10.1287/educ.1080.0052
229. Sculli, D., & Wu, S. Y. (1981). Stock control with two suppliers and normal lead times. *Journal of the Operational Research Society*, 32(11), 1003-1009.
230. Seifert RW, Thonemann UW, Hausman WH. Optimal procurement strategies for online spot markets. European Journal of Operational Research. 2004;152(3):781-799.
231. Seyi-Lande OB, Arowogbadamu AAG, Oziri ST. Geomarketing analytics for driving strategic retail expansion and improving market penetration in telecommunications. International Journal of Multidisciplinary Futuristic Development. 2020;1(2):50-60.
232. Shapiro A, Dentcheva D, Ruszczyński A. Lectures on stochastic programming: Modeling and theory. SIAM; 2009.
233. Sheffi Y, Rice JB. A supply chain view of the resilient enterprise. MIT Sloan Management Review. 2005;47(1):41-48.
234. Sherbrooke CC. METRIC: A multi-echelon technique for recoverable item control. Operations Research. 1968;16(1):122-141. doi:10.1287/opre.16.1.122
235. Shittu H, Opara IS, Elumilade RA, Adeniji IO. Hydrogen as a secondary energy carrier: Modeling its integration in national grids. Iconic Research and Engineering Journals. 2019;3(1):628-643. doi:10.64388/IREV3I1-1713909
236. Shittu H, Shittu MA, Adeleke OJ, Adedokun OJ. Blockchain based energy trading models for peer-to-peer renewable microgrids. International Journal of Research in Electrical and Electronics Engineering. 2021;4(3):1-19. doi:10.34218/IJREEE_04_03_001
237. Silbermayr L, Minner S. A multiple sourcing inventory model under disruption risk. International Journal of Production Economics. 2014;149:37-46. doi:10.1016/j.ijpe.2013.03.025
238. Silver EA, Pyke DF, Thomas DJ. Inventory and production management in supply chains (4th ed.). CRC Press; 2017.
239. Snyder LV, Atan Z, Peng P, Rong Y, Schmitt AJ, Sinsoysal B. OR/MS models for supply chain disruptions: A review. IIE Transactions. 2016;48(2):89-109.
240. Song JS. The effect of leadtime uncertainty in a simple stochastic inventory model. Management Science. 1994;40(5):603-613. doi:10.1287/mnsc.40.5.603
241. Sun J, Van Mieghem JA. Robust dual sourcing inventory management: Optimality of capped dual index policies and smoothing. Manufacturing & Service Operations Management. 2019;21(4):912-931. doi:10.1287/msom.2018.0731
242. Sunday, E. A., & Omoegun, G. O. (2018). Integrating solar power solutions in small-scale manufacturing industries in Nigeria. *International Journal of Scientific Research in Science, Engineering and Technology*, 4(8), 832-853.
243. Sunday EA, Omoegun GO. Optimizing electrical load distribution for hybrid solar installations in developing economies. International Journal of Scientific Research in Mechanical and Materials Engineering. 2019;3(6):27-47.
244. Sunday, E. A., Omoegun, G. O., Essien, M. A., & Oluokun, O. A. (2020). Transitioning from reactive to predictive maintenance in mechanical systems. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology*, 6(6), 425-447.
245. Svoboda J, Minner S, Yao M. Typology and literature review on multiple supplier inventory control models. European Journal of Operational Research. 2021;293(1):1-23. doi:10.1016/j.ejor.2020.11.023
246. Swaminathan JM, Shanthikumar JG. Supplier diversification: Effect of discrete demand. Operations Research Letters. 1999;24(5):213-221.
247. Tang CS. Perspectives in supply chain risk management. International Journal of Production Economics. 2006a;103(2):451-488. doi:10.1016/j.ijpe.2005.12.006
248. Tang CS. Robust strategies for mitigating supply chain disruptions. International Journal of Logistics Research and Applications. 2006b;9(1):33-45. doi:10.1080/13675560500405584
249. Tapiero CS. Value at risk and inventory control. European Journal of Operational Research. 2005;163(3):769-775. doi:10.1016/S0377-

2217(03)00808-7
250. Thomas DJ, Tyworth JE. Pooling lead-time risk by order splitting: A critical review. Transportation Research Part E: Logistics and Transportation Review. 2006;42(4):245-257. doi:10.1016/j.tre.2004.11.002
251. Tomlin B. On the value of mitigation and contingency strategies for managing supply chain disruption risks. Management Science. 2006;52(5):639-657.
252. Tomlin B. Impact of supply learning when suppliers are unreliable. Manufacturing & Service Operations Management. 2009;11(2):192-209. doi:10.1287/msom.1070.0206
253. Tomlin B, Wang Y. On the value of mix flexibility and dual sourcing in unreliable newsvendor networks. Manufacturing & Service Operations Management. 2005;7(1):37-57.
254. Tonoyan, Albert, Dada, Oluwatosin, & Ayivi-Donkor, Steve Senyo. (2021a). Advances in demand forecasting: Machine learning algorithms for revenue projection and financial planning accuracy. *Gyanshauryam, International Scientific Refereed Research Journal*, 4(1), 282-317. https://doi.org/10.32628/GISRRJ120361
255. Tonoyan, Albert, Dada, Oluwatosin, & Ayivi-Donkor, Steve Senyo. (2021b). Predictive cash flow modeling in retail: A review of advanced forecasting and working capital optimization. *Shodhshauryam, International Scientific Refereed Research Journal*, 4(3), 366-397. https://doi.org/10.32628/SHISRRJ214349
256. Trigeorgis L. Real options: Managerial flexibility and strategy in resource allocation. MIT Press; 1996.
257. Trimble C, Kojima M, Perez Arroyo I, Mohammadzadeh F. Financial viability of electricity sectors in Sub-Saharan Africa: Quasi-fiscal deficits and hidden costs (Policy Research Working Paper 7788). World Bank; 2016. doi:10.1596/1813-9450-7788
258. Uchechi N. Mitigating enterprise financial exposure: Standardization of stamp duty policies and class action defense protocols. Iconic Research and Engineering Journals. 2018;2(5):521-551. doi:10.64388/IREV2I5-1722788
259. Uchechi N, Ominyi M. Liability mitigation and dispute prevention in high-value energy service contracts. Iconic Research and Engineering Journals. 2019;3(6):676-705. doi:10.64388/IREV3I6-1722790
260. Uchechi N, Ominyi M. Advances in automated risk assessment frameworks for regulatory deliverables in upstream energy operations. International Journal of Multidisciplinary Evolutionary Research. 2020;1(2):158-175. doi:10.54660/IJMER.2020.1.2.158-175
261. Uchechi N, Ominyi M, Anichukwueze CC, Jones BC. Corporate policy advocacy and regulatory reform: Streamlining statutory bidding workflows in emerging energy markets. Iconic Research and Engineering Journals. 2019;3(5):672-709. doi:10.64388/IREV3I5-1722791
262. Uchechi N, Ominyi M, Anichukwueze CC, Jones BC. Force majeure and contractual resilience in global energy supply chains: A systematic review. International Journal of Multidisciplinary Research and Growth Evaluation. 2020;1(5):1247-1264. doi:10.54660/.IJMRGE.2020.1.5.1247-1264
263. chechi N, Ominyi M, Anichukwueze CC, Jones BC. Standardizing contract review workflows in enterprise legal operations: A systematic review. International Journal of Multidisciplinary Evolutionary Research. 2021;2(2):148-166. doi:10.54660/IJMER.2021.2.2.148-166
264. Unamma, Uchechi Mary-Linda, Ashore-Onisemo, Funmilayo, Iwuanyanwu, Uzoamaka, *et al*. Predictive forecasting for operational resource allocation: A comparative review. Iconic Research and Engineering Journals. 2018;1(9):493-508. doi:10.64388/IREV1I9-1722628
265. Unamma, Uchechi Mary-Linda, Okwesa, Ifeanyichukwu Jeffrey, Iwuanyanwu, Uzoamaka. Data-quality and single-source-of-truth frameworks for inter-agency reporting: A review. International Journal of Social Sciences and Management Research. 2019;5(4):108-131. doi:10.56201/ijssmr.vol.5no4.2019.pg108.131
266. Unamma, Uchechi Mary-Linda, Okwesa, Ifeanyichukwu Jeffrey, Iwuanyanwu, Uzoamaka. Building national analytics capacity: Advances and future pathways. International Journal of Social Sciences and Management Research. 2021;7(4):69-99. doi:10.56201/ijssmr.v7.no4.2021.pg69.99
267. Van Mieghem JA. Capacity management, investment, and hedging: Review and recent developments. Manufacturing & Service Operations Management. 2003;5(4):269-302. doi:10.1287/msom.5.4.269.24882
268. Veeraraghavan S, Scheller-Wolf A. Now or later: A simple policy for effective dual sourcing in capacitated systems. Operations Research. 2008;56(4):850-864. doi:10.1287/opre.1080.0552
269. Vernimmen B, Dullaert W, Engelen S. Schedule unreliability in liner shipping: Origins and consequences for the hinterland supply chain. Maritime Economics & Logistics. 2007;9(3):193-213. doi:10.1057/palgrave.mel.9100182
270. Wang Y, Gilland W, Tomlin B. Mitigating supply risk: Dual sourcing or process improvement? Manufacturing & Service Operations Management. 2010;12(3):489-510. doi:10.1287/msom.1090.0279
271. Weber CA, Current JR, Benton WC. Vendor selection criteria and methods. European Journal of Operational Research. 1991;50(1):2-18. doi:10.1016/0377-2217(91)90033-R
272. Whittemore AS, Saunders SC. Optimal inventory under stochastic demand with two supply options. SIAM Journal on Applied Mathematics. 1977;32(2):293-305. doi:10.1137/0132023
273. Wu, M., Zhu, S. X., & Teunter, R. H. (2013). The risk-averse newsvendor problem with random capacity. *European Journal of Operational Research*, 231(2), 328-336. https://doi.org/10.1016/j.ejor.2013.05.044
274. Xanthopoulos A, Vlachos D, Iakovou E. Optimal newsvendor policies for dual-sourcing supply chains: A disruption risk management framework. Computers & Operations Research. 2012;39(2):350-357.
275. Xin L, Goldberg DA. Asymptotic optimality of tailored base-surge policies in dual-sourcing inventory systems. Management Science. 2018;64(1):437-452. doi:10.1287/mnsc.2016.2607

276. Yang Z, Aydın G, Babich V, Beil DR. Supply disruptions, asymmetric information, and a backup production option. Management Science. 2009;55(2):192-209. doi:10.1287/mnsc.1080.0943
277. Yano CA, Lee HL. Lot sizing with random yields: A review. Operations Research. 1995;43(2):311-334.
278. Yeboah BK, Ike PN. Programmatic strategy for renewable energy integration: Lessons from large-scale solar projects. International Journal of Multidisciplinary Research and Growth Evaluation. 2020;1(3):306-315. doi:10.54660/.IJMRGE.2020.1.3.306-315
279. Yu, H., Zeng, A. Z., & Zhao, L. (2009). Single or dual sourcing: Decision-making in the presence of supply chain disruption risks. *Omega*, 37(4), 788-800.
280. Zipkin PH. Stochastic leadtimes in continuous-time inventory models. Naval Research Logistics Quarterly. 1986;33(4):763-774. doi:10.1002/nav.3800330419
281. Zipkin PH. Foundations of inventory management. McGraw-Hill; 2000.