Review of the Doctoral Dissertation

A more-generalized multiple suppliers, single manufacturer inventory control model with stochastic demand, variable production rate and differing supplier delivery times

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Field of science: Social Sciences
Discipline of science: Management and Quality Studies
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Dissertation year stated on title page: 2026

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1 Subject of the review and general characterization of the dissertation

The doctoral dissertation by Kehinde Adekunle Adegbola, entitled *A more-generalized multiple suppliers, single manufacturer inventory control model with stochastic demand, variable production rate and differing supplier delivery times*, addresses inventory coordination in a supply chain composed of several suppliers and one manufacturer. The dissertation is situated in the field of social sciences and in the discipline of management and quality studies, with a clear methodological orientation toward operations research, inventory theory, supply chain management, and simulation-based decision support.

The scientific body of the dissertation consists of six chapters and appendices. The work begins with the formulation of the managerial and modelling problem, continues with a literature review, develops analytical cost models for homogeneous and heterogeneous suppliers, studies integrated and sequential decision structures, performs numerical sensitivity analyses, and finally uses discrete-event simulation to relax selected assumptions of the analytical model. The appendices provide technical support for the heterogeneous derivation and the Arena simulation implementation.

The research problem is legitimate and relevant. Modern supply chains frequently depend on several suppliers with different production capacities, delivery times, and operational constraints. The dissertation focuses on a setting in which a manufacturer coordinates small and medium-sized suppliers that produce raw materials, while demand for the manufacturer's finished product is stochastic. This is a suitable doctoral-level problem because it combines managerial relevance with nontrivial modelling choices: stochastic demand, variable production rates, batch-size decisions, reorder-point decisions, heterogeneous suppliers, delivery-time differences, centralized coordination, leader-follower decision making, and simulation optimization.

My overall assessment is positive. The dissertation contains a substantial scientific effort and demonstrates that the candidate can formulate a complex supply chain problem, derive an analytical model, implement computational procedures, compare alternative coordination structures, and use simulation to address limitations of closed-form modelling. At the same time, the dissertation requires important corrections in mathematical notation, reproducibility of algorithms, simulation reporting, and editorial consistency. These weaknesses reduce the precision and archival quality of the work, but they do not invalidate the central contribution or the doctoral character of the dissertation.

2 Summary of the scientific content

The dissertation develops a multiple-supplier, single-manufacturer inventory model under stochastic demand. The manufacturer follows a make-to-stock strategy for the final product, while suppliers produce the primary raw material on demand. The manufacturer places replenishment orders when the finished-goods inventory reaches a reorder level. Production starts after the arrival of the first raw-material batch, and the analytical model accounts for the fact that suppliers may have different delivery times.

The first analytical setting assumes homogeneous suppliers. They are identical in production capacity and setup characteristics but differ in the time required to deliver raw materials to the manufacturer. The model derives long-run average cost components for suppliers and the manufacturer, including setup costs, holding costs, production costs, ordering costs, transportation costs, shortage costs, and raw-material holding costs at the manufacturer's warehouse. The decision variables include production rates, batch size, number of deliveries, lot size, and reorder level. The dissertation uses a continuous-review (Q, R) framework under stochastic demand and derives a quantile-type expression for the reorder point under the assumed shortage-cost structure.

The second analytical setting extends the model to heterogeneous suppliers. In this case suppliers may differ in production capacity and may deliver different batch sizes. This extension is scientifically meaningful because supplier heterogeneity is a realistic characteristic of multi-supplier systems, especially when suppliers are small or medium-sized enterprises. The heterogeneous formulation is more complex and is supported by a separate derivation in the appendices.

The dissertation considers two coordination structures. The integrated approach minimizes the overall supply chain cost and serves as a centralized benchmark. The sequential approach is described as a Stackelberg-type structure in which the manufacturer acts as the leader and suppliers respond by adjusting production decisions. The comparison between these approaches is relevant because it shows how the distribution of costs changes when the manufacturer has decision power and suppliers adapt to its operational choices.

The numerical chapter studies base-case scenarios and performs sensitivity analysis with respect to demand, demand variability, raw-material consumption coefficient, manufacturer's holding costs, and supplier production-rate parameters. The results generally show that the integrated solution produces lower total supply chain cost, while the sequential solution may reduce the manufacturer's cost at the expense of higher supplier costs. This is an important managerial insight because it highlights the difference between system-wide efficiency and dominant-party optimization.

The simulation chapter uses Arena and OptQuest to represent supply chain dynamics more flexibly than the analytical model. In particular, the simulation model relaxes synchronized-dispatch assumptions and introduces a dynamic reorder timing buffer as a decision variable. The simulation comparison suggests that flexible replenishment timing can yield cost advantages over a more rigid analytical policy. This is one of the more interesting results of the dissertation, although the causal interpretation should be treated with caution because several policy features change simultaneously in the reported comparisons.

3 Assessment of originality and contribution

The dissertation has a credible original core. Its contribution lies in extending inventory coordination models toward a setting with multiple suppliers, one manufacturer, stochastic final demand, variable production rates, differing delivery times, and heterogeneous supplier capabilities. The work is not limited to a single mathematical derivation: it also compares centralized and leader-follower coordination structures and uses simulation optimization to explore operational flexibility beyond the analytical assumptions.

The strongest original elements are the following:

- the attempt to model a multiple-supplier, single-manufacturer system under stochastic demand while allowing production-rate flexibility;
- the distinction between homogeneous suppliers with differing delivery times and heterogeneous suppliers with different capacities and batch sizes;
- the comparison between an integrated supply chain solution and a sequential manufacturer-led solution;

- the recognition that synchronized analytical policies may be too rigid when suppliers are heterogeneous;
- the simulation-based introduction of a dynamic reorder timing buffer as an operational decision variable.

The contribution is scientifically relevant, but the dissertation should present it with greater precision. Some claims about resilience, generality, and practical realism are broader than what is directly demonstrated. The model minimizes cost and studies inventory coordination. It does not independently measure resilience through disruption recovery, service continuity, robustness, or recovery-time indicators. Therefore, the final version should moderate claims about resilience unless additional metrics are introduced.

The novelty argument would also be stronger if the literature review included a structured comparison table of the closest models. Such a table should compare the number of suppliers, demand assumptions, production-rate decisions, batch-size decisions, delivery-time structure, coordination mechanism, and solution method. This would make the dissertation's contribution more transparent and would reduce reliance on broad statements of novelty.

4 Assessment of the literature positioning

The literature review covers relevant streams: variable production rates, multiple suppliers and one manufacturer, collaboration in supply chain systems, game-theoretic approaches, and simulation of supply chain problems. These categories are appropriate for the dissertation topic, and the candidate demonstrates familiarity with a broad body of related work.

The main weakness is that the review is more descriptive than critical. It often summarizes individual papers one after another without sufficiently comparing assumptions, methods, and limitations. For doctoral research, the literature review should do more than establish topical familiarity. It should clarify exactly which modelling assumptions are absent in prior work and how the dissertation addresses them.

The discussion of variable production rates is useful because it shows that controllable production rates are an established modelling device. However, the review should more clearly distinguish whether production-rate flexibility applies to the manufacturer, the suppliers, or both. It should also state whether prior models assume deterministic or stochastic demand and whether they optimize batch size and delivery timing.

The review of multiple-supplier systems is central to the dissertation but comparatively short. The closest models should be discussed in greater detail, particularly those involving multiple vendors or suppliers, buyer-manufacturer coordination, shipment policies, and heterogeneous suppliers. The dissertation should clearly state what is new relative to these models.

The collaboration and game-theory sections support the managerial interpretation, but they need stronger integration with the mathematical model. If the manufacturer bears all direct and indirect costs, the incentive structure differs from many standard decentralized supply chain games. The literature review should therefore discuss coordination contracts, cost sharing, supplier financing, transfer payments, or other mechanisms that could sustain the collaboration when costs are unevenly distributed.

The simulation literature is relevant but should be more methodologically focused. Since simulation evidence plays a major role in the dissertation, the review should include more precise discussion of simulation verification, validation, warm-up determination, replications, confidence intervals, stochastic optimization, and output analysis.

5 Assessment of the mathematical model and methodology

The analytical model is ambitious and constitutes the technical core of the dissertation. The candidate decomposes the total cost into supplier-side and manufacturer-side components and derives average costs per unit time from inventory profiles. The modelling approach is appropriate for the stated problem and demonstrates doctoral-level engagement with inventory theory and operations research.

Several aspects of the mathematical formulation are strong. The dissertation explicitly distinguishes fixed parameters, decision variables, and dependent quantities. It considers both raw-material inventory and finished-goods inventory. It uses a continuous-review (Q, R) inventory policy under stochastic demand. It recognizes the importance of non-overlapping cycles and excludes pre-emptive cases in which the classical (Q, R) structure would no longer be valid. It also attempts to make the heterogeneous extension analytically tractable by relating supplier capacities, production rates, and batch sizes.

Nevertheless, the mathematical presentation requires substantial technical revision. The main issue is not the absence of a model, but the precision with which the model is presented. The notation is not sufficiently controlled. Some symbols change meaning, some cost parameters are inconsistently subscripted, and several displayed formulas appear to contain typographical or symbolic inconsistencies. These problems make the model harder to verify and reduce reproducibility.

In particular, the following issues should be corrected in the final version:

- all symbols should be standardized in a master notation table with units, domains, and classification as parameter, decision variable, or dependent variable;
- the relation between Q, m, n, T_l, and α should be stated consistently whenever Q appears in an optimization problem;
- the demand variability notation should be unified and the stochastic demand process should be stated precisely;
- cost parameters for manufacturer and supplier production should be consistently denoted throughout the homogeneous and heterogeneous models;
- the raw-material holding-cost parameter at the manufacturer's warehouse should not be confused with the finished-goods holding-cost parameter;
- all shortage integrals should use consistent notation for the random variable, density, and integration variable;
- the probability level in the reorder-point quantile formula should be checked and boundary cases should be explicitly handled;
- feasibility constraints should be checked for dimensional consistency and explained in operational terms;
- duplicate table numbering and inconsistent references should be corrected.

The sequential solution is presented as a Stackelberg approach. The managerial idea is plausible: the manufacturer leads and suppliers respond. However, the formal game-theoretic structure is underdeveloped. A true Stackelberg formulation should define the leader's strategy set, followers' strategy sets, follower best-response functions, the equilibrium concept, and conditions for existence or uniqueness where relevant. If the implemented method is instead a sequential optimization policy rather than a formal game-theoretic equilibrium, the terminology should be adjusted. The scientific contribution would remain valid, but the description should be precise.

The algorithms should also be made reproducible. At present, the pseudocode is not sufficient to allow independent implementation. The final dissertation should state the search grids, bounds, discretization steps, feasibility filters, stopping criteria, computational complexity, and run times. If a grid search is used, the reported solution should be described as optimal within the specified grid. If a heuristic is used, the word "optimal" should be qualified accordingly.

6 Assessment of numerical and simulation analyses

The numerical analysis is valuable because it shows how the analytical model behaves under different parameter values. The base-case comparison between the integrated and sequential solutions supports a coherent interpretation: centralized optimization generally reduces total supply chain cost, while the sequential manufacturer-led policy may shift cost burdens toward suppliers. This finding is consistent with supply chain coordination theory and is one of the main practical messages of the dissertation.

The sensitivity analysis covers important parameters, including expected demand, demand variability, raw-material consumption coefficient, holding costs, and supplier production capacity. The analysis shows that the relative performance of coordination structures may depend on these parameters. The result that the sequential policy can be favourable under some low raw-material-consumption conditions is especially useful because it avoids an overly simplistic statement that one policy always dominates.

However, the numerical analysis is limited by insufficient parameter justification. The dissertation does not clearly state whether the numerical values are derived from an industrial case, previous literature, or illustrative assumptions. If the values are illustrative, the dissertation should say so explicitly and avoid strong empirical claims. If they are intended to represent a realistic case, data sources and calibration procedures should be provided.

The numerical chapter would be strengthened by additional robustness testing. One-factor-at-a-time sensitivity analysis is useful but limited because interactions between parameters may be important. A more convincing computational evaluation would include multi-factor scenarios, random parameter instances, or a design-of-experiments structure. Graphical summaries of total costs, cost components, and cost differences would also improve interpretability.

The simulation chapter is scientifically meaningful because it addresses limitations of the analytical model. The use of discrete-event simulation is appropriate for asynchronous supplier dispatch, different delivery times, and operational event logic that is difficult to incorporate analytically. The dynamic reorder timing buffer is a promising decision variable and can be interpreted as a mechanism for operational flexibility.

The verification of the simulation model against the analytical model is a strength. Matching analytical results under near-deterministic conditions provides evidence that the simulation logic is implemented consistently. However, this should be called verification against an analytical benchmark, not full validation. Validation would require empirical data, expert operational confirmation, or independent evidence that the model accurately represents a real system.

The simulation results indicate that equal-batch dynamic-timing policies can outperform unequal-batch synchronized analytical policies. This is an interesting result, but the current comparison changes multiple features simultaneously: batch-size equality, dispatch synchronization, and reorder timing. Therefore, the dissertation cannot attribute the cost savings solely to the dynamic timing buffer. A stronger design would compare at least four policy variants:

equal batch with synchronized dispatch, equal batch with dynamic timing, unequal batch with synchronized dispatch, and unequal batch with dynamic timing. Such a comparison would isolate the contribution of timing flexibility.

The simulation methodology also needs stronger statistical reporting. The dissertation should report the warm-up selection method, number of replications, confidence intervals, random-number stream management, OptQuest settings, stopping criteria, and stochastic objective treatment. Cost results should be accompanied by variability measures. In addition, simulation output should not be limited to cost. The thesis should also report service levels, expected backorders, frequency of shortages, raw-material inventory, finished-goods inventory, supplier utilization, and production interruptions if relevant.

7 Assessment of appendices and reproducibility material

The appendices are useful and should remain part of the dissertation. Appendix A supports the heterogeneous mathematical derivation, and Appendices B–D provide information on Arena modules, simulation model structure, and output examples. This material improves transparency.

Appendix A should be made fully consistent with Chapter 3. It contains derivation steps that are important for the heterogeneous model, but notation and typographical errors must be corrected. The same symbols and cost parameters should be used in the appendix and the main text.

The Arena appendices are helpful for readers familiar with the software, but screenshots alone are not enough for reproducibility. The candidate should add a formal description of the simulation logic: events, triggers, state variables, cost updates, queue logic, inventory update rules, and optimization variables. A reader without access to Arena should still be able to understand the computational structure. If institutional rules allow supplementary material, the Arena model files, Excel outputs, and OptQuest settings should be archived and referenced.

8 Main strengths

The dissertation has several clear strengths:

- it addresses a relevant and nontrivial supply chain management problem;
- it combines analytical modelling, numerical analysis, and discrete-event simulation rather than relying on a single method;
- it explicitly considers multiple suppliers, differing delivery times, stochastic demand, and variable production rates;
- it distinguishes centralized coordination from manufacturer-led sequential decision making;
- it extends the analysis from homogeneous to heterogeneous suppliers;
- it recognizes the operational limitations of synchronized dispatch assumptions;
- it proposes dynamic replenishment timing in the simulation model, which is a meaningful managerial idea;
- it provides extensive numerical tables and appendices that support the main modelling effort.

These strengths show that the candidate has engaged with a complex scientific problem and has acquired the methodological skills expected in doctoral research involving management science and operations research.

9 Weaknesses and required improvements

The weaknesses of the dissertation are important and should be addressed before final archival submission. They concern mainly scientific precision, reproducibility, and presentation rather than the fundamental relevance of the topic.

Mathematical precision. The notation must be revised systematically. The current version contains inconsistent symbols, duplicate numbering, and expressions that require checking for dimensional and mathematical consistency. This is the most important correction because the dissertation's contribution depends on the credibility of the analytical model.

Formal status of the sequential model. The Stackelberg interpretation must be clarified. If the model is a formal Stackelberg game, the candidate should define the game rigorously. If it is a sequential optimization procedure, it should be described as such. The terminology should not overstate the game-theoretic result.

Reproducibility of optimization procedures. The algorithms must be rewritten in a reproducible format. Search bounds, discretization, feasibility checks, stopping criteria, and implementation details are necessary for a doctoral dissertation based on computational optimization.

Simulation reporting. The simulation study should include confidence intervals, replication design, warm-up justification, random-number stream management, OptQuest settings, and additional operational performance metrics. Verification against the analytical model is useful, but external validation is not demonstrated.

Attribution of simulation gains. The comparison between analytical and simulation policies changes several design factors simultaneously. The dissertation should avoid claiming that cost savings are caused only by dynamic timing unless additional experiments isolate this effect.

Literature synthesis. The literature review should be made more analytical. The final version should include a structured comparison of the closest models and should more clearly identify the exact gap filled by the dissertation.

Managerial interpretation. Claims about resilience and broad practical applicability should be moderated or supported by additional measures. The model provides cost and inventory insights; resilience is only indirectly addressed unless specific resilience metrics are added.

Editorial quality. The dissertation needs systematic proofreading. Grammar, terminology, figure captions, table numbering, cross-references, and spelling should be corrected after the mathematical revision is complete.

10 Final statement

The dissertation by Kehinde Adekunle Adegbola addresses a valid doctoral-level research problem and contains a substantial analytical and computational contribution. The thesis demonstrates the candidate's ability to formulate a scientific problem in supply chain management, develop mathematical models, compare coordination structures, conduct numerical experiments, and apply simulation optimization to a complex operational system.

My final assessment of the doctoral thesis is **positive**. In my opinion, despite the weaknesses identified above, the dissertation demonstrates sufficient originality, knowledge of the research area, methodological competence, and capacity for independent scientific work. The thesis therefore **meets the substantive requirements expected of doctoral theses in the social sciences, in the discipline of management and quality studies**.

The corrections indicated in this review are important. They should be addressed in the final version to improve mathematical precision, reproducibility, simulation reporting, and archival quality. However, these weaknesses do not change my overall positive evaluation of the dissertation.

Final conclusion and recommendation: I issue a **positive opinion** on the doctoral thesis and recommend that it be accepted in the doctoral procedure and admitted to defence, subject to the candidate addressing the major corrections identified in this review.

Reviewer

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