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FMEA MODEL FOR SUSTAINABLE LAND ADMINISTRATION: RESEARCH AGENDA

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ABSTRACT

Review of the failure mode and effect analysis (FMEA) literature portrays its effectiveness as a total quality management and continuous improvement technique. However, the diverse applications of the FMEA model seems to be pretermitted by land administration literature and practice, especially in Nigeria. The criticality of this literature gap is accentuated by several unsustainable practices bedeviling land administration in the country, especially in light of the FMEA principle of prioritizing actual and potential failures, determining their causes, and assessing their effect on a system for the purposes of mitigating them. Thus, the paper was aimed at presenting new research insights upon which the FMEA-shaped gap in land administration literature may be filled, with a view to generating insights on its applicability to sustainable land administration. Findings from the review led to the conclusion that the veracity of FMEA application for sustainable land administration is yet to be adequately and exhaustively researched. Thus, there is need for further research on filling this literature gap.

Keyword: FMEA Model, Land Administration, Sustainability

1. INTRODUCTION

Sustainable land administration is incumbent on commitment to agile, reengineered and continuous improvement processes that that not only mitigate land-based controversies but also assures of peaceful and progressive template for real estate investment. Recent evidence from several developing countries indicates that such commitment to sustainable land administration is encumbered by institutional, environmental, sociopolitical, legal and economic challenges (Bennett et al., 2021; Chigbu et al., 2021; Ewurum, 2016; Nissi et al., 2021; Obi-Aso, 2021). Such encumbrances run afoul of the principles of sustainable development and the criticality of land to all forms of national and economic development present the crucial need for candid introspection and strategic realignment of processes.

One way of achieving this self-examination is through the application of the Failure Mode and Effect Analysis (FMEA) Model. FMEA model is a strategic process of disaggregating and examining the components of a system so as to determine faulty areas, the causes and effect of those affected areas on the entire system (Chioza et al., 2009; Lo et al., 2020). It was first applied in the 1940s by the United States military as a stepwise approach to identifying possible failures within a defined process or design (Stamatis, 2003; Tague, 2005). By implication, it identifies reasons for failure in a system, why such failure occurred, and how it can be mitigated. In line with this analogy, the cruciality of the model to land administration in developing countries like Nigeria cannot be overemphasized if sustainability goals must be attained.

Since its adoption in the 1940s, the FMEA model has increased in academic and practical significance globally. It is indeed pertinent to note the prevalence of its application as a risk management tool (Lo et al., 2020; Ouyang et al., 2020; Shafiee et al., 2019), but this has not also negated its extensive and diverse applications as a system optimization tool (Filz et al., 2021; Ramere & Laseinde, 2021; Villarini et al., 2017). This begs the query on the extent to which the model has been applied as a land administration optimization tool globally, and peculiarly in Nigeria. Empirical evidence in this regard confirms the paucity of research in this area with very few applications of the model in land use (Sang et al., 2018; Zandi et al., 2020) and even more trifling integration of the model in land administration (Choi, 2020).

With the evidential efficacy of the model as a system optimization tool (Chioza et al., 2009; Filz et al., 2021; Lo et al., 2020; Ramere et al., 2021; Villarini et al., 2017), it is indeed worrying that arguably no evidence exists in literature on the extent to which it is adopted by land administrators and real estate consultants in Nigeria, especially in light of a preponderance of land administration issues in the country. It is argued that the model would expose issues as title insecurity, stringent land policy, tenure con flicts, inadequate cadastral designs, technical obsolescence, delayed processes, information mismanagement, poor stakeholder collaboration (Chigbu et al., 2021; Ewurum et al., 2020; Nissi et al., 2021; Obi-Aso, 2021; Ojobor & Ewurum, 2017) and many others yet to be established, as a means of developing strategic pathways for mitigating and attenuating them.

These issues portend both short and long-term costs for sustainable land administration in the country but also presents the opportunity for appraising the criticality, pertinence and veracity of the FMEA model as an optimization tool for sustainability integration in the land administration process. Following this argument, the study presents a review of FMEA model applications and its pertinent prospects in the land administration process in developing countries like Nigeria. This informs the aim of the study, and the aim is based on motivations of establishing empirical status quo as a means of setting apposite research agenda for land administration sustainability.

2. REVIEW OF RELATED LITERATURE

2.1 Failure Mode and Effect Analysis (FMEA) Model

The US military developed the model as one which establishes fault in a system, ascertains its cause and determines its effect on the system. In addition, it prioritizes possible and actual faults in accordance with their potential consequences on the system (Stamatis, 2003). For land administration in Nigeria, the faults are well established as noted earlier, but the lack of evidence citing the application of FMEA portends the prospects of identifying other salient faults, when it is applied. Concurring with this view, Abolade et al. (2018) opine that land administration in Nigeria lacks a distinct process improvement blueprint that targets prevailing sustainability-encumbering issues within the system. This contention lends to the essential need for the application of the model as a means of developing a blueprint for sustainable land administration in the country.

The wide-ranging empirical coverage of the FMEA model justifies this need. From the perspective of healthcare, Rah et al. (2016) see the model as a process reengineering tool for improved performance, in addition to other characterizations of the model as a quality control tool for sustainable manufacturing (Wu et al., 2021); and a risk management tool in construction project management (Abdelgawad & Fayek, 2010). Other delineations of the model across diverse disciplines denote it as a supply chain optimizer that aids the supply chain manager in assessing and qualifying vendors and suppliers (Curkovic et al., 2013), and a change management technique in sports and fitness administration (Alcátara et al., 2002).

From these attributions, a precis of the model does appear which views it as a process reengineering, change management, total quality management, risk management, and system optimizer procedure for continuous improvement. Juxtaposing these attributes to sustainable land administration encumbrances, it is easily clear that the model offers practical pathways for failure mitigation and process optimization in the study area. The study aligns with this logic in the examination of pertinent FMEA model applicati ons for sustainable land administration in developing countries like Nigeria.

2.2 Land Administration

In the wake of the lack of consensual definition of land, Umeh (1967) conceptualized land from the perspectives of the physical, economic, legal, abstract, sociopolitical and spiritual concepts. With this diverse, yet holistic, conceptual overview of land also comes intrinsic challenges embedded in each conceptualization with regards to the use, management and alienation of land interests (Ewurum et al., 2022). Therefore, it can be posited that challenges of sustainable land administration may be perceived from the perspective of physical, economic, legal, spiritual, sociopolitical, and abstract angles. Consequently, we examine litera ture postulations of land from these perspectives.

From the physical perspective, land refers to anything below, above and on the earth surface that can be seen and touched. This is further elucidated with the following avowal:

"Land is a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps), the near-surface sedimentary layers and associated groundwater reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, etc.)" (FAO 1995: 6).

Offering an interesting dynamic, Barlowe (1978) and Umeh (1967) introduced land from the perspective of the sociopolitical, with the elucidation that land can be perceived as group of people with distinct cultural dispositions and orientations. Supporting Umeh's (1967) economic concept of land, Briassoulis (2020) reports as follows:

"the term land refers to a wide array of natural resources above the surface down to some meters below the land surface, consisting climate, land form, soil, vegetation, fauna and water".

This reportage views land as something of value. Extending this value conceptualization of land, Ewurum et al. (2022) posit that land cannot just be limited to a thing of value, but should also be quantified as a tool for value creation. In other words, land is anything that has value and can also be used to create value.

Land, seen from the spiritual concept, embodies it as a sacred entity, subject to reverence and devotion in consistency with ancient African traditional systems (Egbenta, 2012; Ewurum, 2000). Such is characteristic of such traditions as obtained in ancient Igbo land of Nigeria where the supposed goddess of the earth is believed to be residing within the earth crust with prospects of blessing the labours of indigenes residing on the land. As an abstract entity, land refers to anything with quantum of rights and interest (Denman, 1963). Umeh (1967) justifies this land conceptuality with the argument that land extends beyond the physical entity due to its immobility. The logic presented is that since one cannot move land from one place to the other, the essence of its conferment of privilege lies with the proprietary rights and interest it offers the owner.

An embodiment of land from the legal perspective sees it from the perspective of the Latin maxim – quic quid plantatur, solo solo cedit, which translates as land being anything that is permanently attached to the earth surface (Umeh, 1983). This view is corroborated by the Law of Real Property (1959) which views land as "all things up to heaven, and all things down to hell".

The essence of these conceptual characterizations is consistent with our earlier argument that land administration challenges are taxonomized into institutional, environmental, sociopolitical, legal, physical, abstract, spiritual and economic encumbrances (Barlowe, 1978; Bennett et al., 2021; Chigbu et al., 2021; Denman, 1963; Egbenta, 2012; Ewurum, 2016; Ewurum, 2000; Nissi et al., 2021; Obi-Aso, 2021; Umeh, 1967; 1973; 1976; 1983). Therefore, to lay the framework for the introduction of the FMEA model, Table 1 taxonomizes empirical evidence of land administration failures in consistency with institutional, environmental, sociopolitical, legal and economic encumbrances:

Table 1: Taxonomizing Land Administration Failures

Land Administration Failure	*Taxonomy*	*References*
Title insecurity	Legal, Abstract, Institutional	Aso et al. (2020)
Stringent land policy	Legal, Institutional	Aso et al. (2020); Ojobor et al. (2017)
Tenure conflicts	Legal, Abstract, Institutional, Sociopolitical, Spiritual	Aso et al. (2020); Chigbu et al. (2021); Efobi & Anierobi (2013); Egbenta (2012); Ewurum (2016); Ojobor et al. (2017)
Inadequate cadastral designs	Legal, Institutional, Environmental, Sociopolitical, Physical	Abolade et al. (2018); Akingbade et al. (2012); Babalola et al. (2015); Morenikeji et al. (2001); Thontteh & Omirin (2015)
Technical obsolescence	Economic, Institutional	Abolade et al. (2018); Akingbade et al. (2012); Chigbu et al. (2021); Ewurum et al. (2018); Nissi et al. (2021); Obi-Aso (2021); Thontteh et al. (2015)
Delayed processes	Institutional, Legal	Abolade et al. (2018); Nissi et al. (2021); Obi-Aso (2021); Thontteh et al. (2015)
Information mismanagement	Economic, Institutional	Abolade et al. (2018); Aso et al. (2020); Babalola et al. (2015); Nissi et al. (2021); Obi-Aso (2021); Thontteh et

		al. (2015)
Poor stakeholder collaboration	Sociopolitical, Spiritual, Environmental, Institutional, Abstract	Chigbu et al. (2021); Efobi et al. (2013); Ewurum et al. (2020); Ojobor et al. (2017)
Cumbersome land title processing	Legal, Abstract, Institutional, Economic	Abolade et al. (2018); Aso et al. (2020); Nissi et al. (2021); Obi-Aso (2021)
Administrative instability and inconsistency	Institutional, Legal	Aso et al. (2020); Babalola et al. (2015); Thontteh et al. (2015)
Eminent domain mismanagement	Sociopolitical, Economic, Legal, Institutional, Abstract, Spiritual, Physical	Aso et al. (2020); Ojobor et al. (2017)
Inadequate database	Economic, Institutional	Abolade et al. (2018); Nissi et al. (2021); Obi-Aso (2021); Thontteh et al. (2015)
Inadequate sustainability integration in land use processes	Environmental, Sociopolitical, Economic, Abstract, Physical, Institutional	Abolade et al. (2018); Chigbu et al. (2021); Efobi et al. (2013); Ewurum (2000); Obi-Aso (2021); Ojobor et al. (2017)

Thus, from the foregoing, the study examines the FMEA model as panacea to these challenges of land administration, whose conceptuality we adopt as "the process of determining, recording and disseminating information about ownership, value and use of land and its associated resources" in a defined area, in consistency with the avowals of the United Nations Economic Commission for Europe (UNECE). The Commission goes ahead to establish pathways to land administration sustainability through the following processes:

A. Guarantee of title security
B. Viable land tax system
C. Land market supervision
D. Protection of State lands
E. Effective land reform processes
F. Land dispute mitigation
G. Sustainable urban planning and infrastructure development
H. Environmental-compliant land management, and
I. Data management efficiency

The outlined pathways to sustainable land administration mirror the identified administration challenges bedeviling land ownership, use and management in Nigeria, and it therefore becomes clear that finding the faults, causes and effects of the challenges is crucial for land administration sustainability in the country. The study examines the prospects of FMEA model as a blueprint for achieving this sustainability.

2.3 Application of FMEA Model

Failure Mode and Effects Analysis is a model that exposes actual and possible faults of a system, while also identifying the causes and effects of those faults on performance. Studies have relied on this foundation to examine the application of FMEA model in diverse fields with a variety of results. A conceptual and empirical exposition of the model is indicative of a compendium of proponents (Chioza et al., 2009; Lo et al., 2020; Stamatis, 2003; Wu et al., 2021) and antagonists (Hunt et al., 1993; Rudov-Clark & Stecki, 2009; Wetterneck et al., 2004) which suggests that the applicability of the model is not given, but still subject to further empiricism in other climes. This muddle justifies the argument for an investigation into the application of the model to achieving land administration sustainability in the developing world. By this logic, it can be observed that we do not belong to any side of the divide, as a result of inadequate empirical direction on its veracity in land administration. For this reason, the study examines the applications of FMEA with a view to suggesting pathways for an investigation of its veracity to the industry.

Perhaps a core advocacy for the model can be found in Wang et al. (2018) who approached application of the model from the perspective of identifying and mitigating possible system failures. The study employed Fuzzy and Choquet integral approaches to aggregate the failure potentials of a system, using aircraft landing system as a case study. After assigning wights to each potential failure outcome, the study employed the entropy method to prioritize each failure mode leading to a validation of the model as an effective fault finder and system optimizer for aircraft landing systems.

Fan et al. (2020) cited the wide application of FMEA across several industries as a latent failure mode identifier, and further prioritization of the modes for system optimization. The study employed a prospect theory-driven consensus measurement approach to validate the model. Using a team-based approach, the study found that the model enables team members to adjust their system assessment information and reference points as a means of reaching consensual interpretation of the failure modes. This consensus is helpful for a unified corrective measure for failure elimination and continuous improvement.

Zaman et al. (2014) conducted a study on the applications of the FMEA model in the Asian maritime industry. The study employed hazard identification and risk evaluation as proxies of FMEA in assessing safety compliance of ships during traffic periods. Fuzzy method was used to analyze the risk factors – severity, occurrence and detectability. Data was collected with Automatic Identification System equipment and Geographic Information System. Results show that FMEA was effective in preventing collisions amongst ships during peak traffic hours.

Grunske et al. (2007) extended FMEA applications with "traditional model support" to extricate and correct potential failures in safety engineering systems. The study made use of probabilistic fault injection and model checking as proxies, and found that the approaches enabled safety engineers to formally detect possibility of failure modes at a probability that is higher than the tolerable hazard threshold. Coming from the perspective of healthcare industry, Carnero (2020) "introduced" FMEA model in the system analysis of Nuclear Medicine Department of a healthcare organization. The study was hybrid, combining FMEA with intuitionistic fuzzy weighted Euclidean distance operator and the multicriteria method in a simultaneous analysis of "subjective and objective" risk factors. The results identified the following failure modes – improper waste storage, improper container labelling and ineffective waste management.

Research by Nie et al. (2018) focused on sustainable development with the evaluation of the role of FMEA in achieving sustainability through safety and reliability management of supercritical water gasification (SCWG). The study hypothesis suggested that this role is not only positive but crucial in adopting best-worst derivation methods for identifying subjective and objective failure risk factors. The study employed complex proportional assessment method in prioritizing failure modes, and results showed its reliability and validity in managing SCWG.

To enhance prospects of achieving these results, a number of studies (de Souva & Carpinetti, 2014; Kim et al., 2007; Onodera, 1997; Pickard et al., 2005; Yeh & Hsieh, 2007) delineate practical procedures for the application of the model. Of course, variations are expected per industry, but the broad aspects are presented as follows:

a. Build a team of persons competent with the operations and mechanisms of the system.
b. Establish the scope of FMEA with respect to the different aspects that make up the value chain of the system.
c. Designate team members across the FMEA scope with respect to their areas of competence and the attributes of the subsystems that make up the system.
d. The next step is the hazard analysis for the determination of the severity, occurrence and detectability of failure in the system. In other words, this stage covers the determination of the ways failure could happen and how each failure mode, causes, consequences and how they could be addressed. Shafiee et al. (2019) argue that the combination of the severity, occurrence and detectability of failure is indicative of the risk propensity of failure in the system and this is mathematically expressed as:

$$RPN = S \times O \times D \quad \text{Equation (1)}$$

Where RPN refers to the risk priority number.

For each failure mode, the failure factors (S, O, D) are stated on a scale of 1 – 10 as per each failure mode in the system, while the RPN values operate on a scale of 1 – 1,000. While S and O may be deemed self-explanatory, D implies how the process controls installed in the system can detect the chances of failure and expose them to correction. The team's competence and experience come to bear in the aspect of assigning a RPN threshold for each failure mode. For instance, where the threshold is 200, it implies that that aspect of the system is critical and response is classified under – "corrective action required". However, where it falls below 200, say 150, response would be – "consider corrective action". This implies that corrective action is necessary but not critical. It is essential to note that whatever threshold set for the system is a function of the distinctiveness of that system and the competence and experience of the management team. An exposition of this analogy is modeled in Table 2, using a typical land administration system.

Table 2: FMEA of Land Administration

Function	Potential Failure Mode	Potential Effects of Failure	S	Potential Causes of Failure	O	Current Process Controls	D	RPN	Recommended Action
Land title registry	Could not locate file Delay in accessing file	Customer dissatisfaction Low performance Loss of trust in system Customer apathy Encumbrance to land transaction Encumbrance to real estate investment	9 7	Wrong filing Analog processes Error in computing land title information Corruption	7 8 5 6	Employee training and motivation Digitalize process Sanctions None	9 8 6 10	567 448	Employee training and motivation Digitalize process Sanctions

A cursory glance at Table 2 shows that for any such system with the stated RPNs and threshold of say, 200, the chances of failure are indeed critical and there is need for serious reengineering of processes for improved performance. This logic explains the philosophy of the FMEA model.

On the downside, however, the FMEA model has also been subjected to criticisms. For instance, Liu et al. (2018; 2019) argue that traditional FMEA has been subjected to severe criticism that suggest that it limits effectiveness of assessing failure modes, weighting risk factors and ranking failure modes of complex or multisystem. As a result, studies have tended to combine it with other models such as Fault Tree Analysis (Shafiee et al., 2019) and hierarchical TOPSIS models (Liu et al., 2019). Other modifications of the FMEA model introduce a "novel multiple-criteria decision making model" as a hybrid of FMEA to cater for multiple systems (Fattahi et al., 2020), type-2 intuitionistic fuzzy VIKOR approach (Fu et al., 2020), fuzzy analytical hierarchical process (Sagnak et al., 2020), cluster analysis, prospect theory and entropy-based method for large group FMEA (LGFMEA) (Liu et al., 2018), amongst others.

2.4 Critique of Extant Land Administration Literature

From the review, most of the studies on FMEA model have been domiciled outside Nigeria. Without prejudice to indigenous FMEA studies (Ali et al., 2020; Eti et al., 2006; Hassan et al., 2022; Igboanugo et al., 2013; Sunday et al., 2018), none has been applied to land administration. This implies that from the Nigerian perspective, there is no evidence of FMEA adoptions (effective or ineffective) in land administration in the country. In line with the foregoing, what is the implication of applying FMEA model in the Nigerian land administration system? The lack of adequate empirical response to this query exposes a significant lacuna in extant land administration literature. With the diverse foundations of FMEA applications as a single or hybrid model, the study, therefore, sees the crucial need for an evaluation of any of these offshoots of the model with a view to ascertaining the most pertinent and sustainable for the system.

3. CONCLUSION

Upon the review of related literature and the gap identified in extant land administration research, the study concluded that while FMEA is a proxy of total quality management and predictor of continuous improvement in systems, lamentably, the veracity of its application for sustainable land administration is yet to be adequately and exhaustively researched. If this gap continues to exist ion extant literature, land administrators may continue to pretermit the model as an approach for stemming systemic challenges and integrating sustainability in the system. This may have negative externalities for real estate investment in the country with the

attendant implications for economic growth. Following this lucidity, the study sets a research agenda for the investigation of the effectiveness of FMEA model as a predictor of sustainable land administration in developing countries, as Nigeria.

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