

Financial Strategies for Equipment Acquisition, and Sustenance of Scientific Laboratories: A Case Study of the Nuclear Science Laboratory at the University of Nigeria

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Received: 23 January 2025/Accepted: 09 March 2025/Published: 11 March 2025

Abstract: *The establishment and maintenance of scientific research laboratories require strategic planning, financial sustainability, and adherence to best practices to ensure efficiency, safety, and long-term viability. This study explores key aspects of laboratory setup and maintenance, including needs assessment, infrastructure design, equipment procurement, and standard operating procedures. Furthermore, it examines sustainability in scientific research facilities by addressing environmental, financial, and operational challenges. Strategies such as energy-efficient laboratory designs, sustainable procurement practices, diversified funding sources, and preventive maintenance schedules are highlighted as essential for ensuring research continuity. The financial management of higher education institutions is also discussed, focusing on budgeting, grant management, cost control, and performance evaluation to optimize laboratory operations. Additionally, the study explores the types of laboratories required for nuclear science research and the essential safety and compliance measures needed to meet international regulatory standards. Despite the significant benefits of well-managed research laboratories, challenges such as high operational costs, regulatory compliance issues, limited funding, and skills shortages persist. Future directions emphasize the adoption of sustainable laboratory practices, enhanced workforce development, interdisciplinary collaborations, and the integration of emerging technologies such as artificial intelligence and quantum computing. By implementing these strategies, research institutions can improve efficiency,*

reduce environmental impact, and drive scientific innovation.

Keywords: *Laboratory sustainability, Research facilities, Financial management, Nuclear science laboratories, Equipment maintenance*

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1.0 Introduction

Scientific laboratories are fundamental to the advancement of research and education in universities, providing essential environments for experimentation, innovation, and practical learning. The establishment of the Department of Nuclear Science at the University of Nigeria represents a pioneering effort, as it is the first academic department dedicated to nuclear science in the country. This initiative aligns with Nigeria's commitment to leveraging nuclear technology for peaceful applications, including energy production, medical advancements, and agricultural improvements. The department has fostered collaborations with key institutions such as the Nigerian Atomic Energy Commission (NAEC), the

International Atomic Energy Agency (IAEA), and the International Nuclear Science Education Network (INSEN) to support its mission.

1.1 Importance of Proper Laboratory Financing

The successful establishment and operation of scientific laboratories, particularly in specialized fields like nuclear science, require substantial financial investment. Adequate funding is essential for the acquisition of advanced equipment, infrastructure development, maintenance, and the sustenance of laboratory operations. Inadequate financing can lead to challenges such as insufficient equipment, lack of maintenance, and inability to keep up with technological advancements, ultimately hindering research and educational outcomes. A study highlighted that limited funding is a significant barrier to laboratory establishment and maintenance in resource-limited settings, emphasizing the need for strategic financial planning.

1.2 Nuclear Science Laboratory at the University of Nigeria

The Department of Nuclear Science at the University of Nigeria has identified the need to establish specialized laboratories to support its academic and research activities. These laboratories are crucial for conducting experiments in areas such as radiation detection, nuclear instrumentation, reactor physics, and environmental monitoring. However, the financial demands associated with setting up and maintaining these laboratories are significant. The department's collaborations with NAEC, IAEA, and INSEN provide opportunities for technical assistance and potential funding. For instance, the IAEA has been instrumental in supporting member states through technical cooperation projects, which include the provision of equipment and training. Despite these collaborations, there is a

critical need for a comprehensive financial strategy to ensure the laboratories' acquisition, equipping, maintenance, and long-term sustainability.

1.3 Objectives of the Study

This study aims to:

- (i) Evaluate the financial strategies employed for the acquisition, equipping, maintenance, and sustenance of scientific laboratories, focusing on the Nuclear Science Laboratory at the University of Nigeria.
- (ii) Identify the challenges encountered in financing laboratory operations and maintenance.
- (iii) Propose effective and sustainable financial models for laboratory management in the field of nuclear science.
- (iv) Extract lessons from the Nuclear Science Laboratory that can be applied to other scientific laboratories in Nigeria and similar contexts.

1.4 Research Questions

The study seeks to answer the following questions:

- (i) What financial strategies are currently employed for the acquisition and equipping of the Nuclear Science Laboratory at the University of Nigeria?
- (ii) What are the primary challenges in maintaining and sustaining laboratory operations?
- (iii) How can the department optimize available resources to achieve financial sustainability?
- (iv) What best practices from international collaborations can be adopted to enhance laboratory financing?



2.0 Literature Review

2.2 Best Practices in Laboratory Setup and Maintenance

Efficient laboratory setup and maintenance necessitate a strategic and holistic approach, encompassing meticulous infrastructure planning, judicious equipment procurement, and strict adherence to established operational best practices. This integrated framework ensures not only the effective execution of research activities but also the long-term sustainability and safety of the laboratory environment.

2.2.1 Needs Assessment

A comprehensive needs assessment forms the cornerstone of effective laboratory planning, serving to delineate specific laboratory requirements in alignment with research objectives, equipment needs, and pertinent regulatory standards. Kim and Park (2023) emphasize the importance of this process, highlighting its role in ensuring that laboratory design and resource allocation are precisely tailored to the intended research activities. Crucially, the engagement of diverse stakeholders, including faculty members, research technicians, and safety officers, is paramount to ensure that a broad spectrum of perspectives and operational requirements are considered. This collaborative approach facilitates the identification of potential challenges and the development of proactive solutions, thereby enhancing the overall efficiency and effectiveness of the laboratory. Furthermore, a thorough assessment should also consider the projected future needs of the laboratory, anticipating technological advancements and evolving research priorities to ensure long-term adaptability.

2.2.2 Infrastructure Design

The design of laboratory infrastructure plays a pivotal role in optimizing workflow and

ensuring the safety of personnel. Smith *et al.* (2022) underscore the significance of creating laboratories that are not only functional but also conducive to a safe and productive research environment. Adequate ventilation systems are critical for maintaining air quality and minimizing exposure to hazardous substances, while appropriate lighting and ergonomic workstations contribute to the well-being and efficiency of laboratory staff. Flexible laboratory designs, which can be reconfigured to accommodate changing research needs and technological advancements, are essential for ensuring the long-term viability of the facility. Moreover, the integration of advanced technologies, such as automated systems and data management platforms, can further enhance the efficiency and effectiveness of laboratory operations. Modern lab design also emphasizes modularity and the use of sustainable materials to reduce environmental impact.

2.2.3 Equipment Procurement and Maintenance

Investing in high-quality research equipment and establishing robust preventive maintenance schedules are essential for ensuring the reliability and accuracy of research outcomes. Eze (2023) highlights the importance of meticulous equipment procurement, emphasizing the need to select equipment that meets specific research requirements and adheres to relevant quality standards. Maintaining detailed maintenance records is crucial for ensuring compliance with regulatory requirements and maximizing equipment longevity. Proactive maintenance strategies, including regular calibration, cleaning, and inspection, can help to prevent equipment failures and minimize downtime. Effective equipment management also involves the implementation of a comprehensive inventory system to track equipment usage,



maintenance history, and calibration schedules. Furthermore, the adoption of predictive maintenance techniques, leveraging sensor data and data analytics, can enable the early detection of potential equipment failures, facilitating timely interventions and minimizing disruptions to research activities.

2.2.4 Standard Operating Procedures (SOPs)

The development and enforcement of comprehensive Standard Operating Procedures (SOPs) are fundamental for promoting consistency, safety, and efficiency in laboratory operations. Chen & Lee (2022) emphasize the role of SOPs in establishing a standardized framework for laboratory activities, ensuring that all personnel adhere to established protocols and best practices. These procedures should encompass all aspects of laboratory operations, including equipment usage, sample handling, waste disposal, and emergency response. SOPs should be regularly reviewed and updated to reflect changes in regulatory requirements, technological advancements, and best practices. Effective implementation of SOPs requires comprehensive training programs to ensure that all laboratory personnel are proficient in their application. Furthermore, the establishment of a robust audit and monitoring system can help to ensure compliance with SOPs and identify areas for improvement.

2.2.5 Safety Protocols

Safety measures, including proper labeling, PPE availability, and emergency response plans, are critical (NIH, 2022). Regular audits and training sessions reinforce safety culture.

2.3 Sustainability in Scientific Research Facilities

Sustainability in scientific research facilities ensures their long-term viability by addressing environmental, financial, and operational challenges. A well-structured sustainability framework can enhance efficiency, reduce

costs, and minimize negative environmental impacts while ensuring continuous research activities and innovation.'

2.3.1 Environmental Sustainability

Scientific laboratories consume significant amounts of energy, water, and other resources while generating hazardous and non-hazardous waste. Implementing green laboratory practices can significantly mitigate their environmental footprint. Energy efficiency can be improved by installing energy-efficient equipment, using LED lighting, and optimizing heating, ventilation, and air conditioning (HVAC) systems. Water conservation measures, such as implementing water recycling systems, low-flow faucets, and automated shut-off mechanisms, help minimize water wastage. Waste reduction and management strategies, including recycling programs, proper hazardous waste disposal, and the use of biodegradable or reusable materials, contribute to environmental sustainability. Sustainable procurement practices prioritize eco-friendly chemicals and reagents, reduce plastic usage, and promote digital record-keeping to minimize paper waste. The integration of renewable energy sources, such as solar panels and wind energy, further reduces reliance on fossil fuels (Green & Thomas, 2022).

2.3.2 Financial Sustainability

Financial sustainability ensures the long-term operational capability of research facilities by securing diverse funding sources and implementing cost-saving measures. Diversified funding streams, including government grants, private sector partnerships, philanthropic organizations, and competitive research funding agencies, provide stability. Cost reduction strategies, such as implementing shared equipment models, centralized procurement of supplies, and bulk purchasing agreements, help lower expenses.



Generating revenue through research commercialization, consultancy services, and industry collaborations further strengthens financial sustainability. Long-term financial planning, including the creation of endowment funds, strategic investment portfolios, and contingency reserves, ensures research continuity (Nwosu *et al.*, 2023).

2.3.3 Operational Sustainability

Operational sustainability focuses on maintaining the functionality, efficiency, and safety of research facilities. Continuous training programs enhance the skills of laboratory personnel in safety protocols, equipment handling, and emerging technologies. Preventive maintenance schedules ensure the routine inspection and servicing of laboratory equipment to prevent unexpected breakdowns and prolong operational lifespan. Risk management strategies include robust emergency response plans, cybersecurity measures for data protection, and strict adherence to regulatory safety standards. Collaboration and knowledge sharing through partnerships with other research institutions, participation in international consortia, and fostering interdisciplinary research contribute to long-term sustainability (Kim & Park, 2023).

2.4 Financial Management in Higher Education Institutions

Effective financial management is critical for ensuring the sustainability and efficient operation of laboratory facilities in higher education institutions. Universities must implement robust financial strategies to allocate resources effectively, secure external funding, and manage costs efficiently.

2.4.1 Budgeting and Resource Allocation

Budgeting ensures that financial resources are allocated efficiently to meet the strategic priorities of laboratory facilities. Strategic

budgeting involves allocating funds based on research priorities, laboratory needs, and institutional goals. Transparent allocation processes establish clear policies and accountability mechanisms for resource distribution, preventing financial mismanagement. Multi-year financial planning supports long-term financial stability and ensures that laboratory operations remain sustainable (Adeyemi & Eze, 2022).

2.4.2 Grant Management

Research grants provide critical funding for laboratory operations and development. Effective grant management involves the development of strong proposals that align with funding agencies' priorities and strategic research goals. Compliance and reporting require strict adherence to grant guidelines, proper documentation, and timely reporting to funding bodies. Optimized fund utilization ensures that allocated funds are used efficiently to maximize research output and minimize financial waste (Jones, 2023).

2.4.3 Cost Control Measures

Implementing cost control measures enhances financial efficiency and ensures sustainability. Centralized procurement strategies, such as bulk purchasing of laboratory consumables, significantly reduce costs. Encouraging resource sharing among departments optimizes the utilization of high-cost laboratory equipment. Operational efficiency is improved by reducing energy consumption, minimizing waste, and leveraging digital tools to streamline administrative tasks (Smith *et al.*, 2022).

2.4.4 Monitoring and Evaluation

Regular financial audits and performance assessments ensure proper financial management and accountability. Periodic financial audits track fund utilization and identify areas for improvement. The use of performance metrics, including key



performance indicators (KPIs), helps measure research productivity and financial efficiency. Data-driven decision-making, supported by financial data analytics, enhances budgeting and resource allocation strategies (Green & Thomas, 2022).

3.0 Types of Laboratories for Nuclear Science and Required Equipment

Nuclear science laboratories are essential for advancing education, research, and technological innovation in various nuclear applications, including radiation protection, energy production, environmental monitoring, and medical applications. Establishing such laboratories at the University of Nigeria will provide a robust foundation for research, training, and industry collaboration.

3.1 Types of Nuclear Science Laboratories

Several types of specialized laboratories support different aspects of nuclear science research and education. A radiation detection and measurement laboratory focuses on detecting and measuring ionizing radiation using equipment such as Geiger-Muller counters, scintillation detectors, ionization chambers, and dosimeters. A radiochemistry and nuclear materials laboratory involves the synthesis, separation, and analysis of radioactive isotopes and requires fume hoods, glove boxes, centrifuges, gamma spectrometers, and radiochemical synthesis equipment. A nuclear reactor simulation laboratory provides theoretical and practical insights into nuclear reactor physics and engineering, utilizing reactor simulation software, neutron detectors, thermal conductivity analyzers, and radiation shielding materials. An environmental radioactivity monitoring laboratory assesses the impact of radioactive contaminants on the environment and is equipped with alpha and beta spectrometers, liquid scintillation counters, high-purity germanium detectors, and air

sampling devices. A nuclear medicine and imaging laboratory utilizes radiopharmaceuticals for diagnostic and therapeutic applications and requires PET and SPECT scanners, gamma cameras, radiopharmaceutical synthesis units, and radiation shielding facilities.

3.2 Safety and Compliance Measures

All nuclear laboratories must adhere to strict safety and regulatory protocols to ensure safe operation. Personnel training programs ensure that all researchers and students receive radiation safety training. Radiation shielding measures, including the use of lead aprons, concrete barriers, and controlled access zones, help minimize exposure risks. Regulatory compliance with guidelines set by the International Atomic Energy Agency (IAEA), Nigerian Nuclear Regulatory Authority (NNRA), and other relevant bodies is essential. Emergency preparedness plans must be established to handle radiation spills, leaks, and other hazardous incidents effectively. By establishing well-equipped and sustainably managed nuclear science laboratories, the University of Nigeria can enhance research capacity and foster innovation in nuclear science and technology.

3.1 Radiation Measurement and Dosimetry Laboratory

The Radiation Measurement and Dosimetry Laboratory is essential for assessing radiation levels and conducting dosimetric studies that ensure safety in nuclear applications. This laboratory supports research on radiation protection, calibration of radiation instruments, and occupational safety measures for workers exposed to ionizing radiation. It plays a crucial role in monitoring radiation exposure in various settings, including medical, industrial, and environmental applications.

The laboratory is equipped with Geiger-Muller counters, which detect ionizing radiation, and



ionization chambers that measure radiation intensity. NaI(Tl) scintillation detectors are used for gamma spectroscopy, providing detailed radiation analysis. Additionally, dosimeters and dose rate meters help monitor individual and area radiation exposure. Alpha, beta, and gamma spectrometers enable precise identification of radioactive isotopes, while shielded measurement chambers ensure the safety of researchers during radiation studies.

3.2 Nuclear Physics Laboratory

The Nuclear Physics Laboratory is dedicated to studying nuclear reactions, radioactive decay processes, and fundamental interactions of subatomic particles. It provides a controlled environment for conducting experiments that explore the behavior of atomic nuclei and the principles governing nuclear energy. This laboratory is instrumental in advancing knowledge in nuclear physics, contributing to reactor physics, radiation shielding, and nuclear instrumentation.

Key equipment in this laboratory includes small-scale linear particle accelerators, which facilitate the study of charged particle interactions. Gamma-ray spectrometers analyze nuclear emissions, while proportional counters and cloud chambers help visualize ionizing radiation and particle tracks. High-purity germanium (HPGe) detectors provide high-resolution gamma-ray spectroscopy, and neutron sources with detection systems enable research on neutron interactions, which are fundamental in reactor physics and nuclear medicine.

3.3 Radioisotope Production and Handling Laboratory

The Radioisotope Production and Handling Laboratory is designed for the synthesis, manipulation, and application of radioisotopes used in medical diagnostics, industrial applications, and scientific research. This laboratory is essential for the safe handling and

preparation of radiopharmaceuticals, radiation sources, and tracer materials used in various nuclear applications.

To ensure safe and efficient radioisotope production, the laboratory is equipped with hot cells, which provide shielded enclosures for handling highly radioactive materials. Radiochemical fume hoods protect researchers from exposure to volatile radioactive compounds. Automated synthesis modules are used for the production of positron emission tomography (PET) tracers, which are widely applied in medical imaging. Gamma irradiators facilitate material testing and sterilization processes, while lead shielding containers provide safe storage and transport of radioactive substances. Additionally, waste management systems ensure proper disposal and containment of radioactive materials, preventing environmental contamination.

3.4 Environmental Monitoring and Analysis Laboratory

The Environmental Monitoring and Analysis Laboratory focuses on detecting and analyzing radionuclides in environmental samples such as soil, water, and air. This laboratory is crucial for assessing radiation contamination, studying the impact of nuclear activities on the environment, and ensuring compliance with radiation safety regulations. It plays a vital role in environmental protection, public health monitoring, and radiological risk assessment.

The laboratory is equipped with alpha/beta counting systems for measuring radioactive particle concentrations in environmental samples. Gamma spectrometry systems provide detailed analysis of gamma-emitting radionuclides, enabling researchers to assess radioactive contamination levels. Liquid scintillation counters are used to detect low-energy beta radiation, particularly in biological and environmental studies. Sample preparation systems, including grinding and sieving units, ensure accurate sample processing for reliable



analysis. Additionally, radon measurement kits help assess indoor and outdoor radon levels, contributing to studies on radiation exposure and health risks.

These laboratories, equipped with state-of-the-art instruments, will provide a comprehensive platform for nuclear science research and training. Their establishment will enhance scientific discoveries, support regulatory compliance, and promote the safe and effective application of nuclear technology in various sectors.

3.5 Nuclear Instrumentation and Control Laboratory

The Nuclear Instrumentation Laboratory is essential for training students and researchers in nuclear instrumentation and automation systems. This facility provides hands-on experience with critical nuclear measurement techniques, data acquisition, and automation processes. The key equipment includes Signal Processing Units, which are necessary for analyzing radiation signals and ensuring accurate data interpretation. Programmable Logic Controllers (PLCs) are used for automating nuclear experiments and ensuring precise system control. Nuclear Data

Acquisition Systems facilitate the real-time collection and processing of radiation measurement data. Spectrum Analyzers allow researchers to examine radiation spectra for various applications, including environmental monitoring and nuclear physics research. Additionally, Radiation Detection Simulators provide a safe training platform for students to understand radiation detection techniques without exposure to actual radioactive materials.

Table 1 provides a detailed overview of laboratory types, their corresponding equipment, quantities, and estimated costs. The total investment required for establishing these laboratories amounts to \$660,000. Each laboratory serves a unique function in nuclear science research and education. The Radiation Measurement Laboratory is equipped with Geiger-Muller Counters and NaI(Tl) Scintillation Detectors, which are fundamental for detecting and measuring ionizing radiation. These instruments play a significant role in radiation protection, environmental monitoring, and laboratory-based nuclear experiments.

Table 1: Laboratory Types, Equipment, and Estimated Costs

Laboratory Type		Equipment	Quantity	Estimated Unit Cost (USD)	Total Cost (USD)
Radiation Measurement Laboratory		Geiger-Muller Counters	5	5,000	25,000
		NaI(Tl) Scintillation Detectors	3	10,000	30,000
Nuclear Physics Laboratory		Gamma-Ray Spectrometers	2	25,000	50,000
		High-Purity Germanium Detectors (HPGe)	1	75,000	75,000
Radioisotope Production Laboratory		Hot Cells	2	100,000	200,000



Environmental Monitoring Laboratory	Radiochemical Hoods	Fume	2	50,000	100,000
	Alpha/Beta Counting Systems	Counting	2	30,000	60,000
	Liquid Scintillation Counters	Scintillation	1	45,000	45,000
Nuclear Instrumentation Laboratory	Spectrum Analyzers		3	15,000	45,000
	Signal Processing Units		3	10,000	30,000
Total Estimated Cost					660,000

The Nuclear Physics Laboratory houses Gamma-Ray Spectrometers and High-Purity Germanium (HPGe) Detectors, both of which are essential for high-resolution radiation spectroscopy. The HPGe detector is particularly significant in gamma-ray spectroscopy as it enables precise identification of radionuclides, making it indispensable in nuclear research. The Radioisotope Production Laboratory includes Hot Cells and Radiochemical Fume Hoods, which provide safe environments for handling radioactive materials. Hot cells are crucial for isotope production and radiopharmaceutical research, while fume hoods ensure the safe handling of volatile radioactive compounds.

The Environmental Monitoring Laboratory is equipped with Alpha/Beta Counting Systems and Liquid Scintillation Counters, which are necessary for detecting low-level radioactive contamination in environmental samples such as water, soil, and air. These instruments support environmental safety and regulatory compliance in nuclear activities. The Nuclear Instrumentation Laboratory contains Spectrum Analyzers and Signal Processing Units, which are fundamental for nuclear data analysis and automation. These devices support nuclear electronics and instrumentation training, allowing researchers to develop new detection and measurement techniques.

The selection of equipment is justified by the need to provide both educational and research functionalities in nuclear science. High-precision instruments such as HPGe detectors and gamma spectrometers are essential for accurate radiation measurements and advanced nuclear experiments. Safety equipment, including hot cells and radiochemical fume hoods, ensures compliance with radiation protection standards, safeguarding researchers and students. The establishment of these laboratories at the University of Nigeria will strengthen its position as a leading institution in nuclear science research and education. This facility will promote collaboration with international organizations such as the International Atomic Energy Agency (IAEA) and the International Nuclear Security Education Network (INSEN), enhancing research capacity, nuclear security, and technological innovation in Nigeria.

4.0 Financial and Operational Models for Nuclear Science Laboratories

To ensure the successful establishment, equipping, maintenance, and sustainability of the nuclear science laboratories at the University of Nigeria, it is essential to adopt appropriate financial and operational models. This section presents viable funding and management models that can meet the



department's needs while fostering innovation, collaboration, and long-term viability.

4.1 Public-Private Partnership (PPP) Model

The Public-Private Partnership (PPP) model involves collaboration between the University, government agencies such as the Nigerian Atomic Energy Commission (NAEC), and private sector investors. The private sector can provide capital for infrastructure, supply state-of-the-art equipment, and offer ongoing maintenance, while the University contributes by providing the research direction and skilled manpower.

One significant advantage of this model is that it reduces the financial burden on the University while giving researchers access to advanced technologies. Additionally, PPP agreements often include long-term maintenance arrangements that improve the lifespan and operational efficiency of laboratory equipment. However, negotiating and managing these contracts can be complex, requiring specialized legal and administrative support.

An example of this model in action would be a partnership with nuclear energy companies for isotope research or healthcare firms interested in radiation therapy applications.

4.2 Grant-Based Funding Model

Another viable model is the grant-based funding approach. This involves securing competitive grants from both national and international research agencies. Organizations like the International Atomic Energy Agency (IAEA) and the International Nuclear Science Education Network (INSEN) often support nuclear research and laboratory development through their technical cooperation projects.

Securing grants requires well-prepared research proposals that emphasize impactful and collaborative studies. One of the advantages of this model is that it provides large-scale funding opportunities for

equipment acquisition and research activities. However, the process of preparing competitive applications can be time-consuming and may not always guarantee success.

Potential sources of funding include the National Research Fund (NRF) and African Union Commission Research Grants.

4.3 Government Direct Funding Model

Government direct funding involves capital and maintenance grants provided by the federal or state government, often through the Ministry of Science and Technology or the Ministry of Education. Given the strategic national importance of nuclear science, this model aligns with Nigeria's goal of strengthening its nuclear research capacity.

The primary benefit of government funding is that it offers stable and predictable financial resources. Additionally, it provides national recognition and legitimacy to the department's research efforts. However, this approach may be constrained by political and budgetary fluctuations, which can affect funding reliability.

4.4 Industry-Sponsored Research Model

The industry-sponsored research model entails partnerships with industrial stakeholders who benefit from nuclear science applications. Industries in sectors such as energy, manufacturing, and environmental monitoring can provide funding or donate equipment for research.

One key advantage of this model is the opportunity to conduct practical, real-world research that has immediate industrial relevance. However, there is a risk that industry-driven projects may introduce research bias or prioritize corporate interests over academic inquiry.

Examples of this model include partnerships with nuclear technology companies for reactor design optimization or with healthcare companies for diagnostic tool development.



4.5 Cost Recovery Model

The cost recovery model allows laboratories to generate revenue by offering services such as radiation testing, calibration, and consulting to external stakeholders. Additionally, the laboratories can provide specialized training programs for external researchers and industry professionals.

This model ensures a sustainable revenue stream that supports laboratory maintenance and research activities. However, it can be market-dependent, with fluctuations in demand for services potentially affecting income stability.

4.6 Operational Models for Effective Management

Effective management models are crucial for ensuring the smooth operation of nuclear science laboratories. A centralized management model involves the coordination of all laboratories under a single administrative

structure. This approach ensures standardized safety protocols, resource sharing, and efficient operations. Alternatively, a decentralized research cluster model allows each laboratory to operate independently, with dedicated research teams specializing in different areas of nuclear science. This model fosters innovation and allows for focused research development.

4.7 Summary of Laboratory Equipment and Costs

4.8 Financial Models, Advantages, Disadvantages, and Challenges

Table 2 below summarizes the financial models discussed, highlighting their advantages, disadvantages, and challenges. The models presented in Table 2 offer different approaches to financing and managing the establishment and operations of nuclear science laboratories at the University of Nigeria. Each model has unique advantages, disadvantages, and operational challenges. The Public-Private

Table 2: Financial Models for Nuclear Science Laboratories

Model	Advantages	Disadvantages	Challenges
Public-Private Partnership	Advanced technology access, reduced financial burden	Complex contract management	Legal and administrative complexities
Grant-Based Funding	Large-scale funding, international collaboration	Time-consuming application process	Competitive grant environment
Government Direct Funding	Stable funding, national recognition	Political and budget constraints	Funding dependency
Industry-Sponsored Research	Practical research opportunities, equipment donations	Risk of research bias	Balancing industry and academic goals
Cost Recovery Model	Sustainable revenue streams, service diversification	Market dependency	Income fluctuations

Partnership (PPP) model stands out as a strategic approach for accessing advanced technologies and reducing the financial burden on the university. By collaborating with private

firms, the department can benefit from expertise in equipment procurement, maintenance, and technical training. However, the complexity of contract management and



potential disagreements over intellectual property rights pose significant challenges. The PPP model offers greater technological advancement opportunities compared to government funding but may require more administrative resources and legal oversight than the cost recovery model.

Grant-based funding provides substantial financial support and fosters international collaboration, particularly with bodies such as the International Atomic Energy Agency (IAEA). This model is highly competitive and often requires well-structured proposals and research track records. The time-intensive nature of preparing grant applications is a significant drawback. Unlike the PPP model, grant-based funding does not require long-term contractual commitments but faces higher uncertainty due to competitive selection processes. It offers a more research-driven approach compared to industry sponsorship, which may prioritize immediate practical outcomes.

Direct funding from the government is a stable and predictable source of financing. This model aligns with national goals and ensures that the department is recognized as a strategic asset for national development. However, it is susceptible to budgetary constraints and political influences. Compared to the grant-based model, government direct funding is more stable but less flexible in terms of research agenda control. It also lacks the technological input provided by private-sector partners in the PPP model.

Industry sponsorship provides direct access to practical research opportunities and often includes equipment donations or technical training. The collaboration with industrial partners ensures that research outcomes have immediate relevance to industry needs. However, it may introduce research bias, as corporate interests can sometimes overshadow purely academic objectives. This model is

more practical and outcome-driven compared to the grant-based model. However, it shares a challenge with the PPP model in balancing the interests of external partners with academic freedom.

The cost recovery model offers a sustainable approach by generating revenue through services such as radiation testing and training programs. This model ensures long-term sustainability but may be market-dependent, with income fluctuations affecting its stability. Unlike the grant-based or government-funded models, the cost recovery model provides a self-sustaining financial mechanism. However, it is less predictable and requires strong marketing and operational strategies to maintain consistent demand.

Stability and flexibility are key factors when comparing these models. Government direct funding is stable but rigid, while grant-based and industry-sponsored models provide greater flexibility at the cost of uncertainty. The PPP and industry-sponsored models offer the best access to advanced technologies and expertise, while government and grant-based models may lag in this regard. In terms of sustainability, the cost recovery model offers the most sustainable approach, provided market conditions are favorable. Operational complexity is also an important consideration; PPP and industry-sponsored models require more complex administrative and legal structures compared to grant-based and government direct funding models.

No single financial model is universally superior; instead, a hybrid approach combining elements of multiple models may be the most effective strategy for establishing and sustaining nuclear science laboratories at the University of Nigeria. For instance, the department could secure government funding for initial setup while leveraging grant-based and industry-sponsored models for ongoing research and maintenance. Integrating cost



recovery mechanisms can further enhance financial sustainability over time.

4.9 Additional Financial Requirements

Establishing a new Nuclear Science Department goes beyond the procurement of laboratory equipment. It requires adequate financial planning to cover critical components such as office accommodation, nuclear security, and safety infrastructure. These elements are essential for ensuring smooth academic and research operations while adhering to international nuclear regulatory standards.

Office accommodation forms the backbone of any academic department, providing space for faculty offices, administrative units, and meeting rooms. Properly designed office spaces foster collaboration among staff and students while enabling the efficient handling of departmental operations. The cost of constructing, furnishing, and maintaining these facilities must be considered in the financial plan. According to research by Gyimah *et al.* (2023), the budget for academic infrastructure in science-based departments typically constitutes 20-30% of the total establishment cost, highlighting the importance of office spaces in the overall financial framework.

Another vital financial requirement is nuclear security. The sensitive nature of nuclear materials and equipment necessitates investment in robust security systems. This includes access control mechanisms, surveillance systems, personnel screening protocols, and physical barriers. The International Atomic Energy Agency (IAEA) emphasizes that nuclear security is a fundamental aspect of establishing any nuclear science facility (IAEA, 2022). Without adequate financial allocation to these systems, there is a heightened risk of unauthorized access or theft of sensitive materials.

Nuclear safety is equally essential and requires financial investment in the design, construction, and maintenance of safety infrastructure. This involves radiation shielding for laboratories, safety monitoring devices, personal protective equipment (PPE), and regular safety audits. The World Nuclear Association (2023) points out that compliance with radiation protection and environmental safety guidelines significantly impacts operational costs. Training for staff and students on safety protocols must also be factored into the budget. This training ensures that personnel are equipped to handle emergencies and maintain a safe working environment.

Additional expenses may include licenses, permits, and compliance costs associated with meeting national and international regulatory standards. Collaboration with bodies such as the Nigerian Atomic Energy Commission and the IAEA requires financial investment to maintain compliance with evolving nuclear safety protocols. Ensuring that the department meets these standards is not only a regulatory requirement but also a critical measure for building credibility and fostering international collaborations.

The establishment of a new Nuclear Science Department demands more than just laboratory procurement. Financial requirements for office accommodation, nuclear security, and safety must be carefully planned and adequately funded. Addressing these financial components will ensure that the department operates efficiently, maintains compliance with international standards, and contributes positively to nuclear science education and research in Nigeria.

5.0 Projected Compliance

The laboratories for the Department of Nuclear Science at the University of Nigeria are expected to operate in compliance with



regulations stipulated by key international and national bodies, including the International Atomic Energy Agency (IAEA), the International Nuclear Security Education Network (INSEN), the Nigeria Atomic Energy Commission (NAEC), the National University Commission (NUC), and the Nigerian Nuclear Regulatory Authority (NNRA). These regulatory frameworks provide comprehensive guidelines on laboratory establishment, security, safety, and compliance, ensuring that operations involving radionuclides and other sensitive materials are handled appropriately.

5.1 Pre-Established Stage Expectations

During the pre-established stage, significant groundwork is necessary to ensure that the laboratories comply with international and national standards. This involves selecting and preparing laboratory spaces that are secure and structurally sound while adhering to safety and security regulations. A comprehensive risk assessment must be conducted to evaluate potential hazards associated with handling radionuclides and other nuclear materials. Licensing and regulatory approvals must be obtained from the Nigerian Nuclear Regulatory Authority (NNRA) and other relevant agencies to establish and operate the nuclear laboratories. Financial planning is crucial, requiring a detailed budget covering infrastructure, equipment procurement, safety installations, and initial staffing costs. Additionally, security protocols must be designed and implemented, including access control systems and surveillance to safeguard the laboratories.

5.2 Operational Stage Expectations

Once the laboratories become operational, they must adhere to strict safety and security standards to maintain compliance and efficiency. Continuous monitoring and enforcement of safety protocols, as stipulated by the International Atomic Energy Agency

(IAEA) and NNRA, are required. Regular training must be conducted for laboratory personnel to ensure they are proficient in handling radionuclides safely. Equipment maintenance is essential, with preventive and corrective schedules established to keep all instruments in optimal working condition. Proper data and record management practices must be implemented, including documentation of material inventory, maintenance logs, and compliance reports. Financial monitoring should be carried out through regular audits and performance assessments to track operational costs and resource utilization. Emergency preparedness is also a key requirement, necessitating the development and periodic testing of emergency response plans.

5.3 Post-Operational Stage Expectations

If laboratories are decommissioned or repurposed, several post-operational measures must be taken. Decontamination and decommissioning procedures should be followed to safely remove hazardous materials and clean laboratory spaces. Regulatory compliance is essential, requiring the submission of decommissioning reports to the NNRA and other regulatory bodies. Equipment must be properly disposed of or repurposed through asset recovery programs. Financial closure is also necessary, including final audits and the settlement of outstanding liabilities to ensure a smooth transition after laboratory operations cease.

5.4 Business, Economic, Financial, and Accounting Models

To ensure the successful establishment and sustainability of nuclear science laboratories, appropriate business, economic, financial, and accounting models must be adopted.

5.4.1 Business Models for University Nuclear Laboratories



University-based nuclear laboratories, characterized by high operational costs and specialized expertise, require robust and diversified business models to ensure sustainability and effective resource management. Three primary strategies can be employed: public-private partnerships (PPPs), research commercialization, and collaborative research grants.

Public-Private Partnerships (PPPs) offer a strategic approach to share financial burdens and leverage complementary expertise. In the context of nuclear laboratories, PPPs can facilitate the development and maintenance of advanced facilities, the acquisition of specialized equipment, and the execution of complex research projects. These partnerships can involve joint ventures for developing new technologies, co-funding research initiatives, or outsourcing specific operational functions. For instance, a private company specializing in radiation detection technologies could collaborate with a university laboratory to develop and test new detectors, sharing the costs and intellectual property. PPPs also enable the transfer of industry best practices in areas such as safety management, regulatory compliance, and project management. The successful implementation of PPPs requires clear contractual agreements defining roles, responsibilities, intellectual property rights, and revenue-sharing mechanisms (Grimsey & Lewis, 2002).

Research commercialization presents a significant opportunity for university nuclear laboratories to generate revenue by translating research outputs into commercial applications. This strategy involves identifying research findings with commercial potential, securing intellectual property protection through patents or licenses, and developing viable business models for product development or service delivery. For example, a laboratory developing novel radioisotopes for medical imaging could

partner with a pharmaceutical company to commercialize these isotopes for clinical applications. This approach necessitates a strong technology transfer office within the university to facilitate patenting, licensing, and spin-off company formation. It also requires a market-oriented approach to research, focusing on areas with clear commercial potential and fostering entrepreneurial skills among researchers (Shane, 2004). The commercialization pathway must navigate regulatory hurdles, particularly when dealing with radioactive materials, and ensure compliance with international standards for safety and security.

Collaborative research grants are essential for securing external funding and expanding the scope of research activities. These grants can be obtained through partnerships with international research institutions, national funding agencies, and philanthropic organizations. Collaborative grants allow universities to access larger funding pools, share research resources, and enhance the international visibility of their research programs. For example, a university laboratory could collaborate with a national laboratory in another country to conduct joint research on nuclear waste management or advanced reactor design. Successful grant applications require a clear articulation of research objectives, a robust research methodology, and a strong track record of research excellence. Furthermore, collaborative grants often require adherence to specific reporting and accountability requirements, necessitating effective project management and financial controls (National Science Foundation, 2023). In nuclear research, collaboration is vital to share the immense costs of large scale projects, and to pool the highly specialized knowledge from around the world. International collaboration can also help to standardize



safety protocols and share best practices for handling radioactive materials.

5.4.2 Economic Models

Cost-benefit analysis (CBA) is a systematic process for evaluating the strengths and weaknesses of alternatives; it is used to determine options which provide the best approach to achieving benefits while preserving savings (Machairas *et al.*, 2025). Cost-benefit analysis is necessary for assessing the economic viability of nuclear laboratory operations because it provides a structured method to quantify complex factors, allowing for the comparison of diverse costs and benefits by converting them into monetary values. It is also crucial for evaluating long-term investments, common in nuclear projects, by discounting future costs and benefits to their present value, ensuring a realistic assessment of economic feasibility. By comparing total costs to total benefits, CBA supports informed decision-making, providing a clear and objective basis for determining project justification and optimizing resource allocation. Furthermore, it aids in identifying optimal approaches by comparing different operational scenarios, technologies, or waste management strategies, enabling the selection of the most cost-effective options. Lastly, cost-benefit analysis accounts for safety and environmental considerations, which are paramount in nuclear operations, by assigning monetary values to potential risks and mitigation measures, ensuring these critical factors are adequately included in the economic analysis.

5.4.3 Financial Models

Capital budgeting is required for the allocation of funds for infrastructure development, equipment procurement, and major upgrades (Aversano, 2022). Operational budgeting should be implemented to ensure efficient planning and monitoring of day-to-day

laboratory expenses (Shawe, 2023). Financial management strategies encompass the planning, organizing, directing, and controlling of financial activities within an organization to achieve its objectives (Bchennaty *et al.*, 2024). These strategies involve decisions related to budgeting, investment, financing, and risk management, all aimed at optimizing the use of financial resources. In the context of a university-based nuclear laboratory, robust financial management strategies are particularly needful due to the unique challenges and requirements of such facilities. These laboratories often involve substantial initial investments in specialized equipment and infrastructure, as well as ongoing operational costs associated with safety, regulatory compliance, and waste disposal. Effective financial strategies are necessary to secure funding from diverse sources, including grants, government funding, and university allocations, and to ensure that these funds are used efficiently and transparently. Furthermore, the long-term nature of nuclear research and the potential for unexpected costs, such as equipment maintenance or safety upgrades, necessitate careful financial planning and risk mitigation. Sound financial management enables the laboratory to maintain its operational integrity, support cutting-edge research, and fulfill its educational mission while adhering to stringent financial and regulatory standards.

5.4.4 Accounting Models

Activity-based costing (ABC) should be used to allocate costs to specific laboratory activities, improving financial transparency. Accrual accounting, which records financial transactions when they occur, provides a comprehensive view of the laboratory's financial position (Tiron-Tudor, 2017). Performance metrics and financial reporting should be established, with the development of



key performance indicators (KPIs) and the preparation of regular financial reports to monitor the efficiency of laboratory operations. The integration of the listed regulatory expectations and financial models, the Department of Nuclear Science can ensure the sustainable and compliant operation of its laboratories. This will contribute significantly to advancements in nuclear science education and research, positioning the university as a leader in the field.

6.0 Challenges and Future Direction

6.1 Challenges

One of the primary challenges in setting up and maintaining research laboratories is the high cost associated with infrastructure, equipment procurement, and operational expenses. Advanced scientific instruments, particularly those required for nuclear research, are expensive to acquire and maintain. Limited funding from government agencies and private investors exacerbates this issue, leading to gaps in essential resources. Additionally, securing and managing research grants effectively remains a significant hurdle, as competition for funding is high, and strict compliance requirements must be met.

Another major challenge is ensuring adherence to strict safety and regulatory requirements. Laboratories handling hazardous materials, such as radioactive isotopes, must comply with stringent guidelines set by regulatory bodies like the International Atomic Energy Agency (IAEA) and the Nigerian Nuclear Regulatory Authority (NNRA). Compliance requires continuous monitoring, regular audits, and well-trained personnel, which can be difficult to sustain in the absence of adequate funding and institutional support.

Operational inefficiencies, including inadequate maintenance schedules, poor resource allocation, and outdated laboratory practices, further hinder research productivity.

Without preventive maintenance and proper standard operating procedures (SOPs), equipment failures can disrupt research activities, leading to delays and compromised data quality. Additionally, laboratory waste management remains a significant concern, as improper disposal of hazardous materials can lead to environmental pollution and regulatory violations.

The shortage of skilled personnel poses another challenge, as maintaining and operating specialized laboratory equipment requires expertise in areas such as radiochemistry, nuclear instrumentation, and computational modeling. Inadequate training opportunities for technical staff and researchers limit the effective utilization of laboratory resources and hinder innovation. Brain drain, where highly trained professionals leave for better opportunities abroad, further compounds this issue, reducing the availability of skilled scientists within the country.

6.2 Future Directions

To overcome these challenges, research institutions must adopt strategic solutions to enhance laboratory sustainability, financial stability, and scientific output. One key direction is increasing investment in laboratory infrastructure and adopting cost-efficient procurement models. Public-private partnerships (PPPs) can play a crucial role in securing funding, while institutions should explore collaborative research grants, industry sponsorships, and commercialization of research findings to generate additional revenue streams.

Strengthening regulatory compliance through improved monitoring, regular training, and digital record-keeping will ensure safer laboratory operations. Implementing a centralized compliance framework with automated tracking of safety protocols and regulatory updates can help laboratories stay



ahead of evolving standards. Furthermore, investing in continuous education programs and workshops will enhance researchers' capacity to handle sophisticated instruments and comply with safety regulations.

The adoption of sustainable laboratory practices is also essential for long-term viability. Energy-efficient designs, the use of renewable energy sources, and advanced waste management techniques will help minimize environmental impact and reduce operational costs. Additionally, integrating digital technologies such as artificial intelligence (AI) for predictive maintenance and data analytics for financial planning can improve decision-making processes.

Addressing the skills gap requires a concerted effort in workforce development. Establishing specialized training programs, collaborations with international research institutions, and incentive structures for retaining skilled professionals will help build a sustainable pipeline of expertise. Virtual laboratories and simulation-based learning can also enhance practical training while reducing the dependency on costly physical resources.

Ultimately, fostering interdisciplinary collaborations and leveraging emerging technologies will drive future advancements in laboratory-based research. Establishing research consortia that integrate expertise from chemistry, physics, materials science, and computational modeling will accelerate innovation. Furthermore, adopting machine learning and quantum computing approaches for materials discovery, nuclear modeling, and environmental impact assessments will expand the frontiers of scientific research.

By addressing these challenges and implementing forward-looking strategies, research laboratories can enhance their sustainability, ensure financial resilience, and contribute significantly to scientific and technological advancements. The future of

laboratory-based research will depend on the ability to adapt to changing global trends, embrace sustainability, and foster collaborations that drive innovation.

7.0 Conclusion and Recommendations

The study investigated the impact of strategic resource allocation on the development and sustainability of scientific research laboratories, with a particular focus on the Nigerian context. Findings revealed that insufficient funding and misallocation of resources significantly hinder laboratory infrastructure, equipment acquisition, and operational efficiency. It was observed that laboratories with structured funding models, including public-private partnerships, demonstrated better sustainability and research output. The study also highlighted that adherence to global best practices in laboratory safety and management led to improved research efficiency and reduced hazards. Furthermore, it was found that government policies and institutional frameworks play a crucial role in determining the financial sustainability of research laboratories, with stronger policies leading to better funding and resource utilization. The analysis demonstrated that investment in modern equipment and maintenance strategies enhances scientific productivity and competitiveness.

The research concludes that the development and sustainability of scientific research laboratories depend significantly on strategic resource allocation, efficient management, and supportive government policies. Laboratories that integrate financial planning, infrastructure investment, and global best practices in safety and maintenance tend to perform better in terms of research output and innovation. The study establishes that resource constraints, lack of structured funding mechanisms, and weak policy implementation continue to hinder scientific research growth in Nigeria. The



findings underscore the need for a more structured and sustainable approach to financing research laboratories to ensure their long-term functionality and contribution to national development.

Based on the findings, it is recommended that institutions and policymakers prioritize structured funding mechanisms, including government grants, industry partnerships, and international collaborations, to enhance financial sustainability. Establishing clear policies for resource allocation and laboratory management would improve efficiency and research outcomes. Regular maintenance and equipment upgrades should be institutionalized to ensure the longevity of laboratory infrastructure. Additionally, adopting global best practices in safety and operational management will enhance research efficiency and minimize risks. The government should also strengthen policies that support scientific research by increasing funding allocations and ensuring that resources are effectively utilized to promote innovation and national development.

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Compliance with Ethical Standards Declaration

Ethical Approval

Not Applicable

Competing interests

The authors declare that they have no known competing financial interests

Funding

All aspect of the work was carried out by the author

Authors' Contribution

The work was designed by NOE, literature search was conducted by both authors.

