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# Equipment Maintenance Challenges and Solutions for Capacity Building and Sustainability in the Training of Engineers: the Case for the University of Zimbabwe

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**Abstract**

Engineering equipment in some Higher Education Institutions (HEIs) in Sub-Saharan Africa is underutilized, obsolete or in poor working condition owing to lack of expertise, aging or maintenance-related challenges respectively. A research initiated by the Network of Users of Scientific Equipment in Eastern and Southern Africa (NUSESA) and funded by the Swedish International Development Cooperation Agency (Sida) was carried out by 4 faculties of engineering in Southern Africa to establish common challenges, their causes and to propose solutions. The study revealed that the faculties shared similar problems such as no proper maintenance documentation, no local suppliers for spares and inadequate expertise. The importation of spares usually leads to prolonged lead times and delays in timely repairs to malfunctioning equipment and thus obsolescence. This paper proposes smart procurement partnerships between industry and HEIs, based on the findings from the University of Zimbabwe (UZ). Following the survey and analysis of data obtained, recommendations were made and implemented and have assisted in building capacity in acquisition, maintenance and management of laboratory equipment and sustaining these in the training of engineers.



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*Keywords:* Acquisition, Analysis, Data Collection; Maintenance; Repair; Training; Utilization

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## 1. Introduction

Most HEIs in Sub-Saharan Africa equipped their engineering laboratories during the colonial era (1960 – 1980) when they were managed as colleges of universities, mainly from Europe. The equipment came along with academic and technical staff who had the capacity to use them in the training of engineering students. However, these colleges became fully fledged universities and were weaned off to operate independent of the parent universities [1]. Most of the expatriate lecturers and technical staff returned to their home countries having trained a few of the local academics and technicians but unfortunately they did not leave any sustainability plans in place for either replacement or repair of the donated equipment. This led to deterioration of some of the laboratory equipment because of lack of maintenance or utilization [1]. This problem prompted and brought together universities with Science and Engineering faculties in Sub-Saharan Africa to develop solutions to these challenges, thus giving birth to NUSESA in 1989, with 5 founding members, i.e. Malawi, Mozambique, Tanzania, Zambia and Zimbabwe who later secured financial support from Sida and by the turn of the new millennium, there were 14 members [2]. Research output may have been seriously affected by laboratory equipment challenges, prompting the regional bloc to come up with long term strategies for sustainable development through the broad objectives of; improving acquisition, use and maintenance, enhancing capacity building and sustainability, stimulating a maintenance culture and developing collaborative training, research and exchange of staff among the faculties of engineering [3]. A regional task force from 4 universities of Dar es Salaam, Eduardo Mondlane, Makerere and Zimbabwe was set up to carry out surveys and establish common challenges and proffer solutions for the maintenance of scientific equipment in the region. The findings were consolidated into a regional report, the basis on which this paper is developed, focusing on the Faculty of Engineering at UZ, with occasional reference to the other 3 universities while drawing inferences from the analysis and stakeholders' recommendations on developing effective maintenance policy frameworks for training, capacity building and sustainability.

## 2. Literature review

Due to high costs associated with the replacement of parts or equipment failing due to lack of preventive maintenance, equipment owners are increasingly emphasizing the need to maintain and calibrate equipment as well as replace parts in an organized manner [4]. Traditionally, not many organizations emphasized the need for planned maintenance in order to enhance the life spans of their equipment [5]. Development and aid organizations such as the British Overseas Development Authority (ODA), German Technical Cooperation Agency (GTZ, now GIZ), and Sida provided support for the purchase of new equipment and left the maintenance of such equipment to the recipients, who in most cases were local governments responsible for funding HEIs. Unfortunately these authorities rarely found the funds to maintain the equipment, in some cases leading to obsolescence [5]. The need to maintain equipment has been receiving attention from researchers and practitioners in recent years [6]. Due to rapid changes in technology, engineering and scientific equipment has been evolving at the same pace. The traditional supplier companies are in developed countries that have the potential and capacity to keep pace with these rapid changes, which technologies have brought some degree of complexity that require continuous training of practitioners. [7, 8]. Unfortunately, recipients of such equipment in the developing world have evidently lagged behind owing to lack of financial capacity, resulting in the continued reliance on expertise from the developed countries. In a research to ascertain challenges in transforming manufacturing organizations into product service providers, it was observed that manufacturing output in the UK had remained fairly stable but profitability had been declining, attributed to global competition which forced Original Equipment Manufacturers (OEMs) to cut down their costs in order to maintain or improve profitability [9, 10]. This resulted in rapid changes to their new equipment and the technology that drives them, hence the need to adopt flexible systems management that are adaptive, responsive and agile for an organization's key functions including maintenance [11]. Sustainability is often referred to as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs [12, 13], thus it is the capacity to withstand any setbacks that may arise in the use and maintenance of the equipment.

Developing countries can utilize engineering activities in education and research to introduce appreciable added value to their resources through income generation such as consultancy work in addition to training students and the funds generated can be invested in training users [14]. However, to implement this, requires changing the mind-sets of the authorities and practitioners, requiring innovations and reforms in engineering education [15]. In recent years, maintenance is no longer taken as an aftermarket service needed for equipment to be functional but an inherent part of the equipment or service function of the system [12]. Aid organizations usually request recipients to provide sustainability plans to ensure that their donated equipment is not put to waste. Some institutions have failed on account of this requirement, hence the need to develop innovative ways to capitalize on the opportunities presented by these organizations. Investing in equipment through Public Private Partnerships (PPPs) and specifically, the Build-Operate-Transfer (BOT) model has become the norm, where private firms enter into contracts with public institutions, a typical example being road toll gates [16, 17]. The BOT concept can be extended and used in the purchase of equipment, where private firms enter into contracts with public institutions to acquire and utilize the equipment respectively [18]. The BOT is usually a specialized concession in which the private firm's Research and Development (R&D) function can be performed by an HEI to carry out research and provide required results using the equipment for an agreed period with activities usually sufficient to cover the cost of the equipment, at which point the ownership will be transferred to the HEI. However, a number of risk factors such as cost, anticipated revenue, operating environment, contract duration and equipment life-span have to be considered before parties commit themselves [19]. This paper focusses on and answers questions on the status of equipment, acquisition, maintenance and strategies to keep the equipment functioning and how to build capacity to sustain the equipment.

## 3. Research methodology

Broad guidelines were provided at the commencement of the project but were later refined when it became apparent that information that was being presented was not in a standard format. The refinements collapsed the anticipated activities into 3 main ones, i.e. data collection, data analysis and stakeholders workshop. An inventory form was designed to capture standard information such as functionality, existing records and operational manuals and estimation of value and age of the equipment that had missing records. This involved physical counting and inspection, driven by the departments' chief technicians, while effort was also made to contact the OEMs for more detailed information. A questionnaire was also designed to assist in capturing experts' opinions on equipment sourcing, use, maintenance, problems encountered and user training. This was meant for the various stakeholders involved in the use of laboratory equipment, i.e. lecturers, students, technical staff and other stakeholders from outside the universities, who also use similar equipment in their day to day activities. The data collected was presented both in descriptive form followed by statistical analysis. Inferences and conclusions were drawn from the analyzed data in some cases using pair-wise analysis before compiling the final report at stakeholder workshops held by each of the 4 faculties and also included invited industry practitioners.

## 4. Results

The Faculty of Engineering at UZ was established in 1974 with the 3 traditional departments of Civil, Electrical and Mechanical Engineering, supported by the ODA in terms of equipment, constituting 70% of the equipment in the faculty [20]. In the mid-1980s, GTZ provided support for the establishment of the departments of Metallurgy, Mining and Surveying, constituting 21% of equipment in the faculty. Thus, the bulk of the equipment came from OEMs in the UK and Germany. The rest of the equipment came through other cooperation agreements with organizations such as the Japan International Cooperation Agency (JICA), United States Agency for International Development (USAID), UNESCO-IHE and 7% from the Government of Zimbabwe. The trends in the other universities, especially Makerere and Dar es Salaam were almost the same, where the bulk of their support came from the UK while support for Eduardo Mondlane came from Portugal. Although the equipment is still in use, the average age has surpassed 20 years, a trend that is not commensurate with technology institutions mandated to develop human resources for the rapidly changing technology. As shown in Fig. 1(a), about 61% of all the equipment was classified as still functional but with almost 10% not being utilized at all because of lack of expertise. While it is understandable that the equipment's main purpose is for research and teaching, the use in consultancy (Fig. 1(b)), which can raise income for maintenance and professional development of operators, was low due to the young and inexperienced academics in most of the departments. Civil Engineering had a balanced use of their equipment due to the high number of PhD holders, coupled with a high number of postgraduate students.

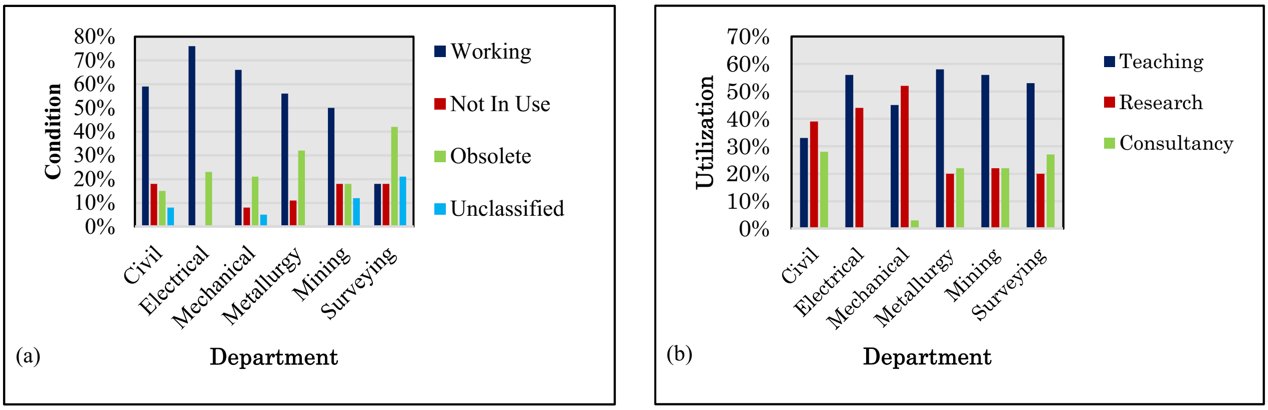


Fig. 1(a) Condition of equipment (b) Utilization of equipment

As shown in Fig. 2(a), most of the equipment in the three traditional departments were maintained by expertise from within the departments, while for the other departments, expertise from outside the university, albeit within the country, was required. The bulk of the maintenance funds (98%) were provided by the university. Except for Civil Engineering and Metallurgy, most of the equipment spares were almost exclusively imported as shown in Fig. 2(b). In general, the 6 departments faced common challenges such as; shortage of spares, lack of maintenance expertise and funds, outdated equipment and technology such that OEMs were no longer able to support.

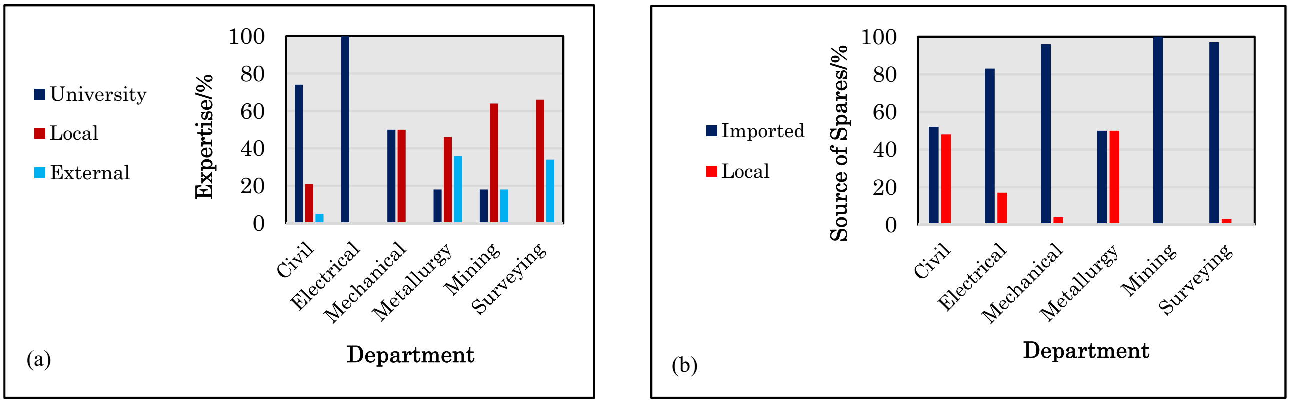


Fig. 2(a) Maintenance expertise (b) Source of spares

## 5. Smart procurement partnerships

Evidenced by the results for obsolescence and underutilisation, coupled with the old conventional equipment at the UZ, a mirror image scenario of the other faculties in Southern Africa, the situation must improve to ensure the proper training of engineers. Although this may not be the case with the more developed nations like South Africa, the general observation pointed to the need for smart acquisition and utilisation of such equipment. In view of the unpredictable and unsustainable donor support as well as the low industrial activities in Zimbabwe in recent years, this research proposed a new paradigm shift to Smart Procurement Partnerships (SPPs) with industry through PPPs, modelled along the concepts of BOT as shown in Fig. 3, with the overall objective of increasing students' access to technology, relevant curricula, quality of engineering graduates and industry savings on R&D costs, which can be undertaken fully by the HEIs based on the form of agreement entered into. The agreements between HEIs and industry can be in the form of single partnerships or consortiums where more than one company or HEI are involved, premised on the focus for core business for each party, production and making profit for industry and R&D and training for the HEIs, the strengths of which can be capitalised on for both parties.

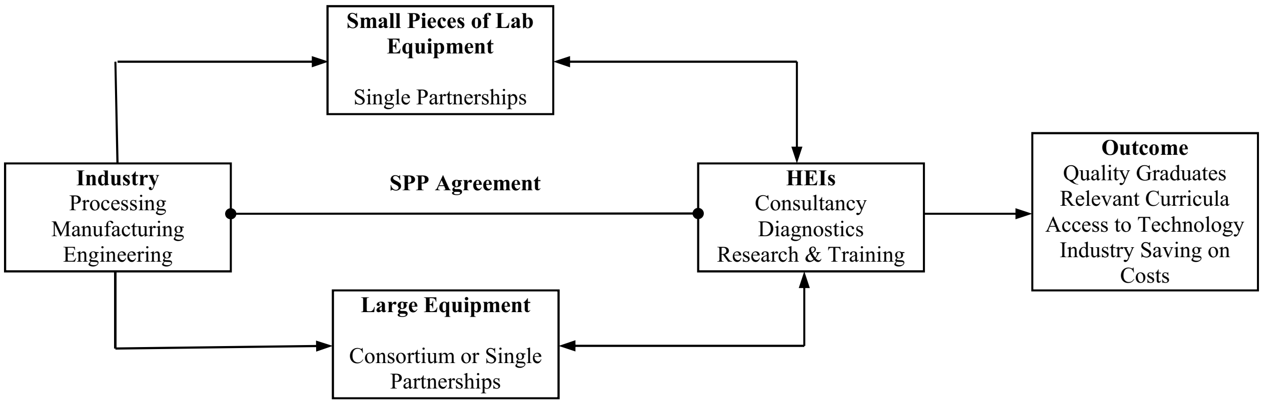


Fig. 3. Smart procurement partnership model for laboratory equipment

## 6. Discussion and recommendations

A pair-wise analysis of factors was used in determining underlying patterns and relationships between the factors, using recorded details. Most of the departments exhibited moderate age and technology related challenges, with indications that much of the obsolescence of equipment was maintenance related. Older equipment in the first 3 departments was still more functional than the latter, possibly attributed to the issue of language where the equipment from Germany had manuals written in German. Departments with higher percentages of working equipment also tended to have higher utilization, a trend that is expected [21]. Civil and Mechanical Engineering departments had a high underutilization of working equipment pointing to the need to train more operators. Surveying had very high-cost but mostly obsolete equipment and of the working equipment, the department had the least utilization owing to the unusually low-establishment and high-turnover of staff. Most of the technicians had at least 10 years of experience with the same equipment but still needed hands-on maintenance training to ensure maximum and proper utilization of the equipment [22]. The shortage of spares and local maintenance expertise were the two main challenges identified, followed by outdated technology and lack of adequate funding to support maintenance. The survey also revealed the desire by experts to be innovative through fabrication of some of the spares as an alternative way to dealing with problems associated with costs and importation of spare parts [23, 24].

A maintenance policy must be put in place to address issues of procurement and use of life-cycle costing in establishing the basis for purchasing while obtaining and keeping user service manuals and where necessary, translate them to English. Owing to the underutilization of equipment it was recommended to dispose of duplicate equipment and then develop a faculty pool of common equipment that can be utilized to the maximum while channelling funds realized from the disposal for training and purchase of spares. The same principle can be extended to collaborating institutions, where expensive and specialized equipment as well as maintenance expertise can be shared, having taken into account the logistics and costs. Similarly, through PPPs, HEIs can enter into SPP agreements with the industry to purchase specialized equipment and have access to these for training purposes, similar to BOT models, while offering research and analysis services to industry. Most spares can be fabricated in the faculty workshops and thus effectively substituting the imported ones. Procurement should never be left to individuals as this has the risk of acquiring equipment that can only be used by individuals who upon leaving the university, the equipment goes into the class of working but not being used category. Higher level and postgraduate courses with practical elements are required to ensure maximum utilization of equipment and the promotion of research based learning through which capacity can be built by fostering a culture of practical research. Capacity can also be built without encountering huge costs, through training and regional exchange of staff and centres of excellence by establishing a common framework, regional training needs and budget to facilitate the movement and exchange of staff and training. Aid organizations are in support of this framework and it will thus be easier to apply for financial support [2]. Short courses for industry technicians with a cost recovery approach for sustainability as well as use of virtual learning facilities are other ways that can be explored to reduce costs while building capacity.

## 7. Conclusions

A significant number of laboratory equipment in the Faculty of Engineering at the UZ was underutilized, obsolete or in poor working condition owing to lack of expertise, aging as well as maintenance-related challenges. The research highlighted the need for proper documented maintenance procedures and the use of preventive maintenance as well as import substitution for spares. Collaborations with other institutions through pooling of resources and exchange of staff were recommended as part of the cocktail of solutions to build capacity in maintenance and management of equipment in the training of engineers. Collaborations with the private sector through BOT and SPP models were also recommended, as well as increased use of the equipment for consultancy and research to generate income to sustain their function and maintenance, thus reducing obsolescence. Most of these recommendations have gradually been implemented and have assisted the UZ in managing their equipment.

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