

# Maintenance Management of Hospital Equipment: A Case Study for Public Hospitals in Kenya

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**Abstract**—The evaluation of the existing facilities maintenance management practices and processes in major public hospitals in Kenya has been studied. The study was established to determine how they managed the life cycle of the medical equipment. The results offered management the opportunity to appraise the overall maintenance program being made by the facilities maintenance management. It also sought improvement of efficiency and more effective utilization of available resources. A computer programme was developed to improve the status of the facility maintenance management in the major hospitals in Kenya. Interviews were used to obtain detailed information concerning the performance of the maintenance organizations. The structured interviews were carried out with key personnel of each organization categorized into three respondent groups, namely the hospital, consultant and contractor. Eight hospitals replied positively to the questionnaires. The results were analyzed and displayed in a histogram with assistance of a Statistical Package for the Social Sciences (SPSS) program. The challenges encountered in this research included hospital's policy and technological resources. The completion of the study assisted the facilities maintenance management in the hospitals to determine its performance status and pin-point areas where there are short-falls in the organization's service. The maintenance computer program was developed based on the results to improve the existing facilities maintenance management practice and processes in major hospitals in Kenya. The program developed guides the user on the causes of the fault in the medical equipment, and possible personnel to handle it.

**Keywords**—Health facilities, Maintenance, Medical equipment management

## I. INTRODUCTION

Medical or Biomedical equipment management is a fundamental part of managing a clinical or biomedical engineering department. It includes the business processes used in interaction and oversight of the medical equipment involved in the diagnosis, treatment, and monitoring of the patient. The related policies and procedures govern activities from the selection and acquisition through the incoming inspection, acceptance, maintenance, and eventual retirement and disposal of medical equipment. Maintenance management of medical equipment involves other essential activities which ensure that equipment is effectively planned and budgeted for, procured and operated etc. Human factors engineering is used to influence medical device procurement decisions in hospitals. The process ensures that the safest and most efficient and effective devices are purchased. Human factors engineering is frequently being cited as an important method to reduce medical error and adverse effects and to increase patient safety, when it is applied to the design and evaluation of medical devices [1]. Figure 1 shows a cycle of activities in the life of equipment under equipment management [2]. The medical equipment management professionals ensure that equipment used in the patients care are operational, safe, properly configured to meet the mission of the medical treatment facility and continue to function effectively in a good working condition. The maintenance of the hospital assets in a cost effective manner is aimed at long-term preservation of the asset value. For example, proper maintenance can extend the life of

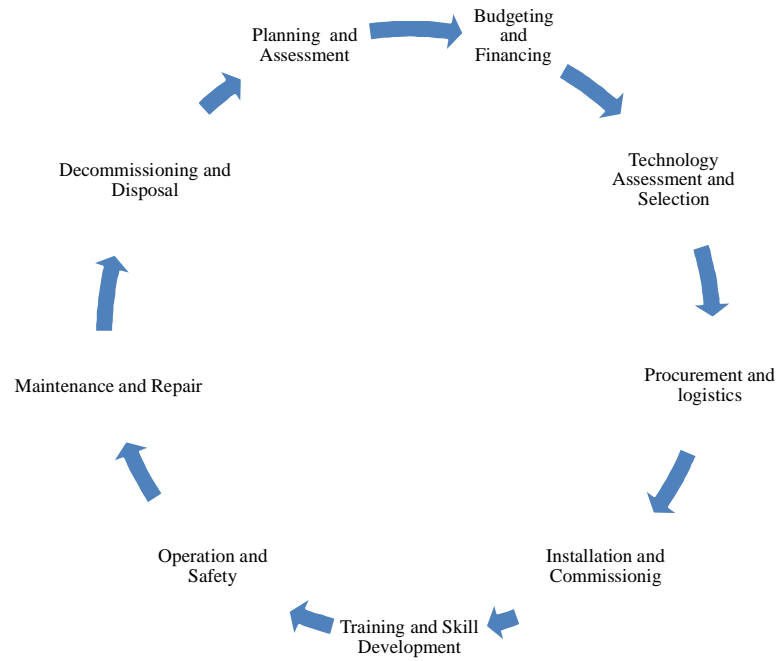


Fig. 1. Medical equipment cycle.

equipment. This is essential for providing good health services and saving the scarce resources.

The facility maintenance managers in major hospitals in Kenya use the Planned Preventive Maintenance (PPM); its concept of Monitoring and Evaluation system to reduce and eliminate unpredicted malfunctions of the equipment. However, there are problems that occur suddenly and therefore cannot be detected or prevented by PPM measures [3].

## II. OVERVIEW

The public health system consists of the following levels of health facilities: national referral hospitals, provincial general hospitals, district hospitals, health centres, and dispensaries. National referral hospitals are at the apex of the health care system, providing sophisticated diagnostic, therapeutic, and rehabilitative services. The two national referral hospitals are Kenyatta National Hospital in Nairobi and Moi Referral and Teaching Hospital in Eldoret. Provincial hospitals act as referral hospitals to their district hospitals. They also provide very specialized care. The provincial level acts as an intermediary between the national central level and the districts. They oversee the implementation of health policy at the district level, maintain quality standards, and coordinate and control all district health activities. District hospitals concentrate on the delivery of health care services and generate their own expenditure plans and budget requirements based on guidelines from headquarters through the provinces [4]. The Planned Preventive Maintenance system which is being used by facility maintenance managers in Kenyan public hospitals involves several essential elements which includes; labelling of equipment

which has to be affixed with a unique equipment number for each device, technical documentation, inspection, service schedules and procedures, inventory system which is used to provide consistent, accurate and up-to-date information on the hospital equipment. In monitoring and evaluation a variety of forms are used: equipment record sheet, request sheet, job card, history card, inspection and service forms etc. Hospitals could perform pre-determined services

travel and incurring huge expenses in the process. But it is not that treatment is not available in the country. Specialized brachytherapy equipment capable of destroying cancer cells in the early stages had been lying idle both at Nyanza Provincial General Hospital and Kenyatta National Hospital.

The equipment for the Nyanza General Hospital was acquired in 1998 by the government at a cost of Sh30 million and was installed in 2002. The equipment at Kenyatta Hospital was installed in 2001; it was yet to be used on a single patient. As the machine from Kenyatta National Hospital gathers dust for unclear reasons, Nyanza General Hospital had incurred huge costs through repairs and maintenance of their equipment. The hospital had flown in teams of engineers several times from the Netherlands, where the brachytherapy equipment had been sent for repair [9]. The article **'The eyesore that is Kenya's hospitals'** exposed the sorry state of government hospitals. It indicated the dilapidated facilities that can barely cope with emergencies and do not adhere to clinical guidelines. The audit conducted by Ministry of medical services established scores of hospitals have failed to live up to their ethics, raising questions about the safety of patients [10].

Research on strategic management of technology in public health sector was conducted in Kenya and South Africa [11]. The main objective was to investigate factors contributing to health care equipment problems and associated technological investments in public hospitals [11]. The research reviewed the processes of equipment planning, procurement and management in ten public equipment maintenance institutions. Fifty six questionnaires were mailed to target technology managers, clinical/medical engineers and technicians in public hospitals in Kenya and South Africa. Thirty eight equipment maintenance experts participated in the survey where majority of them were drawn from teaching hospitals. After the research it was evident that the way health technology is managed in health care institutions directly affects the quality of treatment patients receive [12]. Despite the strategic importance of technology in health care being documented widely in scientific literature; equipment planning, procurement and management have not received the attention they deserve in the transformation of health care service in the two countries under the survey [11].

On the basis of the results of the research, several recommendations were proposed;

- 1) hospitals need equipment assets management systems for monitoring equipment life-cycle costs, maintenance costs and management of equipment replacement.
- 2) there is need to strengthen and streamline management of technical infrastructure for health care equipment selection, procurement and maintenance management.
- 3) to achieve optimum utilization of expensive equipment, specialized departments in public hospitals, such as radiation therapy, radiology, nuclear medicine and renal units, should be permitted to provide specialized technological services to private patients to generate funds for equipment maintenance.

The research concentrated on equipment maintenance experts from public hospitals in Kenya and South Africa. The questionnaires were emailed to the respondent in their respective institutions [11]. The study on maintenance management of hospital equipment: A case study for public hospitals in Kenya ensured that the maintenance organization from public hospitals were interviewed. The main objective being to evaluate the existing hospital facilities maintenance management practices and processes. The research reviewed the activities in the life of equipment under maintenance management by public hospitals in Kenya. A computer maintenance program was developed to assist the maintenance organization.

### III. METHODOLOGY

Fifteen questionnaires were completed by the facility maintenance managers in the hospitals and other health care companies that played the role of agents or suppliers. The distributions of the respondent were 8 in-house technicians from public hospital, 5 suppliers and

#### MONITORING AND EVALUATION SYSTEM FOR MEDICAL EQUIPMENT PROGRAM

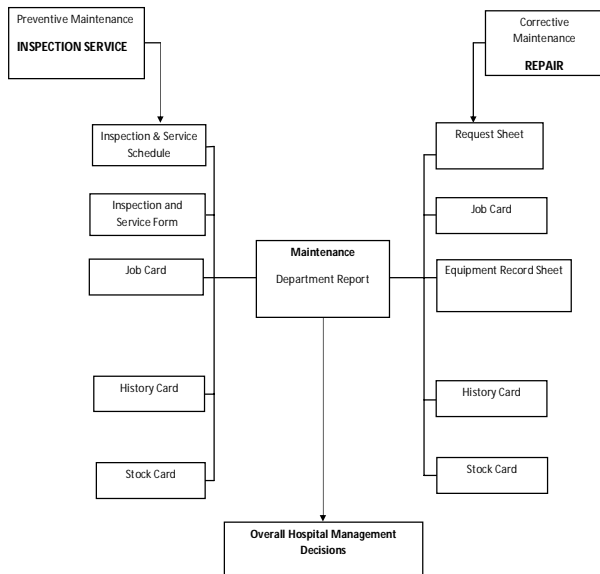


Fig. 2. Monitoring and evaluation system

on a particular equipment or perform corrective maintenance on breakdown equipment as shown in Figure 2. However, a great number of equipment faults occur because of the deterioration of equipment caused by wear and tear of equipment.

#### A. Case Study on Medical Equipment Failure

Patients suffering from kidney failure have been in trouble following the breakdown of a dialysis machine at the Nyanza Provincial Hospital [5]. Equipment may be used until repairs are no longer possible. It is important, therefore, that original parts are available so that the facilities maintenance organization can use the correct parts when repairing or ordering devices [6]. The minister for medical services had to explain why cervical cancer radiotherapy machine at Kenyatta National Hospital has been inoperative for the past four years [7]. The East Africa Standard media established that Kenyatta National Hospital had been burdened by obsolete equipment some of which never worked from the time they were purchased that is if they were installed at all. For instance the embalming machines, three X-ray machines, Sterile processing unit (SPU), Laundry equipment and dental facilities are among a huge portfolio of non-functional equipment [8]. The sorry state of cancer treatment was revealed by the Nation Media Group in Nyanza Provincial General Hospital where the brachytherapy equipment used to treat cancer, was found to be lying dormant. For the last six years, most Kenyan cancer patients had to seek treatment outside the country, enduring lengthy

2 contractors. The questionnaire comprised of seven parameters of equipment life cycle which was adequately answered by the technicians in their respective institutions. The questionnaire had two main parts; Section A and Section B. In section A, the questionnaire defines the goal of the research and outlines the seven main parameters to be interviewed on. In section B, each main parameter had several questions in which the facility maintenance managers were required to answer are appropriate.

#### IV. RESULTS AND DISCUSSION

The results were introduced into the SPSS program which is a powerful statistical analysis and data management system. The histograms were developed for each of the seven parameters as presented below;

##### A. Technological Assessment and Selection

The combined percentage mean ratings for public, consultant and contracted maintenance organizations were 67, 80 and 87 percent respectively. The finding shows that the maintenance managers from the public hospitals need to improve on technology assessment of the equipment and their selection before the institutions buys them. Public hospitals are not effective in terms of proper selection as this has contributed to the failure of the equipment management in their institutions. Most of their practices lead to early failure rate of the equipment either through manufacturing faults, design faults and misuse of the equipment as they selected faulty equipment. The following factors are not wholly considered; safety, infection control and decontamination, effective performance of the equipment, full life cost, reliability of the equipment, availability of spare parts and installation requirements. The public facility managers should consider medical equipment performance with reference to the change of environment before purchasing the equipment; they should advise the supplier to undertake environmental measures and ways to reduce the environmental impact on medical equipment. The equipment should be bought from reliable companies. Technical and user manuals should be provided and the equipment should have standard parts before the purchase. The availability of spare parts will reduce the down time of the medical equipment. Increasing numbers of medical devices and complexity with increased attention to field problems has led to an increase in the number of recalls. The absence of Unique Device Identification (UDI) means hospitals often must use manual and imprecise systems to find and properly identify recalled devices. Implementing UDI in combination with device tracking would potentially increase patient safety and decrease the work load and cost to address recalls. Finding patient care devices when and where clinicians and other personnel need them is crucial to patient care. The maintenance managers from most of the hospitals fail to assess the new technology when selecting new equipment thus compromising the patient safety.

##### B. Procurement and Logistics

The combined percentage mean ratings for public, consultant and contracted maintenance organizations were 62, 76 and 74 per cent respectively. The maintenance organizations from public hospitals do not have excellent procedures to acquire the best equipment in their procurement processes. The institutions managements or hospital boards do not involve the facility maintenance managers in equipment selections or evaluations. This has contributed to acquisition of incorrect equipment by the hospitals or equipment with no spares parts. The warrants of the equipment do not cover most of the crucial needs which leads to earlier failure of the equipment. The equipment are compromised due to lack of co-operation between hospital management and facility maintenance managers. The facility maintenance manager from public hospital should develop an up to date computerized inventory system. This will aid the maintenance department on identification of the type and correct number of equipment in the system.

##### C. Installation and Commissioning

The combined percentage mean ratings for public, consultant and contracted maintenance organizations were 74, 83 and 86 per cent respectively. The public hospitals maintenance managers however had lower standards compared to the rest of the organizations. This is because most of public hospitals maintenance team do not implement basic requirements procedures of installation and commissioning of medical equipment properly. Furthermore, there existed some areas of weakness revealed from the evaluation on maintenance management of public hospitals; applicable standards and codes of the equipment does not appear on most of the equipments labels after an installation procedure has been performed. In-service training and technical manuals are not always provided. The availability of the operator's manuals, technical and in-serving training by some of the consultants and contractors has proven difficult to acquire. The facility maintenance managers from public hospitals should ensure that the equipment are safe to use and meets all required standards. Equipment should meet the specified performance criteria and should not be damaged. They should also match with the order and be delivered complete with specified accessories. Equipment should be placed on a routine maintenance programme and the maintenance personnel should be trained and conversant with its use and servicing arrangements. The availability of the technical and operational manual in every equipment being installed guarantees proper equipment managements. Technical training to facility maintenance managers ensures that medical equipment are properly managed. The suppliers may not offer training to the public hospital maintenance team as result they lack specialized training for modernized equipment.

##### D. Training and Skill Development

The combined percentage mean ratings for public, consultant and contracted maintenance organizations were 47, 62 and 72 per cent respectively. The training of equipment users and maintenance managers reduces the equipment downtime. To reduce the possibility of equipment malfunction following service or repair, all personnel involved in maintaining and servicing equipment should be trained fully to appropriate standards. From the data collected it demonstrated several weaknesses and failures by the facility maintenance managers. Public hospital maintenance organizations have no computerized medical maintenance system which could either predict necessary preventive maintenance or analyze the data streams to predict calibration problems. The in-service training programs are not normally provided to the new employees, on all equipment involved in frequent operator errors or after the purchase. The training may be conducted by supplier agents. However, the organization does not fully maintain equipment manuals and training guides. The organizations do not document orientation and annual review of employee proficiency in use and safety of each type of device. The technicians are not well trained and most of them do not proceed for specialized training especially on medical equipment training. Equipment training is necessary in managing risk and establishing expectations for safe, quality and effective use. All health care employees who use medical equipment should be oriented to each type of device and be able to demonstrate proficiency in its use. In a given piece of equipment there are maintenance problems of different levels of complexity. The majorities of the problems are relatively simple and can be corrected by in-house maintenance manager trained in front-line maintenance. Training of public hospital maintenance team to a high level of skills has proven to be expensive although necessary. Furthermore, upon completion of their training staff are often lured away by companies paying higher salaries. However during the purchase of new equipment, suppliers can be requested to train in-house technicians in maintenance, often at no cost. Public hospitals maintenance organizations always take advantage of the opportunity during the purchase of new equipment by inclusion of this condition in the tender or purchase order. The concept does not work for their system as they lack credible training therefore unable to repair most of the equipment. They are ranked to be "fair" on their performance

on training and skill development. The facility maintenance managers in public hospital should acquire proper training in order to repair the equipment effectively.

### *E. Operation and Safety*

The combined percentage mean ratings for public, consultant and contractor maintenance organizations are 63, 83 and 81 percent respectively. The results denote the organizations to be at the best position on the issue of operation and safety. With the exception of facility managers from public hospitals, other organizations were almost performing at the same position. The finding revealed that public hospital facility managers are not well equipped for the maintenance purposes, although most of their institutions have state of art medical equipment. Testing procedures for the medical equipment are not properly documented. They do not necessarily bring unsafe equipment operation to the attention of user and their supervisor by either placing the stickers on the medical equipments to indicate their conditions or through other means.

The inspection of the equipment by the facility maintenance managers is performed to establish medical equipment achieving all applicable safety standards. The equipment should perform in accordance with the manufacturer's specification. Equipment passing the safety inspection should be tagged with an inspection sticker and entered into the inventory maintenance program. Equipment not passing safety tests are not placed into the service and should be tagged as 'defective'. The facility maintenance managers do not have proper tools to determine the safety and functional test hence contributing to faulty medical equipment being used by the patients. To provide an electrically safe environment for all patients, visitors and staff ensure compliance with applicable codes and standards by the maintenance managers. Improvement on some of the failures by the public hospitals maintenance and contractors organizations could transform the maintenance management of hospital equipment into better system.

### *F. Maintenance and Repair*

The combined percentage mean rating for the public, consultant and contracted maintenance organization are 58, 75 and 81 per cent respectively. Maintenance not only has a positive impact on the safety and effectiveness of healthcare technology, but also has two important economic benefits:

- It increases the lifetime of equipment and thus helps to save scarce investment resources;
- It enhances the demand for health services. Demand for services availability is crucial of functioning healthcare technology.

Healthcare equipment that is out of order quickly leads to a decline in demand, which will in turn reduce the income and quality of services of the health facilities. The hospital may lose clients if, for example, it becomes known that malfunctioning of medical equipment, for instance if sterilization equipment may endanger the health of the patients. Similarly, patients will avoid visiting health facilities which do not possess functioning diagnostic equipment. The maintenance managers are required to accomplish the maintenance for medical equipment in a timely, economical, and professional manner. Due to ever-changing operational requirements and conditions, effective maintenance management requires leadership, planning, organization, assignment of responsibilities, functions and resources, direction, and flexibility. Management of resources (tools, test equipment, standby equipment, spare parts, time, and personnel) should be a daily concern. All resources must be present in sufficient quantity when needed to accomplish the maintenance objective. The findings reveal that the public maintenance managers are ranked as 'fair' at 58 per cent. The other maintenance organizations had complied with the most of the standard as they were operating above 60 per cent of the combined mean. The facility maintenance management in the public hospital do not adhere mostly on basic fundamentals when performing maintenance to the equipment; their inventory systems

are not up to date. Improper documentation in the inventory system leads to poor selection and procurements of equipment and delay in the maintenance management. Inadequate spare parts lead to most of valuable equipment to lay dormant. This has been contributed by poor co-operation of suppliers to hospital management and lack of team work in facility maintenance managers. The planned preventive maintenance is not prioritized leading to failure of the equipment due to undetectable defects, low safety factors, abuse and natural failures. The public maintenance managers do not have adequate information of most of the products thus developing ineffective manuals. Adequate professional training to both operators or users and facility maintenance managers will reduce frequent failure and improve on maintenance management in the public hospital. The faults that occur suddenly and which are not detected or prevented by PPM measures should not take longer to be repaired. The computer program developed assists the facility maintenance manager to overcome this challenge. With help of it, adequate time is created for repairing the faulty equipment thus improving the efficiency of maintenance management in hospitals.

### *G. Decommissioning and Disposal*

The combined percentage mean rating for the public, consultant and contracted maintenance organizations are 44, 63 and 85 per cent respectively. The maintenance managers from the institution should be consulted before disposal process is completed. All safety requirements should be adhered to before equipment is released. There are few challenges which need some improvement in decommissioning and disposal of medical equipments. Public hospital maintenance organizations should be put in place appropriate program for liquidation of aged and unreliable facilities. Toxic equipment infection control companies are rarely consulted for the cleaning schedules or procedures before the equipment is disposed in public hospitals. The finding revealed the public maintenance managers were operating in 'a fair standard' as per their combined mean of 44 per cent. The organizations dismantle old units to provide spare parts for similar units. They are not included in recommendation for and assistance in disposition of equipment by replacement, refurbishment, upgrading or declared obsolescence. Improper method of acquiring medical equipment contributes to obtaining faulty equipment in the inventory system with unclear guarantee. Most of this equipment are disposed due to lack of spares as they lay dormant occupying space in the maintenance workshop. Decommissioning and disposal process provides an opportunity for cultivating technical innovation using local resources. The disposed equipment may be re-used or recycled by the facility maintenance managers. This will need the facility maintenance managers to be highly trained to manage the equipment effectively. Decommissioned equipment must be deleted to update the inventory system with fresh information.

### *H. Program Development*

The survey conducted focused on four groups, each group represented by two types of equipment. The hospital maintenance computer program was developed based on the results to improve on the existing facilities maintenance management's performance by the major public and private hospitals in Kenya. The program restricts the operator to enter only valid data by checking the validity of data code and data format. The program reports the possible causes of the medical equipment faults and the possible personnel to handle the fault in the equipment. The program development begins from identification of the category in which the equipment is categorized. The equipment is identified in terms of its category and whether the equipment is in the inventory. This approach reduces accumulation of paper work in the office and proper monitoring of the equipment. The system diagnosis the possible causes with relation to their possible faults in the equipment. It further guides the user to identify the possible personnel to handle the fault in the equipment. The program makes decision on which fault in the diagnosed equipment to be repaired by the supplier, the contractor or the in-house technician.

## V. CONCLUSION

The public hospital maintenance managers are operating in 'a fair standard' as per their combined mean on seven parameters in the questionnaire. The organization fails to assess the new technology when selecting new equipment thus compromising the healthcare and patient safety. Lack of proper involvements of the organization on procurement of the medical equipment has contributed to acquisition of incorrect equipment by the hospitals or equipment which have difficulties in acquiring spares parts for them. The technicians are not well trained and most of them do not proceed for higher learning especially on medical equipment training. The institutions do not provide job training to their staff at national and international level. They lack proper training therefore unable to repair most of the modernized equipment. The performance of scheduled preventive maintenance services on the medical equipment does not take priority over corrective repairs in most of the hospitals. Public hospitals have no quality control system for the repair and preventive maintenance. Technical manuals are not fully utilized when repairs are made, maintenance on the medical equipment are not done on the stipulated time frame. Deferment of maintenance may be required due to non-availability of manpower or other extenuating circumstance for instance lack of spare parts. Implementation of the developed computer programme shall improve the maintenance practices by detecting the faults in the shortest duration. The program reports the possible causes of the medical equipment faults and the possible personnel to handle the fault in the equipment.

## VI. RECOMMEDATION

The following recommendations need to be considered by public hospital maintenance organization;

- 1) The organization to improve on technology assessment of the equipment and their selection before the institutions buys them.
- 2) All personnel involved in maintaining and servicing equipment must be trained to appropriate standards.
- 3) All resources required by the maintenance organization must be provided in sufficient quantity by the hospital management when needed to accomplish the maintenance mission.
- 4) The planned preventive maintenance should be prioritized.
- 5) Appropriate program for liquidation of aged and unreliable facilities should be put in place.
- 6) The organization to implement and improve on computer prototype program developed in order to accommodate more equipment.
- 7) With respect to further study the following should be improved;
  - Computerization of medical equipment to send report in advance when it fails.
  - Computerization of Inventory system to improve in the maintenance activities by assisting the technician simultaneous access to equipment history, rapid archive of data as well as vendor information and safety alert.
- 8) Equipment bought should be put into use immediately e.g from the case study of Nyanza hospital, a machine is bought in 1998 and installed four years later
- 9) Adhere to the procurement Act of Kenya which guides clearly on process and liabilities incase of a compromised process or commission and omission malpractises.

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