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The root causes of ineffective and inefficient healthcare technology management in Benin public health sector

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KEYWORDS
Healthcare technology management;
Policy and management tools;
Root cause analysis;
Corruption

Abstract
This study aims to identify the root causes and solutions of main problems facing Healthcare Technology Management in Benin's public health sector. Conducted in Benin from 2008 to 2010, two surveys were used with key actors in Healthcare Technology Management. The first survey was based on 377 questionnaires and 259 interviews, and the second involved observation and group interviews at selected health facilities

The findings of the two surveys show that the problems are based on both high- and low-level corruption, characterized by self-interest and unwillingness of the policy makers to solve healthcare care equipment and maintenance problems. Appropriate solutions include: (i) development of policy and management tools to guide distribution, (ii) the use of reference price lists for procuring equipment, (iii) development of policy and management tools to guide financial resource allocation on the life cycle cost of the equipment, (iv) creation of a healthcare equipment and maintenance directorate, (v) development of policy and management tools for obsolete equipment, and (iv) the development of a new healthcare technology management policy with a budgeted action plan.

We suggest that much can be improved by the strict development and implementation of policy and management tools, as well as regulations at each level of the Healthcare Technology

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Management process. A key role has to be attributed to the technical specialists, and the end users of equipment in healthcare facilities. Furthermore, there is a need for capacity building in Healthcare Technology Management institutions.

Introduction

Healthcare technologies offer many benefits and have greatly enhanced the ability of health professionals to prevent, diagnose and treat diseases [1]. The quality of healthcare delivery can be assessed along the STEEEP criteria of being Safe, Timely, Effective, Efficient, Equitable, and Patient-centered [2]. However, many developing countries in general, and Benin in particular, face problems in satisfying these due to the limited availability, or lack of, healthcare technologies.

Healthcare technology is defined as the application of organized knowledge and skills in the form of devices, medicine, vaccines, procedures and systems developed to solve health problems and improve the quality of lives [1,3-8]. When used in this paper, the term is used as the different types of devices or equipment used in health facilities, encompassing medical equipment for clinical use, hospital furniture, vehicles, service supplies, plant, communication equipment, firefighting equipment, fixtures in the building, office equipment, office furniture, training equipment, walking aids and workshop equipment [3].

Healthcare Technology Management (HTM) in developing countries has a great number of contextual challenges. Since about 95% of the healthcare technology used in these countries is imported [9], mismatches commonly occur as the technology development process happening in developed countries has not accounted for the specific demands of the environment of placement. These mismatches in the transfer process, from high-income countries to non-producing countries, affect both the cost and the use of the technology [10-15].

Healthcare provision in Benin is delivered through both the public and private health sectors. The public healthcare delivery system has been reorganized on the basis of decentralization policies and comprises three hospital levels (the primary or zone hospital, the secondary or departmental hospital and the tertiary or university hospital), and many health centers. The zone hospital remains the first referral hospital and most heavily used facility, compared to health centers and polyclinics [16]. Many technical reports have described weaknesses in Benin's public HTM system which contribute to low quality, cost-ineffective and inefficient community healthcare [17-24]. Many facilities, particularly primary and secondary hospitals, still lack the basic technologies they need to provide standard care, as equipment is unavailable, inoperative, misused or inappropriate. The situation is most severe in health facilities located in remote areas with implications for the treatment and prevention of diseases. Although huge financial resources have been injected into the acquisition of devices, not enough attention has been paid to their strategic management. While some equipment has been donated, a significant portion has been purchased with loans provided by bilateral and multilateral agencies which will have to be paid back.

Since 1995, many seminars, talks, workshops, discussions and surveys have been organized with diverse stakeholder groups participating, however, they have yet to be effectively translated into a successful policy [17,21,24-28]. The first national maintenance policy for healthcare infrastructure, equipment and vehicles of 2002 was promising, but its implementation was halted due to a lack of political will and budgeted action plan. There have been some piecemeal attempts by the Ministry of Health (MoH), and some isolated, short-term actions of donors to support the development of maintenance and healthcare technology repair capacities, but these have not proved to be comprehensive strategies to deal with this wicked problem. Similar problems regarding policies for HTM have been reported in many sub-Saharan Africa countries, as well as other low-income countries [3,4,8,11,15,29-36].

The objective of this study is to identify and assess the deeper causes of problems facing HTM in Benin's public health sector, and to identify the ways in which these problems can be addressed in order to meet the STEEEP criteria. The research question is thus:

> What are the root causes of ineffective and inefficient HTM in Benin's public health sector and how could they be addressed?

The second section presents the methodology including the research materials and methods used for data collection, followed by a description of the results. The final section discusses the findings of study.

Methodology

Desk research was conducted using the data (two surveys and a desk study) of a previous study [37], in which 12 main problems were identified relating to *major enabling inputs or import and use activities* of the Temple-Bird Healthcare Technology Package System (TBHTPS) [15]. The two surveys were conducted in 117 selected health facilities. The first survey was based on 377 questionnaires and 259 interviews, and the second involved observation and group interviews at selected health facilities. The surveys also asked key actors in HTM to identify cause(s) of the problem(s), according to 12 components of an adapted TBHTPS framework. These actors were policy makers, planners, and administrators at the MoH; (ii) hospital managers and directors; (iii) end users of medical equipment; (iv) biomedical, clinical, or healthcare technology engineers and technicians; (v) local and foreign suppliers, and; (vi) international organization representatives i.e. bilateral or

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multilateral health development partners. Root Cause Analysis (RCA) was used to organize the topics and their related causes into hierarchical trees, through a process of iteratively "asking why" to sort the symptomatic problems from their deeper causes [38,39]. In the present case, the analysis was based on constructing 10, topic-related problem trees. Subsequently, according to probable links between the 10 problem trees, three larger problem trees were constructed (Figures 1-3). Finally, analysis of these trees helped to identify causes that could be effectively addressed by policy interventions, i.e., those root causes that produce several negative symptoms at the same time, and for which feasible solutions could implemented.

Results

Perceived causes of each problem and their shortlist solutions

Table 1 presents the causes of problems in HTM in Benin; ascribed by the respondents of questionnaires and interviews. The root cause analysis yielded three problem trees (Figs. 1-3). Main problems in HTM are positioned at the top of the problem trees, with those below being deeper, and causally related, problems. Thus, problems positioned lower are, themselves, causes of problems placed higher in the tree. The deepest level of problems relates to historical and/or cultural system constraints which are the hardest to change, such as in this case, the culture of corruption and self-interested attitudes of those in power. In between the deepest and most surface level problems, the intermediate problems/causes are the most accessible to policy interventions, as their solution would have a positive impact on problems higher up the causal tree, as well as being a cured symptom itself, of problems rooted at a deeper level. In each of the trees, the color of the boxes is used to identify characteristics: (i) components of HTM, according to the adapted TBHTPS framework, are blue; (ii) problems associated to these components are grey; (iii) deeper causes of each problem are orange; (iv) problems associated to components of HTM that are also a deeper cause of another problem are grey, surrounded by an orange box (v) intermediate causes of each problem are black, (vi) root causes of each problem are double-lined black, (vii) devised solutions are green.

Figure 1 shows the first problem tree that links together four smaller trees previously constructed. This problem tree

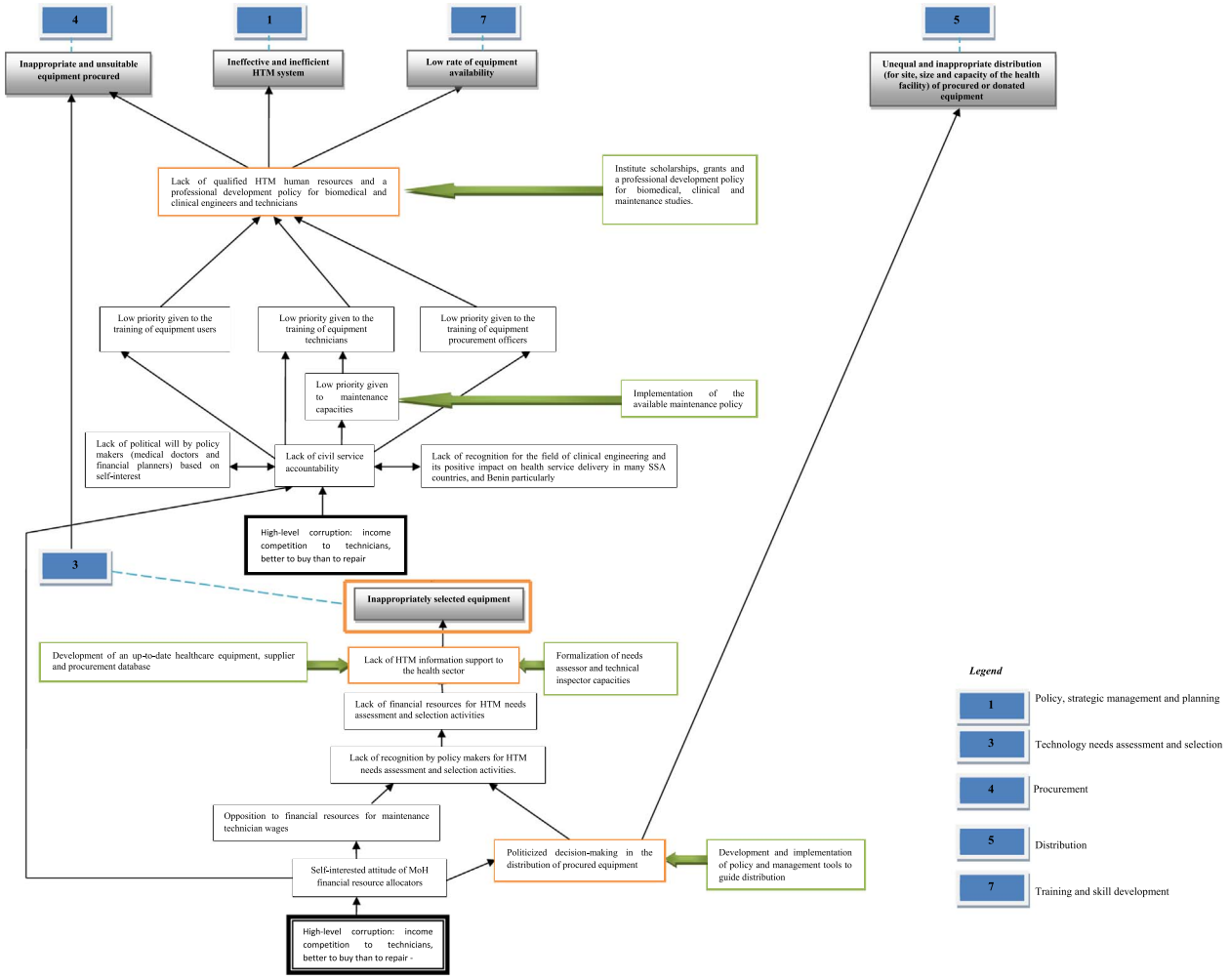

Figure 1 Problem tree based on inter-related HTM activities, the enabling inputs 1, 3, 5, and 7, their related problems, causes and possible solutions.

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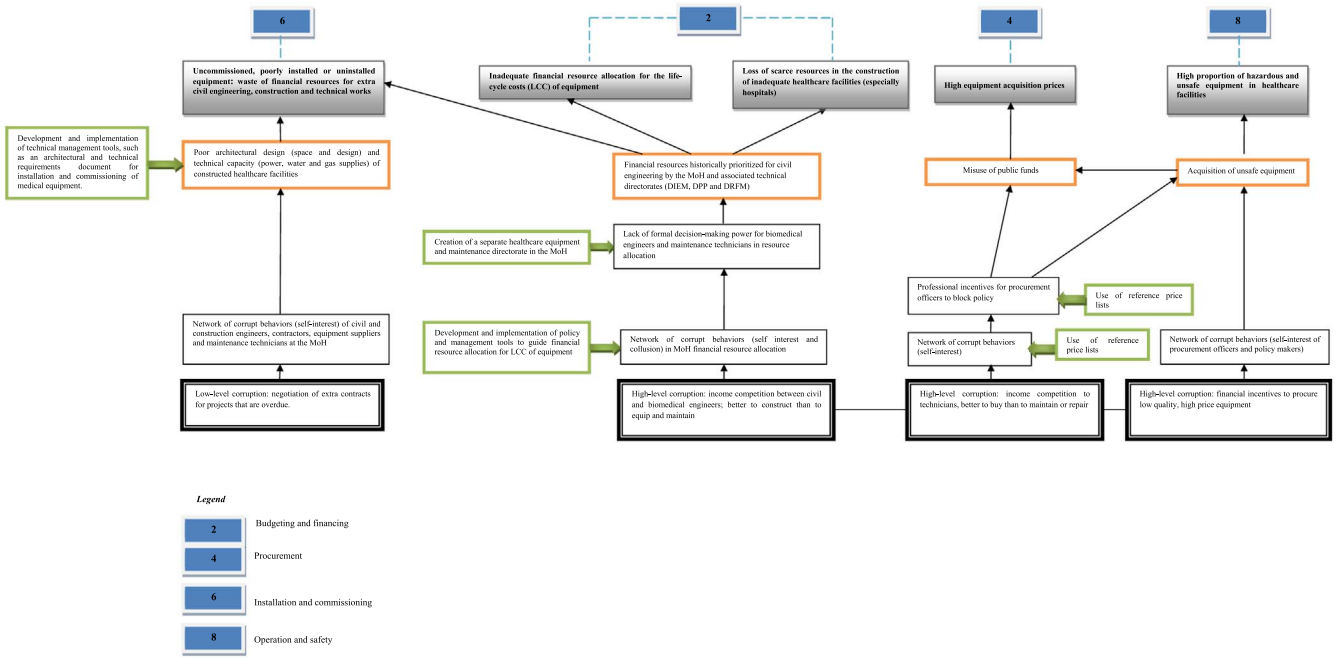

Figure 2 Problem tree based on inter-related HTM activities, the enabling inputs 2, 4, 6 and 8, their related problems, causes and possible solutions.

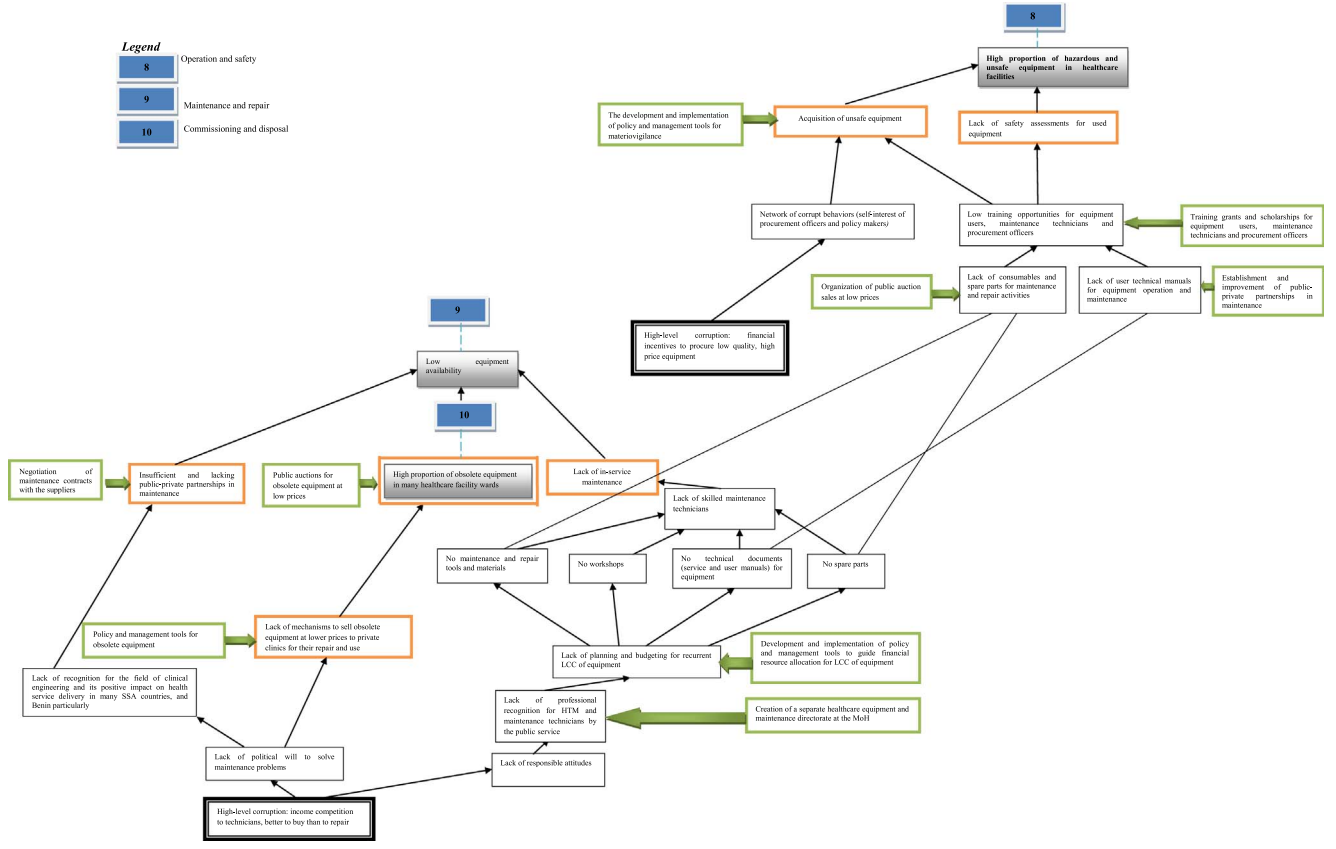

Figure 3 Problem tree based on inter-related HTM activities, the enabling inputs 8, 9 and 10, their related problems, causes and possible solutions.

covers five components of the TBHTPS framework (policy, strategic management and planning, 1; technology needs assessment and selection, 3; procurement, 4; distribution, 5, and; training and skill development, 7) and their related problems, causes, and possible solutions. It can be seen that the three of the main problems detailed in Figure 1

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Table 1 The causes of problems in HTM according to questionnaire respondents and interviewees.

Problems	Causes
1 **Policy and strategic management and planning** * *Ineffective and inefficient HTM system*	- Low priority given to the HTM system activities apart from procurement - Lack of implementation of the available maintenance policy - Lack of policy and management tools - Lack of qualified human resource - Lack of civil service accountability
2 **Budgeting and financing** * *Loss of scarce resources in the importationof inappropriate medical devices* * *Inadequate financial resource allocationfor the life cycle cost (LCC) of the equip-ment.*	- Unequal dispatching of the MoH financial resource first of all by the Directorate of Infrastructure, Equipment and Maintenance by - usually allocating 1/3 of the infrastructure cost to the equipment. - Unequal dispatching of the MoH financial resource by its planning &forecasting and financial departments in the budget document. - Lack of policy and management tools on resource allocation of LCC of equipment. - Lack of national equipment and maintenance Directorate at the MoH that will focus its activities only on equipment and - maintenance. - Existence of conflicts of interest in the dispatching of the MoH financial resource. - Lack of decision power by the minority Biomedical/Clinical/ Maintenance Engineer and Technicians.
3 **Technology needs assessment and selection** * *Inappropriate selected equipment*	- Unbudgeted and unavailable financial resource for HTM needs assessment and selection activities. - Lack of HTM information support to the health sector. - Lack of awareness of importance of HTM needs assessment and selection activities. - Thinking of wastage of financial resource for minority and non-priority class of maintenance technicians. - Politicizing of the distribution of being procured equipment
4 **Procurement** * *High acquisition cost* * *Inappropriate and unsuitable procured equipment*	- Allocation of excessive money for procurement activities. - Everybody wants to work as procurement officer. - Lack of policy and management tools for effective adjudication of contracts - All kind of corruption - Abuse of the public funds for private gain.
5 **Distribution** * *Unequal and inappropriate distribution(site, size, capacity of the health facility)of procured or donated equipment*	- The distribution of healthcare equipment is highly politicized. - Lack of policy and management tool to guide the distribution - To allow powerful politicians to be more popular in their elected region, village or town or in a new political area.
6 **Installation and commissioning** * *Uninstalled and commissioned equipment due to inadequate architectural design (space and design) and technical capacities (power, water and gas supplies)*	- Many new constructed and already officially received health-care facilities used to be the object of important rehabilitation works to allow the new equipment to be installed - Lack of technical management tools as: The Architectural and technical requirements for installation and commissioning of medical equipment. - The lack of these technical management tools usually could be in favor of the civil engineering entrepreneurs, the suppliers and some time also the maintenance technicians
7 **Training and skill development** * *Low rate of equipment availability*	- Low training opportunities to the human resource (users and maintenance Technicians and Engineers). - Lack of Biomedical/Clinical/Maintenance engineer, and technicians' human resource or carrier development policy. - Lack of well trained human resource (users and maintenance Technicians and Engineers. - Unawareness of this new field of carrier in many Sub Saharan Africa countries in general and in Benin particularly
8 **Operation and safety** * *High proportion of hazardous and unsafe equipment in healthcare facilities*	- Lack of equipment safety assessment activities for in use equipment. - Lack of policy and management tools for materiovigilance.

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Table 1 (*continued*)

Problems	Causes
9 **Maintenance and repair** * *High proportion of unavailable equipment*	- Lack of consumables and exploitable user manuals - Lack of safe cares in the public healthcare facilities. - Lack of good maintenance planning and budgeting for the recurrent cost of LCC of the equipment. - Lack of the intensification of "in-service maintenance". - Improving maintenance and repair problem could reduce the illegal interests of corrupted procurement officers. - No valorization of the maintenance technician public service in Benin. - Lack of strong public-private collaboration in maintenance and repair. - Lack of healthcare technical service in the public hospitals - Lack of technicians maintenance tools - Lack of technical instruction documents - Lack of adequate budgetary provision for equipment maintenance - Lack maintenance contracts with the suppliers - Unavailability of equipment spare parts - Lack of a national equipment and maintenance Directorate at the MoH that will focus its activities only on equipment and maintenance.
10 ***Decommissioning and disposal.*** * *High proportion of obsolete equipment in many healthcare facility wards*	- Lack of the public auction sale at low prices - Lack of policy tools - The acquisition of the disposal equipment at lower price for repair and use in the private clinics

(ineffective and inefficient HTM system; low rate of equipment availability; inappropriate and unsuitable equipment procured) all share a common cause of a *lack of qualified HTM human resources and a professional development policy for biomedical and clinical engineers and technicians. Inappropriate and unsuitable equipment procured* relates to both the procurement, and technology needs assessment and selection components of the TBHTPS framework. The latter connects the *inappropriate and unsuitable equipment procured* problem to one of its deeper causes, *inappropriately selected equipment*. The deeper cause of the problem *unequal and inappropriate distribution (for site, size and capacity of the health facility) of procured or donated equipment*, which relates to component 5, is the *politicized decision-making in the distribution of procured equipment*. The root cause underlying all problems in components 1, 3, 4, 5 and 7 is high-level corruption due to the *income competition to technicians* that describes the preference of policy makers in the MoH to buy more equipment over repairing the faulty, in order to conserve the cost of hiring maintenance technicians. This culture of *better to buy than repair* engenders (i) the self-interested attitude of MoH financial resource allocators and (ii) a lack of civil service accountability. There are many intermediate causes for the problems detailed in Figure 1, some of which could be amenable to feasible and acceptable policy interventions. Four have been indicated in green boxes.

The solutions devised for the *lack of qualified HTM human resources and a professional development policy for biomedical and clinical engineers and technicians* and *the lack of HTM information support to the health sector* relate to capacity building in HTM. Both of these are contributory causes of four of the main problems illustrated in Figure 1, the *ineffective and inefficient HTM system, inappropriately selected equipment, inappropriate and unsuitable equipment procured*, and the *low rate of equipment availability*. The solutions comprise (i) institute scholarships, grants, and a professional development policy for biomedical, clinical and maintenance studies, (ii) formalization of needs assessor and technical inspector capacities and the (iii) development of an up-to-date healthcare equipment, supplier and procurement database. A solution to counter the *politicized decision-making in the distribution of procured equipment*, that leads to unequal and inappropriate distribution, is the development and implementation of policy and management tools to guide distribution. Additionally, the implementation of the available maintenance policy priority could counteract the *low priority given to maintenance capacities* that begets many of the main problems listed in Figure 1.

Shortlist solutions

Shortlist solutions were selected with respect to their place in the problem trees (the lower their position, the more dominant causes are affected), their connectedness to symptoms, their feasibility, acceptability, efficiency, cost-effectiveness and sustainability. In order of decreasing importance, the shortlist solutions were: (i) the development and implementation of policy and management tools

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to guide distribution, and (ii) the implementation of the available maintenance policy.

Figure 2 shows the second problem tree, illustrating the relationship between problems and deeper causes for four components of the TBHTPS framework (budgeting and financing, 2; procurement, 4; installation and commissioning, 6; operation and safety, 8). As in Figure 1, it can be seen that the underlying causes of problems in components 2, 4, 6 and 8 are both high- and low-level corrupt practices, comprising the *self-interested attitude* and *collusive practices* of procurement officers, policy makers, construction contractors, equipment suppliers and technicians in the MoH. Other root causes of problems emerging from components 2, 4 and 8 are due to high-level corruption from *the income competition between civil and biomedical engineers, income competition to technicians*, and the *financial incentive to procure low quality, high price equipment*. Conversely, root causes of problems in component 6 are due to low-level corruption characterized by the *negotiation of extra contracts for projects that are overdue*.

A solution to the *poor architectural design (space and design) and technical capacity of (power, water and gas supplies) constructed healthcare facilities*, that causes the waste of equipment through poor or lacking installation and commissioning, was suggested as the development and implementation of technical management tools, such as an architectural and technical requirements document for installation and commissioning of medical equipment. *The professional incentives for procurement officers to block policy and the network of corrupt behaviors*, which contribute to procurement problems *(high equipment acquisition prices and high proportion of hazardous and unsafe equipment in health facilities)*, could be opposed by the use of reference price lists during procurement processes. Additionally, the development and implementation of policy and management tools to guide financial resource allocation for the life-cycle costs (LCC) of equipment could prevent the *network of corrupt behaviors in MoH financial resource allocation* and reverse the *lack of formal decision-making power for biomedical engineers and maintenance technicians in resource allocation*. Both of these are intermediate causes of the *loss of scarce resources in the construction of inadequate healthcare facilities*, the *inadequate financial resource allocation for the LCC of equipment* and the *uncommissioned*, poorly *installed or uninstalled equipment* found in health facilities. The *lack of formal decision-making power for biomedical engineers and maintenance technicians in resource allocation* could also be improved by the creation of a separate healthcare equipment and maintenance directorate in the MoH.

Shortlist solutions

From Figure 2, the shortlist solutions for the problems identified, in order of decreasing importance, are: (i) the use of reference price lists, and (ii) the development and implementation of policy and management tools to guide financial resource allocation on the LCC of equipment.

Figure 3 presents the third problem tree, related to three components of the adapted TBHTPS framework (operation and safety, 8; maintenance and repair, 9; commissioning and disposal, 10). Among the 15 intermediate causes illustrated, priority was given to five for which policy interventions might be possible: (i) *low training opportunities for equipment users, maintenance technicians and procurement officers,* (ii) *lack of consumables and spare parts for maintenance and repair activities,* (iii) *lack of user technical manuals for equipment operation and maintenance,* (iv) *lack of planning and budgeting for recurrent LCC of equipment,* and (v) *lack of professional recognition for HTM and maintenance technicians by the public service*. The root causes underlying problems related to components 8, 9 and 10 are, again, forms of high-level corruption based on *financial incentives to procure low quality, high price equipment* and the *income competition to technicians*. This misuse of power for private gain is exemplified by the (i) *network of corrupt behaviors (self-interested attitude of procurement officers and policy makers),* a (ii) *lack of political will to solve maintenance problems,* and a (iii) *lack of responsible attitudes*.

The *high proportion of hazardous and unsafe equipment in healthcare facilities* is a direct effect of the *acquisition of unsafe equipment*, which could be solved through the development and implementation of policy and management tools for materiovigilance. The solutions for the *insufficient and lacking public-private partnerships in maintenance,* and the *lack of mechanisms to sell obsolete equipment at lower prices to private clinics for their repair and use,* which cause the *high proportion of obsolete equipment in many healthcare facility wards* and *low equipment availability,* comprise the (i) negotiation of maintenance contracts with suppliers (ii) public auctions for obsolete equipment at low prices and (iii) policy and management tools for obsolete equipment. Finally, solutions of (i) training grants and scholarships for equipment users, maintenance technicians and procurement officers, the (ii) establishment and improvement of public-private partnerships in maintenance, (iii) public auctions for obsolete equipment at low prices, the (iv) development and implementation of policy and management tools to guide financial resource allocation for the LCC of equipment, and the (v) creation of a separate health equipment and maintenance directorate at the MoH could combat the *low training opportunities for equipment users, maintenance technicians and procurement officers, the lack of user technical manuals for equipment operation and maintenance,* the *lack of consumables and spare parts for maintenance and repair activities,* the *lack of planning and budgeting for recurrent LCC of equipment*, and the *lack of professional recognition for HTM and maintenance technicians by the public service,* respectively, that, in combination, lead to the *high proportion of hazardous and unsafe equipment in healthcare facilities* and *low equipment availability.*

Shortlist solutions. From Figure 3, the shortlist solutions for the problems identified, in order of decreasing importance, are: the (i) creation of a separate healthcare equipment and maintenance directorate at the MoH, the (ii) development and implementation of policy and management tools to guide financial resource allocation for LCC of equipment, and (iii) policy and management tools for obsolete equipment.

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Appropriate solutions emerging from the RCA

Appropriate solutions were selected considering the ability of the MoH to implement them immediately. The above shortlist solutions were further narrowed down using more stringent criteria of feasibility, acceptability, efficiency, cost-effectiveness, and sustainability. These solutions are: (i) the development and implementation of policy and management tools to guide distribution (for problems 3.1, 4.2 and 5.1), (ii) the use of reference prices list (for problems 4.1 and 8.1), (iii) the development and implementation of policy and management tools to guide financial resource allocation for LCC of equipment (for problems 2.1 and 6.1), the (iv) creation of a separate healthcare equipment and maintenance directorate at the MoH, (v) the implementation of the available maintenance policy and (vi) policy and management tools for obsolete equipment.

Discussion

In the first sub-section, (i) the perceived root causes of each problem, as identified by respondents and interviewees, and (ii) the priority solutions to tackle these problems and improve HTM, given considerations of STEEEP criteria, are explained and interpreted. The second sub-section discusses limitations in the methodology employed.

Explanation and interpretation of the perceive root causes of each problem

Applying RCA to the interview and questionnaire data showed that the most prominent root causes underlying problems in HTM are corrupt practices by public officials, at high- and low-levels. These practices, in order of their impact on HTM, are (i) *self-interested attitudes, collusive behaviors and a lack of responsible attitudes* (i.e. not acting in the best interests of the public) exhibited by procurement officers, policy makers, construction contractors, equipment suppliers and MoH technicians towards solving maintenance problems and to financially profit from procurement activities, and (ii) a *lack of civil servant accountability, a lack of recognition* for the field of clinical engineering and its positive impact on health service delivery, and, an *unwillingness* demonstrated by some policy makers (managing medical doctors and financial planners) to solve problems in HTM.

For rational priority and agenda setting, the root causes of problems at the intermediate level are more accessible and feasible for policy instrument interventions. The three main root causes at the intermediate level are (i) the unavailability, or limited availability, of equipment and healthcare structures, (ii) the unsafe and poor state of healthcare equipment in healthcare facilities and (iii) the loss of scarce national resources. Although problems themselves, these causes are at the root of ineffective and unsafe diagnoses, treatments and preventions which characterize the ineffective HTM system.

Differences were found in the amount and type of root causes that were be identified by different actor groups. Root causes were most commonly identified, in decreasing order, by: 1) biomedical, clinical healthcare technology engineers and technicians; 2) end users of equipment; 3) hospital directors and managers; 4) international organization representatives; 5) policy makers, planners and administrators at the MoH, and; 6) local and foreign suppliers. This trend is similar to the findings of previous research [37] - which investigated the perceptions of actors with regards to severity of problems in HTM - with the exception of suppliers of equipment and policy makers, planners and administrators at the MoH, whose places in the order were swapped. The consensus, or disagreement, of actors could be categorized into three groups. There is a consensus amongst biomedical, clinical, healthcare technology engineers and technicians, the end users of equipment, and the hospital directors and managers. As all of these actors works within health facilities, it could be that the types of problems that occur are common, or that problems and their causes are already widely known amongst health facility staff. The policy makers, planners and administrators at the MoH, and the international organization representatives, also commonly identify the causes of problems. The suppliers of equipment, however, do not recognize ineffective procurement issues, in which they argued that public procurement of goods or services remains a business issue worldwide. Suppliers most commonly stressed other factors, such as political circumstances, as causes of problems in HTM.

Explanation and interpretation of the appropriate solutions to improve HTM in Benin

Developing and implementing a policy and management tool to guide healthcare equipment distribution ranked highest as a solution, given considerations of feasibility and acceptability i.e. solutions that can be implemented immediately. This solution is equivalent to creating standard lists of the equipment required (e.g. per room or per department) for different types of health facility (e.g. referral hospital, district hospital, health center) given the services provided, which has already developed during a pilot project and a draft version is now available. Once this document has been validated, it will be widely disseminated and used to guide the distribution of equipment at each healthcare facility level and assist budgeting decisions. The development of a reference price list ranked second as an appropriate solution, as a draft for Zone Hospitals was already developed during the aforementioned pilot project. The reference price list will be extended to cover all standard equipment and will guide the financial adjudication of public procurement equipment contracts. The development and implementation of policy and management tools to guide financial resource allocation for LCC of equipment ranked as the third most appropriate solution, as more information and reporting on the costs of spare parts, consumables and continuing operation of equipment is needed. Alongside this, a reference document on the architectural and technical requirements for installation and commissioning of medical equipment is a key policy and management instrument for budgeting and financing to guide estimations of the LCC of equipment. This document has already been developed for Zone Hospitals and will be extended to other healthcare facility levels.

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The creation of a national healthcare equipment and maintenance directorate was ranked as the fourth most appropriate solution. Although the creation of a dedicated directorate would have a very positive impact on HTM in Benin, it would require many financial, material and human resources, as well as strong political support to institute. The implementation of the available maintenance policy would be greatly expedited upon the creation of a healthcare equipment and maintenance directorate; both time and resources could be saved by using it to guide technical decision making, as opposed to developing another policy. Furthermore, the lack of policy and management tools for obsolete equipment would be rectified, as these are already incorporated in the available maintenance policy.

Strategies for implementing the selected appropriate solutions to satisfy STEEEP criteria

According to the responses of the different interviewees, the improvement of Benin's HTM system might be attainable when the individual perspectives of key actors in HTM align. The observation that most interviewees highlighted problems which other key actors, outside their own group, were responsible for, stresses our contention that this issue is basically a multilevel system problem. As a consequence, we should acknowledge and identify, at each level, the relevant key actors who are important as enablers towards more effective and efficient HTM processes. At the highest level are policy makers, planners, administrators at the MoH who possess legitimate "problem solving power". At the lowest level, and outside the MoH influence, are the local and foreign suppliers. These two key actor groups have been identified to have the strongest influence on the management of healthcare technologies in Benin. Following these, hospital directors and managers and international organization representatives have intermediate power positions, as they are able to solve problems that fall in their jurisdiction. Biomedical, clinical and healthcare technology engineers and technicians, and the end users of the equipment, have less political and economic power, but possess (or might possess in the future) some power through their technical knowledge. The alignment of perspectives regarding problems and solutions in HTM would enable a major leap in organizing better healthcare support at the technical level [40,41].

The monitoring and evaluation criteria for the proposed interventions and instruments, to enable simultaneous system change in HTM, might be deduced from the RCA problem trees. If the logic of the RCA is correct, it follows that identified problems will become less problematic when deeper causes (sub-problems) of these problems are tackled via the implemented interventions and instruments. Changes necessary to improve HTM in Benin comprise:

(i) The political need to strengthen capacity in HTM institutions

- The creation of a dedicated Healthcare Equipment and Maintenance Directorate within the MoH;
- Civil servants demonstrating a high level of concern for the well-being of the country, respecting that public goods and services are sacred, and working to defend and maintain them;
- Individual or self-accountability of all key actors.

(ii) Development and implementation of strict policy and management tools

- Implementation of an up-to-date version of the existing maintenance policy for healthcare infrastructure and equipment;
- Reference price lists for healthcare equipment;
- Development of healthcare equipment technical service capacities in the zone and departmental hospitals, with specific emphasis on the training of users and maintenance technicians;
- An up-to-date national list of essential medical equipment;
- Development of the architectural and technical installation requirements document for healthcare equipment at each healthcare facility level;
- Efforts to decrease the influence of external support agencies that come with tied aid, low utility equipment donations and the competitive international tender.

(iii) Regulations at each level of the HTM cycle.

- A national policy for acceptance of donations;
- Ensuring that public servants (policy makers, hospital directors and managers, equipment users and equipment technicians and engineers) are held responsible for administrative misbehaviors;
- Regulations to enforce sanctions on the misuse of public funds for private gain in public institutions, independent of political or social status.

Although this blueprint of policy actions appears ambitious during a period of simultaneous good governance challenges in Benin's HTM system, it follows from a systems approach which states that many small changes implemented at all levels of a system in unison, might achieve more significant improvements than radical reforms targeting specific problems. There is evidence of this, particularly in sub-Saharan African countries, where multiple and specific development projects backed by different aid agencies have had limited impact, or potentially exacerbated the situation, in the absence of coordinated efforts [42,43]. An example of this is the great improvement in self-accountability accomplished in Costa Rica's HTM system [14], where individuals displayed a dedication to their job which could not be explained by the level of their salary or their position in the staff hierarchy. They demonstrated an energy and motivation which inspired themselves, as well as the people around them, to overcome obstacles and find ways of dealing with practical problems in innovative ways. This edifying example of equipment users, maintenance technicians and managers taking ownership of actions to improve the system is missed in HTM in Benin, yet here we have delineated a path to approach more effective and efficient HTM processes.

The main question thus arises as to how to change can be realized, in order to satisfy STEEEP criteria and improve

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Benin's HTM system? That is possible when the perspectives of dominant HTM actors change. This change could be induced via the inclusion of biomedical, clinical and healthcare technology engineers and technicians, as well as the end users of equipment, in decision making processes for HTM. International organization representatives and hospital directors and managers have the political and administrative power, with greater influence on policy makers and healthcare technology suppliers, to mobilize support for changes in HTM. Depoliticizing public services and improving the motivation and accountability of public servants would contribute to effective improvement.

Limitations and strengths of the methods used

RCA is an instrument to scrutinize rich and complex data by focusing on dependencies and relations; strictly speaking, it only offers options for policy development that are rational. However, one limitation might be that small sub-problems resistant to change could destabilize the systems approach to changing HTM processes. Nevertheless, the participative approach to data collection - by interviews, focus group discussions and expert meetings [see 44] - has also worked to make stakeholders in HTM aware of the advantages of a more efficient HTM system, and showed this could be attainable when each actor chooses to play a slightly different role in the future. Furthermore, the study benefits from the unique position of the first author as a high-level civil servant in the MoH, who is in a privileged position to mobilize support from current political actors.

Conclusion

This study addressed the root causes of problems facing healthcare technology management in Benin's public health sector and the possible solutions to satisfy STEEEP criteria.

Root cause analysis was used to investigate the problems and ascertain the chain of causal relationships. From the analysis and discussion of the findings, it was found that the deepest root causes of problems related to culturally-embedded practices of high- and low-level corruption i.e. *self-interest and the unwillingness* of policy makers to solve maintenance, and related, problems. Feasible solutions for policy interventions looked at causes and problems at the intermediate level of the causal chain.

Appropriate solutions, in order of decreasing priority, are: (i) the development and implementation of policy and management tools to guide distribution, (ii) the use of reference price lists, (iii) the development and implementation of policy and management tools to guide financial resource allocation for the life-cycle costs of equipment, (iv) the creation of a healthcare equipment and maintenance directorate at the Ministry of Health, (v) the implementation of the available maintenance policy, and (vi) policy and management tools for obsolete equipment. Many improvements can be made by ensuring the strict implementation of policy and management tools, as well as regulations, at each level of the healthcare technology management cycle. A key role has to be attributed to the technical specialists, e.g., the biomedical, clinical and healthcare technology engineers and technicians, and the end users of equipment in healthcare facilities. These changes, however, do not require vast financial resources to be successful, but only several coordinated slight redirections in the current behavior of the stakeholders towards an increased level of concern for the well-being of the country, supported by the proposed set of policy instruments that affect multiple levels. Furthermore, there is a need for strengthening capacity in healthcare technology management institutions. This change could be supported and facilitated by hospital managers and directors and international organization representatives, i.e. Benin's health development partners.

Author contribution

The first and sixth author collected the data, under the supervision of the fifth and last author. The first, second, third, and last author analyzed the data. The first, fourth and last author drafted the manuscript, which was subsequently checkedby all other authors.

Conflict of interest

None declared.

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