Biomedical engineering in Somaliland

Needs assessment report

October 2013 assessment

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List of acronyms

A&E	Accident & Emergency
ADFA	Australian Doctors for Africa
AH	Alhayatt Hospital
AMEK	Association of Medical Engineering of Kenya
ARV	Antiretroviral
AMREF	African Medical and Research Foundation
BME	Biomedical Engineering
BMET	Biomedical Engineering Technologist
CEmOC	Comprehensive Emergency Obstetric Care
CPD	Continual Professional Development
COOPI	Cooperazione Internazionale
EAUH	Edna Adan University Hospital
EC	European Commission
EWH	Engineering World Health
FEAHEA	Federation of East African Hospital Engineering Associations
FINNSOM	Finland-Somali Association
HAVOYOCO	Horn of Africa Voluntary Youth Committee
HGH	Hargeisa Group Hospital
HIOHS	Hargeisa Institute of Health Sciences
HIV	Human Immunodeficiency Virus
HND	Higher National Diploma
HTI	Hargeisa Technical Institute
ICRC	International Committee of the Red Cross
ICT	Information and Communication Technology
ICU	Intensive Care Unit
IFHE	International Federation of Hospital Engineering
ILO	International Labour Organization
IOM	International Organization for Migration
ISO	International Organization for Standardization
JCI	Joint Commission International
KNH	Kenyatta National Hospital
KMTC	Kenya Medical Training College
MoH	Ministry of Health
MoE	Ministry of Education
MSF	Médecins Sans Frontières
NICU	Neonatal Intensive Care Unit
NNM	Nooleynta Naruurada Mustaqbalka
OPD	Out Patients Department
SOMLA	Somaliland Medical Laboratory Association
SRH	Sexual and Reproductive Health
THET	Tropical Health and Education Trust
ToR	Terms of Reference
UNICEF	United Nations Children's Fund
UoH	University of Hargeisa
WHO	World Health Organization

Acknowledgements

This report was prepared for THET Somaliland to share the results of a baseline needs assessment of biomedical engineering (medical equipment maintenance and management) in Somaliland. The assessment was undertaken in order to identify key gaps and advise on appropriate capacity building opportunities to address them.

The consultant (Shauna Mullally) is very grateful to the THET Somaliland team, who provided excellent logistical and administrative support for the assignment. She would also like to thank all of the people interviewed for this assessment, many of whom took significant amounts of time out of very busy workdays to share their experiences and conduct hospital tours.

The views expressed in this report do not necessarily represent those of the people interviewed during the assessment or preparation of this report. Full responsibility for the contents of this report rests with the consultant.

Executive Summary

Most low-resource health systems face significant challenges managing and maintaining their medical equipment, and often lack what they require to diagnose, treat, monitor and rehabilitate their patients. This translates directly into poor outcomes for patients, and negatively affects the health workers who care for them.

Somaliland's challenges with medical equipment are more acute that most. In 2013, THET recruited a consultant to undertake a needs assessment of biomedical engineering in Somaliland, in order to identify key gaps and provide recommendations to address them. This report is the outcome of the assessment. It includes summaries of the stakeholders visited during the assessment, key findings and recommendations for THET and partners in Somaliland.

During early October 2013, a total of 18 stakeholders were visited in Somaliland including four hospitals in Hargeisa and Boroma, training institutions (universities and a technical college), equipment suppliers and other relevant organisations. Semi-structured interviews took place at the hospitals with senior staff, heads of departments and maintenance staff, where present. Five stakeholders in Nairobi, Kenya were then visited to evaluate opportunities for collaboration.

Somaliland's hospitals face significant challenges with their medical equipment. The vast majority is donated, either by charities or partner organisations for programmes or as part of general health system strengthening support. Donations are much needed, yet they are not always made appropriately and are very infrequently sustainable in the absence of a medical equipment management system.

The hospitals have very few maintenance staff responsible for medical equipment, typically one handyman (one hospital had more, another had none). The maintenance staff were very resourceful but did not have formal training on medical equipment, nor did they have the resources (tools, engineering equipment or a functional workshop) to do their job effectively.

There are currently no training programmes for biomedical engineering personnel in Somaliland at any skill level, from craftsperson to technician, technologist or engineer. From this assessment, there do not appear to be any qualified biomedical engineers working full time in the country, let alone within the health system. One of the most skilled technical service providers in Somaliland is the lead technician for the largest laboratory equipment supplier in the country.

Opportunities exist to address these gaps in biomedical engineering capacity. Several partners have or are planning to deliver short training courses on equipment maintenance and management. The main medical training college in Kenya has a well-established and respected biomedical engineering programme and can accept foreign students and help design specific curricula for other countries. Training institutions within Somaliland are also interested in offering a new programme in biomedical engineering, with support through partnerships.

The main training recommendations in this report cover short-, medium- and long-term suggestions for capacity building:

SHORT TERM: Organise a short in-country course on basic equipment maintenance for technical staff and on basic equipment management for technical staff and administrators (co-learning)

MEDIUM TERM: Sponsor select technical staff to be trained in Kenya or somewhere else regional, both at a training college and on practical attachment within a health facility

LONG TERM: Develop an appropriate BME programme in Somaliland, through partnership support from regional and/or international organisations

Additional recommendations are included for organisations procuring and donating equipment, partnerships and human resource improvements for biomedical engineering in Somaliland.

1 Introduction

1.1 Background

Health facilities in low-resource settings often lack the medical equipment needed to diagnose, treat, monitor and rehabilitate their patients. Most face significant challenges maintaining and managing the equipment they do have. Studies indicate that upward of 40% of medical equipment is out of service in developing countries, as compared with less than 1% in higher-resource countries[1].

Equipment maintenance *includes both routine servicing (also called planned preventive maintenance) and repairs (also called corrective maintenance) by trained biomedical engineering professionals, as well as routine care performed by equipment users.*

Equipment management *includes all activities across the equipment's life cycle that ensure it is appropriately and optimally used such as: assessing the need, sourcing (procuring/soliciting donations), managing the delivery logistics and installation, managing the inventory and maintenance programme, providing training, supporting safe use, and finally disposing of it.*

One key contributor is the lack of trained biomedical engineering (BME) personnel at various skill levels to maintain and manage the equipment. Many countries in Africa, for example, do not have a single training programme for biomedical engineering[2], meaning maintenance staff learn about medical equipment 'on the job' in the hospitals. The majority of low-resource hospitals have difficultly finding qualified technicians and engineers locally (more than 75% in sub-Saharan Africa)[3].

Low-resource health facilities often rely significantly on equipment donations; the World Health Organization (WHO) estimates that up to 80% of medical equipment in developing countries is donated or funded by international donors and foreign governments[4].

When national policies and standardised lists of medical devices (including specifications) aren't available, each partner procures different equipment, from different suppliers with different technical services (such as installation and preventive maintenance). This equipment is much needed, but the lack of standardisation makes maintenance and management more difficult.

Somaliland's health system is more fragile than most, lacking basic infrastructure and skilled health workers. Its challenges with medical equipment are also understandably acute. The vast

[1] Howitt P et al., The Lancet and Imperial College London (UK) Commission: Technologies for global health The Lancet, Volume 380, Issue 9840, Pages 507 - 535, 4 August 2012. Available: http://www.thelancet.com/commissions/technologies-for- global-health

[2] WHO, Biomedical engineering training worldwide: http://www.who.int/ medical_devices/support/en/

[3] Mullally S., 'Clinical engineering effectiveness in developing world hospitals', M.A.Sc. Carleton University (Canada), 2008: 198 pages.

[4] Dyro J., 'Donation of medical device technologies' in Clinical engineering handbook, Elsevier Academic Press, 2004:155–158.

majority of equipment is donated or funded by partners, there is very little resource or capacity within the health facilities to maintain and manage the equipment effectively and there are no training programmes in-country to train biomedical engineering professionals.

1.2 Methodology

THET Somaliland contracted the consultant to undertake a baseline assessment of current medical equipment maintenance and management capacity in Somaliland, in order to be able to advise on appropriate capacity building activities to address the most critical needs. The terms of reference are presented in Appendix A.

The assessment was undertaken during the first two weeks of October 2013. It included interviews with key stakeholders (health facilities, training institutions, partners, equipment suppliers and professional associations) and assessments of the medical equipment in the hospitals visited.

At the health facilities, senior staff members (directors and matrons) and the in-charges of all relevant areas (labour and delivery, operating theatre, medical imaging, laboratory, etc.) present were interviewed. Maintenance personnel, where in post and present, were interviewed also.

A semi-structured questionnaire (Appendix B) formed the basis of the interviews, and interviewees were encouraged to speak freely about their challenges with medical equipment. Interviewees' verbatim responses are included in this report through quotes, which are anonymous to maintain confidentiality.

Meetings were also conducted with stakeholders in Nairobi to explore opportunities for partnerships, including: the main referral hospital, the technical training institution for biomedical engineering, the Ministry of Health (MoH), and the Kenyan professional association for biomedical engineering.

Appendix C presents the full list of interviewees and the meeting schedule. Secondary documentation was also reviewed during the assessment and the writing of this report. The list is presented in Appendix D.

1.3 Overview

This report is broken into three main sections:

Stakeholder profiles: provide a brief overview of each organisation, with a focus on medical equipment maintenance, management and human resources for BME.

Key findings: provide an overview of Somaliland's current baseline for: equipment maintenance and management, biomedical engineering personnel and training, procurement and donations.

Recommendations: provide suggestions to THET Somaliland and other stakeholders to begin to address the gaps identified during the assessment. Some of these are practical suggestions such

as potential training programmes in nearby countries, while others are longer-term activities that may be implemented to build BME capacity.

2 Stakeholder profiles

2.1 Health facilities

Four hospitals in Somaliland were visited: two in Hargeisa (Edna Adan University Hospital and Hargeisa Group Hospital) and two in Boroma (Boroma Group Hospital and Al-Hyatt Hospital). Details of the specific medical equipment within these facilities can be provided upon request.

2.1.1 Edna Adan University Hospital

Edna Adan University Hospital (EAUH) is a 60-bed non-profit teaching hospital in Hargeisa that has grown from a maternity hospital to one that also offers general medical and surgical care for adults and the paediatric population. The hospital is a teaching hospital that trains nursing and midwifery trainees, as well as laboratory technicians and pharmacists.

Senior administrators were interviewed and then the following wards and departments were visited to assess the equipment and speak with users and technical staff: delivery room; C-section theatre; main and minor operating theatres; sterilisation room; neonatal intensive care unit (NICU); main clinical laboratory and training laboratory; and generator building. There is also a new x-ray department that has been built and is awaiting a new machine.

Much of the hospital's equipment has been donated by a variety of partner non-governmental organisations (NGOs), including Australian Doctors for Africa (ADFA), Direct Relief, the United Nations Children's Fund (UNICEF) and the World Health Organization (WHO). Devices are also procured by hospital administrators, often in Nairobi (Crown Healthcare is a popular supplier) where they are sometimes sent back to the supplier for servicing. Occasionally, visiting medical volunteers from abroad will also bring equipment along with them.

While the supply of equipment seems relatively good (i.e. lots of equipment is donated to or procured by the hospital), there is little coordination between donors and no standardisation of equipment. For example, all three incubators in the neonatal intensive care unit (NICU) are different models, as are all three aneasthesia machines in the theatres. This makes training, use and maintenance of the equipment more challenging.

The hospital has one technician who underwent a 6-month, hands-on electrical course at HAVOYOCO skills centre sponsored by the hospital. He is responsible for the generator, basic electrical work and recently underwent a one-day troubleshooting course on maintenance for the hospital's new anaesthesia machine. Administrators highlighted the need for more technical expertise not only in equipment maintenance but also in equipment management.

The hospital's main service provider within Somaliland is Human Care Diagnostics, although they are not specialised to offer services on all devices in the hospital. Equipment is occasionally

brought to Nairobi for servicing and in the past has also been sent to Dubai, at great cost to the hospital. There is also a biomedical engineer from abroad who occasionally visits Somaliland to perform maintenance work on contract for various institutions who has been hired by EAUH.

A significant number of medical volunteers from abroad share their skills at EAUH, both on short visits (2-3 weeks) and longer placements (sometimes several years). They are often involved in both teaching and clinical work, and come from within the region (i.e. Kenya) as well as further afield (i.e. the United States, Australia, etc.) and work in a variety of specialities such as critical paediatric care, fistula repair and anaesthesia. There is an opportunity for the hospital to recruit a volunteer biomedical engineer through one of the many partner organisations.

2.1.2 Hargeisa Group Hospital

Hargeisa Group Hospital (HGH) is the main referral hospital in Somaliland. It has approximately 300 beds and offers emergency services, surgery and orthopaedics, internal medicine, mental health and specialised paediatric and maternal health services.

The hospital's matron was interviewed, and then the following areas of the hospital were visited: medical imaging (x-ray); laboratory; blood bank; delivery room; NICU and intensive care unit (ICU); four operating theatres (major, minor, orthopaedic, and obstetrics and gynaecology); and haemodialysis.

HGH faces significant challenges with their medical equipment; many of the wards lack adequate basic devices such as blood pressure machines, basic resuscitation devices and oxygen. There is a significant amount of sophisticated equipment that has been provided through support from donors, including laboratory and blood bank equipment, imaging equipment, aneasthesia and resuscitation devices and a new dialysis suite that was fundraised for locally but local maintenance capacity for these technologies is very limited.

Some donations have been very well received, particularly those that were instigated by the hospital or for which the hospital and donor are in regular contact, while others have been less sustainable. For example, two good quality, pre-owned ventilators were donated for the hospital's new ICU, but the staff require training to use them safely, and the hospital is having difficulty sourcing the tracheotomy tubes for them within Somaliland.

Much of the HGH's laboratory equipment has been provided through assistance from partners, including the WHO, UNICEF via the Global Fund's HIV programme, Progressio UK and the Zamzam Foundation of Somalia. The Finland-Somali Association (FINNSOM) and the International Organization for Migration (IOM) have provided a mobile x-ray machine and sonographer training through their MIDA project. ADFA and Noleeynta Naruurada Mustaqbalka (NNM) also both support the hospital through capacity building in the theatre and NICU respectively.

The hospital has a small maintenance team who require skills upgrading, including two electricians, two plumbers and a carpenter. The electricians look after the generator, electrical wiring and some cold chain equipment in the laboratory and blood bank. The hospital does not have staff trained specifically on medical equipment and this is a critical skills gap.

The maintenance team does not currently have a functional workshop. This is due to change in 2014-2015 through a European Commission (EC)-funded United Nations Office for Project Services (UNOPS) hospital rehabilitation project at HGH. The project includes a 'clinical engineering' (i.e. biomedical engineering) component to rehabilitate the workshop and train the maintenance personnel.

Repair works and ad-hoc training for the maintenance staff has also been provided by a biomedical engineering technologist (BMET) from Kenya, who has been visiting HGH every 6 months since mid-2011, through Health Poverty Action (HPA)'s 3-year medical equipment maintenance training programme.

The BMET's reports are very detailed and useful for anyone undertaking biomedical engineering work at the hospital, and are being included with this report for THET Somaliland. More details on these two projects are provided in the relevant sections of this report.

Equipment maintenance is a very large challenge for HGH. There are significant maintenance issues with most of the analysers in the laboratory, including the main CD4 counter that is used for HIV diagnosis and viral load monitoring for antiretroviral (ARV) patients. The main service provider is Human Care Diagnostics, and similarly to EUAH, HGH requests servicing for non-laboratory devices from the company as well, because there are no other local providers.

Further training is necessary for the staff who use the equipment as well as for technical staff to perform maintenance on it. In the imaging department for example, the radiographer installed a new x-ray film processor himself. When there are issues with the x-ray system, he calls in a local electrical engineer and together they attempt to troubleshoot the problem. The department also has a new CT scanner, which is awaiting installation by an engineer from Egypt. Training will be essential for this sophisticated device to be used safely and properly.

2.1.3 Boroma Group Hospital

Boroma Group Hospital (BGH) is a regional referral and teaching hospital in Boroma. It receives patients from the region as well as from the nearby area of Ethiopia and offers emergency and maternity services. After meeting with the hospital administrator and main maintenance technician, the following areas were visited: x-ray, theatres (major and minor), sterilisation, accident and emergency (A&E), delivery, laboratory, and outpatient clinic.

Like other facilities, BGH faces acute challenges with its medical equipment. For example, there is only one functional ultrasound machine in the outpatient clinic and no method of safely transferring patients from the maternity ward. The hospital also hosts anaesthetic trainees but there is currently no functional anaesthesia machine. All x-ray processing is manual and there is only one x-ray technician who works without backup.

The hospital has received significant amounts of equipment through various partners over the years, including surgical equipment, x-ray, sterilisation and oxygen equipment from the International Committee of the Red Cross (ICRC), Cooperazione Internazionale (COOPI), Merlin and UNICEF. Much of the equipment in the laboratory has been provided through support from UNICEF. Minor devices are generally procured on the local market.

There is one maintenance technician at the hospital. He has no formal training but was an assistant to a local electrician and acquired many skills through that. He also works as a mechanic in Boroma. He reported that there was a biomedical engineer at Amoud University several years ago who spent a week at BGH and he learned from him as well.

He has no tools or test equipment for his maintenance work; when he needs to open up a machine to troubleshoot it, he has to borrow a screwdriver from the garage. The only parts available in Boroma are fuses. For any other part, he needs to source them from electronics shops in Hargeisa. He is also responsible for the hospital's generator and electrical system.

2.1.4 Alhayatt Hospital

Alhayatt Hospital (AH) is the teaching hospital affiliated with Amoud University. Both Boroma institutions were built through support from the Amoud Foundation based in the US. The hospital hosts a significant number of volunteer medical experts from many different countries including Saudi Arabia, Pakistan, the US and the UK. It is run mainly by a group of Somali diaspora who spent years working in health systems abroad before returning home.

The following areas of the hospital were visited: x-ray and ultrasound, main clinical and pathology laboratories, outpatients department (OPD), surgical wards, sterilisation, two operating theatres (one orthopaedic), the nursery and NICU. There are some relatively sophisticated devices that have been brought by visiting clinical lecturers, such as an endoscopy suite and an automated pathology system.

Approximately 80% of the hospital's medical equipment is donated. A significant proportion of this comes from donors in the US, which poses infrastructure problems for the hospital because the American equipment runs on a different voltage. Electrical transformers are therefore required to enable the equipment to run on Somaliland's electrical system. When these 'blow' they can damage the equipment and result in electrical work being required regularly.

Alhayatt Hospital does not have any medical equipment maintenance staff. They contract local electrical engineers from Boroma when maintenance is required; some of whom are qualified while others are not. They also have a part-time electrician on call. When equipment faults arise, everyone pitches in to try to repair the device.

Much of the support for equipment comes with visiting clinical experts, who consult technical staff from their own institutions and then bring along the spare parts required. The current Pakistani sonographer in particular is very handy and has ordered and assembled various devices for the hospital. There is a significant need for more biomedical engineering capacity at the hospital, both for equipment maintenance and management.

2.2 Training institutions

There is currently no accreditation process for engineering curricula or programmes. Any institution that wishes to start a new programme and has the resources to do so may. The universities have internal processes for new programme approval that must be followed.

2.2.1 University of Hargeisa

The University of Hargeisa (UoH) has an engineering faculty that currently offers civil, mechanical, telecommunications and electrical engineering. The electrical programme is 5 years and the current fourth year cohort is the university's first. Due to limitations with lab facilities and teaching capacity, the programme does not offer a significant amount of practical instruction.

The engineering faculty does not currently have partnerships with outside institutions in higher-resource settings but is keen to develop them. They were visited recently by the International Labour Organization (ILO), which has produced a curriculum resource package for labour intensive road engineering projects, for example.

While all engineering programmes are currently five years, UoH leadership (the president, vice-president/dean of medical faculty and dean of engineering) were very receptive to the possibility of developing a shorter diploma programme in biomedical engineering (i.e. 1-2 years) and proposed the possibility of partnering with other universities (such as Gollis or Amoud) to develop and run such a programme.

To develop such a programme, UoH would require support for curriculum development, lab facilities and programme delivery (theory and practical). They are keen to recruit engineers from higher-resource settings (graduate students, retired professionals, etc.) to help develop programmes and do some English training on the side; the university would provide accommodation and a living stipend.

Hargeisa hospitals expressed interest in accepting students on practical attachments. This would be valuable for the hospitals as well as the trainees. In the absence of trained biomedical engineering professionals currently working in the hospital, mentorship would need to be arranged for the student trainees.

2.2.2 Hargeisa Technical Institute

Hargeisa Technical Institute (HTI) offers project-based vocational training in technical subjects such as mechanics, electrical and plumbing. Each year of a programme (from 1-3) corresponds to a level of certification in the subject and includes 8-9 months of training at HTI and a 2-month internship. The institute is supported by Save the Children and the Norwegian Refugee Council (NRC), and has very good training laboratory facilities.

HTI has begun offering upper level courses in plumbing, electrical, office management, and information and communication technology (ICT) through support from Save the Children. The first cohort of third-year (level 3) electrical students is due to commence next year. HTI does not currently offer electronics, which would be required as fundamental learning for a biomedical engineering programme.

2.2.3 Hargeisa Institute of Health Sciences

Hargeisa Institute of Health Sciences (HIOHS) offers a 3-year diploma programme in nursing, and recently (March 2013) began a 3-year biomedical scientist/laboratory technology diploma programme with support from the WHO. Both programmes are broken into 'professional' and 'supporting' courses, and place students at hospitals in Hargeisa for practical attachments.

HIOHS has training labs for both programmes and some equipment in each. They have problems with maintenance and tutors frequently try to repair the equipment. HIOHS leadership (president and head of programmes) both had significant experience in the health system with medical equipment and it's associated challenges.

2.2.4 Gollis University

Gollis University, in Hargeisa, launched their engineering faculty in 2009 with a focus on telecommunications. The faculty has three sub-faculties: civil engineering, computer engineering and telecommunications engineering. It also offers first year electrical and electronics courses. Three-year diploma programmes have the possibility of being converted into four-year degree programmes.

The university has partnerships with several institutions abroad, including Jomo Kenyatta University of Agriculture and Technology and Malaysia Open University. The process for initiating a new programme begins with a department proposing the programme to the president's office. A committee is then developed to oversee curriculum development, laboratory space and equipment and recruitment of lecturers.

2.2.5 Amoud University

Amoud University in Boroma offers health science programmes through faculties in medicine, nursing, midwifery, dentistry, pharmacy, laboratory technology and public health. The university's website indicates they have a faculty of civil engineering, however this wasn't confirmed during interviews.

There are a significant number of volunteer lecturers from abroad at Amoud University who also do clinical teaching at Alhayatt Hospital. Many of the volunteers have been placed through SomDev (a UK volunteer sending NGO), and others have been recruited through various US organisations affiliated with the Amoud Foundation.

THET has offered significant support to the nursing and midwifery programmes, including the provision of training mannequins and equipment. The university and Alhayatt Hospital also have a partnership with Kijabe Hospital in Kenya for nurse anaesthetist training and surgery.

There would be many opportunities to recruit biomedical engineers through these partner organisations who could work at the university and Alhayatt Hospital. Leadership at the university indicated that traditionally with experts, comes curriculum and then programme development.

2.2.6 Others

The Horn of Africa Voluntary Youth Committee (HAVOYOCO) offers skills training in a variety of subjects including technical vocational training.

2.3 Equipment suppliers

Four known wholesalers in Hargeisa supply medical equipment. Human Care Diagnostics specialises in laboratory equipment and is the only one that provides after-sales technical support from a qualified technologist.

2.3.1 Human Care Diagnostics

Human Care Diagnostics in Hargeisa is the largest supplier of laboratory equipment in the region, supplying devices from Germany, the US, Denmark, India and China to all regions in Somaliland and parts of Somalia and Puntaland. The company has supplied equipment to a large number of partners, as well as hospitals directly, including: UNICEF, WHO, World Vision, Caritas, IOM and Médecins Sans Frontières (MSF) Belgium, France and Holland.

They have a small engineering workshop where 2 full time technicians maintain their equipment under warranty, and provide services for customers from across the country for other devices as well. The workshop has basic spare parts, tools and test equipment (such as a digital multimeter) and specific test equipment for the laboratory analysers supplied by the manufacturers.

Due to the severe lack of skilled service providers in Somaliland, Human Care Diagnostics gets sent all types of medical equipment from the hospitals for repair, including anaesthesia machines, ultrasound machines, patient monitors and oxygen concentrators.

Their technical staff are highly skilled to service lab devices, having been certified by the manufacturer's engineers, but they may not have the necessary knowledge or tools and test equipment to properly service other devices.

When they can't fix the equipment, they help customers source new items. They have also started supplying more non-laboratory supplies due to demand, such as nasal prongs and tubing for oxygen concentrators, and are starting to regularly supply imaging equipment as well (ultrasound and occasionally mobile x-ray).

The company's main technician has a background in laboratory technology. He trained his assistant technician and is beginning to train others for different regions of Somaliland. He is incredibly busy, being one of the most highly skilled technical staff not only in Somaliland, but also in the wider region.

Their service is very professional and most partners and hospitals reported good service, although wait times due to high demand still impact lab services. They train users on daily and monthly maintenance during installation, do routine preventive maintenance on their machines and are in regular communication with the manufacturers' engineers when troubleshooting.

2.3.2 Indian Ocean

Indian Ocean supplies a large range of disability aides. They also supply very basic medical devices such as thermometers, blood pressure machines, haemoglobin meters and first aid kits. They process large orders from hospitals and also sell directly to medical and nursing students.

Indian Ocean processes special orders for non-stock items very infrequently. The company does not offer warranties on the items sold unless specifically requested, in which case the original supplier (i.e. not Indian Ocean) provides them to the customer.

2.3.3 Dalson Pharmaceutical

Dalson Pharmaceutical is predominantly a medicine and supply wholesaler. They do not stock many medical devices (other than very basic ones) but do process requests for larger specific items by identifying suppliers abroad (often in Dubai) and importing the specified equipment. No one from the company was interviewed because they did not have time when they were visited.

2.3.4 Others

Bucangargar also supplies very basic devices such as thermometers, stethoscopes and blood pressure machines. They were not visited during the assessment due to time constraints. Some interviewees indicated that their supply of these basic devices is erratic.

2.4 Partners

2.4.1 Health Poverty Action

Health Poverty Action (HPA) works with the maternity and paediatric wards and the sexual and reproductive health (SRH) programmes at Hargeisa Group Hospital and with all of the wards at Berbera Hospital. They have supplied medical equipment for their programmes, such as new theatre equipment for their comprehensive emergency obstetric care (CEmOC) programme, and were able to provide local supplier information.

After realising how much equipment was out of service at Berbera Hospital and other facilities, they recruited a Kenyan biomedical engineering technologist (BMET) to provide practical maintenance training to select technicians initially from Berbera, Burao and Hargeisa. The BMET trainer did an initial assessment in mid 2011 to prepare for the training course and the first 3-week course was offered to seven staff from the selected areas in late 2011.

Since then, one-week training courses have been offered every 6 months at Berbera Hospital. Unfortunately some of the initial trainees were not technical staff and therefore could not apply what they were taught in the course. There are also challenges with trainees changing from course to course. Three of the trainees from Berbera Hospital have been consistent attendees throughout the courses and have also shadowed the trainer while he does repairs at the hospital.

This is excellent practical training, and places the hospital in a good position to become the site of future maintenance training courses and possibly in the longer term even a maintenance referral workshop. The BMET also visits HGH during his visits and does maintenance work there. In Nairobi, he sources tools and test equipment and provides an interface with Kenyan suppliers for spare parts and information.

His reports are very thorough and are being provided to THET Somaliland along with this report. A meeting took place with him in Nairobi (he works at Kenyatta National Hospital) and he is an excellent technical resource for anyone working in BME capacity building in Somaliland. HPA's medical equipment maintenance training programme is 3 years and scheduled to complete in mid-2014.

2.4.2 UNOPS

Through funding from the EC, UNOPS has sub-contracted an Italian organisation to implement a rehabilitation project at Hargeisa Group Hospital. The project includes a clinical engineering work strand, with plans to rehabilitate the maintenance workshops to raise them to a functional standard, and to provide basic training to the maintenance staff. Basic workshop tools and test equipment will also be provided. The project also includes plans to perform a thorough equipment inventory to identify priorities for maintenance. Training is scheduled to take place in early 2014, with 8-12 modules for various learning areas identified.

2.4.3 World Health Organization (WHO) laboratory programme

The WHO's laboratory officer in Somaliland, who used to work in the lab at HGH, performed a baseline assessment of laboratory capacity, including equipment, as part of an African Medical and Research Foundation (AMREF)-sponsored course in medical laboratory practices and management. This work complements a recent assessment undertaken by SOMLA (see below) and THET to define the baseline for laboratory capacity in Somaliland.

2.4.4 Others

Needle Pathology Laboratory in Hargeisa was also visited. Needle is a new private laboratory in Hargeisa founded by several SOMLA leaders. It has very good machines, including a 5-part differential haematology analyser (the hospital laboratories have 3-part differential machines). The lab uses the Lancet laboratory in Nairobi as it's reference lab, and would like to implement a quality system that can be accredited in the coming years.

2.5 Professional associations

There is a very newly formed engineering association within Somaliland that may be useful to meet with when BME capacity building initiatives are being implemented; due to time limitations and difficulty contacting them, they were not met with during the visit.

2.5.1 Somaliland Medical Laboratory Association

The Somaliland Medical Laboratory Association (SOMLA) is a nationwide association of medical laboratory professionals (laboratory technicians) that was established in 2006 and became very active in 2010 with support from THET, setting up governance and management structures, training staff and developing a website.

SOMLA has approximately 100 registered members in both public and private labs, and estimates that there are approximately 250 laboratory technicians working in Somaliland. The association performed an assessment of laboratory facilities and staff in Somaliland's eastern regions in late 2013 and ran a continuous professional development course for members.

SOMLA leadership have a significant amount of experience with laboratory equipment and highlighted the following general challenges: lack of maintenance and quality control, poorly coordinated donations, inadequate consultation with health facilities prior to receiving equipment (for issues such as mains power, training, supply chain for reagents, etc.) and costly equipment servicing (abroad) often with poor results. The lack of trained biomedical engineers was also identified as a critical gap.

The lack of standardisation with lab equipment is also a serious challenge because many brands provide 'closed systems', which means their machines only run using their reagents. This results in more training, maintenance and supply chain requirements, and less redundancy (i.e. when one analyser is down, the other can not necessary be used if its own reagents are not in stock). Supply chain of reagents is a big challenge and analysers are often out of service for weeks waiting on a new shipment.

2.6 Kenyan stakeholders

Medical engineering (biomedical engineering) training colleges in Kenya began in the late 1970s and the profession is very well established in the country.

2.6.1 Kenyatta National Hospital

Kenyatta National Hospital (KNH) is the main peri-statal referral hospital in Kenya, with a bed capacity of more than 1800 beds. It offers specialised services such as haemodialysis, chemotherapy and radiotherapy, cardiac and neurological intensive care units and has sophisticated infrastructure such as medical gas production on site. The hospital has received International Organization for Standardization (ISO) 9001 accreditation and is now working towards accreditation by the Joint Commission International (JCI).

KNH has a very well established biomedical engineering (BME) service, with just fewer than 30 staff spread across the hospital's different wings. The BME service is coordinated by the head of department, who sits within the larger maintenance department, and has specialised staff in smaller workshops in the following hospital areas: dental, medical gases, renal, ICU, theatre and maternity, A&E, wards and clinics, and radiology.

At any one time, the hospital hosts approximately 30 biomedical engineering student trainees from Kenya Medical Training Centre (see below). The department captures monthly equipment downtime and preventive maintenance statistics, and the hospital is currently opening a calibration laboratory on site for test and measuring equipment.

There is clear separation of responsibilities between the BME team and other maintenance teams, such as the electrical department. The BME staff, mainly technologists, are well trained on the devices within their area of responsibility but lack basic knowledge of more specialised high capital equipment in the hospital (such as endoscopy, radiotherapy, CT and MRI), which is maintained on 5-year service contracts with external providers.

2.6.2 Kenya Medical Training College

The Kenya Medical Training College (KMTC) currently offers 2-, 3- and 4-year courses in medical engineering: certificates, diplomas and higher national diplomas (HNDs) respectively. There are plans to expand to offer a 5-year degree in medical engineering as well in the near future. KMTCs fall under the Ministry of Health (MoH), not the Ministry of Education (MoE), and the curriculum for each programme was designed specifically to meet the training needs of the MoH.

KTMC has various campuses across the country and places medical engineering trainees at various institutions based on their level of training. The certificate programme is offered in Meru, Loitokitok and Kilifi, while the diploma programme is offered in Eldoret and Nairobi. All HND trainees are based at the Nairobi campus and do practical attachments at KNH.

The college is able to accept foreign students, who may apply either independently or through sponsorship from their own government. It is also able to design courses specifically tailored to other government's needs. For example, it developed and ran a medical engineering course for the government of Namibia, which was designed specifically to meet their MoH's needs.

2.6.3 Ministry of Health

The Ministry of Health has two biomedical engineers on staff who have coordinated medical engineering in Kenya's public hospitals for over 15 years. One of their biggest challenges identified is human resources within district hospitals. A public sector hiring freeze and healthy private sector in Kenya has meant there is a BME skills shortage within the public hospitals.

A joint MoH and AMEK (see below) assessment revealed approximately 300 technicians and technologists working in public hospitals nationally, which is approximately 30% of the required number. A second challenge is with specialisation for sophisticated equipment. The MoH is very open to BME training partnerships to improve these two areas.

2.6.4 Association of Medical Engineering in Kenya

The Association of Medical Engineering in Kenya (AMEK) is a well-established professional association for medical engineering professionals in Kenya, including members from both the

public and private sector. It promotes the profession and offers continual professional development (CPD) to its members on equipment management and hospital planning.

AMEK runs an annual scientific conference and exhibition; the most recent one took place in November 2013. They are also a member of the International Federation of Hospital Engineering (IFHE), and involved in starting the Federation of East African Hospital Engineering Associations (FEAHEA) with colleagues from Uganda, Tanzania, Rwanda and Burundi.

3 Key findings - needs assessment and capacity requirements

3.1 Equipment maintenance

Equipment maintenance is one of the most significant challenges faced by the hospitals that were visited. There is a critical shortage of trained medical equipment personnel in Somaliland. This assessment did not find a single trained biomedical engineer in the country. The most skilled individual appears to be Human Care Diagnostic's main technician.

"Maintenance and troubleshooting are the biggest problems we have with our laboratory equipment."

"Maintenance is the very biggest problem we face; we are like drivers without a mechanic."

“Maintenance is our biggest problem. Every morning we have a meeting about it. Everyone tries to help: the doctor, the electrician… everyone.”

The hospitals also lack functional workshops for maintenance. Basic tool sets are absent, and there is no basic test equipment, such as oxygen analysers to verify oxygen output levels, or digital thermometers to measure the set temperature of an incubator. This lack of maintenance capacity has obvious, critical implications for the state of medical equipment - and in turn patients - in Somaliland's hospitals. It also means a very low return on investment (ROI) for the purchase of new equipment.

3.2 Equipment management

Similarly, equipment management capacity is extremely limited. Without appropriate training or resources, it is very difficult for existing staff who are already stretched to implement elements of an equipment management system such as proactive equipment planning, standardisation, establishing a maintenance system, managing supply chain for equipment consumables and spare parts, and life cycle management of the device.

> "[Partners] do ask us what we want but we don't always know. We don't always have the knowledge to know what we need."

Equipment management capacity must be built alongside equipment maintenance capacity. Without it, the maintenance personnel won't have what they need to do their job effectively and put training into use.

3.3 Human resources (biomedical engineering personnel)

Like other technical professions, biomedical engineering staff can be trained to work at various skill levels, from artisans to technicians, technologists and engineers. As a general rule of thumb, the various levels would split their time between maintenance (hands-on) and management (planning) activities as follows: artisans - 90/10%, technicians - 80/20%, technologists - 60/40% and engineers 10/90%.

Appendix E provides detailed definitions of the various biomedical engineering skill levels and references to guidance on optimal staffing of each skill level in a low-resource health system. These staffing levels are theoretical, however they do provide a good benchmark against which to measure progress towards building BME capacity in Somaliland and staffing health facilities. Currently, the baseline is very low, with some artisans in place, and a few staff who are untrained but appear to function at the technician level for medical equipment.

3.4 Training

The need for training is great: both for formal programmes to train biomedical engineering professionals, and also within health institutions to train equipment users and maintenance staff.

None of the training institutions in Somaliland currently offer programmes in biomedical engineering at the different skill levels, although many are keen to do so but require support to do so. HPA's maintenance training programme for staff at Berbera Hospital is an excellent initiative that should be replicated, although it has been noted by the trainer that the skill level of the trainees was lower than expected at the course outset.

Health-facility based training should in theory be part of a CPD programme for clinical and technical staff, however it is recognised that the facilities in Somaliland are severely resource constrained. The training for users when a new device is installed varies by company/donor/contract. It is good practice to always train users with the introduction of a new device. Training of trainers can be a very effective model for this.

"Even if we get the equipment, there is not enough knowledge. There is no engineer to install: only us. If there is a problem there is no engineer: only us."

"We need more training. Otherwise, as soon as this equipment breaks down we have to stop using it."

"The doctor who knew how to use [the electrosurgical unit] has left so we don't use it."

3.5 Procurement

Procurement in low-resource settings like Somaliland is often difficult, due to limited knowledge and a small supplier base. Quality can be a concern because most low-resource setting governments do not have robust regulatory processes for medical devices, meaning that anyone can import anything and market it as a medical device.

The health facility leadership interviewed had good knowledge of what their facility required and generally seemed able to source items from Nairobi, or through a local wholesaler with specifications that were used to source the item from a supplier abroad. However this makes maintenance more challenging in the absence of local service providers. Ideally, equipment would be standardised to simply training, maintenance and supply chain.

"When we purchase locally, the quality is not good. But when we purchase outside, it's very expensive."

3.6 Donations

Equipment donations are vital to Somaliland's health system, but the experience is not always positive. Some donors seem to send very appropriate items and supply them with the necessary supplies, but this is not always the case. Some equipment is not donated with transformers, user or service manuals, or even the necessary parts to function. For example, an anaesthesia machine was donated without a vapouriser, rendering it unusable.

Training is rarely provided for second-hand equipment donations, making it difficult for clinical staff to use the equipment, and technical staff to maintain it. Many of the partners mentioned in this report have long-standing relationships with the health facilities they donate to and this ongoing communication and partnership can greatly reduce inappropriate donations. Health workers and partners alike must be sensitised to good equipment donation practices.

"Please ask us what we need before sending something. Otherwise it will just sit in the corner."

"We don't get manuals with the equipment that comes so we don't know how to use it."

4 Recommendations

Much can be done in Somaliland to begin to build capacity to address the gaps identified.

4.1 Training

4.1.1 Short-term

In the short-term, THET may wish to support short in-country courses in very basic equipment maintenance and equipment management. UNOPS is offering a similar training programme at HGH and would be an excellent partner organisation. HPA would also have much learning to contribute based on their experience with their own training programme in Berbera.

The BMET trainer from the HPA programme would be very well placed to instruct the basic maintenance course, knowing the trainee skill level and local context very well from his 6-monthly visits since 2011. The UNOPS project engineer is also recruiting instructors regionally and would be a good source of potential trainers, as would Kenyan contacts from KNH and AMEK.

In-country cooperating partners may have run similar training courses elsewhere (for example, JICA has run medical equipment maintenance and management programmes in many countries in East and Southern Africa, including Zambia and Tanzania); it would be useful to discuss with partners to see if any are involved in similar programming elsewhere and may wish to contribute.

For a short course on equipment maintenance, the baseline skill level is very low and the course would need to accommodate this. Some similar short-courses teach trainees by the device (for example: this is a suction machine, this is how it works, these are common faults and this is how you repair them). Others start with the basic technical knowledge areas that apply to all devices and build the course content that way.

For example, Engineering World Health (EWH) is a US-based organisation that has set up BME training programmes in low-resource settings with an evidence-based curriculum developed by Duke University covering the most basic 'knowledge areas' technical staff need within a low-resource hospital to perform equipment repairs; mechanical, electrical, plumbing, motors and power supply. Each of these areas is broken down into 'units' and 'skills'. For example, the 'leaking' unit within the 'plumbing' knowledge area covers the following skills: finding holes,

cutting tubes, electrical tape, epoxy, superglue, rubber patches and melting tube[5]. (Introductions to EWH and Duke University can be provided upon request.)

In a setting where many technical staff working the hospital would have undergone formal training in areas such as mechanical or electrical technology prior to joining the workforce, the first option (i.e. training by device) would be appropriate. For the Somaliland context, with such a low skill level of those staff currently in place, the second option (i.e. training by basic technical knowledge area) may be more appropriate.

For a short course on equipment management, it's important that technical staff and more senior decision makers (such as hospital administrators and/or directors) learn about equipment management together. In practice, the technical staff member will have the information required to manage equipment (for example, this oxygen concentrator is broken and I need this part to repair it) and the senior decision maker will have the authority to do so.

Some training resources for equipment management are listed in Appendix F.

4.1.2 Medium-term

Kenya's training programmes for BME professionals are very well established. Sponsoring several lead technical staff from Somaliland to attend KTMC's programme, beginning with a 2-year certificate course with a practical attachment in a Kenyan hospital, would be an excellent investment. As with other similar initiatives (sponsoring training abroad), retention of trainees would need to be considered.

Kenya has one of the strongest foundations in BME training in Africa, but there are other programmes in the region that have been established within the last decade also. There are programmes in Ethiopia, Rwanda and Uganda, as well as THET Zambia's new flagship 3-year diploma programme that began in Sept 2013. South Africa, like Kenya, has a long established BME profession and very good training programmes also.

Introductions to any of these programmes can be provided upon request.

4.1.3 Long-term

In the long-term, Somaliland should have a BME training programme of its own. Planning for this does not need to wait, but it's recommended that the short- and medium-term training options be considered alongside any work to establish a BME training programme in Somaliland.

The technical institutions (HTI or the universities included in the assessment, depending on the level of training) are well placed to host such a programme. Generally, biomedical engineering

[5] Malkin R. and Garst. M, 'An Evidence-Based Curriculum For Biomedical Technician's Assistants In Resource-Poor Settings', IET AHT Conference, London UK (2010), Available: http://dhtlab.pratt.duke.edu/sites/dhtlab.pratt.duke.edu/files/An%20Evidence-Based%20Curriculum%20for%20Biomedical%20Technician's%20Assistants%20in%20Resource-Poor%20Settings.pdf. See also: Evidence-based approach to the maintenance of laboratory and medical equipment in resource-poor settings, Available: http://link.springer.com/article/10.1007/s11517-010-0630-1

programmes are most appropriate within technical institutions or university faculties (i.e. technology or engineering programmes) as opposed to health-science oriented settings because of the shared technical content and ability to share laboratory space with other technical programmes, such as mechanical and electrical technology.

For example, in Zambia half of the content in the new BMET programme already existed at the technical college for other similar programmes. THET Somaliland staff may wish to visit THET Zambia staff to learn more about how the BMET diploma programme in Zambia was developed.

Similarly, learning from other institutions in the region - and possibly partnering with them for programme development and delivery - would be very useful. KMTC for example, could help develop a Somaliland-specific curriculum that could either be offered in Kenya or in Somaliland. Other programmes listed in this report can also be approached for collaboration opportunities.

Recruiting a long-term BME volunteer through one of many volunteering sending partners in Somaliland to lead such an initiative is advised, particularly one who has been involved in training programmes or is affiliated with an institution in their home country. THET health partnerships would be one source of UK-based volunteers, BME professional associations would be another. Again, introductions can be provided upon request.

4.2 Human resources (biomedical engineering personnel)

Recognising that Somaliland faces significant challenges with mainstream health workers such as doctors and nurses, it's nevertheless important to advocate for new posts and support for biomedical engineering personnel. Because of the dearth of trained staff at present, volunteers from outside of Somaliland may be the most feasible option in the short term.

Hospitals and universities may request biomedical engineers through their volunteer sending networks. Partners can also advocate through their networks for this. Much can be done by a small group of focused people, as is witnessed by the tremendous amount of health programme development by stakeholders visited in Somaliland.

Advocacy with the MoH and partners may also help raise the profile of biomedical engineering within the health system. Courses on medical equipment management that include ministry planners may also help sensitise and raise the profile of biomedical engineering and good equipment management practices.

4.3 Procurement and donations

Donors who procure equipment for health facilities are encouraged to coordinate where possible to improve standardisation of equipment. Some have specific manufacturers and models they supply based on long-term agreements, but others procure locally through wholesalers and have more flexibility.

When possible, donors should consider supplying the tools and test equipment required for specific medical devices they are procuring for the hospitals. For example, if they are procuring

oxygen concentrators, supplying an oxygen analyser and a toolkit for the maintenance staff at the hospital would equip them to service the equipment, provided they had the appropriate training.

Similarly, those procuring equipment should always ask for the service (maintenance) manual for the device, as some suppliers are willing to provide this. They should specify that they would like basic spare parts with the device, and also request a full spare parts list. WHO guidance on good equipment procurement is included in Appendix F.

For donations, many resources exist to promote good practice. Hospitals that receive equipment and the organisations that provide it to them should be sensitised about good equipment donation practice. THET has recently released a toolkit on good donation practices, and several other organisations provide guidance, which are listed in Appendix F.

4.4 Partnerships

In addition to in country and regional partnerships, THET Somaliland may work with other THET programmes on these activities.

THET Somaliland has a long established partnership with King's Health Partners. This organisation may be a good source of BME expertise. Guys & St. Thomas' (a member of Kings Health Partners) has a medical equipment partnership with two hospitals in Zambia where BMET students will train; perhaps there is a possibility for knowledge sharing.

One interesting model to consider for partnership is a 'multi-country' partnership between Somaliland, Kenya and the UK. The Kenyan BME community has the skills to effectively provide BME training for Somaliland, but lacks skills and knowledge in more specialised 'high tech' training itself. This is the type of training the UK BME community would be well poised to offer. Perhaps this model could be investigated.

Finally, any partners listed in this report may be approached for potential collaboration. Contact details for those outside the scope of the assessment but included in this report can be provided upon request.

Appendix A: Terms of reference

The overall objective of the trip is to perform a baseline needs assessment of medical equipment maintenance and management in Somaliland, in order to identify appropriate capacity building opportunities.

The specific terms of reference to meet this objective are:

1. Meet with Ministry of Health (MoH) and other stakeholders to determine current equipment procurement, maintenance and management practices and challenges.

2. Meet with (two) main equipment suppliers in country to determine their procurement practices and what maintenance services they offer to health facilities.

3. Visit health facilities to interview administrators, senior clinical staff and maintenance staff about equipment practices. Proposed facilities include:

    - Hargeisa Group Hospital (Hargeisa)
    - Edna Adan University Hospital (Hargeisa)
    - Boroma Group Hospital (Boroma)
    - Al Hyatt Hospital (Boroma)
    - And if time permitting:
        i. One INGO-run health centre
        ii. One non-INGO run health centre

4. Meet with vocational training schools/other educational institutions that offer technical or engineering courses in subject areas related to biomedical engineering (such as electrical/electronics engineering) to assess possibilities for future programme development.

5. Prepare summary report of trip, including opportunities for training programmes.

Appendix B: Health facility questionnaire

This questionnaire formed the basis of semi-structured interviews. Note that it was deviated from significantly to be appropriate for the health facilities assessed, and has been retained in this report in the event that it is useful for developing an assessment tool at a later date.

Facility Profile

1. Name
2. Type of hospital
3. Number of beds, known occupancy rate?
4. Proportion of ICU/CCU beds?
5. Services offered
    - Labour and delivery
    - Obstetrics and gynaecology
    - Special baby care unit / neonatal intensive care unit
    - Paediatrics
    - Intensive care unit / critical care unit
    - Internal medicine
    - Surgery / theatre → which types of surgery performed?
    - Dialysis
    - Rehabilitation
    - Ophthalmology
    - Any highly specialised services?
6. Contact information, where available for:
    - Medical director
    - Senior administrator
    - Head of nursing
    - Head of radiology
    - Head of laboratory
    - Head of maintenance

Medical equipment

1. Is there an inventory of equipment? (If so, review it if possible).
2. If yes, what fields are included?
    - Type
    - Manufacturer
    - Model name
    - Age (estimate)
    - Location
    - Year of manufacture (estimate)
    - Serial number
    - Other
3. Approximately how much equipment is out of service?
4. Is there any standardisation of equipment?
5. What equipment is most crucially impacting service delivery (vary by interviewee)?
6. How much of the equipment has been donated?

7. What are the biggest challenges with medical equipment?
8. What type of *medical imaging* equipment is there?
9. What type of *laboratory equipment* is there?
10. What type of *anaesthesia and resuscitation equipment*, if any, is there?
11. What type of *labour and delivery and neonatal care equipment* is there?
12. What equipment most commonly requires repair?

Equipment supply

1. Does the hospital purchase equipment directly from suppliers?
2. Does the hospital receive equipment from international organisations?
3. If so, does it request specific items?
4. What is the process like?
5. Description of a recent procurement exercise and general thoughts?

Donations

1. How much of the equipment in the hospital has been donated?
2. Who has donated it (i.e. diaspora, equipment/medical charities, etc.) and which ones are 'repeat' donors?
3. Where has it been donated from (i.e. US, UK, etc.)?
4. What type of discussion was there prior to the donation?
5. Who initiated the donation?
6. Did anyone provide training on the equipment, for users and/or maintenance staff?
7. Who paid the cost of transportation to the facility?
8. Has a budget been provided (by the donor) or allocated (by the facility) for use and maintenance of any of the equipment?
9. Description of a recent donation exercise and general thoughts?

Maintenance personnel

1. How many staff are responsible for medical equipment maintenance, if any?
2. What department do they belong to?
3. Is it part of a larger department or standalone?
4. What are their job title(s)?
5. What are their roles and responsibilities around the hospital?
6. What is their background?
7. What qualifications do they have?
8. What on the job training have they done?
9. How many years of experience do they have?
10. What is their reporting arrangement within the hospital?
11. Is there a budget for their department, or an overall budget for maintenance?
12. How often (if ever) do they meet the administrators?
13. What equipment (in their words) do they service?
14. Who do they contact for support?
15. Which if any suppliers/manufacturers/other trainers would they contact?

Maintenance workshop

1. Is there a maintenance workshop? If so…

2. Do they have any tools in the workshop?
3. If so, what do they have?
4. If so, where are they from?
5. Do they have any test equipment in the workshop?
6. If so, what do they have?
7. If so, where are they from?
8. If so, have they been trained to use it?
9. Are there any spare parts (generic or otherwise)?
10. Is there adequate space for maintenance activities?
11. Is there a system of work in place in the workshop?
12. Is there a record of maintenance work?
13. If so, is it current?
14. Is there access to a computer or the Internet?
15. Are there any health and safety procedures in place?
16. Are there any training materials or manuals?
17. If so, where are they from?

Maintenance work

1. What are the 5 most common devices requiring repair?
2. Is there a preventive maintenance (PM) program for any equipment?
3. If so, which equipment?
4. If so, are PM materials available?
5. Is there a written record of repair work orders? If so, how is it used?
6. Are the causes of failure recorded, if known?
7. Are there any records of work directly affixed to equipment (ex: 'last inspected by Mahmoud on Oct 8 2013')? If so, are they useful to equipment users?
8. Is the health facility a referral centre for equipment? Where from?
9. Does it refer? If yes, where to?
10. General thoughts on the referral service?

Equipment management

1. How does overall equipment planning happen at the hospital?
2. Is there a medical equipment management committee?
3. What is the process for selection of equipment?
4. Does the hospital have a list of equipment needs?
5. Do individual heads of areas have one?
6. If so does the list feed into planning?
7. Is there an inventory of medical equipment or several different ones?
8. If yes, who updates it, how often and for what purpose? Does it feed into planning?
9. Is there a more general inventory of the hospital's assets?
10. If yes, who updates it, how often and for what purpose?
11. Does it feed into planning?

Equipment budgeting

1. Is there a budget to buy new equipment?
2. If so, is it fixed or ad hoc?

3. If it's fixed, how much is it each year? Approx. % of hospital's budget?
4. Is there a budget for maintenance?
5. If yes, how it is allocated?
6. Are there budgets to operate equipment (i.e. for consumables)?
7. If yes, who holds them?

Special areas

Medical imaging

1. What medical imaging equipment?
2. What type of x-ray (if any)?
3. What type of ultrasound (if any)?

Laboratory

1. What type of chemistry and haematology analysers (if any)?
2. What types of CD4 counters (if any)?
3. Automated or manual microbiology?
4. Where and how are reagents sourced?
5. Are controls available?
6. What is supply chain like?
7. Any standardisation?
8. What training was offered during install? Anything ongoing?

Senior nursing

1. What equipment is on the wards?
2. Is there any oxygen equipment?
3. When something is wrong, who do nursing staff contact?
4. What are the biggest challenges? (top 5)

Labour and delivery and neonatal care

1. Incubators and resuscitaires?
2. Caesarean section theatre?

Theatre(s)

1. How many, what equipment in place?
2. General aneasthesia or regional/local?
3. Backup generator?
4. Oxygen within the theatre?
5. Electro-cautery?

Stakeholders in the hospital

1. What is the experience of the equipment users?
2. How much interaction do they have with the maintenance staff?
3. What is the experience of senior administrators?
4. Do hospital stakeholders seem to have similar priorities for equipment?

Appendix C: List of interviewees and meeting schedule

Organisation	Name	Position	Email	Phone	Date
SOMLA	Muhyadin Ahmed	Executive director	Somlaorg@gmail.com	634462378	01-Oct-13
SOMLA	Ali Ahmed Ali	Vice chair	Caliqani@hotmail.com	634417120	01-Oct-13
SOMLA	Khadar Ibrahim	Chairperson	Khaderibrah@gmail.com	634138523	01-Oct-13
SOMLA	Omar Ali Hassan	Board member	Omarh431@gmail.com	634420144	01-Oct-13
Human Care Diagnostics	Khadar Hassan Kamil	Sales and marketing	Khadar14@gmail.com	634421473	01-Oct-13
Human Care Diagnostics	Mokhtar Mohammed Hassan	Sales and marketing	Mokhtar-barwaqo@gmail.com	634420536	01-Oct-13
Health Poverty Action	Rohit Odari	Country representative	rohit.odari@healthunlimited.org	634751096	01-Oct-13
Edna Adan University Hospital	Roda Ali Ahmed	President (EAU)	rodaali556@gmail.com	634152510	02-Oct-13
Edna Adan University Hospital	Hosea Cheruiyot	Anaesthetist trainer	hoseacheruiyot@yahoo.ca	634806820	02-Oct-13
Edna Adan University Hospital	Hassan	Dean of Academic and Student Affairs	-	634467168	02-Oct-13
Edna Adan University Hospital	Mubarak Mohamed	Anaesthetist trainee	mubaarigmohamed@yahoo.com	634184263	02-Oct-13
Edna Adan University Hospital	Abdi Hussein	Handyman/electrician	-	-	02-Oct-13
University of Hargeisa	Dr. Abdi H. Gass	President	agass@hargeisauniversity.com; agass08089@yaoo.com	634838394	03-Oct-13
University of Hargeisa	Dr. Derie Ismail Ereg	Vice-president/dean of medical school	deriaereg@hargeisauniversity.com; dr.deriaereg@yahoo.com	634427253	03-Oct-13
University of Hargeisa	Eng. Hassan Jama	Dean of engineering	hjderia@hotmail.com	634466111	03-Oct-13
Hargeisa Group Hospital	Hadan	Assistant to director	-	-	03-Oct-13
Hargeisa Group Hospital	Hassan Mire Guled	X-ray in-charge	-	-	03-Oct-13
Hargeisa Group Hospital	Ahmed Hashi Farrah	Laboratory in-charge	digaale55@hotmail.com; hashif55@gmail.com	634415507 634243130	03-Oct-13
Hargeisa Group Hospital	Mukhtar Sheik Abdi Bashir	Blood bank in-charge	-	634410403	03-Oct-13
Hargeisa Group Hospital	Mohammed Ahmed Hergeye	Lab tech/maintenance lead	trimail66@gmail.com	634461115	03-Oct-13
World Health Organization	Mohamad Jama Ayaanle	Laboratory officer	ayanlem423@gmail.com	634423477	03-Oct-13
Hargeisa Institute of Health Sciences	Ahmed Mohammed Deria	President	ammderia@yahoo.co.uk	634869304634414955	05-Oct-13
Hargeisa Institute of Health Sciences	Duale Ali Dahir	Head of programmes	dadahir@hotmail.com	634032826	05-Oct-13
Human Care Diagnostics	Abdilali Mohamed Fahiye	Service engineer	engfahiye@gmail.com	634455300	05-Oct-13
Hargeisa Group Hospital	Fadumo Adbi Kahin	Matron	fadumokahin@gmail.com	634241128	05-Oct-13
Hargeisa Group Hospital	Leila Mohamed Abdi	ICU in-charge	leila_120@hotmail.com	634462143	05-Oct-13
Hargeisa Group Hospital	Ahmed Husain Jama	Theatre in-charge	axmed_30@hotmail.com	634403409	05-Oct-13
Hargeisa Group Hospital	Qureshi Mohd Imran	Dialysis technician (in-charge)	lucky.taaki@gmail.com	634815928	05-Oct-13
Hargeisa Group Hospital	Hadan Muhamoud Osman	Delivery in-charge (midwife)	hbiibaa80@hotmail.com	634113996	05-Oct-13
Boroma Group Hospital	Dr. Ismail H. Mohamed Aye	Director	drayeh1@gmail.com	634456233	07-Oct-13

Boroma Group Hospital	Mohamed Al Mohamed	X-ray technician (in-charge)	-	-	07-Oct-13
Boroma Group Hospital	Abulrahman Mohamed	Theatre in-charge	-	-	07-Oct-13
Boroma Group Hospital	Dr. Mustaphe Adraala	Labour and delivery in-charge	-	-	07-Oct-13
Boroma Group Hospital	Abdi Nasser (Abdaleali Ahmed)	Technician	-	-	07-Oct-13
Alhayatt Hospital	Dr. Nimo Abubakar	Director	nimoabubakar@gmail.com	634452269	07-Oct-13
Alhayatt Hospital	Hilal Bouh	Administrator	h.bouh@hotmail.de	634525988	07-Oct-13
Alhayatt Hospital	Dr. Tim Fader	Family medicine physician and lecturer	-	-	07-Oct-13
Alhayatt Hospital	Dr. Ted Sigimoto	Surgeon and lecturer	-	-	07-Oct-13
Amoud University	Richard Dilworth	Physics and engineering lecturer	rtdilworth@somdev.org	-	07-Oct-13
Amoud University	Fadma Abubakar	Dean of nursing	fadmaomer@hotmail.com	-	08-Oct-13
Amoud University	Mohamed Ahmed Aare	Dean of public health	kaydaare@gmail.com	-	08-Oct-13
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Appendix D: Additional documentation consulted

The following documents were consulted during the assessment and preparation of this report:

1. HPA report 'Report On The Rapid Facility Assessment Survey Conducted In The Sahil Region' (2011)

2. Various reports by Mr. Zakaria Awadhan (BMET trainer for HPA project):
   - Assessment And Repair Of Medical Equipment At Hargeisa General Hospital
   - Basic Tools 14.3.2013
   - Berbera Final - Needs Assessment
   - HME Report 2.6.2013
   - HME Report 17.12.2012
   - MEM Report 25.5.2013
   - MEM Report 30.12.2012
   - Report On The Medical Equipment Maintenance Training Program

3. IOM report 'Health expertise from the Somali diaspora in Finland' (2009), available: http://publications.iom.int/bookstore/index.php?main_page=product_info&products_id=586

4. Australian Doctors for Africa (ADFA) report 'Somaliland report 2012' (2012), available: http://ausdocafrica.org/doc/Somaliland_Report_2012.pdf

Appendix E: Guidance on biomedical engineering skill and staffing levels

The 'How to Manage' Series for Healthcare Technology provides the following definitions for biomedical engineering skill levels:

Craftsperson: skilled person who works with their hands; a craftsperson is someone with craft skills such as a plumber, carpenter or electrician. The category encompasses both those with informal training (such as handymen) and also trade-test holders at various levels (known as 'artisans' or 'assistants').

Technician: someone skilled in a craft such as mechanics, refrigeration, electricity with academic knowledge of how to put the science of their skills into practice. This category ranges from those with a craft certificate at various levels from a vocational training college, to those with a basic-level technical diploma from a technical college.

Technologist: someone highly-skilled in a craft such as refrigeration, electronics, electricity, with considerable academic knowledge of how to put the science of their skills into practice; someone with a technical diploma at various levels from a technical college.

Engineer: someone qualified in a branch of engineering such as electrical, mechanical, or electronics, with advanced academic knowledge of controlling, designing, and building equipment, and using their skills to develop original ideas. This ranges from someone with a higher national diploma from a technical college to someone with a bachelor degree in engineering.

The following tables (copied directly from the guide) provide recommendations on staffing numbers of these different skills levels in a typical low-resource health system:

BOX 28: GTZ and WHO's Suggestions for Minimum Staff Requirements at Different Levels of the HTM Service

Location	Label	Level of training	Number of staff
Ministry	Chief Engineer / Manager	Masters (MSc)	1, as head of the HTM Service
	Engineer	Degree (BSc) or Higher National Diploma (HND)	2 – 4
Regional level	Engineer	BSc or HND holder	1, as head of the HTM Team
	Technologist	Diploma holder	2 per every 100 beds in the regional hospital (from a mix of disciplines)
	Technician, artisan, handyman	Certificate holder, trade test holder, informal training	3 per every 100 beds in the regional hospital (from a mix of disciplines)
District level	Technologist	Diploma holder	1, as head of the HTM Team
	Technician (polyvalent)	Certificate holder	2 per every 100 beds at the district hospital
	Artisan, handyman	Trade test holder, informal training	3 per every 100 beds at the district hospital (from a mix of disciplines)
Health centre	General health staff	Informal training	Several appointed as maintenance officers

BOX 29: Suggestions for Staff Development Needs According to Hospital Size from a FAKT International Seminar

Label	Level of training	Number of staff per hospital type				
		1000 plus beds	500 plus beds	200 – 300 beds	100 plus beds	30 plus beds
Engineer	BSc or HND holder	2 minimum	2	1	0	0
Technologist	Diploma holder	10	5 – 7	2 – 4	2 minimum	0
Technician	Certificate holder	20	10	4	2 – 4	1 minimum
Artisans:						
electrician	Trade test holder or informal training	6 plus	3 – 6	2 – 3	1 – 2	
plumber		6 plus	3 – 6	2 – 3	1 – 2	
carpenter		5 plus	3 – 5	1 – 3	1	
mason		3 plus	2 – 3	0 – 1	0	
painter		2 plus	1 – 3	0 – 1	2	
car mechanic		3 plus	2 – 3	1 – 2	0	
Support staff	Relevant test certificate or informal training	2	1	1	1	

'How to Manage' Series for Healthcare Technology: Guide 1 – How to Organize a System of Healthcare Technology Management (2005), available: http://www.healthpartners-int.co.uk/our_expertise/how_to_manage_series.html

Appendix F: Resources for training programmes, procurement and donations

Training resources

http://dhtlab.pratt.duke.edu/bmet-training-bta-skills-curriculum

http://www.frankshospitalworkshop.com

http://labspace.open.ac.uk/course/view.php?id=5842

Resources for medical equipment management (including procurement)

The WHO's Medical Device Technical Series provides guidance on:

- Needs assessment
- Procurement
- Donations
- Inventory management
- Maintenance
- Setting up a maintenance management system

Other WHO resources on the main medical devices website include:

- Profiles of innovative new medical technologies designed for use in low-resource settings
- Fact sheets on core medical devices that are important for operations in health facilities
- Profiles of biomedical engineering success stories in Brazil, Peru, Jordan and the Gambia

The 'How To Manage' Series for Healthcare Technology Series provides guidance on setting up and running a medical equipment management system in a low-resource setting:

- How to Organize a System of Healthcare Technology Management
- How to Plan and Budget for Healthcare Technology
- How to Procure and Commission your Healthcare Technology
- How to Operate your Healthcare Technology Effectively and Safely
- How to Organize the Maintenance of your Healthcare Technology
- How to Manage the Finances of your Healthcare Technology Management Team

Donation resources

THET's 'Making It Work: A toolkit for medical equipment donations to low-resource settings', available: http://www.thet.org/health-partnership-scheme/resources/publications/making-it-work-a-toolkit-for-medical-equipment-donations-to-low-resource-settings

WHO's Medical Device Donations Guidance, available:
http://whqlibdoc.who.int/publications/2011/9789241501408_eng.pdf

CHA's Medical Surplus Recovery Resources, available:
http://www.chausa.org/internationaloutreach/medical-surplus-recovery

HUMATEM's Resource Library, soon to be translated into english and available here:
http://www.humatem.org