LIST OF APPENDICES

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Appendix I

Scoping Research: Interview Questions:

**Donation Organizations**

1. What are the most common types of equipment requested and donated (particularly permanent, reusable equipment)

2. What level of refurbishment do you usually perform on a piece of donated equipment? (cosmetic repairs, part replacement?)

3. Do you ever receive donations which are not in suitable condition to send to partner hospitals but contain components that could still be re-used or recycled?

4. What are common problems faced by local biomedical engineers, and does their training prepare them for this?

5. What are the biggest challenges to helping hospitals gain self sufficiency with new medical equipment, and how do you overcome them? Are there any particular types of equipment that are difficult to hand over?

5. When making assessments of recipient hospitals, is there a minimum set of resources or infrastructure they need in order to receive some types of equipment?

6. Do you provide service support to your recipients?

**For-Profit Medical Equipment Companies**

1. What are the biggest challenges to overcome in training and handover of the device?

2. Have you faced challenges in integrating the machine with the rest of the hospital's devices, infrastructure (for repair/sterilization) or organisational setup?

3. How do you try to improve repair and maintenance of the device? Do customers buy service contracts and if so why/why not?

4. What kind of challenges have you faced (legislative/organizational) in terms of getting the machine accepted by Ministries of Health or NGOs?

5. When making assessments of recipient hospitals, is there a minimum set of resources or infrastructure they need in order to receive some types of equipment?

6. What are common problems faced by local biomedical engineers, and does their training prepare them for this?
Appendix II

Scoping Research: Summarized Interview Results

Interview Participants

Quote references:
IA - International Aid (Jim Loeffler)
GL - Global Links (Angela Garcia)
MD - MDaaS (Oluwasoga Oni)
GH - Gradian Health System (Margaux Bellier)
THET - THET (Derived from report ‘Making It Work’)
NB - Nina Boersema
JGM - Jose Gomez Marquez
BG - Bill Gentles
ALS - Ana Laura Santos

IA - International Aid
US-based equipment provision NGO. They ask a (subsidised) price for their equipment, to give incentive to maintain it, and provide 2 years of remote tech support after purchase. They recalibrate and do small repairs on equipment before it is sent out. Tend to work with individual hospitals or health NGOs

GL - Global Links
US-based equipment donation NGO. They provide equipment for free, and do so to only a small number of countries so they can maintain relationships. They also limit themselves to simple equipment, as they don’t want to be responsible for the hi-tech stuff breaking (which it inevitably will without support). Like to work with Ministry of Health and decide how to meet health targets.

MD - MDaaS
Nigerian startup company, providing refurbished complex surgery-room medical equipment (X-rays, patient monitors, respirators) as a service model including repair, maintenance and installation.

GH - Gradian Health
For-profit company which sells sturdy anaesthesia machines which can work even with no oxygen or power supply if required. Installation, training and continuous support is financed by their non-profit wing.

THET - Tropical Health and Education Trust
Global NGO focused on training health professionals. Published several reports on good practice for medical equipment donation

NB - Nina Boersema
Student graduating with Philips Healthcare in refurbished and remanufacturing of equipment.
ALS - Ana Laura Santos
TU Delft PhD student studying medical equipment use and transfer in humanitarian disaster situations.

Hospital management

Need buy-in from the whole hospital - up to the person setting the budget - to get the equipment running long-term. - IA
Training makes a big difference. You can train the techs but that doesn’t always convince the administration - techs are low status. - IA
Some people we train and work with “get it” - they have a preventative maintenance budget. - IA

Different types of hospitals

“Faith-based hospitals generally have more funds than public hospitals” - GH
“Central hospitals have more funding staff and organization than rural clinics” - GH
“Rural clinics have things like power cuts and consumable shortages, but you don’t need to design those in for a teaching hospital in the city. But bigger hospitals still have power fluctuations, humidity and high temperatures which degrade equipment” - MDaas
Hospitals with the lowest level of funding are the most dependent on donated medical equipment. They are anxious to receive donations, even if a large percentage of them can’t be used. Donations may be their only source of [equipment] - BG

Financial decisions about equipment

Hospitals have an internal economy - sometimes scarce things can be charged a premium for by staff, so they make money - GH
If they are being donated equipment, then it makes better financial sense to wait until it breaks down and get another one for free than to maintain, especially since technician quality is not guaranteed - GH
Donation disrupts maintenance culture - it’s easier to let it break then be given another one. No incentive for maintenance - IA
If machines are subsidized/donated, you don’t get market feedback because people politely accept and don’t voice concerns. - MD
Doctors buy Chinese equipment, it is cheap but the lifespan is quite low - 12-13 months
So doctors consider the cost of buying 1 good refurbished EU/US/Japan-made once and maintaining it versus buying 5-10 chinese machines in the same time-span...but often that works out on the Chinese machine’s favour - MD
Some hospitals not aware of hidden costs of ownership (operating, maintenance, transport, installation, data gathering, staff, training, decomissioning, administration, supply) Est. cost of ownership: 10% of initial cost per year - THET
People need to understand the true cost of equipment - they only see the first “sticker” price and don’t budget for training, maintenance and other supporting costs - GL
Make sure space has actually been allocated for the equipment - sometimes this is a problem. - THET
[The neediest hospitals] typically have an ill-equipped maintenance unit, and so may have limited success in using donated equipment unless they receive substantial support from the donor. Again, this seldom happens. - BG

Relations with patients

There has to be confidence in the community or people won’t come to the hospital. - GL
Some people ask for things like CAT scans, because they are ‘high-status’ items...but these are not the best, most cost effective way to improve overall health outcomes - GL
Some very complex equipment is requested by hospitals for status reasons. Hospitals are competing for customers, so they want to be able to say “we have a C-arm” or “we are the only hospital with an MRI”. - IA
A lot of people ask for CT/MRI or other fancy equipment when they’re not even close to being able to maintain it - they’re competing for patients. - IA

Maintenance (preventative)

Lack of a preventative maintenance culture: “In many African languages, there isn’t even a word for it…” - GH
Lack of maintenance culture: when it breaks down, that’s when you call for a technician. Then the technician comes (it takes him a long time), and sometimes they make it worse! It’s hard to get trained as a technician, the materials are not available. No formal training so most are apprentices. About 10% are pretty good. The other 90% are awful - MD
In many countries, E.g. in Benin, there is no contract service. Sometimes when a technician shows up he does not have the right tools, or has never seen the machine before. - GH
Breaking isn’t a problem, lack of preventative maintenance is a problem. Some equipment will last for 20 years if you maintain it, a few months if you don’t (e.g. oxygen concentrators: lifetime is 15 years if filters are changed, 4 months if not changed) - IA
For certain projects, e.g. dialysis, there definitely needs to be a tech doing maintenance. Others e.g. dopplers, the user (OBGYN or midwife) already know how to use it/hopefully also maintain it... - GL
Training of biomedical engineers is difficult: often they have little experience because they have no machines to train on. - GH
[For our work] On-site training of physicians also difficult - low volumes of patients mean sometimes there is no patient to train on when we come to deliver and install the equipment - GH
Doctors don’t know when a machine is broken, or close to breaking - GH
HR is very important - need skilled biomedical techs - GL
Has to be good waste management, biohazard management - GL
They need to have access to consumables (batteries, paper), a maintenance department - IA
In our first pilot (of leasing machines) consumers expected us to provide them with consumables also - MD
Ideal situation: supplier should install and test equipment in from of a local tech - THET
Make sure they have access to testing and diagnosis equipment - THET
Biggest challenges to hospital self-sufficiency with equipment are Training for users, training and tools for maintenance staff (or biomedical staff) - BG
[Biomedical engineers in Ghana] are quite well educated, but may lack specific training on specialized devices. Many donated devices will not be common in Ghana, so they will be unfamiliar with them, and will need to be trained by the donor. This seldom happens. - BG
[The neediest hospitals] typically have an ill-equipped maintenance unit, and so may have limited success in using donated equipment unless they receive substantial support from the donor. Again, this seldom happens. - **BG**

**European/American Equipt. Manufacturers**

Have high-quality reputation and process to upkeep, so can’t make ‘simpler’ equipment - **ALS**

Companies like Philips include their maintenance and installation staff training as part of their quality assurance. For example when they install in a big private hospital in India, they fly their own staff there as part of the deal. They are very reluctant to use local technicians - **NB**

Sometimes Siemens etc make simpler versions (reduced functionality) for ‘Africa models’ - **ALS**

There are some ‘made for Africa’ machines (Air Liquide) - ‘stripped down’ but nobody bothers to make it appropriate, or actually ask what environment is like - they just make it cheaper. - **GH**

Large part of the products of medical suppliers now is from consumables and services. So even if the equipment is appropriate, it’s not very profitable unless that supply chain can be provided. - **GL**

Doctors in Nigeria face a financing decision-making problem: new machines are pricey, but used machines have no service support - **MD**

New equipment is designed better and more robustly than it was. However, GE, Philips etc cannot see the Nigerian marketplace. Feel like they cannot compete (with chinese prices) When they do, then they will modify. - **MD**

**Asian Equipment Manufacturers**

Cheap chinese machines (some use the CE mark to mean “Chinese Export”!!). These are simpler and cheaper, not as good quality. - **GH**

Indian/Chinese make equipment, basic stuff. Even though it may not be as good as the refurbished. - **IA**

Chinese/Korean equipment is typically cheaper, but once it breaks down, they won’t supply you with spare parts. They are just equipment vendors, not service providers. - **MD**

**Donation Organizations**

We turn away hi-end imaging equipment because we don’t want it to turn into E-waste and have to assume liability (e.g. don’t want to have to pay for decomissioning x-ray). but we do want to guarantee liability...so we only donate and ship simple things - **GL**


There are a handful of organizations in the US which manage donated equipment, and only 3 or 4 of them that do it right - **IA**

Refurbishment level depends on the equipment. For instance, patient monitors, we replace battery, screen if necessary. Repaint. Check latex tubing, pinch valves, to see if they have eroded and need replaced. Recalibrate - **IA**

Some donation organizations send things without the manual - people can’t work it. Or without consumables - **IA**

**3rd-Party Re-sellers/Auction Houses**
In US: If parts of a medical device can be reused, if they still have value, then they will be stripped from the medical device and resold. E.g. vaporizers, components stripped. - GL
As for recyclable materials (e.g.), the market for these is v. low right now, so it’s not worth the money for anyone to reuse them. - GL
If it’s still functional there are some 3rd-party dealers selling as-is: Centurion.com. They buy a lot of used machines and remarket. http://www.centurionservice.com/ “Biggest auction house for used medical equipment”. - GL
As for recyclable materials (e.g.), the market for these is v. low right now, so it’s not worth the money for anyone to reuse them. - GL

3rd-party used buyers, LICs
What happens after machines are broken? They gather dust...or sell to people who harvest it for spare parts (scrap... - MD

Policymakers/Ministries of Health (HICs)
Manufacturers or govts. have a regulation change (around a 7 year cycle) which forces updates - making functioning equipment obsolete - IA

Policymakers/Ministry of Health (LICs)

- MoH tender bids written by people not involved, or without expertise, or corrupt, so end up referring to specific brand of equipment (deliberately or undeliberately) or excluding parts of the market. - GH
- MoH will already have public health agenda targeting different areas - GL
- [Our NGO] Works with people higher up the health system to decide what are the larger goals/health outcomes they want to achieve. - GL
- Depending on country, procurement is sometimes a random hospital-by-hospital process, other times done centrally on 1 year tender bids from MoH. - THET
- Some govts, e.g. Zambia, do not allow part procurement outside the country - THET
- Some govts ban refurbished equipment (even though it might be better than cheap Chinese new...) - THET
- Often procurement happens without prior diagnosis of what is needed.- THET

NGOs/Sponsors
Global health NGOs: surgery not a top priority compared to other diseases (malaria, etc) - GH
Global orgs do not support it - WHO only has one member of staff responsible for medical devices - JGM
NGOs also have devices as a low priority - the Gates Foundation funds them, but only 100,000 per device, which is not enough for the R&D required - JGM

PROBLEMS

Technical, product based

Need consumable parts (e.g. doppler needs gel, x-ray machine needs readouts, printouts) - GL
More electronics = more sensitivity to power fluctuations - GL
Greater complexity = less likely to survive - GL
Main things which are requested (e.g. anaesthesia machine, vital signs monitor, x-ray) are also the things that are least likely to survive - GL
Electrocautery units v. high priority - they have very high breakdown rates - IA
Imaging equipment - getting away from large units which roll around. They don't ship well - IA PCBs vibrate loose during shipping - IA
The power supply - hi-tech, sensitive to fluctuation. - IA
Instead, smaller, portable unit. Travel well, portable, more robust. Digital power. These are more expensive, newer tech. - IA
Oxygen concentrator: Takes oxygen out of air, supplies it to patient. Very susceptible to clogging of filters, especially floor not cleaned. If you don't clean them monthly, will die within months. But they can last years. - IA
Electrocautery units break all the time: Power surges generate excess heat in components, start to wear down. - IA
X-ray: not shipping the kind of big x-ray system you see in a doctor’s office. Instead kind used for home-healthcare: 90-95% of the functionality. - IA
Types of equipment that last: surgical lights, OR table, pulse oximeters, suction pumps, beds - IA
We recommend that users use a battery backup (UPS “Uninterruptible Power Supply”). But they don’t do it. Why? Don’t know how, or don’t have money - IA
Factors which are important for a ‘Nigerian’ machine: High tolerance for power variations (ask what biomeds say about device) and Resistance to humidity - MD
Design of biomedical equipment takes its cue off the airline industry - there is a lot of ‘design lock’ which makes it difficult to respond to needs of particular user or environment - JGM
Medical equipment manufacturers make “made for Africa” machines, but the profit margin is small so this is the first thing to be cut. - JGM
Medical equipment has a very slow development cycle, no difference with equipment design for developing world. Gene Expert technology; if you trace all the papers back through it, the core science was published in 1998. Then patent was granted several years later, technology commercialized only recently - JGM
Ghana gets much hotter than Canada, so overheating will be a problem for some equipment. - BG
Power blackouts and brownouts and surges are a frequent occurrence that put a strain on power supplies in the devices, as well as on the sensitive electronics. - BG
Ghana operates on 220 - 240 volts whereas Canada is 110volts 60 Hz. Canadian or US equipment must be adapted to the higher voltage. On newer devices, this may simply be changing a switch or jumper, but older devices will often require a stepdown transformer. If the device consumes a lot of power, e.g. an X-ray machine, a stepdown transformer would need to be very large. - BG
Failures will occur if the recipient doesn't realize that the stepdown transformer is required. They connect the device to 220v mains power and it immediately goes up in smoke. - BG
Some equipment manufacturers make ‘for Africa’ devices with reduced functionality. But these can never really be “appropriate” in price because they don’t want to compromise the quality of their production line - AL

High priority equipment:
- Electrocautery units - very high priority, break very easily, even in US. Way technology is.
- Incubator
- Defibrillator
- Surgical units, lights - good, long lasting
- Endoscopy
• Ultrasound - IA
X-ray: come with either batteries or capacitors. Batteries you can move it around, but after a few months the batteries get worn out, have to buy new one. Also much heavier. So go with capacitors. - MD
Sometimes machine is great, really robust, but it costs too much. - MD

Global-system based
People are willing to pay a sticker price for machines, but not for training, maintenance and services around it - GH
“I’ve seen a lot of student design competitions…” for appropriate-technology designed machines but not a lot of these get to market - GL
There are a lot of hackathons and short projects, but not the continued research funding. No-one would replace federal funding on Alzheimer’s research with a hackathon - JGM
Can’t manufacture in Africa as quality would not be good enough, and inter-Africa shipping is more expensive than Europe-Africa - GH
2nd-hand European or American equipment: better, won’t break down as easily. BUT the spare parts are in Europe, so it’s difficult to restock, and can’t get anyone in to fix anything if it goes wrong. - MD
Factors affecting equipment degradation: power fluctuations, humidity, dust - MD
No reportage on machine failure, no statistics on how bad product design or product failure (machine downtime) affects health outcomes. Reported as infrastructural issues, whether it’s that they were missing a 9V battery or the hospital went on fire. - JGM
Global organizations need to be on board with medical devices designed for the developing world. Much easier to get a grant for a piece of equipment which is “recommended by the WHO” - JGM
Appendix III

Site Notes: Shadowing Benelux Field Service Engineer

User Observation Field Service Engineer

Main Takeaways:
- Replacement parts: sometimes suppliers make small updates which don’t quite fit with machine
- Laptop needed in order to log in and check the system for error logs
- Documentation which is not required is not used
- Repair timing secondary to needs of hospital - cannot use room if room is needed

Sequence Model

(pre-callout): Trigger, scheduled in calendar by RSE
Someone had noticed the battery leaking “I think somebody here noticed it”
Arrive at hospital
Went to see department manager, said they had been scheduled.
Department manager arranges a room he can work in, arranges for X-ray machine to be transported in.
Takes out toolcase.
 Notices radiologist has forgotten to bring in monitor, asks for it
Porter brings in new battery
Porter asks for documentation to send old battery back today
FSE unscrews panels from side of X-ray
Looks at battery - confirms acid is leaking
Looks on top of battery - confirms date (2010), needs to be changed
Unpacks new battery
Unscrews and swings out control panel
Removes battery wire connections from control panel
Removes battery wire connections to computer (one slightly hidden, takes more time + screwdriver angle extension)
Picks up battery, puts directly into cardboard box
Lifts in new battery
Lifts up washers with screwdriver to put under battery

Radiologist comes in - they need this room. Need to wheel the machines out temporarily.

Comes back in, wheels machines back in.

Notices wire connection on new battery pack has plug, not screw connection - strips wires to fit in screw connection.

Puts wires back into place.
Zip ties wires to lie along straight bundle.
Swings control panel in and out to see how wires lie
Zip ties again

Starts to screw control panel back in, notices holes don’t line up properly.
Checks to see - notices bracket is slightly bent
Removes bracket, straightens with pliers
Screws bracket back
Screws control panel back in.

Trigger: work completed, now needs to test.
Plugs power in and switches the machine on
Checks for battery light - not on
Realises has forgotten to connect battery wires to power pack - connects

Trigger: notices key missing
Goes to ask radiologist for machine key

Moves C-Arm so that the x-ray plate end is facing upwards
Places “test box of stuff” including image phantom on C-arm
Retrieves key, puts it in to access machine
Logs in to machine
Moves behind screen, pushes button to start a test x-ray
Checks picture
Checks Amperage reached by the X-ray machine (X-ray machine automatically goes to this amperage)
Takes out copper test plates (to check how high a current the machine can pull)
Places on x-ray plate
Takes another X-ray
Checks Amperage reached by X-ray

Takes USB cable, plugs laptop into X-ray testing port

Starts “BV Scope” software on laptop
Accesses log file, checks for errors
Trigger: notices two errors related to battery voltage
Decision: this must be to do with the battery, no additional problems

Goes into “Additional power source”
Notes in system that new battery has been added

Exits system

Attaches side panels back onto machine
Throws away form given by battery manufacturer (“No-one uses it...it’s stored in the system anyway”)

Trigger: Radiologist comes in and says room needed for emergency test again

Decision: Can’t do preventative maintenance today, needs to come in and do it tomorrow.

Packs up equipment.

Goes to head of radiology department, says he needs to go in tomorrow.
Notes, Technical:

- Several different types of screw used - need different screwdrivers, wrenches etc
- Swing-out panel not designed well for continued moving in and out
- Battery - sometimes newer versions had small differences (E.g. the end of the wires). Tells story - apparently they changed the size of the battery, and one machine doesn’t fit it anymore - have to put a whole new attachment on when the battery is changed.
- Since batteries are hazardous waste, Philips takes responsibility for shipping the old one back
- Reason for battery - huge power spike if using a particularly large patient...

Notes, User

- “Sometimes it's very stressful...you go there, you’re in for preventative maintenance and they call you in because something has broken in the OR and there’s a patient on the table.”
- “You have to deal with the customer. It's different in different parts of the Netherlands - in the south everything is a bit more rushed, and they're putting more pressure on you.”
- “You get to know all the local mechanics. Some of them have engineers on Philips level, who have been trained by Philips...at others then you trust them to change a fuse, that’s it.”
- “Twenty years ago I was out fixing everything with this toolkit. Now if my laptop crashes I don’t even bother leaving the house.”

Images from Observation study:

Trial scan on “phantom” (box of tools)
Leaking battery

Rewiring
Appendix IV

Field Research Benelux Remote Service Engineer

Context: RSE Benelux.

High-level Sequence model:

1. Gets call through CCC (Customer Call Centre) - based off who is free. Could get colleague-completely different person!
2. Sees who the customer is (note: how? And how are calls prioritized?)
3. Makes evaluation (“I know all the customers personally, what their competence is”)
4. Talks through problem with customer - tries to figure out the problem.
   a. [Possible - looking at log file to see about faults]
5. [Possible] Passes it onto other RSE with different expertise
6. Checks customer service contract to see whether he can provide a part or send out a service engineer (“sometimes this is difficult...there are so many contracts”)
7. Discusses options with customer if no service contract available
8. Checks part availability (and price, if PO necessary)
9. Checks FSE availability in Gantt chart
10. Enters decision into OneEMS
11. Creates a service work order in
12. Puts that in Gantt chart, FSE gets text message saying that he has been rescheduled (“but he can’t check on OneEMS what the problem is if he’s driving in a car!!)
13. RSE makes call to FSE to tell him what the situation is
   (Note: sometimes this doesn’t happen!! Then the FSE gets there and they are asking the same questions...it’s only repetition for the customer!!)
14. FSE drives out to situation
15. [Possible] FSE calls RSE for support
16. At *last resort* call the factory engineers

Example 1:

Got a call from a customer who is experiencing problems. RSE knows that the technician is competent, so he asks him to open up the machine and take a look inside at the batter. Asks him - look at the battery date, is there green crystallization on the contacts? Sees the battery is from 2010. The RSE says they should order a new battery. He knows this hospital is competent, so he goes into the parts-ordering system, checks if the battery is available, orders it, and tells the customer when it will arrive. [note: high priority customers get high priority orders]. He says that if they call him when it arrives, he can guide them through installation. He doesn’t hear from them so calls to check up, and they say “we already installed it”.


Example 2:
Gets a call from a customer who says that part of the machine is not working. He guides him through some troubleshooting questions, asks some questions. Knows that something needs to be opened up, but clear the technician doesn’t know the machine very well.

Systems not individual components. This is partly due to the design of new things, but also due to the fact that it’s very difficult to take individual components out of the circuit boards.

User Notes:
High power distances, cannot joke/contact (Different in Nederland than in Belgium)
Gets to know competence of each customer/client (has around 100 he services)
“Customers who are priviledged to call us directly…” Department head, technician.
Sometimes difficulties in communicating...when the room gets very busy and noisy and you are speaking very softly.

Technical Notes:
For preventative maintenance there is a checklist system, but made own docs because it’s more closely related to what the service engineers see, expertise (“somebody somewhere made it…”). Shares it personally with whoever needs
FSE sometimes doesn’t get short note explaining previous context

Detailed Sequence Models

Observed Case 1:
Customer called yesterday, strange artifacts
Spoke to on the phone, asked him to start up RSN but the radiography tech did not know how to start it up (engineer was out).
So asked him to download log file and send it to him on WeTransfer [note: log files big, sometimes information is deleted from the back end if left too late...]
Looked through log file to see if there were any errors...didn’t seem to see any.
Spoke to his colleague (using messenger) who knows more about this
Forwarded log file to him

Observed Case 2:
Background: Customer called earlier - imaging problem (wavy lines on the screen)
Recieved phone call: Andre. Notes down the system number on book (NRZ65). (‘Message’ also appears on screen’)
Asks about problem.
Asks what has been done previously.
Andre doesn’t know: he knows his colleague Hans has done something on the same system but doesn’t know what.
RSE asks if client can wiggle the cable.
Customer (on the phone) wiggles the cable
Customer (while on the phone) takes back off computer - wiggly lines disappear
RSE tells him to put on static strap and take out video card, clean the contacts and see what happens.
Customer says yes and will call back.
Goes into OneEMS and puts in System number - shows is renier de graaf. Also shows it’s maybe already in progress??
RSE opens new case
Logs as ‘corrective maintenance’, ‘remote service’
Logs labour time (0.5 hrs, always)
After case created, edits case activity
“Problem description” -> text field
“Troubleshooting action” -> enters in text field.
Replicates information in physical book

30 minutes later, Andre calls back again, hasn’t worked
RSE takes decision to send FSE out
Looks at FSE Gantt chart, sees that colleague is already at Renier de Graaf on monday
Closes actions
Is asked “was patient there?” “should alarm have gone off”

Enters:
“Customer Symptom Code” -> from drop-down list (“I just choose which one is the closest”)
“Engineer Failure Code” -> from drop-down list
“Repair Activity Code” - > from drop-down list
Appendix V

Field Research Egypt/South Africa: Radiology Clinics

The following text was used during interviews with radiographers in South Africa and Egypt. The text is in two parts – the first a short survey in order to benchmark them against other clinics in Africa. Secondly there is an interview regarding repair and maintenance. This interview was used as a guide for the conversation, with interviews diving further into different areas depending on the user’s response.

Logistical Questions:

- How many radiographers do you have?
- In-house technicians or IT/network people that help?
- How many need access?
- Access to tablets or smartphones in clinic?
- English reading skills (of potential operators)
- Previous data on machine downtime
- Operating hours of the clinic
- Approximate number of scans per day/week?

Machine Repair Servicing: General

- Approx. how many times in the last year have you had machine downtime due to an error/breakage? (ERROR FREQUENCY LAST YEAR)
- What was the last time there was a machine failure, and what happened? LAST MACHINE FAILURE
- What is your standard course of action when a machine failure occurs? STD COURSE OF ACTION
- How long does it usually take for a machine to be fixed once an error occurs? What are the longest parts of the process? HOW LONG WHAT PARTS OF PROCESS
- Is it always possible to quickly report an error and request machine repair? ERROR REPORTING
- **General**: What is your experience with repair & maintenance service? Common problems? Things you most wish could be improved? **GENERAL EXPERIENCE**

**Remote Assistance:**
- How often have you fixed or tried to fix a problem with remote assistance (with the phone assistance of a Company service engineer)? – **REMOTE ASSISTANCE**

- What was the last time you fixed or investigated a problem with remote assistance, and what happened? - **LAST TIME**

- When calling customer service, is it always possible to explain to the engineer what the problem is? - **EXPLANATION**

- If they ask you to perform a task, is it always possible to understand the instructions? - **INSTRUCTIONS**

**Types of Failure/Self Repair**
- What is the most common error or failure you experience? **COMMON ERROR**

- How many times in the past have you experienced the following errors? (How frequently – month, year, etc)

  - Unclear image
  - Unknown objects (artifacts) in the image?
  - Failed exposure
  - System not indicating ready for exposure
  - X-Ray Tube error
  - Room power failure
  - Calibration
  - Workstation not turning on
  - Software error/crash
  - Log-in issues
  - Connection cable failure
Network connection error (RIS/DICOM procedure failed)
Connection issue wireless detector (if applicable)
Mechanical movement errors
Fan errors
Others _____

- How do you deal with each of the above errors? Are there any which can be fixed without the assistance of a service engineer? If so, can you explain how they are fixed? **HOW DO YOU DEAL WITH ERRORS**

- If you had no access to a service engineer, how confident would you be of solving the above problems yourself? **SCALE OF 1 to 3**

  0 – Would not know where to begin
  1 – Have some idea of what steps I could try, but not sure
  2 – Know the steps I should carry out, but wouldn’t want to do them myself
  3 – Know the steps I should carry out, and would be confident trying them myself

- Are there any other people that you have used or would use as a resource to fix small equipment errors (E.g. electrician)/hospital technician – **OUTSIDE SUPPORT FOR ERRORS**

- What do you think are the most common causes of machine errors? Are there things you can do to make the machine less likely to break? – **YOUR OPINION ON ERRORS? MITIGATION**

- Are there any small repair or maintenance tasks that you already perform in-house (E.g. cleaning the machine)? – **IN HOUSE**
Appendix VI

Field Research Egypt/South Africa: Ultrasound Clinics

The following text was used during interviews with doctors operating ultrasound machines in South Africa and Egypt. The text is in two parts – the first a short survey in order to benchmark them against other clinics in Africa. Secondly there is an interview regarding repair and maintenance. This interview was used as a guide for the conversation, with interviews diving further into different areas depending on the user’s response.

General Questions

- Operating hours of the clinic
- Approx. number of patients daily, approx. number of scans daily
- Number of ultrasound machines
  - Number of operators
  - Have tablets/smartphones with browser access?
  - Moved around a lot
  - Connected to hospital network (PAC server)
  - IT/network support/In-house technicians?
- Do you currently have a service contract for any of their equipment, if so which ones and what providers?
  - (if yes) How satisfied are they with this service?

Machine Failure & Downtime

- Approx. how many times in the last year have you had machine downtime due to an error/breakage?
- What was your last service request about?
  - How was it solved?
  - How much did it cost?
• What is your most common service request?
  □ Poor image quality/artifacts
  □ Transducer failure
  □ Power module failure or error
  □ External power failure/error
  □ Software crash/refuse to start
  □ Broken fan
  □ Broken connector

• Do you have historical records for machine downtime (that are possible to share)?

• What is the current internal procedure for dealing with a machine error?

• Are there any issues with the machine you could tackle on your own?

• How is repair & maintenance currently budgeted for?

• Does the clinic undertake any preventative maintenance activities or minor repairs in-house already?

Service Provision

• General: What is your experience with repair & maintenance service? Common problems? Things you most wish could be improved?

Specific questions:
• Ease of access: Is it always possible to quickly report an error and request machine repair?

• Wait times: How long does it usually take for a machine to be fixed once an error occurs? What are the longest parts of the process?

• Remote access: How often are issues fixed remotely (in conversation with a Philips remote service engineer)? Are there any issues with phoning the helpdesk?

• Repair quality: Are they satisfied with the quality of repairs?
Appendix VII

Baseline Data for Hospitals

Hospital 1

Modalities: DXR/CT/MRI

Type: Private hospital  
Location: Johannesburg  
Patient volume: 5-10/day  
Radiology Staff: 8

Technical support: No biomedical engineer, IT & Facilities support

Self-help capabilities:
- Basic troubleshooting: [restarting machine, adjusting grid]
- Perform calibrations
- Not confident following remote instructions

Service history/requirements:
- Have service contract
- CT/MRI machines have service issues with time-to-diagnosis, part replacement & recurring errors
- Uptime critical for CT/MRI, not for DXR equipment (low volume, scheduled appointments)

Site technical analysis:
- Connected to peripherals on hospital network
- Good 3G signal measured in room

Hospital 2

Modalities: MRI

Type: Public hospital  
Location: Pretoria  
Patient volume: 10-15 patients per day  
Radiology Staff: 10 radiographers  
Technical support: No biomedical engineer, IT & Facilities support

Self-help capabilities:
- Restart the machine
- Capable of fixing problems due to incorrect presets
- Comfortable following remote orders to check lights, open up machinery etc.

Service history/requirements:
- Have service contract
- Have a good relationship with company service engineers but would like more frequent preventative maintenance

Site technical analysis:
- Connected to peripherals on hospital network
- Bad 3G signal
Hospital 3

Modalities: DXR

Type: Radiographic Centre
Location: Central Cairo
Patient volume: 60/day, 1-3 scans per patient
Radiology Staff: 10
Operating hours: 9am-9pm
Technical support: No biomedical engineer, IT & Facilities support
Self-help capabilities:
- Basic troubleshooting: (restarting machine, adjusting grid)
- Do not perform calibrations
- Confident following remote instructions
Machine history:
- Purchased 2012
- Frequent failures (1-2/month) mostly related to image quality & software crashes
Service historyrequirements:
- Have service contract
- Uptime & fast fix critical, because of high volume and knock-on clinical effect (delayed scan can delay surgeries).

Site technical analysis:
- Connected to peripherals on hospital network
- 3G signal patchy (room blocked for radiation). Space identified to place 3G aerial outside & wifi router inside

Hospital 4

Modalities: DXR, CT

Type: Private hospital
Location: Cairo
Patient volume
Radiology Staff: 8
Technical support: No biomedical engineer, IT & Facilities support
Self-help capabilities:
- Basic troubleshooting: (restarting machine, adjusting grid)
- Perform calibrations
- Not confident following remote instructions
Machine history:
- Purchased 2012
- Frequent failures (1-2/month) mostly related to image quality & software crashes
Service historyrequirements:
- Have service contract
- Uptime & fast fix critical, because of high volume and knock-on clinical effect (delayed scan can delay surgeries)

Site technical analysis:
- Connected to peripherals on hospital network
- Good 3G signal measured in room
Hospital 5
Modalities: DXR/CT/MRI

**Type:** Private hospital  
**Location:** Cairo  
**Patient volume:** 20-30 per day  
**Radiology Staff:** 11  
**Technical support:** One biomedical engineer for hospital, IT & Facilities support  
**Self-help capabilities:**  
- Daily maintenance checklist, cleaning  
- Basic troubleshooting tasks  
- Calibration  
**Machine history:**  
- DXR purchased August 2015, used at capacity since March 2016  
- Repeated transformer problems, failed exposures  
**Service history/requirements:**  
- Have service contract  
- Fix time not critical for DXR, as they have other machines they can use. CT extremely critical as only one and used for ICU  

Site technical analysis:  
- Connected to peripherals on hospital network  
- Good 3G signal measured in room

Hospital 6
**Modality:** Ultrasound

**Type:** Private OBGYN clinic  
**Location:** Johannesburg  
**Patient volume:** ~10 per day  
**Operators:** 1 [Doctor]  
**Technical support:** No biomedical engineer, IT & Facilities support  
**Self-help capabilities:**  
- Work around basic errors  
- Referring to manual  
- Basic cleaning & upkeep  
**Machine history:**  
- Purchased ~January 2015  
- Only errors: required software error and file saving error, user is working around  
**Service history:**  
- Has service contract, has not used service with Philips.

Site technical analysis:  
- No connection to clinic network  
- Good 3G signal measured in room  
- Machine mainly stationary, moved ~1/month to ICU
Appendix VIII
Interview Results & Transcript, Hospital 1

Summary: Repair Questions

- What is the most common error or failure you experience?
  Detector plate not connecting

- How many times in the past have you experienced the following errors? (How frequently – month, year, etc)
  - Unclear image – 1 per 2 weeks
  - Unknown objects (artifacts) in the image? <1 per month
  - Failed exposure – 1-2 per week
  - System not indicating ready for exposure 1-2 per week (related to detector error)
  - X-Ray Tube error – <1 per year
  - Room power failure - Never
  - Calibration - Never
  - Workstation not turning on - Never
  - Software error/crash - Never
  - Log-in issues - Never
  - Network connection error (RIS/DICOM procedure failed) – 1 per month
  - Connection issue wireless detector (if applicable) 1-2 x every week
  - Mechanical movement errors Never
  - Fan errors Never
  - Others _____
  - Temperature: 1-2 times per year

- If you had no access to a service engineer, how confident would you be of solving the above problems yourself? SCALE OF 1 to 3

  0 – Would not know where to begin
  1 – Have some idea of what steps I could try, but not sure
  2 – Know the steps I should carry out, but wouldn’t want to do them myself
  3 – Know the steps I should carry out, and would be confident trying them myself

  - Unclear image – 2
  - Unknown objects (artifacts) in the image? 2
  - Failed exposure – 2
  - System not indicating ready for exposure 2
  - X-Ray Tube error - 0
  - Room power failure – N/a  (Building facilities issue, would call them)
  - Calibration - 3
  - Workstation not turning on - 0 (Never experienced)
  - Software error/crash – 0 (Never experienced)
  - Log-in issues - 0 (Never experienced)
  - Network connection error (RIS/DICOM procedure failed) – 1
  - Connection issue wireless detector (if applicable) - 2
  - Mechanical movement errors 0 (Never experienced)
Transcription interview radiographers

Is there any time you can think of where this would have helped?

Our Philips is still new, we are still fine. Maybe with the other machines in the department, but the Philips is still fine.

Even with the other machines in the department, are there times where this could have helped?

So many times! Especially out bucky room. Sometimes were busy and then it Stops working, don’t know what to do. They call the guys out. So maybe if we had this we could have went in, logged in connected, try solve the issue right then and there get a technician quick if they can’t help us online but I think this is going to be helpful.

I was just asking, were there any times you can remember where this would have helped?

As she mentioned, yeah it would. But so far for the machine, for the dura diagrost we are still sharp. It hasn’t given us any problems, it is doing well.

But other machines there have been problems

Yeah there have been problems and we have to call them out...they try over the phone to sort it out but it doesn’t work. But I think with this system it is much better, it will be easier.

Why doesn’t it usually work over the phone?

Over the phone it’s not on the machine side. And whatever information you give them it’s like maybe you forgot something, then it’s ok let me just go double check, or write it down, then you have to go up and down.

So a lot of back and forth.

Are there any problems you think could happen with Teleservicing?

Does it use – network wise – if there’s no coverage, will the message still go through?

For instance for the log file uploads and the messages it waits and then as soon as there’s network coverage again it goes through.

I think that’s the only disadvantage – to say that if there is no network then the message won’t go through. And as much as you might not know when the network will next be available...then it [the maintenance] just gets stuck there. But is there an alternative of phoning maybe?

Yeah could do

In case the network is not available.

So I suppose for the phone option it could go straight through gsm or something.

So going back to the questions about servicing – I know that the Philips machines are still fine. But for the others, how many times in the last year have you had machine errors.
Generally machine errors it’s countless…but servicewise they come every quarter to come and do the service and either upgrade, the CT or whatever.

And then the errors...how many times a month?

Almost every week. To be honest, the problem is not getting solved. It tends to be repeated.

So you think it’s gone and then it comes back?

And as much as they’ll come, they’ll see the problem, they’ll sort it out, but it’s not permanently sorted. I think that’s our frustration?

Could you give me an example of a repeating problem?

You know, whereby you have the erect and the supine bucky – you know, two buckys. It will work on the erect and but not work on the supine, for no reason. Until the technicians come and maybe they’ll upload software, or upgrade software...not really upgrade software, but whatever it is they do, software-wise then table will be fine, both of them will be working then suddenly it will go...like, at present. That’s why it’s a problem. And it’s not being sorted out.

Even though they’ve also been doing stuff on the erect to sort this out. What happened then, did they have to upgrade software again?

Yeah, I think it’s more of an upgrade, I don’t know what they do. I don’t think it’s an upgrade because an upgrade will be done every few months. It’s sort of restarting, or calibrating, if you may say. It’s something that can only be done by them.

When a machine fails so if for instance you’re operating a machine and there’s an error – what do you try and do?

We try and switch it off, before we call them out. Restart reboot switch off everything then switch it on again after a couple of minutes...see...sometimes it works after we’ve switched it off 3 times. Sometimes it doesn’t work like with the supine now, we switch on off and on...and it’s not working. So that’s what we usually do.

How many times does that fix it?

Almost once every week...if not every second week.

Is this only for one machine?

For now.

How many machines do you have in the department?

Five.

So is that weekly errors across five machines?

Not all five. The others are fine. It’s just the one that is more giving us problems compare to the others.

How long does it usually take for a machine to be fixed? I know it varies.

It depends. If they have to order a part it will take days. But if they don’t order a part well...2, 3 hrs it can take them, to sort it out.

And can they usually fix it on the first time?

Some, some. Depending on the problem.

So what’s usually the longest part of the repair process
The parts. The parts is the problem, because then you wait for days.

When you’re waiting, for instance to come and fix it...how much visibility do you have of what’s going on...do you know when it’s going to arrive? Do you have a good idea of when you’ll be able to get the machine up and running again?

Not really. They’ll tell you, maybe then, and then soon it’s like. Noo, the part hasn’t arrived yet, we’re waiting for authorization...

What about coming in and visiting, do they tell you about that as well?

Yes.

About the service, they’ll make a booking.

But if you have a repeated problem, like with the supine bucky, do you know when they’ll come in and fix?

Yes.

But it could change if the part takes a long time

Is it always easy to actually request the repair?

Yeah, well, it’s not difficult.

It’s easy to get them to start the process?

Yes. They’ll always respond to you, to say how far they are.

You said you’ve had no problem with the DuraDiagnost so far – have you ever had to call Philips?

No.

Okay – so we’re doing pretty well.

In general for repair and maintenance though, if you could improve one thing about it, what would you improve?

I would prefer if maybe they can have parts in your premises. That would make it easier, you know. I mean if you keep parts in for one machine, nearby, and if that part is used for some other practice, just replace that part to be there. And I think there are more commoner ones, these ones are more commonly replaced. There are those that are maybe expensive you can’t keep for long. But there are those that are many, you can keep onsite, for when the customer needs to be replaced. Or maybe if they are overseas, I think with other companies they take less time. With other companies they are big, they will take 2 days or so.

What’s the longest a part has taken to get there?

The tube. Yes, the tube. To get a tube it’s difficult. (of course, I’m talking of other companies, not you). It took 2 or 3 days.

What’s the impact on you when the tubes break?

It’s great. We can’t work without a tube.

On the machine you lost the tube on, how many scans per day did you do on that machine?

Like for CT scans .I think we did like 15 to 20 patients per day.

When you realise a machine’s down, presumably you have to reschedule.

Yes.
Do you take emergency patients?

We do

So what happens if it’s broken

We have to turn them away

So we were talking about remote assistance – calling them over the phone and trying to diagnose what’s wrong... how often have you actually managed to fix a problem by calling them remotely, just over the phone?

I think sometimes it has been working but sometimes... not. Depends on what machines as well?

What’s the difference between machines?

MRI and ordinary X-ray room is different. MRI sometimes has to do with ZXY planes. And they tell you to go to the generator room, switch this and pull this out... and if you are not familiar with the terms, it’s a problem. Whereas with the ordinary X-ray room it’s simple. They tell you to go to the settings because switching off and on is just simple and straightforward.

X-ray compared to MRI it’s a lot simpler, the types of problems that come up

Have there been times where you have managed to solve something just with someone directing you?

Even amongst ourselves you just reboot the machine.

For the MRI machine, if the engineer is telling you to go to the control room and says “switch this do that”, if you are not comfortable then you’ll say to him?

Yes, yes if you’re not comfortable. Because as I said because sometimes he mentions in their language, you know, the technical language. We don’t understand.

So they’ll say for example go to this circuit board...

Yes, yes, they’ll say “this RF parts” or whatever...

Are they labelled clearly?

Not really

There’s no clear indication that which is the one?

Yes.

So maybe if for example there was a sticker code... go to A, go to B, would that help?

Yes

Is it usually possible to explain to them what the problem is, do they understand you?

Yes, sometimes there’s a message on the system, and error code. Then you give them the code.

What if it’s something like, the image quality is bad.

I think so far we’ve been explaining what you see more, like for example with the image you don’t see an error but you see that the image is not good quality. That constant artifact that you see, just state it as it is.

Do they usually understand what you’re talking about?
So far, yeah.

And so they can usually diagnose it based on your description?

Yes, if it’s something that they can try to help you on the phone then they’ll do that. But if they can’t then they’ll try to give you and estimation as to what time they will be there.

What sort of things are they good at sorting over the phone and what do they have to send someone for?

Parts issues, someone has to come out.

With our detector that time they tried to solve it over the phone but obviously that didn’t work.

And when they talk to you over the phone what did they ask you to do?

They’ll tell us unplug it there check is it in, check the plug in thingies

Then they’ll ask for response like switching the light on...how is the light, is it on or off?

And can they remotely access your machine also?

With some they can, CT and MRI they can.

I sort of asked this already but when they ask you to check this light, is it always easy to understand them?

At times you don’t understand, as I said, it’s more technical language.

Unfortunately all my questions are about the Philips machines so maybe these will be a bit different but what do you think...what’s the most common error you get?

Not with Philips! We haven’t had any issues

For the other machines?

Detector not connecting.

Are there any other common errors?

Maybe it’s the detector there’s one detector for both erect and supine, so when you take it out and switch it, supine erect, erect, supine, there is wear and tear. So that damages the cord. So sometimes you’ll see a little bit of wires.

If that happened would you ever change the wire yourself?

No, no we don’t.

So I have a list of failures here and I know that not all of them apply because they’re based on Philips machines, but how often do you get these types of errors? How frequently?

Unclear image?

Every 2 weeks, per machine.

Artifacts?

No. Because sometimes it can’t expose, also that. Messages to say the detector is not connected?

Failed exposures.

A lot. Then we switch off. I’m sure every week, more than twice.
And how many times do you get artifacts from the image?
Not often.

Do you ever have the system refusing to expose?
Yes, if the detector’s not connected.

How many times does that happen?
A lot. Weekly.

Tube error?
I think there was a time they change the tube almost the whole month, it was rejecting the tube, it was giving us a problem. But I think once it’s properly in it doesn’t give us any problems. 1 year or less.

Do you ever have problems with the hospital power network?
No

Calibration errors
No

Workstation not turning on or not connecting
No

Software crashes
No

Can’t log in?
No

Connection failure
Yes, with the detector.

What about network connections – to the printers?
Philips does not have connection to the printers, but yes with the others, we have connection problems to the printers.

How often?
Once a month

Mechanical failure errors?
I think that one it goes back again to the one detector issues.

The mechanical parts don’t jam?
No

Problems with fans?
No.

It sounds like you get a lot of detector network errors...

For each of these how do you usually deal with these errors?

Detector errors?

Turn it off and turn it on

Does that usually fix it?

Sometimes, sometimes not...

Are there other things you might try if you couldn’t get a hold of the service engineer?

What else...no, no.

I’m going to go through the list again...in a situation where you didn’t have a service engineer to hand, how confident would you be of solving the problems yourself. On a scale of zero to 3. [Insert explanation] *NB make clearer

I think it really depends on the machine...

Let’s stick to the standard X-ray...Fuzzy image?

I try...I think it might be 2...you know okay the machine is giving you something like this you turn it off...you wait...disconnect the detectors then take it from there.

And what about the failed exposure, not exposing at all.

It’s similar, switch off, switch on.

And for “it’s not ready, it can’t connect”?

Same, - 2

Tube failure?

0 – We can’t do anything about that.

You said you didn’t get mechanical failures or calibration errors...

If you did ever have a software error, what would you do?

0 – call them out.

And presumably for calibration

You know for Philips we do calibration ourselves. So if it wants calibration, detector cailibration you can operate it. – 3

You don’t get power failures.

Do you ever get problems with power levels – I’ve heard from some hospitals they give an error because the grid power is above or below a certain level...

No, we don’t get that.

What about with the detector connection failure
Switch it off, and then if it’s still not working then we give up and carry on and call them.

Okay, we’ll call that two

Network connection to the printer? Yeah someone will come out and fix, or Nadine will come out.

If there was a printer error, you wouldn’t really do it yourself?

We would call Nadine, she’s the IT lady who checks the networks.

If there was something jammed with the mechanical parts?

I think we don’t get jammed parts.

But if it happened would you just call someone?

I’ve never had experience with that so I would probably call out.

So things you’ve not experience before you would call someone.

Yes. After I’ve switched it off.

You mentioned the IT person…are there any other service people in the hospital you would use, for example an electrician.

There’s a serviceguy there…they work together with workshop the workshop guys.

They’re servicing the whole building? What kind of issues do they fix?

High temperature maybe to cool down the system, the air cons.

Do you often have problems with high temperature?

It’s not so often.

But maybe in summer…does the machine ever start giving you feedback is too hot.

You can feel our department – it’s cold. Then they’ll come and adjust it too high, and it will start to affect the machines. Then they’ll come and put it like this again. So they can’t get it to a nice average.

And does the machine give you error messages...

If it’s too hot, yes.

And what do you think – I know you’ve already talked about detector errors being really common, and you already mentioned that you thought detector errors were because of the wear and tear of transferring What do you think is the most common cause of error – what do you usually think causes a problem.

With detector it’s definitely the wear and tear, we do a lot of patients and we’re constantly taking it from erect and supine, supine to erect...

And what about the things like unclear images?

Which we hardly have…I don’t really know,

I think when it happens it’s really due to incorrect positioning. Or incorrect selection of exposure. But it doesn’t just happen that if you get correct positioning and correct exposure and you get an error, no...

It will be a radiographer’s error.
So does that happen if someone is not experienced with that type of exposure?

Yes.

For things like if you had a network or printer connection issue. What’s the most common cause?

Maybe the…I don’t know…the cord is loose somewhere...yeah, we don’t really....[use them]

Other errors that are not mentioned?

No I think our biggest error is the detector…the detector is our killer.

Are there any questions you have about teleservicing?

From my side no...

Is there any features you think it could have...what would you like it to do?

Have a technician on site!

Notes & Observations:

- More confident on errors that they have previously experienced
- MRI especially – difficult to understand over the phone (they cannot speak the same “technical jargon” and are less confident following directions.
Appendix IX

Hospital 2 Interview Transcript

Interview with head radiologist

What was the last issue you had?
Cariology null (this is when you’re doing cardiology and have a ‘null’ setting that isolates the information you want)
Artifact issue: “It was a mess, it looked bad.”

How was it resolved:
An application specialist in the UK sent a new protocol (settings) and it improved a lot.

How long did it take you to fix? How many visits from the application specialist?
A lot - we only do cardio on fridays, so he had to come in on fridays to see the problem, and sometimes he had something to do on fridays, so it took several weeks.

We could send videos - we could do that on our phones, but it’s difficult to get it to come out right.

Constraints on Teleservicing:
- Can’t take a camera into the MRI space

What do you resolve by yourself?
- Most application errors we know how to fix ourselves - e.g. things to do with changing the view window/presets. Or if we have a problem, the first thing we’ll do is to restart the machine.
- We know our boundaries, we don’t call them for every little thing, but only when we need them.
- I was so sure that the last error was to do with the R-Amplifier, but it wasn’t, only to do with the tube. Better - much cheaper!
- Radiologist is a 3 year diploma for general - covers medical, technology etc. Then there’s 1 year if you want to specialise, for example in nuclear.

Quality of service
- It’s usually very easy to interface with them over the phone. They know how to ask the right questions
- Compared to other suppliers - don’t use other suppliers in this lab, but know from other departments that they really have to fight to get them recognised.
- We want service 3 times a year, not 2...when we see the stuff that comes out of the filters when they change it...we don’t want that removed less frequently!!
Appendix X

Hospital 3 Interview Transcript

What is your biggest problem?
Image quality is very bad. Here [workstation] it is showing very bright. But then as soon as I order it to print, you see another image.

Which one is better?
Here [the workstation] very good. I take the patient, I am satisfied. But I don’t have these results on my film.

So on the screen but not on the film?
Yes

Have you called the Company to resolve?
Yes, a lot of times.

What did they do?
They are dealing with…and send us many experts, from India, from Africa, from China – yes, that’s happened. But we don’t get what we ask for. Still we have a gap here.

Is it a constant problem, is it all the time, or only sometimes?
No, we are dealing with it. But still have the problem and it’s not solved.

I’ve taken time to make this gap reduced. But it still isn’t?

Could you see benefits to idea of Remote Servicing?
This benefit you are talking about, very good. Gives us a lot of solutions to our problem. Mainly that we are dealing with this machine daily, from 9am to 11pm.

Can you think of a time when it would have been very useful? To be able to video the service engineer for instance.
I can make it at once – I want to deal with it at once. I don’t have time to address these problems. It is enough for me that the problems are every case. Every case I deal with it it comes with a problem, because they are patients. Enough for me with patients. I can’t deal with patients, and the machine, and everything else.

You don’t need another patient.

Have you ever had to cancel a patient appointment because the machine has broken?
Yes, many times.

How many times per year?
Per year? Per months!

The number of times we stop because we can’t get the results deal with are clinically repetition

My film here, they are making a lot of things outside, in many countries to see and deal and make a surgery, depending on these films. So if the film is not acceptable for them we cannot give the patient the film, because the quality of film is not usual for this site.
And so you said there are doctors depending on your scans to make decisions about surgery?

This is our work, and every one of our colleagues ten years hard work. Really all of them, hard workers, when I tell you 60 case per day – for this room only, for this machine only. We have three other rooms, and we have a digital unit to make examinations. So we will do all the exams.

Everything internally? All the patient preparation?

In shifts, yes.

I know you said, per month, but – how many times in the past year have you had the machine out of use because it was broken.

More than 20 times!

For 2 or 3 days it’s stopped working.

You have to put the software anew from the site, and you eliminate the whole cases.

Twenty times from four years ago?

From installation twenty times the system software crashed.

Always the corruption is coming from the computer?

I think the problem is partly solved after UPS was installed

We still have a problem, but not the same rate.

But you have to know that this is a major problem in Egypt.

From 1 years ago it’s fixed.

After the UPS was installed there was fewer problems.

From 6 months ago, 3 times.

How frequently do you get the errors – once per month, twice per week. Happens all the time...

Unclear image

All the time

Do you ever get artifacts in the image?

No, no.

Do you have a failed exposure?

Intermittent. 10 times per 6 months.

Do you ever have problems with the system saying that it’s not ready for the exposure?

No

X-ray tube:

No, no.

Problems with power in the building?

Fixed with UPS
But we have two main high lines – high tension power automatically short.

**Do you have errors with calibration?**

Already the system required calibration, it's normal, but he waits for the service staff to come and do it.

**How often?**

Depending on the setting...you can set it for 3 months, or 1 year.

**So you were never trained by the company to do the calibration yourself?**

In the cat scan, I change the calibration daily.

**Do you call them remotely or do they come here?**

They come here.

**Do you have problems with the workstation not turning on?**

No.

**Software crash.**

Yes, mentioned already.

**Unable to log in?**

No.

**DICOM error – connection to printer?**

Staff of IT, in case there is an issue, is not mentioned before.

**Detector plate? No**

**Any mechanical/physical problems with the system?**

(point to tape)

From working with the machines...sometimes...put over the detector, crashing ins

**For some of the errors you had, what do you do when they happen.**

**If you get a blank image what do you do?**

We will wait a little while then do it again.

**Not restart system?**

No

If we don’t need it very hard, we will wait for a little while and after that

And the patient is still there...

Or make him put his clothes on and wait outside until I be sure that everything is working properly.

**What do you do, you wait and test exposure again.**

**Do you use something to test?**

Somehow we are doing that when we still have the...same issue. And mainly the staff that are making general tests for the making or starting of where or...from the Company, they do that. Just for testing
Waiting after 1 minute, and the patient is waiting, then make another exposure, if it’s okay then go.

If not, he is telling the patient go outside, wait 5 minutes, testing on something, for example a mobile. Check the image with the display and ask the patient come it.

**What if you check the mobile and it’s still not working?**

Call the company And then...what about for the calibration you also call Philips...

**For the software crashes. What do you do.**

Just call the Company...or we are making shut down and start again.

If not working then ask the help from our service engineers.

Those are really the main errors...exposure, unclear image. When someone calls Philips, is it someone in the room who calls.

The hotline, go to the website, you can call. Usually they come and in the same day or the next day...and they deal with our problem.

**Is it always fast enough to report an error to the company?**

Yes, very good.

We have hotline and the phone number for the staff there.

**So you can call them directly?**

But depending on the hotline, because they are making the order of the call dispatching, we have to

We can’t depend on that as we talk to the person directly because they have to take the order directly

**So first you would call [the FSE] and try to sort it out over the phone?**

FSE: *As usually from my side, the customer call me, I try to fix it by phone, if not, I ask them to call the call centre for dispatching someone. Because the call covered and recorded in the call centre.*

**How often have you managed to fix a problem just with a remote engineer.**

Really we are depending on that because they are friends, and we have good relations between us. And if it’s something we can manage it, okay. It will be enough, alright.

**What sort of things can you manage to fix remotely yesterday.**

Measure...the ones that make me stop. The machines not starting up problem, or problem in software...you know that most important thing that we have to deal with the company all the way. But if something already have experience how to manage, I need a reading from one of the engineers, so I talk to them, solves the problem and it will be enough for me. I consider this machine it’s not mine, it’s Philips. So it’s Philips image. So I talk to him like he are sitting beside me.

For him to come here, it has to be something I can’t deal with.

Maybe the grid positioning...right. Light positions. Handswitch has problems. Something that I’m used to deal with the machine.

Because we have 30 years experience. So I see a lot of machines, Philips, and other brands...

So from our experience we deal with something you can manage. Make use. Like if we have a problem with the machine restarting we will wait a little while and wait to start again...and again, and again, until we are...we have to call the service engineer.

**And so if you have a problem with the grid or the light positioning...?**
We don’t need to make from it a problem! I want to solve it already?

**If you have called the service engineer and he was saying try this or do this...is it usually easy to understand?**

Of course! For him, step-by-step. Usually I put the machine in my sight and deal with every word that he say. And usually I get my result.

**Is it always easy to explain to the remote engineer what’s going on?**

Yes, they are here in Egypt. You can always understand.

**In general what do you think you be improved about repair in maintenance? If there was one thing you could improve about the repair process?**

The most important thing that we are the highest response that is my satisfaction...it depends if he knows something come here like GE. We have many machines here with GE. The most important thing – they deal with everything at once. GE has a warehouse, parts are shipped better.

**Further challenges:**

Need to reach certain standards

Always very busy, very stressful. So many patients per day.

**Interview with General Manager:**

**What problems do you have with service?**

Well service...not what we would like, especially on the CT. (this is a 3rd party). Always having problems with it.

Took 30 days to be resolved. That’s 30 days – the machine was not usable, I had to turn away patients. I’m losing money, I’m losing my reputation from all the customers (doctors) that I do scans for...400,000 Egyptian pounds were lost from that failure.

They don’t do everything at once – they’re not expert. The quality of the engineers is not good.

**Longest part of the process?**

It takes time to diagnose, and it takes time for the parts to be ordered.

They come, and they don’t know what is the problem. So then they order a part – and they wait for that part to come. And then they install it – oh, wait, that’s not the problem. They order a new part, then we have to wait for that part. They come, they send various experts in...still the problem can’t be fixed.

Some companies have proactive maintenance – this is very good. They say, before it breaks “we are coming to replace your tube” – and they replace it. We can schedule it, we don’t have to turn away patients because we know when it’s going to happen. That’s fine.

**Do you have service contracts for all your other machines?**

Yes, of course.
Results of Customer Survey/Interview:

When is repair particularly critical?

This would be particularly good for CT, because this is used for emergencies and without CT the entire emergency department, ICU etc shuts down, and don’t have a backup.

What is your standard course of action when a machine failure occurs?

If a small error, restart the system. Then call hospital biomedical engineer, who gets in touch with Philips. Not critical for DuraDiagnost as have other DXR machines.

How long does it usually take for a machine to be fixed once an error occurs? What are the longest parts of the process?

Maximum time has been 1 week, waiting for a part.

What is the most common error or failure you experience?

Transformer problems, failed exposures.

How do you deal with each of the above errors? Are there any which can be fixed without the assistance of a service engineer? If so, can you explain how they are fixed?

Software crashes: Turn it off and restart. Several times until the problem fixes.

Are there any other people that you have used or would use as a resource to fix small equipment errors (E.g. electrician)/hospital technician

IT department, facilities department

Are there any small repair or maintenance tasks that you already perform in-house (E.g. cleaning the machine)?
Do a daily check on One & Off Key, Calibration, Diaphragm, Bucky Table & Stand, Centre of the Tube, Lead Apron & Accessories, Infection Control Items, Emergency medicine. Notify Biomed department if not working.
Appendix XII

Hospital 5 Site Notes

Install base: DXR, CT, Mammography

Hospital: Private hospital

Biomedical engineer: Yes, works with all equipment, 3 days per week.

Procedure for reporting error:

If it’s one of the days the biomed is in they call him, otherwise they directly call CCC.

Before calling the biomed will turn the machine completely off and on again

Error history:

Once 4 of the detectors broke on the CT, it was not usable – was broken for an entire month

Worst (most common) error is a ring artifact. Needs parts replaced, usually.

If we see artifact we make calibrations, if that doesn’t work, call Philips.

Omni:

Collisions, serial charger (?), shifted grid

Remote calling:

Sometimes do a remote call; once the digital imaging unit was down, the power was off it was not starting up. Called the engineer, he asked biomed to open the cover, check the contacts. [moved the contacts] and it was fixed.

1 year from starting up there were a lot of problems...they spent six weeks together every day working on the machine, so from that he did get some training. This is for DXR

For CT I don’t like to try (even with remote help) to many problems in the software, don’t understand, more experience.

Self-help:

Most of the time do own calibration: if it doesn’t work, call Philips. Used to do daily, now probably weekly.

Equipment:

CT – 20-30 patients per day

For me, I prefer analogue.

Concerned about price “this helps you more than it will help us”. So what is the price? If it can be offered at a lower cost.

GE, Toshiba (has experience in other labs) much better because they are able to more quickly replace parts.
If it can do predictive maintenance, if we can schedule a part to be replaced beforehand, this would definitely be worth it. Otherwise we are waiting...okay we understand there are delays, they are in customs; but why can’t you keep stock in a warehouse? Why when there are common parts that break, are they not here?

[I think that after 3 months, surplus are sent back]

All equipment bought 8-9 years ago, still in good working condition

(Why? She (the radiologist) takes very good care of it – if she sees a single screw loose she contacts the biomed). Cleaned regularly. They always make sure to handle it carefully.
Interview Notes: South Africa Field Servicing Engineers

Remote Servicing

- Video conferencing would be really good. Sometimes you ask “is this light red?” And you know it should be red, because you’re pretty sure you know what the issue is. But then they keep insisting, no, it’s not on. And you get there, and the light is red - they didn’t understand what you meant.
- We already use whatsapp with the customers - they send us a picture of what is wrong.
- Sometimes the fix is really simple but you can’t tell the customer to do it remotely. A common one is that the bed is out of alignment and won’t roll in; the solution is to give it a whack so it shifts. But sometimes I have to come out...i’ve travelled 3 hours just to kick a bed.

Do you think there have been times when they’ve not done the troubleshooting you told them to remotely just because they want to see you come over?

There have been times I’ve suspected...like they just want the day off, or something. Once came, the system was off, and someone had flipped a manual switch. There was no automatic trip, someone had to have pushed it. Can’t prove, but we do suspect.

Parts ordering issues

- Sometimes changing parts is the only surefire way to know that the part is fixed. We once spent ages trying to convince the RSE there was something wrong with the coil - we would do a fix, but then the problem would start to come back after a few weeks...our fix obviously wasn’t addressing the root cause.

- The RSEs don’t want to take the responsibility to say “yes, order the part” especially if it is expensive. They have to give the go-ahead on the expensive parts.

- In this case, the customer was left with an application error for several months
- Sometimes if there’s an application error you can send a picture or screenshot to the RSE and they say “No, I want DICOM files”. And you think - can you not just send me an indication? A best guess?”

Idea from engineer:

Measure voltage at each point, then display it on a map so you could see what voltages there are.

Summary:

- Disconnect between FSE and customer, FSE and Tier 2. Customer and FSE have communication issues, RSE has issues with confidence in diagnosis, since he has to authorize the ordering of a new part.
- Self-test results often confusing - give conflicting results and don’t usually pinpoint easily the part that is wrong.
- Various things that can be diagnosed with sight and sound: good!
Appendix XIV

Task sequence model, South Africa FSE Observation Study

Logs separate subsystems
- Says that there is an error
- Goes to check the lights on the RF amp at the back (Is a tube damaged? Can you remember which one you replaced last? There’s no space to put a label on the top...)
- Goes through log file, checks through. “Sometimes you’re looking for 2 things that shouldn’t be happening at the same time - a combination of errors.”
- Fails test again: First troubleshooting action - restart RF amp and try again
- Run selftest. Not working.
- Identify in log file error 95.
- Says: I know from experience that this is a board connection error - an engineer in Holland (that he phoned, Tier 2) told him once that this is what it was
- Second troubleshooting action: turn whole thing off, open the back of the RF amp. Unscrew the affected board slightly, shoogle the connectors and plug back in again.
- Check to see if all the lights go on.
- Run test: “Non-recoverable error”
- Third troubleshooting action: reboot the entire system
- Run test again: No immediate ‘non-recoverable’ error like before
- But testing subsystem there is an error ‘PMJ control failed
- Screenshot error and save
- Fourth troubleshooting action: Happen to have a spare PA tube in the car, let’s replace it and see.
- Run test: now it’s still an error, but not the same error - to do with connectivity.
- Engineer convinced is the part not seated properly
- Go to the back of the machine - lights are alternating between pause and on and there is a clicking noise you can hear when you put your ear against the machine.
- Has had this before - means that the thing isn’t seated properly
- Have to take it out and reseat it again...
- Reseat put back. Returning to same error m
- Error message, PMJ failure
- Look up errors: 62
- Troubleshooting guide for error 62 says that if you turn off and one, replace the tube and it still doesn’t work then you have to replace the board.
- Book time for next friday to replace the board.
- (Back in office: “why didn’t you just replace the whole RF? They’re under warranty!”)
Appendix XV

Notes from Observation Study of RSE in Egypt

Look for last errors: all these happened in the same day (checks Outlook)

Open, have link and can download attachment (log file)

Looking through log file in CAT analyser

Filter for “Error” and “Fatal” <- just to check, know from experience needs calibration

None of these are related to the problem

Get email back from FSE – now says it is a know issue, can you contact Tier 3? Didn’t tell you that before. <- FSEs missing knowledge, RSEs missing context. How do the FSEs know exactly what is relevant to tell them?

Log file: notice most of the error codes 005

Check what machine is

Machine is DuoDiagnost

Go to the Philips database/catalogue

URF – names of most common error notices.

Searches for some of the ones in the log file – e.g 00M0

Can’t find.

Log file again – says 00M0 usually related to errors 00H -> Knows from experience – that type of error related to generator

Decides to ask engineer can he please send the generator log file

Oops – forgot to read case description. Normally would do that.

Reads case description -> Engineer has done a lot of work beforehand. Skims over issue, must be missing something. Frustration? writes long email, gets back 6 word answer.

Confirm: asks him to make tube calibration and send the tube log file.

Go to mail, look for appropriate template: “DX empty template”

Type “Please try to make the tube adaptation” “Your DXR T2” (changes signature line)

Log labour hours (0.5)

Go to ROC, update the case

Route case (solved: from my side, it is solved, until he comes back to me with more information that the calibration has not worked)
New case 2

Case history – he had a problem with the router. Colleague didn’t know how to solve the problem, so he found the manual and extracted the relevant pages for them, and sent.

Tier 3 have now just sent the entire manual – lazier than him!

“Action required” shows if there is new activity

New case 3

Case – customer (who is in Sarajehvo!) does not want remote service, and so since they have gotten rid of it it is giving them an error message. <- possible barrier: not great English for either sender or receiver...

They would also like to know how to change the potentiometer

Just change configuration of remote service (he will send email to instruct)


Lots of searching and lots of slow loading!

Sometimes by the time it’s loaded you forget what you were working on!

Need to check that it’s exactly the correct PCB – for slightly different versions and model numbers there are different instructions.

For ordering a part: FSE should send a picture of the part or code #, description, then then know if it’s exactly the right code number

Checks the picture, and compares the picture with one in the catalogue – then confirms to the FSE that he can order.
Artifact showing troubleshooting isolation practice
Appendix XVI

Field Research: Cluster Maps

Hospital 1
Hospital 2
Hospital 3
Hospital 4
Hospital 5
FSE (South Africa)
RSE (Egypt)

remote service: they use a different (technical) language
remote service: a lot of back-and-forth over the phone
remote service: easy to tell error code
remote service: easy to explain unclear image
Can't always rely on mobile connection - is unreliable
already use whatsapp with customers

 Tier 2: skim-reads long email, misses some details
 reply email from FSE reveals new context
 you tell them exactly what you've done and they ask you to do something you've already done (Tier 2)

LACK OF CONTEXT

easy on the phone - they ask the right questions
sending screenshot to Tier 2

Tier 2 insists on DICOM files...can you not just make a best guess from the picture?
FSE writes long email, Tier2 6 word reply
REPORTING ERRORS

call RSE directly, if need FSE call CCC for dispatch
always easy to get a hold of service (GE) on the phone
always possible to report errors
call biomed, who calls CCC
goes to head radiographer, if he's not in phone
remote service: easy to explain as based in Egypt
non-fluent English between Bosnian FSE & Egyptian Tier 2
government hospital doesn't allow supplier VPN connection
remote service: Not confident following orders on MRI
remote service: easy to follow instructions - go step by step
remote service: DXR simple, normally just told to switch on and off
remote service: MRI esp ask you to go to generator and switch things off, pull things out.
remote service: CT don't even try, not confident
remote servicing: once fixed took cover off and moved contacts with remote guidance
FOLLOWING ORDERS
RSN error message: Tier 2 will instruct how to change settings
FSE needs to make calibration and tell Tier 2 whether it has failed
send videos on their phones "not quite right"

only do cardiac on fridays - modality specialist had to fit with that schedule
X-ray tube failure - infrequent but took long time to fix
detector plate failure - engineers changed software but problem returned
null issue fixed by presets sent from UK
Problem with repeated errors - engineers come out but issue comes back
changing parts sometimes only way to ensure fix
CT ring artifact worst error
more software crashes before UPS installed
sometimes errors not diagnosed first time
we have to deal with customers asking why not fixed...not Tier 2
we need to have spare PA tube - replace and sec
problem with image - philips sent lots of experts, long time, but still not fixed
common problems on DXR: image quality, software crash
most frequent error detector failure
old machine is never complaining!
CT - came and replaced a part but was wrong, had to wait and order again
RECURRING ERRORS
**Prefer GE proactive maintenance - plan around scheduled part repair**

**Ordering parts takes time**

**Takes so long for parts to be shipped out, so repair takes longer**

**Give estimate for part delivery, not always accurate**

**Ordering parts most lengthy part of process - takes 2-3 days**

**4 detectors broke on CT, not usable for a month**

**GE has warehouse, they ship quicker**

**RSE unwilling to allow new part ordered - fix took 1 month**

**Order new time to replace part**

**Part ordering: needs to be exact model & version**

**Error Diagnosis**

1st TS action: restart amplifier and try again

2nd TS action: unscrew board and wiggle connections

3rd TS action: reboot entire system

MRI: problem with null for cardiac "looked a mess"

Tube difficult to replace - easy to break when seating

Fault isolation: first play about with the machine to see whether the fault is

Self-tests confusing, don't always tell problem

After rebooting, self-test shows errors in different part of system

Can't take camera near MRI itself

Sign of tube not seated: clicking noise and alternate light-flashing

Error 62 in TSing guide - if these steps don't work, replace board

Idea from FSE - why not display voltage at each point in system on a map?
CAT analyser - filter FATAL & ERROR

look for combinations of errors in the log file

error 62 in TS guide - if these steps don't work, replace board

since knows is generator, asks for generator log file

1st TS action: restart amplifier and try again

2nd TS action: unscrew, wiggle cable

can't take camera near MRA itself

3rd TS action: reboot system

check for lights going off

Tier 2 extracts relevant pages from manual to send to customer

know from experience is calibration, but check in CAT

fault isolation: machine divided into components, if this working, not that component

fault isolation: first play about with the machine to see whether the fault is

self-tests confusing, don't always tell problem

idea from FSE - why not display voltage at each point in system on a map?

after rebooting, self-test shows errors in different part of system
Field Research: Conceptual Inquiry Workflow Models

Workflow models

Sequence Model

The sequence model may be considered the “basic unit” of workflow modelling, since it most closely reflects the way that notes are taken in observational interviews. It simply consists of all the tasks performed by the user in their workflow, in sequences, and the goals and triggers that lead them to perform a particular type of work.

From a “birds eye” view, the task sequence in repair and maintenance showed a similar pattern in all observation studies. A problem is first noticed by the user, who may perform some basic troubleshooting actions if they know how, and then will notify the company. Then the company directs a series of troubleshooting cycles (observing behavior, making a diagnosis, testing an action, observing the outcome), before the eventual final diagnosis and fix. What varied between repair situations was who was physically carrying out these actions. In one case, a Benelux engineer with a trusted customer remotely guided that customer to fix the machine entirely by themselves. In another, an FSE came to the site immediately and began troubleshooting in person. This depended on a combination of factors – primarily the apparently severity of the error, and to what extent the company engineer trusted the customer to fix the machine with remote guidance.
Company Call Centre

- Screens customer
- Passes to next available RSE

Customer

- Call CCC
- Checks who customer is
- Evaluates customer competence
- Asks customer about fault
- Asks troubleshooting questions
- Describes fault
- Performs troubleshooting actions
- Describes outcome
- Performs troubleshooting actions
- Describes outcome
- Takes machine out of working space for FSE
- Sign off as machine fixed

Remote Service Engineer

- Makes preliminary diagnosis
- Asks customer to perform further actions
- Revises diagnosis
- Confirms diagnosis
- Checks customer contract status
- Books new part
- Books FSE
- Hands over to FSE

Field Service Engineer

- Receives booking
- Goes to site
- Checks spare parts arrived
- Rechecks machine to confirm diagnosis
- Changes part/makes upgrade
- Makes machine self-test
- Confirms fix
- Tests with image phantom
- Sign off with customer

The process can be repeated many times if don't trust customer skip to FSE
As well as the overall structure, some valuable insights were also gained from detailed sections of the sequence model. The figure below shows two sections of the sequence model for the South African FSEs. It shows the engineer engaged in an iterative troubleshooting process – first one theory is made, then tested by some action on the machine, then eliminated.

This sequence also shows how many different inputs are consulted during a troubleshooting activity. The engineer first looks at the signal lights from the machine, then a physical part, then a log file, and at one point has to listen to the noise made by the part.

The next sequence model section demonstrates the detailed sequence of an interaction between a customer and RSE in Benelux.
Here, the expert RSE is performing the same process of making and testing theories, but remotely via the hospital biomedical engineer. Because of the remote nature of the call, there is an emphasis on gathering context which the RSE cannot otherwise access. The RSE begins by asking the Biomed questions about the machine history – its behavior, and what troubleshooting actions have been performed on it already. The RSE then relies on the Biomed to carry out his instructions correctly and report back accurately on the observations they make on the machine, so that troubleshooting theories can be confirmed or rejected.
The flow model as described by Beyer & Holtzblatt is intended to show the flows of communication and artifacts between different parties in a work process, and the responsibilities each party takes for this flow. In the diagrams below, circles identify particular (human) actors in the workflow, squares non-human givers or receivers of information (such as databases).

**Benelux**

**South Africa**
The communication patterns between users in Benelux and Africa are similar in terms of the information being transmitted - case history, remote guidance, descriptions of machine behavior, log files, and occasionally photos. The key difference in communication structures is that in Benelux the RSE and FSE both interact with the customer, whereas in Africa there is a more chain-like structure, with the FSE in between the customer and RSE. Both involve at some point inefficient transferal of case information. In Benelux this is usually between the RSE – who initially remotely addresses the case with the customer – and the FSE who is eventually sent to resolve the issue but who has had no previous contact with the case. In Africa, information is lost when the FSE – after attempting to assist the customer remotely or on-site – requests help from a Tier 2 RSE, who then enlists the help of factory engineers or other RSEs. In Benelux, remote communication with the customer encountered fewer difficulties since often the customer representative was also a biomedical technician. In Africa, there were almost no biomedical technicians and so remote customer service was performed with medics or radiographers, who sometimes struggled with the engineer’s technical language.
**Cultural Model**

The Cultural Model is intended to show how the parties in a work structure influence each other, what their expectations are of each other, and what cultural or policy rules restrict them to perform work in a particular way.

**Benelux**

![Cultural Model Diagram](image)

**South Africa**
A key cultural difference between Benelux and Africa is the expectations and pressure directed from the customer towards the Company representative. In Benelux, since RSEs and FSEs both communicate with the customer, both feel equally pressured and responsible for keeping the customer happy. In Africa, the FSE directly interacts with the customer, but Tier 2 (RSE) only directly interacts with the FSE. This means that the FSEs take on the responsibility of delays caused by the RSEs, and the RSEs do not feel the same urgency to satisfy the customer as the FSEs, causing conflict. There is also more pressure from the customer in general in Africa, since users have a high throughput of patients and no back-up machines.

In both cases, a Company “way of doing things” encouraged the replacement of large subsystems rather than individual components. This has more serious consequences in Africa, since larger (and more expensive) parts need approval for shipping from abroad.

As seen in the flow model, the typical confidence and competence of the customer differs greatly between Benelux and Africa. In Benelux the customer was usually represented by a biomedical technician, who was proficient in repair. As can be seen in FIGURE BLAH, the engineer devolved responsibility for repair to the customer depending on how much he trusted in the customer’s ability. In Africa, this level of trust was rarely present with any customer, since most were medics or radiographers not accustomed to machine repair. Customers in Africa also felt themselves to have less responsibility to fix the machine; a telling statement by one Egyptian customer was that “it’s the Company’s machine; not mine”.

Artifact Model
Notable in the artifact model from the Benelux study were the difference between the “official” artifacts that were used by the engineers and the ones created by them to do their job. The computer system used by engineers had an official “checklist” of actions they were supposed to fill out when troubleshooting a system. However, they preferred to use as a reference a pdf created by experienced engineers which showed guiding images, a list of required tools and a list of actions. This was apparently closer to the steps actually taken in the field than the official checklist, and the images and tools lists were helpful, since engineers did not always remember every step.

The call recording methods used by the remote service engineer were also interesting. The RSE was continually switching between a large number of customer cases, and would often have to recall the history of a case at short notice. The official system used fields where cases could be searched by certain keywords. However, the RSE kept his own chronological notebook, since he found the easiest way to find an old case was just to remember how long ago he had talked to the customer. In his own notebook he also did not record everything mentioned in the official fields, but simply important information to that case - for instance, the fault, the case resolution, and any relevant data (e.g. voltage).
RSEs and FSEs in the South Africa/Egypt study created artifacts for two functions: for communication, and to aid in troubleshooting. Emails – which were by necessity used for initial communication between FSEs and RSEs were considered as a communication artifact. Several times during the study, FSE emails were noted which were long and detailed, but were unstructured, sometimes in influent English, and were difficult to extract important facts about the case from at a glance. Because of the number of cases the RSE had to deal with, he did not have time to read long emails in depth and analyse them. He would instead reply with a short request that he hoped would give him a comprehensible fact or data about the error (e.g. requesting a recalibration). FSEs in their observation study confirmed this pattern, and expressed frustration that their detailed descriptions cases were sometimes met with – to them - redundant or irrelevant requests.

One FSE and customer in the South Africa study had begun to use phone messaging service Whatsapp to communicate and guide remote services rather than phone calls. They indicated that transferring a picture on this service so an FSE could directly see the problem was easier than trying to describe it over the phone. Whatsapp images were used to show incorrect X-ray scans, to show indicator lights or numbers on the boards of the machine, and to confirm part numbers so they could be pre-ordered before the FSE’s visit.

The photograph on the lower right of FIGURE BLAH shows a diagram drawn by the RSE to show the fault-finding procedure used by engineers to diagnose a problem. The first step is to discover which sub-
systems of the machine are still functioning, and eliminate them, thus narrowing down the search for the faulty component. Engineers must keep track of which subsystems have been eliminated and which are still under suspicion, and must pass this fact on if they are passing the case on to another expert.

The last artifact noted was a reference manual used by the RSE when talking about a case. The RSE indicated that since he could not see the machine in front of him when guiding a remote repair, he found it helpful to have a picture reference in front of him when directing the FSE, rather than try to remember the machine layout himself. These pictures were also used to double-check parts with FSEs – the RSE would request a picture reference of the part to be replaced and check it against the picture of the machine in the manual.

4.3.2 User personas

User personas were created the South Africa/Egypt stakeholders only, since these are the targets of the design project. These are shown in Figure (BLAH TO BLAH).

It is interesting to note the different contexts of the three users in this situation. Customers primarily think along clinical lines, understand machine failures in terms of clinical consequences. They have little knowledge about the technology behind it, but do think of themselves as experts in the operation of the machines. Field service engineers travel between and remotely guide customers and physically interact with a number of machines and errors, but do not have the same breadth of experience and overview as the remote engineers. Field service engineers and customers also both implicitly understand the local context, and the challenges of infrastructure and environment that it might post.

Remote engineers, by contrast, have a great deal of information about their disposal about the technical workings of the machine, and a wide pool of experts to draw information from. However, it is difficult for them to get a good grasp of the local context, and they are sometimes frustrated by relying on the FSEs for information about a case.

4.3.3 Association Clustering

As well as the more structured methods of analysis, a free clustering of points gathered from the interviews was performed, similar to the method employed in the scoping analysis in Section 2. This led to a mapping of general problem areas, shown on the next page:
Appendix XVIII
Transcription and Summary of Ugandan Doctor/Biomed Interviews

Sheila
Hospital – Regional Hospital in Kampala

Difference in biomed training vs. electrician/mechanic:
Always approach from a patient perspective, take into account things with electrical safety which might not be obvious to others.
There’s still probably a lot of risks, mistakes which are still not reported.

What types of equipment do you work on?
Everything! Called in when any fault – operating table, oxygen machine.
It’s quite common that I am called to fix a machine I’ve never seen before.

What do you do then?
First do the basics – check the power supply etc. Then if I cannot fix it I will note down the serial number, go and look elsewhere for the manuals. Look for manuals online.
Then if we haven’t seen it ourselves check the network. Network is a whatsapp group, very active. Has engineers, technicians, students. Probably about 200 people, coverage of the whole of Uganda. Share if anyone has seen the problem before, who can share the manual, share names of suppliers you can get the part from. Especially with donated equipment - maybe you have that machine type and serial number, another person also has it.

Especially with donated equipment sometimes where is not the manual. Try to find manuals online In that case can use Frank’s Hospital Workshop.
Very new profession in the company – I was the first hired by a regional hospital, now requests for 5 more. Hospitals are very excited
Doctors and nurses still getting used to us. Get to know by word of mouth and with user training – they are starting to know that they should call us when something goes wrong, but sometimes it is 3 days or so before we hear about an error.

Best part of your job
Being called in and fixing something which is critical when the patient is there – then the doctor is happy, the patient is happy, etc.

Is there any customer service?
We have some machines on contract. The suppliers of the oxygen concentrators and the patient monitors. The oxygen concentrator companies still work through us. Send us spare parts to fix. We often have to troubleshoot what’s wrong. We can call them and say okay, we’ve checked this, checked that. Usually easy to explain to them. Sometimes they ask us to do some extra things, they will send us pictures. Also send videos, instructional videos. They send these by email or whatsapp.

What would you change about your job if you could?
Make the acquisition of spare parts easier!
Would be good if I already had a platform, a collection of videos of how to fix them. In the one place.
Would like it if I could have an easy access manual (outline manual) manual is often too big. Takes a long time to look through it to get what you want. Would like to be able to get that information FAST
What I would be looking for with a new machine:
1. How to use it (for the medical)
2. How it works
3. Error codes or list of faults
4. Maintenance instructions
5. Spare parts – how to get them.

Most challenging things:
Currently only one person for whole department. High workload.
Also trying to locate money for the department. Part ordering not as high-priority as pharmacist. Money is not allocated – only if it’s critical will they pay. Even if there are fewer patients being seen – it is only if there are no patients being seen or if the patients start making a lot of noise about it that something gets purchased.

**Ordering parts:**
All in all can take us months, weeks. The whole process – finding out where to get it, getting permission from the hospital, ordering, etc. The machine just sits and waits.

Especially part of troubleshooting is changing parts – you have to change a part to figure out which one works or not!

How do we find? First look around Kampala – suppliers there might say “we can get it, but only in 1-2 weeks”. Then look in Nairobi. Sometimes you have to look further afield, in Europe – for example if there is a doctor going to a conference there you can ask him to bring it back.

Don’t buy second hand spare parts from old machines. Hospital is investing a lot of money so you don’t want to give them a lower quality part.

**Advice for me in making a design?**
Have something that still has this network – not doing it in isolation. Connect network of sorts with some sort of fast way to get at information.

Joseph
Hospital – Rural in Western Uganda

**Daily job of a biomed:** To look at the life cycle of medical equipment
Updating the inventory, servicing and maintenance (planned, preventive and corrective), installation, planning, user training and decommissioning

**Challenges**
Lack of spare parts, service manuals, most medical equipment in Africa are donated equipment hence not supported by manufacturers,
lack of skills on most complicated equipment,
not having data base system for inventory, service and maintenance tags, we also lack tester equipment such as an electrical safety tester and others.

**Further questions:**
how do you deal with unsupported donated equipment, and how do you currently take inventory without a database?
Ugandan health system is divided into various sectors: private for profit, government and private not for profit.
Am working in the private not for profit is the church based hospital called kisiizi Hospital in south Western Uganda for more information Google

Ques 2 I have serviced, repaired and maintained those with available spare parts in the country.
However, I have failed to carry out electrical safety tests and other tests due to lack of the test equipment.
The donated equipment, still remains challenge in terms of spare parts however I have tried to repair, serviced and maintained some using the service manual available on frank work shop .com

The inventory is always carried out using ordinary Microsoft excel

**What types of repair & service do you manage to do without spare parts?**
do you ever ask other biomedical engineers for advice about machines with no service support?
**What are the difficulties of using excel for databasing?**
The only repair and service done are those where I can get spare parts.
How ever at times, I source from the link network of biomedical engineers and other biomedical company in Uganda

**In what way does that network help you?**
Net work , help in terms of knowledge, spare parts because some of our equipment are similar.

**So other people know from where to acquire spare parts?**
Of course
what is the process for finding and ordering spare parts (including how you use the network to find out where to order)?

Most of the the ordering process is done store manager after giving the specifications of the required part
We make requisition with specifications and forwarded to the store manager

do you first have to find out whether it is available in Uganda or is that the responsibility of the store manager?
That is my responsibility to first find

-How do you contact the network you mentioned and who is in it?
The net worked linked with whatsapp
- For inventory system, what kind of information do you need to log and keep track of?

-How do you find out when a piece of equipment in the hospital is broken, and what is the first things you do?

Broken pieces of equipment are brought to the biomedical Dept but the big installed equipment such as washing machine ,vertical autoclaves
Check the tracking and log on the items on the inventory

- Are there any particular challenges to working in western Uganda as opposed to somewhere closer to the capital?

Of course challenges are there: Transport is poor due to roads in upcountry.
2 Dusty area hence blowing every after short period of time
3 Transport charges increased almost every year.
4 Behind the latest technologies.

What pieces of equipment are most difficult to repair?

All of equipment can be repaired as long as you access service manuals
However, automated lab equipment and those that run on software
now days software is confined with regents
Additional training is required
Specific companies always contract for the lab equipment and password protected

Do you ever use the regional workshops for fixing things

No

On the network on whatsapp, is it only biomeds or also suppliers

No ,but different biomeds work in organizations and also including such companies.

Do people ever share documents or manuals through the network?

Not always but it can be done if an individual asks for one.
are there any machine problems that can be fixed without spare parts?

Yes, machines with pneumatic system example, oxygen concentrator, ventilators anaesthetic machines most especially with leaks. Loose connections, Rusty connections steam leakage and so on.

Dr Bruce Kirenga
Regional Hospital, Kampala
Notes from conversation

Personally - uses spyrometers, frequent problem that images not transferring properly. Used an IT expert, does not have a biomedical engineer
Spent ages looking up online, could not find very much information
Service contracts are very expensive - 20% of the price of the machine
Some people keep expensive machines “good” in case they break
University has started biomedical training program, just hired technician
Don’t budget for repair and maintenance. Lack of awareness - used to be just a doctor and his stethoscope, now new machines are coming in.
Manual - easy to read but there are a lot of technical things
Would be better if there were also videos
In Uganda, I think if someone has access to this sort of equipment then someone somewhere should have internet access.
Need to transfer these in the field.
Smaller clinics might not have access to a server for instance
People would probably pay for this service
Different levels of access depending on the person - in some cases it will be a 3rd party mechanic, sometimes biomedical engineer in the hospital, sometimes doctor or nurse themselves.
Appendix XX

Design Concepts User Feedback

Feedback by component

Design 1 - NGO donation preparation environment (labelling components with #s)
- Customer may still not be confident enough - say cable D but where is it? There is also no feedback to the engineer. - SK
- In the past, we have done exactly what you describe when preparing an xray for shipping. We’ve labeled wires and taken pictures. And it is always good to have a step by step procedure for the recipient to follow. The theory is sound. - JL
- Colour-coded wires, labels...we don’t do much of that. But it probably would help. - IC

Design 1 - Interface between customer & engineer (SMS-based)
- Either: combine it with training so that the customers at least know how to do the first step OR: have some kind of reference with images/videos they can also refer to. For example a user manual, or videos installed in a hospital computer or tablet. - SK
- May be better for simpler medical equipment such as patient monitors, anaesthesia machines. Imaging equipment is too complicated, and too expensive, and customers are too wary about touching it. - SK
- Smart Idea to map out with stickers, but i wonder what added benefit does this have to the customer over a phone call? - RZ

Design 1 - NGO engineer home environment
- Like the fact that you can write down notes in the text and then pass it onto someone else, built-in escalation - RZ
- Notes is good - could mention thins like “customer needs to renew their contract” very simple in the escalation - RZ

Design 2 (NGO version) - Repair guide builder/readiness checker
- My favorite part is your initial layout of a procedure to follow. If you can get the recipient to follow a logical process, you are ahead of the game. - JL
- Which experts will you find to know functionality and safety checks? Do you know the European legislation on transfer of electric and electronic equipment in the LMIC ? There is the directive 2012/19/EU on that. All equipment must be functioning. If they are of EC class IIb their performance and safety must be controlled (directive 97/43/Euratom). They must have been controlled less than 6 months before their transfer. X-Ray equipment performances must be in a domain specified by the national regulations, etc… - MP
- Usually, NGOs do not have the capability to do theses checks. when they obtain an equipment from an hospital or clinic or any other person, it is very difficult for them to obtain the
collaboration of the users and biomedical engineer to get the users and technical manuals, parts and consumables. They don’t want to do a last control. If the donation requires a lot of hours to comply with the request of the NGO, the user will prefer to sell the equipment to a reseller or just scrap it. - MP

• Very few NGOs are able to do a « photo guide for common repair processes” ! Some of these processes may be found in the technical manual ! In my opinion, according to what I know from my experience on donations, this image gallery could be done by the volunteering engineers following the exchange of photos during a repair process.. and improved progressively by all engineers or technicians - MP

Design 2 (Philips version) - Pre-troubleshooting guide

• Customer doesn’t understand root cause - they understand how they experience the error. For instance “there are artifacts in the image”, “Unable to push DICOM files” For every error the customer sees there could be a million root causes - SK
• When giving them the initial troubleshooting steps, put a picture in there, ask them how exactly to reach the thing - SK
• Would be especially good for image quality problems - then the really essential thing is to see a picture of the screen. - RZ
• Other question - who is the intended user? The doctor might be useful to use it immediately (because it could clear up the problem through initial troubleshooting steps) but then can they pass it to their biomedical engineer? - RZ
• Having a pre-checklist would definitely help! You need to know what exactly the problem is, what they’ve done already - “did you try that, did you do this?” - IC

Design 2 - Interface between customer & engineer (smartphone-based)

• Could also send videos (particularly if bandwidth is not an issue) which are easier to see how to take something off - SK

• 

• Good additional feature: since you have this link with the customer, give them feedback on the status of the call/part delivery etc - SK
• General comment: may want to involve some sort of technical person. People like this can easily pick up a clue from what you are saying, ordinary doctor or nurse might not be able to. Maybe within the area somewhere is a technician - BK
• Could also work for pictures of test outcomes - RZ
• I already use some of your basic concepts using pictures and Skype/Facetime. I actually love skype/facetime communications because of the face to face, real-time video. One can actually show a specific piece or part on unit. We use digital pictures all the time. - JL
• If it is not intuitive/user friendly/multi-lingual and comfortable for the persons responsible for equipment operations, it will ultimately not be used. - AG
• We use whatsapp. Tried first over email, but found this more convenient. Good for sharing videos/pictures. Get a picture from them, show them a picture of the machine to show what we’re looking for. - IC
Design 2 - Engineer home environment

- Troubleshooting tool - visual representation not necessarily important for Tier 2 as they will know what something means. OneEMS already used as call tracker between different people. Could link this to visual. - SK
- Potential problem - transducers are sometimes moving parts, so would you be able to switch from Machine A to Machine B (if one has the same transducer as the other?) - RZ
- Need a way to keep track of install base status - software updates etc. - RZ

Platform Design

- Could be used in indirect countries with Philips-managed service (ASP) as a way to bridge the knowledge gap between those engineers and the Tier 2 - SK
- Had a spyrometer failure, spent ages looking up online, could not find very much information would save a lot of time if I could just sign up for this - BK
- Would be good if there was some kind of platform, people saying what problems they have encountered before - BK
- Don’t budget for repair and maintenance. Lack of awareness - used to be just a doctor and his stethoscope, now new machines are coming in. - BK
- In Uganda, I think if someone has access to this sort of equipment then someone somewhere should have internet access - BK
- People would probably pay for this service - BK
- Different levels of access depending on the person - in some cases it will be a 3rd party mechanic, sometimes biomedical engineer in the hospital, sometimes doctor or nurse themselves. - BK
- The use of the internet and electronic communications as a whole is vital - JL
- Even if they have spotty, or even reliable internet service, they lack basic training, or you might say “corporate knowledge” of medical equipment management. You can always find someone who is fearless and will try to troubleshoot something by tearing it apart, but frequently there has been no formal training, or like my previous example, there is no history of preventive maintenance or equipment management philosophies. I don’t know how many pieces of equipment I’ve seen torn to pieces only to gather dust and end up on the scrap pile. - JL
- The other two things I think would be HUGE challenges are getting the suppliers of the equipment to follow your example of labeling pictures, and to have a bunch of engineers and technicians available online at any given time. Remember what I said about appropriate and sustainable? Your program assumes the providing NGO would have the knowledge or desire to do it right. Unfortunately, there are many NGOs who just want to send equipment and let the recipients figure it out. - JL
- Group chats: had one in congo. Works well as a social thing, creating community. People start to share pics of them playing soccer, morning prayer…
- Can image you’d want one-to-one if you actually want to start troubleshooting an issue, or if you want to collect data on what’s going wrong… - IC
Appendix XXI: Platform design work

![Diagram of the ecosystem canvas]

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<table>
<thead>
<tr>
<th>Entity</th>
<th>RepairAid</th>
<th>Philips/Other Mfgs</th>
<th>2nd-hand suppliers/ distributors</th>
<th>Biomedical staff</th>
<th>Hospital staff</th>
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<tr>
<td>RepairAid</td>
<td>Quality, customizable remote service communication channels&lt;br&gt;Ways to manage their service support internally</td>
<td>Ways to manage their service support internally</td>
<td>Platform to receive free peer-to-peer advice on repair&lt;br&gt;Hospital device management</td>
<td>Service support</td>
<td></td>
</tr>
<tr>
<td>Philips/Other Mfgs</td>
<td>Reach new customers (with quality, low-cost service support)&lt;br&gt;Quality control of 3rd-party distributor service by standardizing contracts packages&lt;br&gt;Brand improvement through better servicing</td>
<td>Licensed customizable remote channels/extra product information&lt;br&gt;Expert service support for difficult technical problems</td>
<td>Service support (contract or billing basis)&lt;br&gt;Basic free info to do a minimum amount of trouble-shooting and repair without service support</td>
<td>Service support</td>
<td></td>
</tr>
<tr>
<td>2nd-hand suppliers/ distributors</td>
<td>Consumer feedback on reliability and common errors of devices</td>
<td>Able to provide better quality service support</td>
<td>Exchange peer-to-peer advice&lt;br&gt;Pay for whatever level of servicing they can afford</td>
<td>Service support</td>
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