Innovations for maternal, newborn & child health

MAKER MOVEMENT FOR MATERNAL NEWBORN AND CHILD HEALTH
Project Evaluation Findings

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Introduction to the Maker Pilot

Background

Maternal mortality in Kenya decreased from 687 to 510 deaths per 100,000 live births between 1990 and 2015,[1] a 26% reduction far short of the Millennium Development Goal (MDG) target of 75% reduction by 2015. Although no longer current, the MDG target was an important goal during the lifetime of the Maker Movement for Maternal, Newborn and Child Health (MNCH) project. Neonatal mortality also decreased in the country, dropping from 27 deaths per 1000 live births in 1990 to 22 deaths per 1000 live births in 2015.[2] However, when population growth is considered, the overall number of neonatal deaths has increased since 1990.

Medical equipment is especially important for maternal and newborn health. Equipment is used in everything from normal delivery, caesarean section and routine neonatal care to case management of maternal complications and advanced newborn care, including postoperative care for mothers and newborns.

[1] Trends in maternal mortality: 1990 to 2015: estimates by WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division. Geneva: World Health Organization; 2015. [2] Levels and trends in child mortality: Report 2015. UN Inter-agency Group for Child Mortality Estimation. New York: United Nations Children's Fund; 2015. Map image courtesy of Betev, myself (PI) [Public domain], via Wikimedia Commons

Background

This equipment is often unavailable in low-resource settings owing to challenges with cost, imported or donated equipment that is not tailored to meet country needs, limited human resource and heath infrastructure capacity, and lack of standardized regulatory protocols.

When equipment is available, it is often in a state of disrepair and nonfunctional for multiple reasons, including prohibitive costs for procuring replacement equipment and spare parts, inefficiencies in the supply chain, and equipment designs that are not tailored to meet local needs.

The Maker Pilot

This report documents the pilot's period of implementation and evaluates its effectiveness in achieving objectives, with a focused exploration of the pilot's use of human-centered design principles and techniques.

The Maker Movement for Maternal, Newborn and Child Health (Maker) was a pilot project implemented as part of the Innovations for MNCH (Innovations) initiative. Maker, implemented in Kenya, aimed to address gaps in the supply and availability of functional MNCH medical equipment at Kenyatta National Hospital (KNH) and lower-level facilities that are responsible for helping women deliver. Innovations was implemented by Concern Worldwide and John Snow, Inc. (JSI) was the global research partner.

The Maker "hub," comprising physicians, nurses, and biomedical engineers at KNH and a team of engineers at the University of Nairobi (UoN) Fab Lab, was formed to achieve this objective.

The Maker pilot forged strong partnerships between the physicians, nurses, and biomedical engineers at KNH and the engineers at the UoN Fab Lab to build new pieces of equipment or spare parts for select MNCH equipment and improve the supply, availability, reliability and affordability of the equipment.

The Maker Pilot

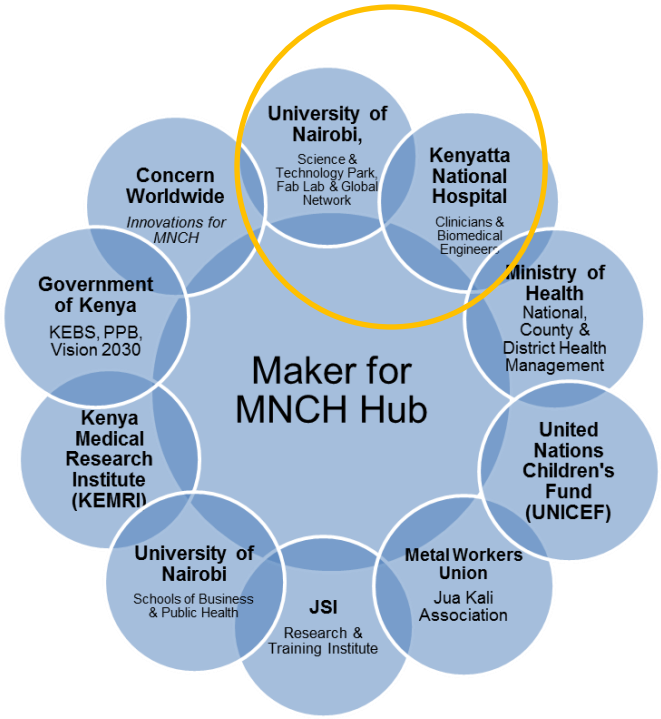


Figure 1: The Maker hub and its collaborators

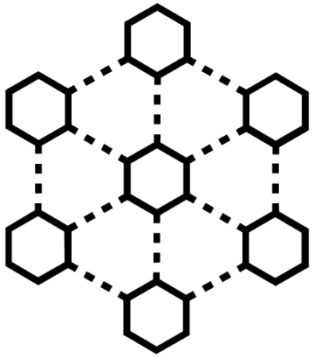
KNH is one of two public sector referral hospitals in the country. The core team of makers , the team that formed the hub in the Maker Movement for MNCH, were primarily representatives from KNH and the UoN Fab Lab. The core team liaised closely with multiple partners and collaborators as part of the implementation strategy.

Figure 1 illustrates the participants in the Maker network, or hub, with a yellow circle highlighting the core team members.

The KNH team included physicians and nurses from the newborn unit and labor and delivery wards and biomedical engineers who maintain and repair MNCH equipment. The UoN Fab Lab team was represented by engineers and public health and business experts.

The collaborators were a combination of government, donors, Ministry of Health, and artisans in the Kenyan crafts community who were kept apprised of project developments so that they could be part of the broader movement and ensure its sustainability.

Maker Definition of Success



Success for the Maker for MNCH pilot was described as follows:

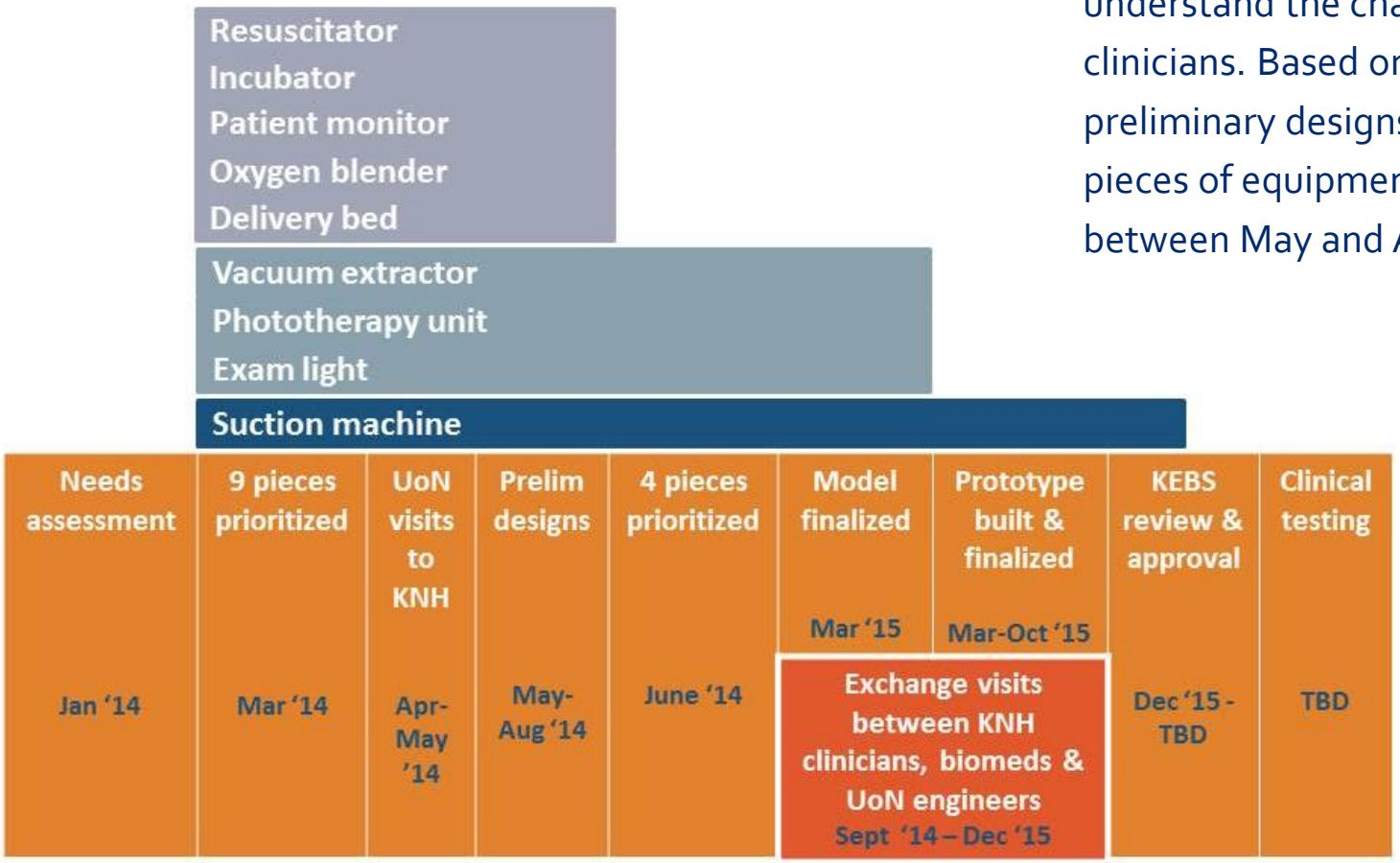
- Creation of the Maker hub and its effective functioning until the project ended (Q1 2016).
- Completion by the Maker hub of design and clinical testing of select pieces of equipment and spare parts in KNH.
- Completion by the Maker hub of its own sustainability plan before the project ended (Q1 2016).

The RME team conducted a needs assessment and two rounds of process documentation (described in detail later) to assess whether Maker was successful in its effort.

Maker Pilot Timeline

Figure 2 presents the Maker pilot timeline and details activities throughout the lifetime of the pilot, from January 2014 to the project end in December 2015.

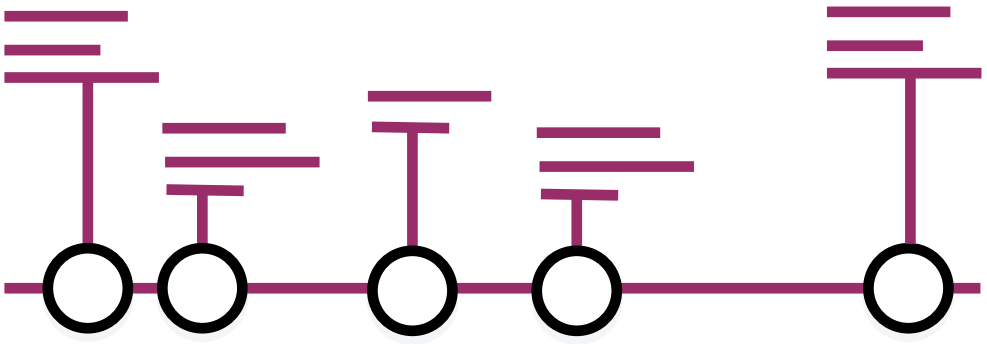
Figure 2. Maker pilot timeline



The needs assessment conducted in January 2014 informed the selection of nine pieces of equipment two months later. Subsequently, UoN engineers began visiting KNH to examine the medical equipment in the labor and delivery and newborn wards to understand the challenges faced by clinicians. Based on these visits, preliminary designs of some of the nine pieces of equipment were generated between May and August 2014.

Maker Pilot Timeline

In June 2014, the Maker hub prioritized four pieces of equipment (the vacuum extractor, phototherapy unit, examination light and suction machine) for design and development. Between September 2014 and December 2015, clinicians and biomedical and UoN engineers began a series of exchange visits at either KNH or Fab Lab to enable the engineers to understand the context within which the nurses worked and to enable the nurses to provide feedback on the designs produced by the engineers.



The computer designs were finalized in March 2015 and the suction machine moved on to the prototyping stage. The prototyping stage was when the engineers began to create physical models of the equipment. Suction machine prototypes were reviewed by clinicians, KNH biomedical engineers to see if the models represented their requests and needs, and the prototype was finalized in October 2015. In December 2015, the suction machine prototype was sent to the Kenya Bureau of Standards (KEBS) for review. The project ended before KEBS approval was received and clinical testing could begin.

The Use of Design Thinking in the Maker Pilot

Definition of Design Thinking

"Design thinking is a powerful approach to innovation that can be used to generate breakthrough ideas." (Brown, 2009)

A **form of inquiry** applied in the conceptual stages of a planning process and subsequent stages of program or product development.

Open-minded, iterative, human-centered and intended to result in new, innovative, groundbreaking solutions.

Used to help define problems/needs and solutions to address those needs.

In the context of global health, use of design thinking/human-centered design aims to create products and services that will improve lives by **tailoring the design of tools or interventions** to improve their uptake and sustained use.

Source: Innovations DT Protocol, 2014

Brown, Tim. 2009. Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation. 1 edition. HarperCollins e-books.

Components of Design Thinking

- Empathy
- Fit
- Buy-In
- Ownership
- Uptake

Source: Innovations DT Protocol, 2014

Components of Design Thinking Explained

Empathy: Designer empathy for end user/target population

Fit of problem definition with target population/user desires, needs, and barriers to MNCH care

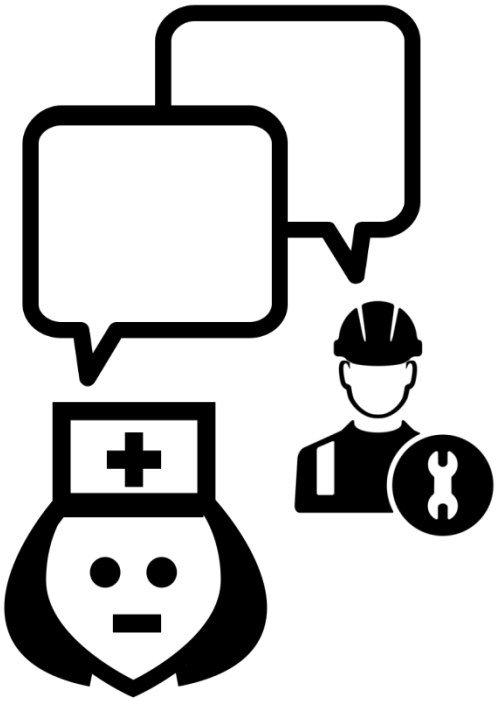
Fit of intervention with target population/user desires, needs, and barriers to MNCH care

User **buy-in** and sense of **ownership** of intervention

Pace of **uptake** of the intervention

Source: Innovations DT Protocol, 2014

The Application of Design Thinking in Maker



Like the other Innovations pilots, the Maker team drew on the principles and techniques of **design thinking** to guide the project. The guiding principles of design thinking were introduced to the Maker team over the course of a 3-hour workshop in March 2014 by the Thinkplace Foundation. Design thinking experts were not engaged during the implementation of the project. The Maker pilot decided not to engage the design thinking experts beyond the workshop and instead chose to adapt design thinking principles of empathy, fit, uptake, buy-in and ownership. Therefore the research propositions for design thinking in Maker examined these five components.

The Maker Research Propositions for Design Thinking

The research, monitoring and evaluation (RME) team explored the following research propositions regarding the application of design thinking in Maker.

Application of design thinking methods and tools within Maker will:

- **Create designer empathy** for end users. The designers were the UoN Fab Lab engineers, and the end users were KNH nurses, doctors and the KNH biomedical team.

- **Result in fit of problem definition with end user desires, needs, and barriers to MNCH care**. For Maker, this meant the engineers would understand the needs of the KNH clinicians and biomedical teams.
- **Result in fit of MNCH intervention with end user desires, needs, and barriers to MNCH care**. End users at KNH reported experience with and perceptions of the prototypes of equipment and the actual pieces of equipment during clinical testing.

The Maker Research Propositions for Design Thinking

Result in end user buy-in and sense of ownership of the MNCH intervention. Result evidenced in the perceptions of end users at KNH of the value of the Maker hub in mitigating the equipment gap at KNH and their willingness to recommend the hub idea as a solution to solving other similar challenges in the health and technology sector.

Result in ownership of the Maker pilot and its outcomes. Result evidenced in the perceived/expressed stake of end users at KNH in the success of Maker, in the value of the hub at solving other similar challenges in the health and technology sector, and in thoughts on the long-term sustainability of the hub.

Demonstrate an increased pace of uptake within Maker. Uptake seen in the acceptance of end users at KNH of the equipment when prototyped and clinically tested (pace of uptake over time, sustained change over time) and hub members' acceptance of the concept of the Maker hub and their interest and stake in keeping it sustainable.

Research, Monitoring and Evaluation Approach

Maker Hypotheses

Definition of sustainability for Maker: the identification of sources of funding in addition to or apart from the current funding through Concern Worldwide and the Bill and Melinda Gates Foundation under the current contract.

The Maker evaluation examined the following hypotheses:

1. Kenya-based physicians, nurses and biomedical engineers from KNH in collaboration with UoN Fab Lab engineers (i.e., key members of the Maker hub) **can design and build** select equipment and spare parts for labor and delivery and newborn care locally.

2. The Maker hub model can address challenges with the availability of equipment for MNCH service delivery through creative collaboration, leadership, and governance and define processes for management and funding and mechanisms for problem solving to ensure its long-term **sustainability.**

Research Questions

The RME team collaborated with the program team to identify the critical questions that would help examine the process by which the Maker hub achieved its objectives.

Maker hub questions:

Did the Maker hub design and build select equipment and spare parts for labor and delivery and newborn care?

What systems did the Maker hub establish to facilitate communication, leadership and management to achieve its objectives?

Can the hub sustain itself beyond the Maker project?

Design thinking questions:

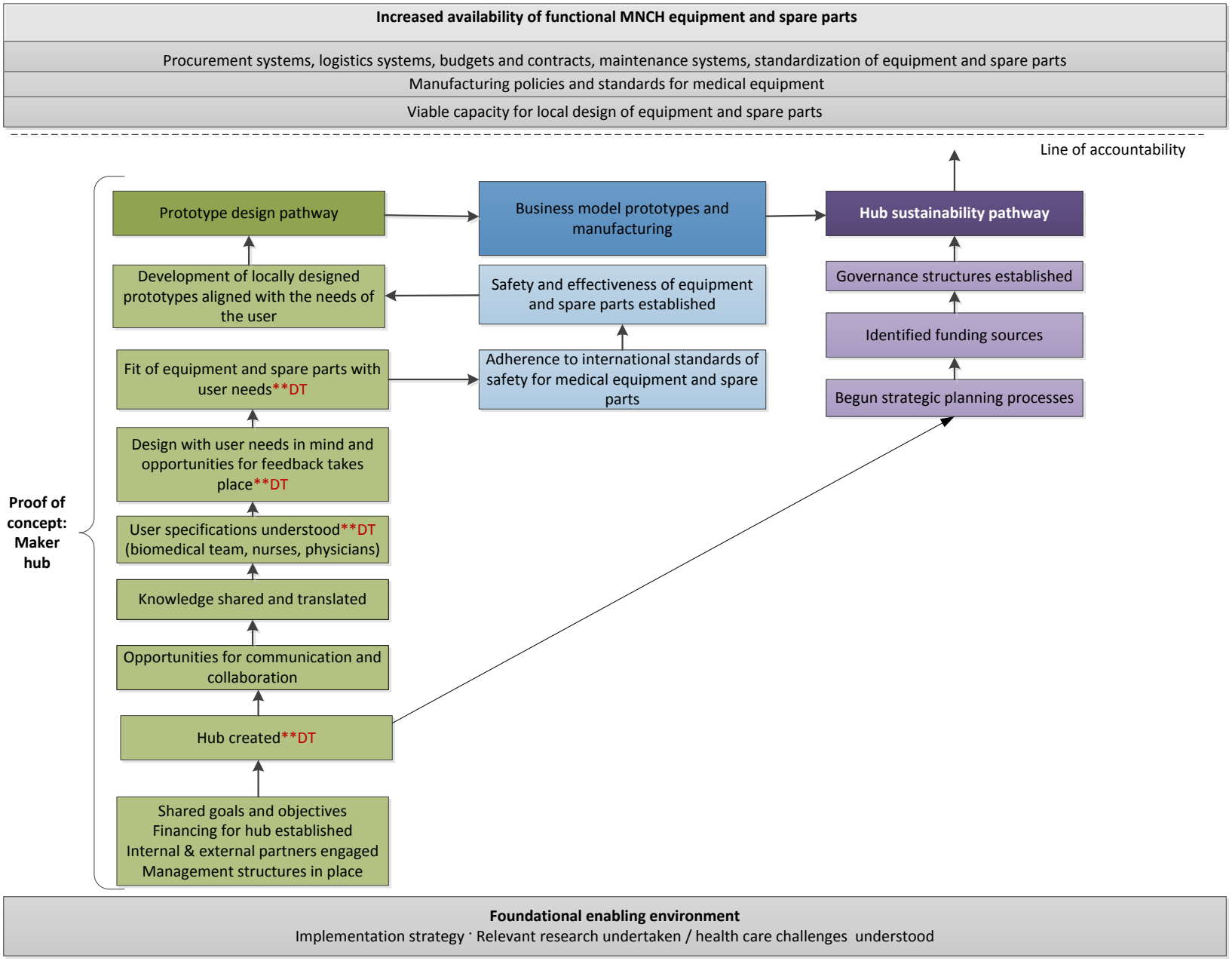
How did the Maker hub incorporate the principles of design thinking into the Maker hub?

Which components of design thinking did they use?

How effective was the use of design thinking for the Maker hub?

Maker Theory of Change (TOC)

Figure 3. Maker Pilot Theory of Change



**DT indicates the specific activities within Maker where design thinking was applied.

Maker Theory of Change (TOC)

While the pathways in the TOC appear linear, many activities were implemented concurrently. The pathways intersect with each other to illustrate activity interdependence and their collective influence on Maker outcomes.

The Maker TOC depicts the pathway to the direct outcome of the project (development of locally designed prototypes of equipment and spare parts) that meet the needs of the end users (biomedical engineers, nurses and doctors) at KNH. The TOC figure is split into four sections: the enabling environment, the proof of concept below the line of accountability, the outcomes above the line of accountability, and ultimate long-term goal of Maker.

The creation of the hub is a key event because Maker was intentionally designed to bring together local experts from various disciplines with the intention of optimizing their capability and understanding of the local context to design prototypes that responded to the resource-constrained environment within which KNH and its sister facilities operate.

Maker Theory of Change (TOC)

- Prototype Design Pathway
- The Hub Sustainability Pathway

The prototype design pathway identifies preconditions that are required for the Maker pilot to achieve its intermediate outcome of developing prototypes. These preconditions include mechanisms for communication, knowledge sharing, and translation and the iterative process of soliciting user input to ensure fit of prototype with user specifications. In addition to the design, the Maker hub also incorporated tests of safety and effectiveness to ensure that the prototypes met established standards as determined by relevant global and local agencies.

The pathway to hub sustainability is influenced by preconditions like planning by the hub through business modeling to identify long-term markets for the equipment, the hub's internal governance and leadership structure, and the systems the hub is putting in place financially and organizationally to ensure that the hub can survive financially after this current funding cycle is over.

RME Activity Timeline

RME activities included a needs assessment, two rounds of process documentation (PD) and ongoing program monitoring during the life cycle of the project between January 2014 and February 2016.

PD was a systematic approach to track emerging barriers and challenges during project implementation. These data were used to enable the hub to reflect on its progress against stated goals and course-correct as needed. These data were collected through interviews and were qualitative.

Program monitoring was a quantitative approach to tracking hub milestones like numbers of exchange visits and partners meetings. These data were used to ensure that the hub met regularly enough and kept their communication channels open to facilitate the exchange of knowledge between nurses and engineers.

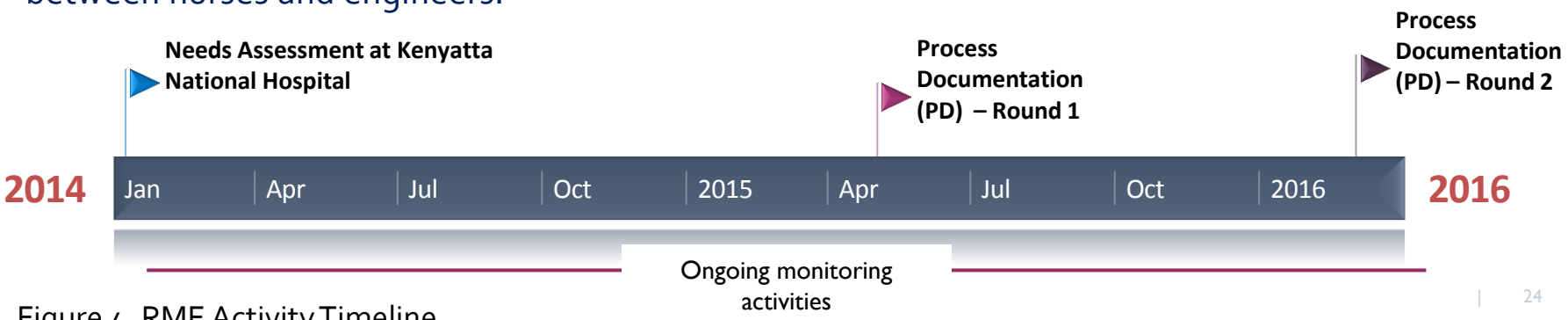


Figure 4. RME Activity Timeline

RME Data Collection

There were three rounds of data collection.

The first round was the needs assessment, the second round was PD in May 2015, and the last round was PD in March 2016.

For the needs assessment primary data were collected through key informant interviews at KNH with clinicians in the labor and delivery and newborn unit. Secondary data were collected from the hospital on maternal and neonatal admissions and maternal and neonatal mortality rates by cause of death between 2013 and 2014.

For Maker, the case study of design thinking was drawn from the PD, since all design thinking activities apart from the ideation pertain to the approach taken to develop equipment prototypes.

For PD, the respondents for all the key informant interviews were the KNH clinicians and biomedical teams, the UoN Fab Lab engineers, the Maker program manager, and the Principal Investigators (PIs).

RME Approach – Needs Assessment

Needs assessment findings:
Equipment unavailable due to repeated breakdown because of reported overuse, difficulty in procuring spare parts or incomplete maintenance.

1. *Patient monitor*
2. *Resuscitation table*
3. *Suction machine*
4. *Drip stand*
5. *Table/bed/trolley*
6. *Incubator*
7. *Vacuum extractor*
8. *Examination light*

Objectives of the January 2014 needs assessment:

1. Describe MNCH equipment procurement and maintenance practices in the labor and delivery and newborn units at KNH

2. Identify the causes of MNCH equipment shortage in labor and delivery and the newborn unit at KNH

3. Provide data on equipment availability and functionality within KNH to facilitate decision making on the select pieces of equipment the Maker hub will build

The results of the needs assessment were used to develop a shortlist of select MNCH equipment to be created by the Maker hub.

RME Approach – Needs Assessment Methods and Findings

Methods: 30 key informant interviews, 12 clinical observations, collection of hospital statistics.

Findings: Multiple pieces of equipment were not available in sufficient numbers and are detailed in the conclusions of the needs assessment. The equipment challenges at KNH were aggravated by the high patient volume and high MNCH mortality at KNH since it is a referral facility.

Underlying factors that drove equipment unavailability and functionality were budget constraints, delays during the contract execution phase of the procurement process, insufficient human resource capacity, inadequate equipment inventory systems, lack of standardization of equipment, and limited inclusion of user specifications during procurement and infrastructure.

RME Approach – Process Documentation (PD)

The objectives of PD were to :

1. *Document the emergence of preconditions and intermediate and direct outcomes of the Maker hub*
2. *Explore the underlying drivers of change that contributed to the pilot outcomes*
3. *Assess the integrity of the project design*

The overall objective of PD was to closely examine the proposed change pathways in the theory of change.

The RME team wanted to describe the process by which the Maker hub collaborated creatively, organizationally and operationally to plan and implement their goal of designing prototypes for the labor and delivery and neonate wards at KNH.

The learning from the PD was meant to inform implementation strategies through the continuous review of project operations and emerging challenges that would influence project outcomes.

Findings

Process Documentation (PD) Round 1

PD Round 1 primarily focused on the systems established to help the hub operate, the initial stages of hub operations, and critical decisions made by the hub to achieve objectives. The findings reflected the results of inquiry on these themes.

PD data collection for Round 1 was conducted in May 2015, 13 months after project initiation.

The JSI team held 15 key informant interviews with UoN Fab Lab students, staff, and current and former PIs; KNH nurses, midwives, and PIs; the Concern program manager as well as the Kenya Bureau of Standards (KEBS).

In addition to the key informant interviews, the team also took observational notes at meetings and conducted document reviews.

Interviews were transcribed and stored in NVivo for coding. Thematic coding was undertaken.

PD Round 1 was conducted by JSI and Ipsos Kenya.

Process Documentation (PD) Round 1

PD findings revealed that the team had established strong **leadership** through visionary leaders at KNH and UoN Fab Lab. The **management** by Concern was greatly appreciated because the Concern program manager played a critical role in facilitating team interactions, managing work plans and schedules, and keeping the project on track to achieve its **milestones**.

Multiple mechanisms for communication were established to enable rapid and effective interaction within the team. Examples included the Maker portal; partner meetings between the clinicians, the engineers and the Concern program manager; and exchange visits. The portal was meant to facilitate coordinating schedules and agendas and ensuring timely progress on milestones.

The partner **meetings** were run smoothly, and team members expressed satisfaction with the opportunities they were given to express their opinions and share their experience with using equipment at KNH.

The findings from the needs assessment were used to **prioritize** the list of equipment to be designed and built by the Maker hub.

Process Documentation (PD) Round 1

Achievements:

- *Effective and regular exchange visits between nurses and engineers*
- *Organization of the hub into teams*

The exchange visits between the nurses and engineers were reported to be effective because they allowed the nurses to describe their frustrations with the current equipment challenges and demonstrate how they used equipment. These demonstrations gave the engineers much needed insights into the problems with the design of the current equipment and what they lacked in meeting the needs of the nurses.

The Maker hub had organized itself into **teams** in order to work on the prototypes for various pieces of equipment. Each team comprised a nurse, a member of the biomedical team from KNH, engineers and professors from UoN Fab Lab, and the PIs, who provided overall oversight and direction. Due to the many pieces of equipment that were being designed, often the teams worked across multiple prototypes, but they ensured they had representation from all the above-mentioned skill areas.

Process Documentation (PD) Round 1

Achievements:

- *Biomedical engineer training on calibration*
- *Approval of the clinical testing protocol*
- *Hub's commitment to the project*

Another achievement of the Maker project by May 2015 was the **training of the engineers** on the KNH biomedical team to enable them to better calibrate equipment. This was considered a significant achievement because it was hypothesized that such skill building would result in a sustainable transfer of skills that would expand the range of repairs and maintenance tasks that could be performed by the KNH biomedical team. The KNH biomedical team was sent to Everett, Washington, in the United States for training.

The **clinical testing protocol was approved**, which meant that as soon as the prototypes had passed all quality assurance checks, they would be clinically tested at KNH.

Overall the Maker hub expressed **strong commitment** to the project, reiterated their enthusiasm for its objectives, and shared that the team was increasingly trusting each others' skills and expertise.

Process Documentation (PD) Round 1

Challenges:

- *Availability/scheduling*
- *Access to the Maker portal*
- *Translation of expertise*

Challenges mentioned by respondents included difficulty in scheduling partner meetings due to the challenging task of **coordinating multiple schedules,** as well the lack of use of the **Maker portal,** which was meant to serve as a work planning system for the entire Maker hub. The hub planned to store important documents on the portal, including engineers' design documents based on their interactions with the nurses; save and update work plans; and enable the hub to track progress against milestones.

However, the server that was used to host the Maker portal was on the UoN server, which restricted access due to intellectual property (IP) issues.

Hub members also acknowledged that it was **time-consuming to translate expertise and experience** between nurses and the engineers and suggested setting aside more realistic timelines for the exchange visits to be less rushed and more focused and in depth.

Hub members recognized the need to plan for financial **sustainability** but had not yet begun to work on it.

Process Documentation (PD) Round 1

Challenges:

- *Procurement delays*
- *Student turnover*
- *IP considerations*
- *Tight timelines*

The hub had also begun to experience **procurement delays** due to bureaucracy at the university. Public procurement is time-consuming, and the hub expressed concern about achieving its objectives in a timely manner due to delays in acquiring the equipment needed to create the prototypes.

Within UoN Fab Lab the engineers were primarily university **students** with one project manager who was an employee of the university and was responsible for the day to day operations of the Fab Lab.

Student schedules, which included exams and summer vacations, interfered with their ability to work consistently on Maker, leading to disruptions in the work program and delays. Students had also expressed interest in retaining **IP rights** to the designs they developed, and resolving this also held up progress.

Given the challenges listed above, the Maker hub suggested that it internally **review timelines and establish a realistic time frame** for the project with a revised list of priorities.

Process Documentation (PD) Round 2

PD Round 2 primarily focused on examining progress on the Maker pilot since PD Round 1 in May 2015 and the hub's use of the recommendations from PD Round 1.

PD data collection for Round 2 was conducted in March 2016.

It sought to study the process by which the remaining prototypes were designed, the status of the safety and effectiveness tests by KEBS, the preparation for the clinical testing, modeling scenarios to examine the viability of the hub, and systems established to ensure the sustainability of the hub.

The JSI team held **12 key informant interviews** with UoN Fab Lab students, staff, and current and former PIs; KNH nurses, midwives and PIs; and the Concern program manager.

The team also conducted observations and undertook document reviews.

Interviews were transcribed and stored in NVivo for coding. Thematic coding was undertaken.

PD Round 2 was done by JSI.

Process Documentation (PD) Round 2

Achievements:

- *Strong leadership by PIs*
- *Working prototype of suction machine*
- *Designs for three pieces of equipment*
- *Maker space at the Science Park*

The **strong leadership** by the PIs and Concern was recognized in PD Round 2. Partner meetings and exchange visits continued between May 2015 and March 2016 but were less frequent because the emphasis was on procuring and building equipment.

Most of the feedback from the nurses had been received, and for the final phase of the project it was decided that the teams would focus primarily on building the prototypes to enable clinical testing before the project end date.

Based on recommendations from PD 1, the hub decided to focus on four pieces of equipment instead of the original nine.

The Maker hub produced a complete **working prototype** of the suction machine, and **designs for three pieces of equipment** were completed: examination light, vacuum extractor, and phototherapy machine.

The **Maker space at the Science Park** was also a major accomplishment of the hub because it would provide critical infrastructure to launch innovative ideas within Kenya by leveraging the capacity for technology and innovation domestically.

Process Documentation (PD) Round 2

Achievements:

- *Same team setup as during PD 1*
- *Hub decides to focus on equipment instead of spare parts*
- *Calibration center at KNH*

The hub **maintained the same team** setup as during PD 1 for the design of the remaining three prototypes. Each team comprised a nurse, a member of the biomedical team from KNH, engineers and professors from UoN Fab Lab, and the PIs, who provided overall oversight and direction.

The hub decided **to focus only on designing and creating prototypes for equipment** and not spare parts, as in the original work plan, due to time constraints.

The **calibration center** at KNH was completed and in use. It had expanded capability in terms of calibration equipment as well as skills of KNH biomedical staff, who felt better equipped to be able to effectively address equipment challenges within KNH.

Process Documentation (PD) Round 2

Challenges:

- *Communication challenges within the hub*
- *Maker portal out of use*
- *Project ran out of time*
- *Additional procurement delays*
- *Student retention*

Nurses reported feeling out of the loop due to time lags between meetings. Nurses working on pieces of equipment other than the suction machine were unsure of the status of the designs and plans to move forward to the prototyping stage.

The Maker portal was not used anymore due to the IP issues identified in PD 1.

While the clinical testing protocol had been approved before May 2015, the clinical testing of equipment could not be undertaken because the **project ran out of time.** One of the main reasons for the delay was the **procurement-related challenges** that the project had to contend with over its life cycle. Some pieces were acquired by the funder, but major pieces of equipment were not acquired in time. The challenges with **student retention** continued between PD 1 and 2.

Due to delays in procurement which affected the ability of the hub to complete its prototypes, the hub expressed disappointment at not meeting its objective of clinically testing the equipment at KNH.

Process Documentation (PD) Round 2: Sustainability

Challenges:

- *Efforts underway to secure resources*
- *Roles of the existing hub members unclear in the new partnership currently being negotiated*

The hub remained enthused about the idea of sustaining itself, and UoN Fab Lab as well as KNH expressed interest in continuing on with other equipment, and the Science Park was seen as a step in the right direction. However, the hub did not have a definite plan for its financial sustainability beyond Maker by the time it ended in Q1 2016.

Maker continues to explore new partnership opportunities with donors and the private sector. Those conversations are in progress.

Also unclear were the roles KNH and UoN Fab Lab would play in new partnerships that were being pursued.

Design Thinking

The Application of Design Thinking in Maker: Designer Empathy

Design Thinking in Maker during PD Rounds 1 and 2 focused on **generating designer empathy** through constant iterative feedback between KNH nurses and doctors as well as the KNH biomedical team and Fab Lab engineers. The exchange visits were set up primarily for this purpose. During each visit the nurses provided their perspectives on current challenges with the equipment they used as well as their preferences for shape, size, color and material of the equipment.

The nurses demonstrated their use of the equipment and provided feedback to the engineers on multiple drafts of designs. This **iterative process** was deemed successful by the nurses and the engineers. The nurses **felt heard** and the **engineers described a deeper understanding** of the context within which nurses operated equipment.

Reflections:

Generating designer empathy–the engineer perspective

UoN Fab Lab designer:

"It was pretty interesting… because they actually explained to us, apart from not having the right number of equipment, also the way it was designed, they wanted a lot of changes, like the nurse would tell us the **handle was too low**, bring the handle up, the gauge is too small so make it bigger and **make the controls a lot simpler**…"

"Let's say it **gave us a broader perception of engineering** as a whole.. the first thing that really opened my eyes was the HCD, I have never really thought of that because as an engineer when I am designing something it's based on what I like, what I want. **Then it actually hit me, no it's what they want, what they need,** so it actually made me realize that design process is actually based on the needs, not just my own innovation…."

UoN Fab Lab designer

Reflections:

Generating designer empathy–the nurse perspective

"What we didn't do is get the equipment away from the ward, we made sure they came to the ward; we didn't put a room somewhere for them to just tell them because they wouldn't have gotten the concept and why it's important."

KNH Nurse

"I can actually say the **engineers have become medics** because when they came here, they learned so fast. It was not very hard to interact with them because they easily got the concept and carried it on."

KNH Nurse

The Application of Design Thinking in Maker: "Fit"

"Fit," as described in the hypothesis, encompasses the following: Result in fit of problem definition with end user desires, needs, and barriers to MNCH care. For Maker, this meant the engineers would understand the needs of the KNH clinicians and biomedical teams.

Result in fit of MNCH intervention with end user desires, needs, and barriers to MNCH care, through reports from end users at KNH of experience with and perceptions of the prototypes of equipment and the actual pieces of equipment during clinical testing.

It was a challenge to ascertain "fit" for all the pieces of equipment the hub wanted to build because the hub ran out of time before it could complete the remaining pieces of equipment. The RME plan included a usability test during clinical testing to ascertain true fit based on use of the equipment by the clinicians.

While we were unable to test the actual equipment prototypes for fit, we inquired after the nurses' perspectives on the designs of various pieces of equipment as they reviewed them. Nurses explained that they observed in each new iteration of design their feedback had been included and expressed excitement in seeing and using the actual products.

The Application of Design Thinking in Maker: "Fit"

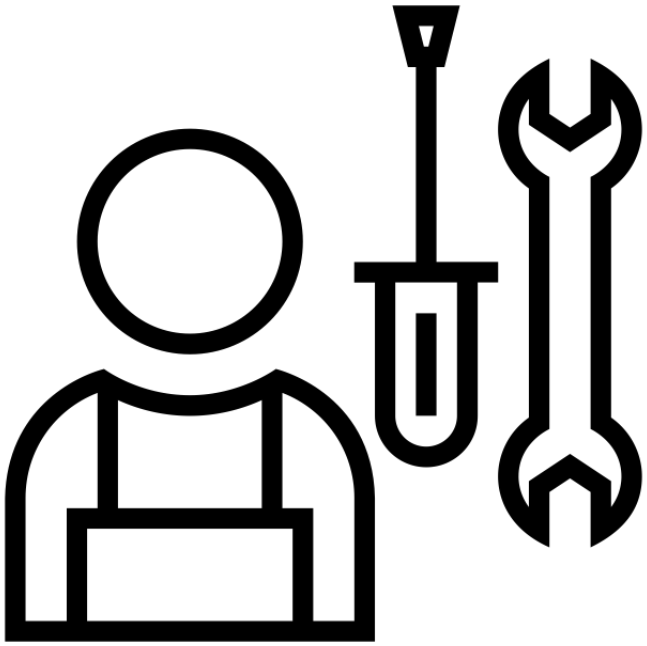
The suction machine (Image 1 to the right) is an example of the result of the iterative feedback loops between the nurses and engineers. The suction machine prototype incorporated the following feedback from the nurses:

- White color to make it easier to spot dirt
- A filter that was easy to clean
- Movable castors so the machine could be wheeled around the hospital easily
- Hardy construction to withstand the uneven hospital floor surface
- Suction bottles made of material that would not break easily
- Suction bottles in holders to prevent them from falling and breaking
- Height of handle to match average height of nurses.

Image 1: Suction machine design

Reflections:

Design thinking and "fit"-- the engineer perspective



"When you are making these designs , getting input from the hospital is quite important, because we in engineering don't use medical stuff, so we could design something that doesn't work well in a hospital environment."

"The success of the first equipment we made--the suction machine--was highly dependent on their input."

Reflections:

Design thinking and "fit"-- the nurse perspective

"There was a lot of cooperation. They would listen and try to modify according to our specifications. They did almost exactly what we anticipated or wanted."

"The last one that they actually showed us was what we expected…" – KNH nurse as she referred to a design of the vacuum extractor

The Application of Design Thinking in Maker: Buy-In/ Ownership/Uptake

We could not test buy in/ ownership or uptake because the suction machine had not been used at KNH as yet because it had not been clinically tested.

Ownership was considered an important byproduct of empathy and fit but could not be tested because equipment had to be used first.

Nurses expressed excitement at the suction machine as well as some disappointment that more prototypes had not been completed as yet.

Conclusions

Conclusions

Recap of the Maker hypothesis and reflections based on findings from PD Rounds 1 and 2

Maker sought to test the hypotheses that:

- Kenya-based physicians, nurses and biomedical engineers from KNH in collaboration with UoN Fab Lab engineers (i.e., the Maker hub) can design and build select equipment and spare parts for labor and delivery and newborn care locally.

- The Maker hub model is a viable model that can address challenges in the social sector through creative collaboration, leadership, and governance processes for management and funding and mechanisms for problem solving to ensure its long-term sustainability.

Based on the extensive data collection and analysis during the life cycle of the project, we can conclude that:

1. The Maker hub was **created and functioned** as envisioned.

2. The idea of engaging clinicians and engineers to design prototypes has been **successfully demonstrated.**

Conclusions

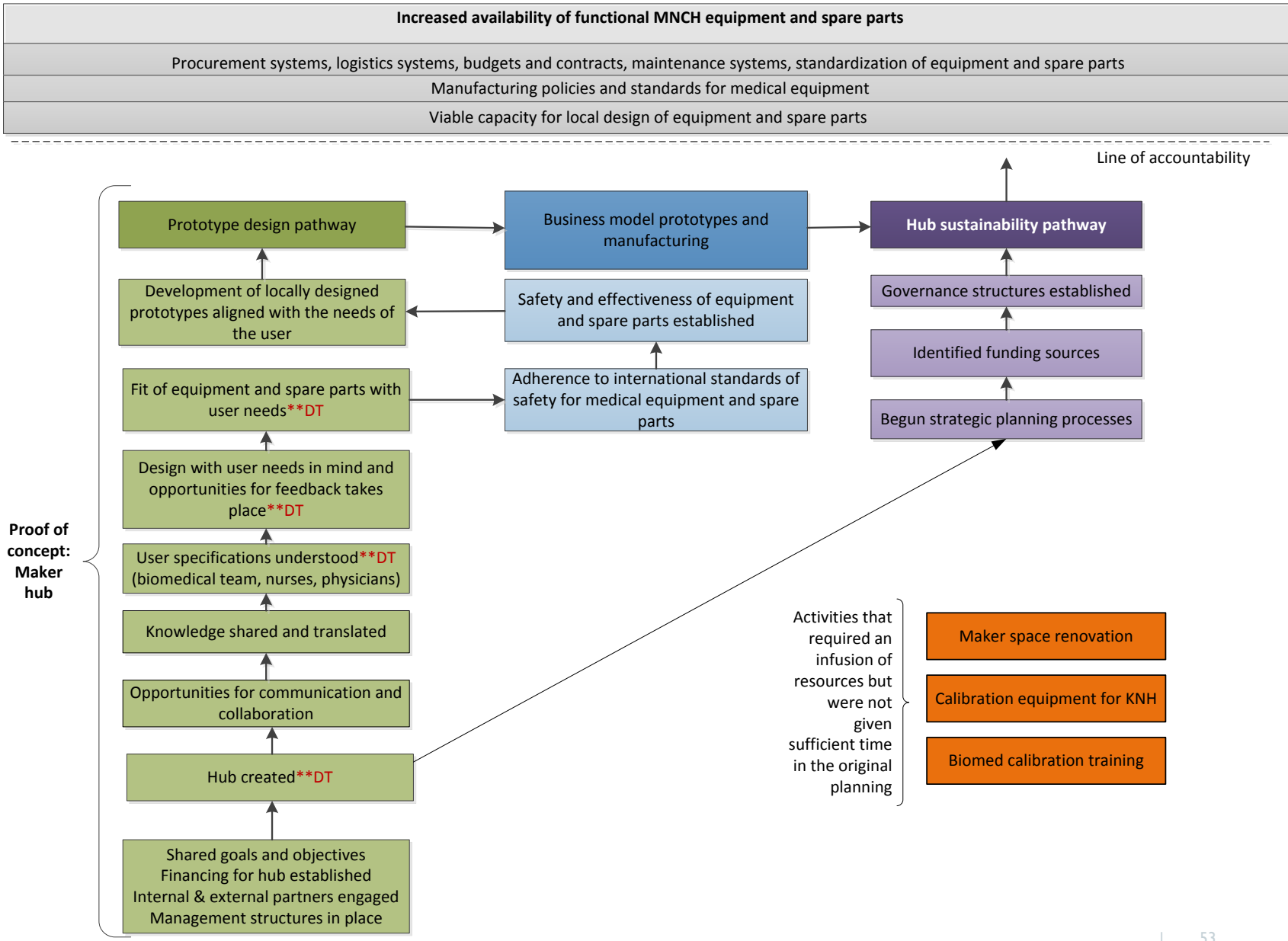
- *Financial sustainability*
- *Clinical testing*
- *Theory of change pathway*
- *Resource planning*

However, the hub did not establish its financial sustainability and did not complete clinical testing of any piece of equipment. It is important for hubs that want to sustain themselves beyond short-term funding cycles to strategize about diversifying their funding sources early on in the project. With additional resources the idea of a hub that engages clinicians and engineers to co-create and collaborate on design and development has potential.

When reviewing the theory of change at the end of the project, it became clear that the hub underestimated what it would take to achieve its objectives. Figure 5 is the revised theory of change with the orange boxes flagging the key activities mentioned here. The main gap was in **operationalizing** its vision due to challenges with continuity and availability of engineering students and lack of local high-quality material and equipment for fabrication, which necessitated international procurement, which came with its own set of challenges. The Maker space renovation, buying calibration equipment for KNH, and the calibration training for the biomedical teams from KNH required more resources and time than initially anticipated by the hub.

Maker Theory of Change (TOC)

Figure 3. Maker Pilot Theory of Change



**DT indicates the specific activities within Maker where design thinking was applied.

Conclusions

- *Coordination and management capacity*
- *Contextual factors like policies*

A hub such as the one formed by the Maker project requires excellent coordination and management expertise in addition to the technical expertise that is brought by the engineers and the clinicians. Coordinating schedules and agendas and ensuring timely progress on milestones is a major and critical role that needs to be factored in when such hubs are envisioned. While the leadership within the hub was lauded during the entire project, there was clear need for deputy-level management and administrative capacity to problem-solve and run the project on a daily basis.

When the Maker project began, the Government of Kenya did not have policies on medical devices and MNCH, so the project spent considerable time supporting the government in establishing such policies, which are the critical backbone of innovation. While this was a tremendous responsibility that the project undertook willingly and successfully, it diverted attention and resources from the objectives the hub had set for itself.

Conclusions

Design thinking

The design thinking component of Maker was limited to the iterative feedback loop between nurses and engineers. This setup was appreciated by both the nurses and engineers. The nurses felt like their needs were heard, and they approved of the suction machine, noting that it took into account their input. The engineers saw this as an opportunity to apply their theoretical foundations to solving real-world problems. The value added of soliciting clinical input was that the nurses could make solutions context relevant.

If the Maker hub continues with its clinical testing, the recommendation is that it complements clinical testing with user input surveys to assess how closely the new equipment meets the needs of the nurses. There is a lot to learn from this process, and the findings from such studies will be highly applicable to the design of innovative medical devices for the purposes of solving global health challenges of access and timely use of medical equipment.

Additional Resources

For additional information about the Maker pilot and evaluation, we invite you to review the resources listed to the right.

"Inception Plan: Maker Movement for Maternal, Newborn and Child Health, Kenya." Unpublished, 2013.

"Maker Movement for MNCH: Needs Assessment." Innovations for Maternal, Newborn and Child Health. July 2014. http://innovationsformnch.org/-uploads/resources/pdfs/Maker_NA.pdf

"Maker Movement for Maternal, Newborn and Child Health: Saving Lives through Locally Designed Equipment." Innovations for Maternal, Newborn and Child Health, 2013. http://innovationsformnch.org/uploads/publications/2013_Project_Brief_Maker.pdf.

"The Maker Movement for Maternal Newborn & Child Health: End of project findings." Unpublished, 2016.

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