Building A Low Cost Obstetric Equipment and Supplies Prediction System Using Modern Mobile Web Technologies

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ABSTRACT The majority of maternal mortalities are due to avoidable delays in medical intervention. Knowing as precisely as possible what a health centre will need to cater to pregnant mothers can greatly improve the ease and speed of providing medical care to pregnant women at health centres. We propose leveraging recent developments brought on by increasing mobile Internet usage to develop low cost solutions aimed at reducing delays in the delivery of medical care. To demonstrate the applicability and potential benefits of such technologies we developed an application built on recent "progressive" web techniques. The application is capable of intelligently predicting the number of pregnant women likely to visit a health in any given month, as well as the medical supplies and equipment that the facility will need to properly attend to them. Predictions will help facilities better plan resource provisioning in order to provide timely medical treatment. Predictions can also improve the currently inadequate referral capabilities in many local health centres. Finally, we demonstrate how such a project can take advantage of the numerous currently available cloud computing solutions to lower the costs of deployment.

1. Introduction

1.1 Problem

Uganda has the 37th highest maternal mortality rate in the world [1]. According to the 2016 Uganda Demographic Health survey [2], maternal mortality in Uganda is caused by:

- Pre-existing medical conditions accelerated by pregnancy (28%)
- Bleeding (27%)
- Eclampsia (14%)
- Sepsis (11%)
- Obstructed labour (9%)
- Unsafe abortion (8%)
- Blood clots (3%)

Maternal deaths resulting from the above conditions can be reduced or prevented through timely medical treatment [3] [4]. Some of the factors causing delayed medical intervention at health facilities are inadequacy of referral systems and shortage of supplies and equipment [3].

1.2 e-Health programmes in Uganda

A 2017 review of 48 e-Health programmes in Uganda [5] shows that the country recognizes the potential benefits of e-Health in improving health care in Uganda. This paper focuses on how the technical implementation of such programmes can be improved with modern technologies, most of which did not exist or were not used when these 48 programmes were trailed or implemented. To demonstrate this, we propose a solution concept in the maternal health field and proceed to implement it using said technologies.

1.3 Progressive Web Applications

Progressive Web Applications (PWA) are mobile applications delivered through the web [6]. PWAs function like native mobile apps but do not need to be downloaded from an app store.

The main attraction of PWAs for the project is the service worker component. The service worker is a key component of PWA architecture that sits between the application and the Internet allowing it to work offline or on low quality networks as can be the case in rural health centres in countries like Uganda. PWAs can use significantly less data than traditional native applications [7], load instantly and are always up to date [8]. Figures 1 and 2 shows the difference in view on a tablet and a computer.

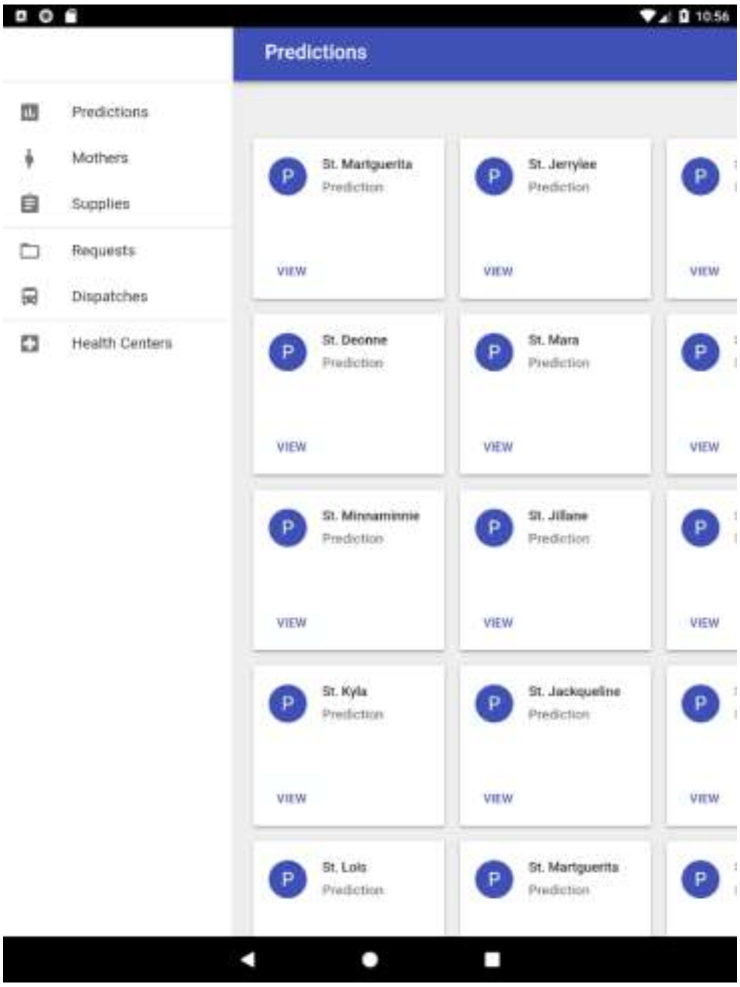

Figure 1: The PWA running on an Android tablet

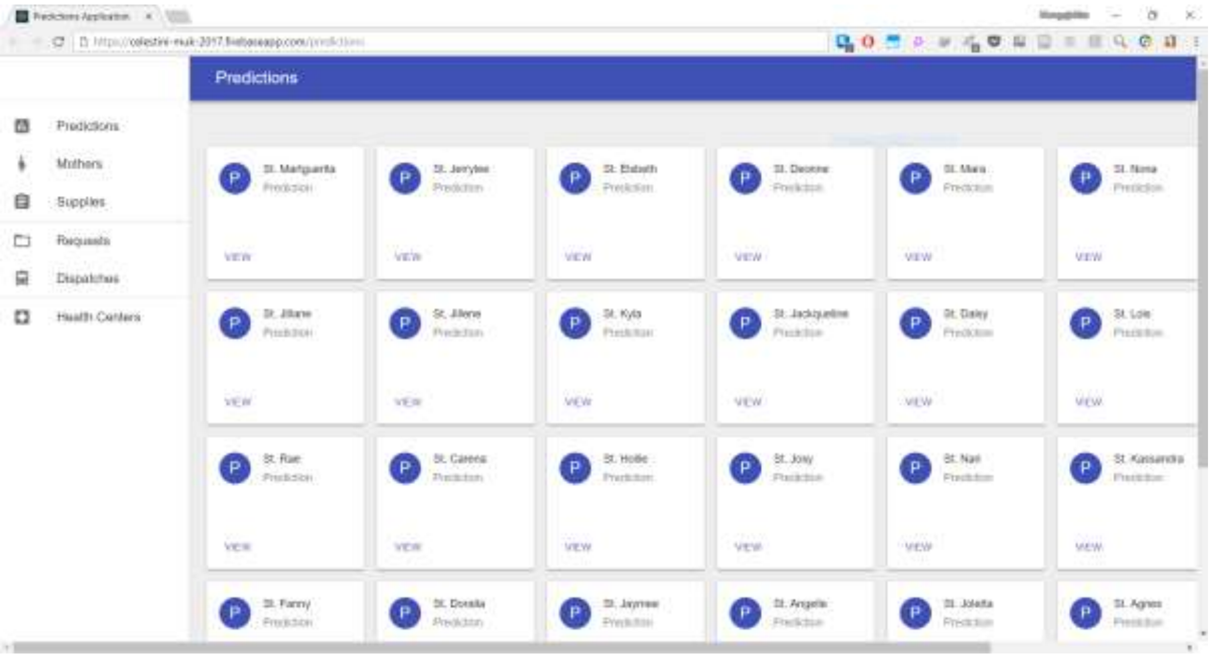

Figure 2: The PWA running in a web browser on a computer

1.4 Leveraging low cost application development and deployment solutions

Internet usage has been increasing globally and in 2018, the number of global Internet users stood at 4.1 billion [9]. Over time, this trend has led to innovations around the technologies that are used to build, deploy and run the websites and applications that bring users to the Internet.

One key development is cloud computing [10] which has significantly reduced the infrastructure costs of running web applications [11] [12].

The project's front-end makes use of the *React JavaScript framework* [13]. The framework simplifies development of relatively complex user interfaces [14]. *React* is paired with *Material-UI* [15], which is a collection of *React* components that implement Google's Material Design [16]. This combination permitted focus on our unique solution instead of spending time building basic user interface components.

The solution's backend is entirely made up of microservices. The microservice software architectural style structures an application as a collection of loosely coupled services, which implement specific capabilities or routines [17]. These microservices are platform agnostic: They have been built and deployed on a Google service called *Firebase*, specifically its cloud functions service [18] but could have just as easily used Amazon Web Service (AWS) *Lambda* [19], Microsoft's Azure functions [20], or a custom deployment using a docker cluster [21] [22].

Currently all the main cloud computing providers have free usage tiers [23] [24] [25] which can be used to drive infrastructure costs during development to nearly zero. Throughout the development of our solution we stayed within the *Firebase* free tier [26] without having to constrain our software development in anyway.

The microservice architecture and cloud deployment path were both chosen for their numerous benefits such as easy scaling, ease of maintenance, robustness and fault-tolerance [27] [28] among other benefits. The application can be rolled out to all the 3000 plus health centres in Uganda and still run smoothly.

The microservice architecture can also significantly reduce deployment costs [29] [12]. This, coupled with the already low cost of cloud computing, goes a long way towards reducing the overall monetary cost of web-application based interventions in economic development challenges.

Firebase also provided us with an easy to integrate authentication framework [30] and a scalable NoSQL database [31] (Figure 3).

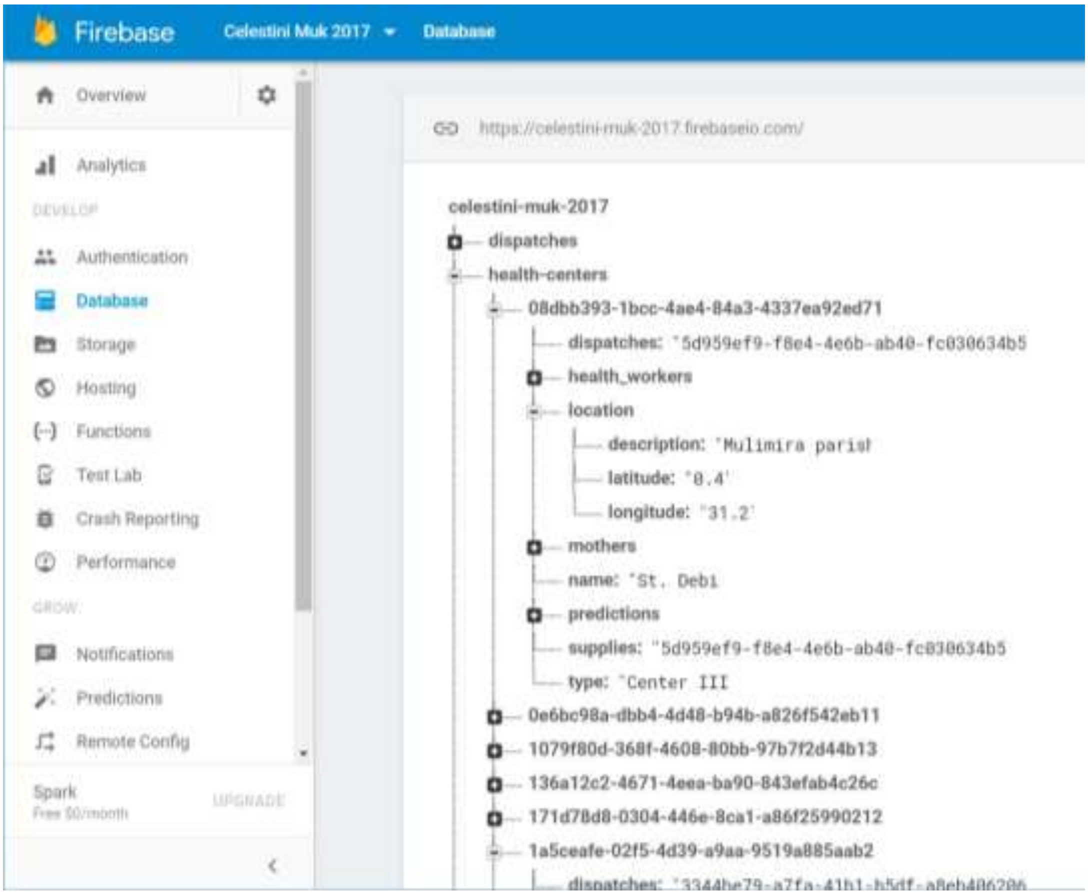

Figure 3: Firebase dashboard showing mock data in our database

2. Building a Solution Using Progressive Web Applications (PWA)

The solution is a web application capable of predicting the medical supplies and equipment that a health facility will need in a month. These predictions can be used to reduce delays at health centres when used to better plan and deploy obstetric equipment and supplies. Predictions can also be used to inform referral decisions.

Broadly, the solution works in the following ways:

1. Health workers register pregnant women on to the system.
2. The system then takes the information on all registered mothers and generates a prediction of medical supplies that the health centre will need in order to properly attend to mothers during antenatal visits or when they are giving birth.
3. The prediction for a given month is shown side by side with information on a health centres current supplies. The current supply units are highlighted in green or red depending on whether or not they are sufficient to handle the mothers expected to visit the health centre in any given month.
4. The list of predictions is accessible by the suppliers. Suppliers in this case refers to both the internal and external suppliers of the health centre. External suppliers in Uganda include the National Medical Stores (which is a government entity mandated to procure, store & distribute

essential medicines and medical supplies to all public health facilities in the country) and NGOs such as Joint Medical Stores. Internally, predicted supplies are also visible to the health centre personnel in charge of distributing supplies to different departments within the health centre. Suppliers (internal or external) can then respond to supply requests that they have accessed.

5. Medical workers can view the supplies of the health centres nearest to them so that they can redirect mothers. This option comes in handy in case a health centre is lacking (or is running short of) specific items and needs to refer mothers to a different facility.

The prediction algorithms are influenced by:

- The location of a health centre.
- The number of mothers likely to visit that health centre in a month.
- How far along with the pregnancy these mothers are.

2.1 Registering health centres onto the system

Health centres are added onto the system from a user interface in which the health centres name, sub-counties and parish (these are administrative divisions used in Uganda) it is located in and its precise geographical co-ordinates in World Geodetic System 1984 (WGS84) format are recorded. Such WGS84 longitudinal and latitudinal co-ordinates of a location can be obtained from a mapping tool such as Google maps.

2.2 Registering mothers

According to the Uganda Demographic and Health Survey 2016, 98% and 97% of pregnant women in urban and rural areas respectively had at least had one Antenatal Care Visit (ANC) during the previous pregnancy. It is in the earliest of these visits that a mother is registered onto the system.

As is demonstrated in Figure 4, the number of weeks the expectant mother is pregnant as well as the mother's location are two of the compulsory pieces of information the application must capture. This is because both data points heavily influence our predictions. Names are only required for administrative purposes on the part of the health workers registering the mother during an ANC visit.

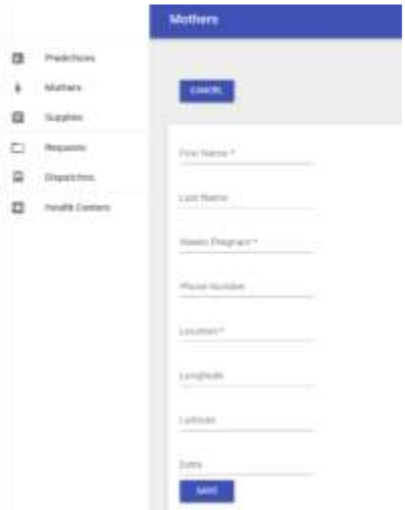

Figure 4: Registering mothers

The mother's location is important because it influences our estimate of the number of mothers likely to visit a health centre in any given month.

The mother's location can be supplied as a sub-county or parish. If a location is supplied as one of these, the sub county or parish is matched with the corresponding sub-county and parish information of health centres in our database (shown in Figure 3) to predict which health centre the mother will likely go to for an ANC visit.

Location can also be supplied as a set of WGS84 longitude and latitude coordinates in case the mother is comfortable with sharing this much information. In this case the health centre will need network connectivity that is reliable enough to load Google maps and the registering personnel require the knowledge of how to use the mapping tool. Once the map has loaded, the mother can provide her precise location.

Location information is then used in a clustering sub-routine that matches mothers' locations with co-ordinate information from the health centres' database to predict which health centre each mother will likely go to for ANC.

2.3 Generating predictions

The system is capable of tracking and predicting the supplies of 20 items (core obstetric equipment) required to adequately meet the needs of pregnant women.

These items are tape measures, fetoscopes, blood pressure machines, weighing scales, timing watches, thermometers, catheters, surgical gloves, umbilical cord clamps, resuscitation units, surgical blades, baby weighing scales, suturing kits, cotton wool, cannulas, oxytocin, urine testing kits, Human Immunodeficiency Virus (HIV) testing kits, blood grouping kits and blood for transfusion.

Algorithms were developed to predict the volumes for each individual item. Some algorithms were straight forward, for example, to estimate how many blood grouping kits will be need in a month the predicting subroutine simply multiplies the number of mothers expected to visit in a month with the number of kits needed for each mother.

Other algorithms were obtained from consulting with gynaecologists and mid-wives with decades of experience in Uganda's health sector. For example, for estimating how many units of blood for transfusion are required in a month, medical personnel informed us that 10% of mothers that give birth will likely need a blood transfusion. The algorithm we developed in this case looks at the number of weeks pregnant to estimate how many mothers will give birth in a health centre in a month and estimates how many units of blood the predicted 10% (of births in that month) will require.

As is demonstrated in the screenshots in Figure 5, predictions are displayed side by side with the health centres current supply. The rationale for this is that the health workers using the system will be more aware of how much of a particular item they need and contrast it with how much they lack in existing store supplies. They can then plan accordingly.

The health centre must ensure to regularly update their current supply status. The application provides a form for them to easily do this.

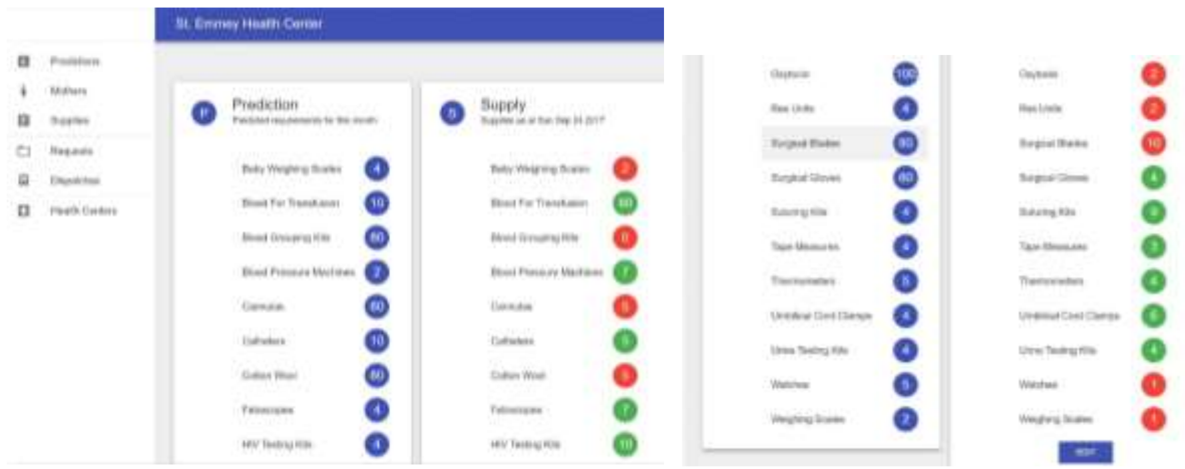

Figure 5: Prediction shown alongside current medical supply

2.4 Viewing predicted supplies to help with referral

In case a health centre finds itself lacking the supplies to handle a particular situation, medical personnel can use the system to view the five nearest health centres surrounding them and what those centre's current supply levels are.

Figure 6: Health centres filtered to the nearest five

The five health centres supplies can then be reviewed to select the one most suitable for handling a particular case before sending the mother there.

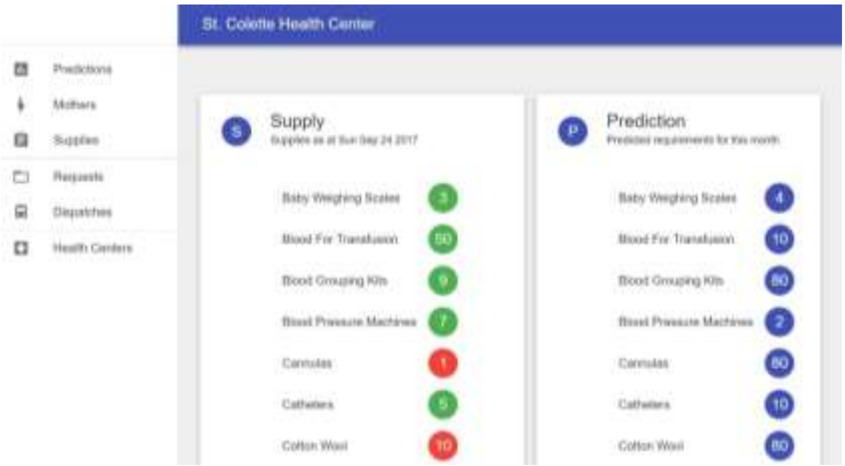

Figure 7: Viewing a different health centres supplies

2.5 Viewing supply requests

As earlier stated, the list of predictions is accessible by both internal and external suppliers. External suppliers include the National Medical Stores and Non-Governmental Organisations (NGO) such as the Joint Medical Stores. Internally, predicted supplies are also visible to the health centre personnel charged with the distribution of supplies to different departments within the health centre. This is especially useful for large health centres such as hospitals (as opposed to smaller health centre III's and IV's). Figure 8 and 9 show how supply requests can be viewed. Suppliers can then respond to the requests.

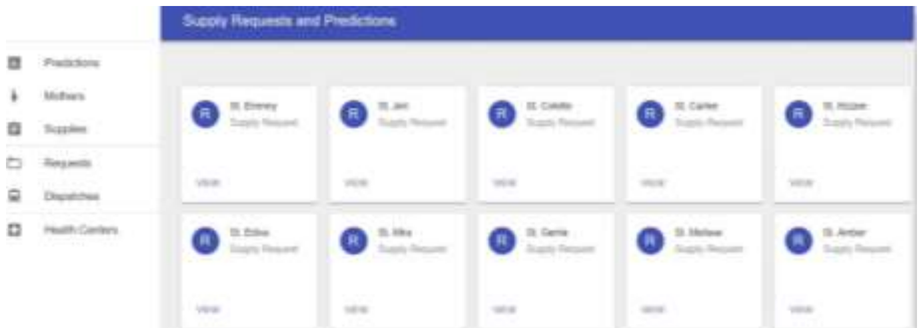

Figure 8: Viewing supply requests

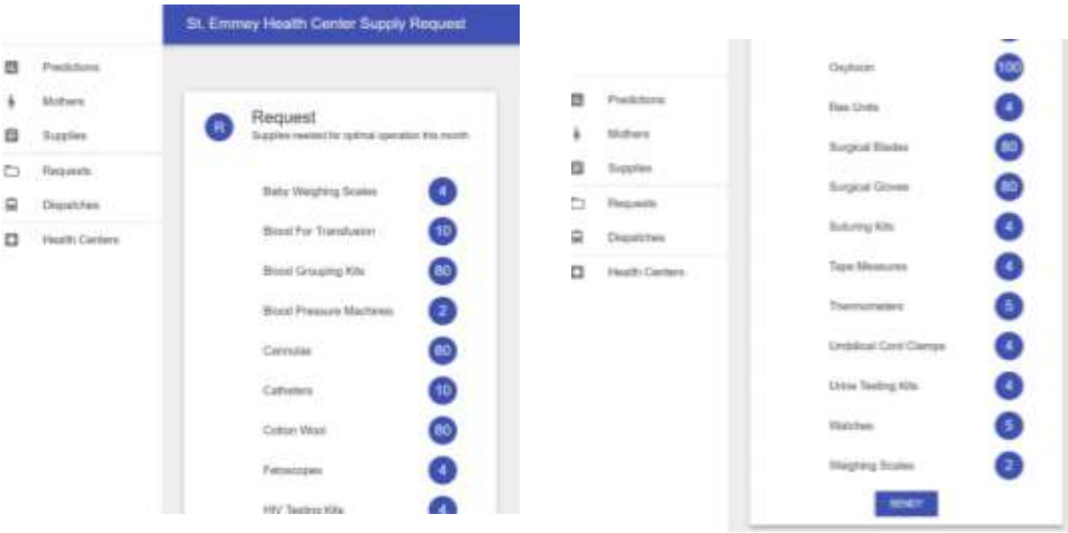

Figure 9: Supply requests in detail

3. Proposal Validation

This proposal was presented before a panel of doctors, a midwife, a gynaecologist, health care policy analysts and engineers during a maternal-healthcare themed design thinking workshop organised by the Resilient Africa Network (RAN). RAN is a partnership of 20 universities in 13 African countries that aims to strengthen the resilience of communities by nurturing and scaling innovations. Recommendations from members of the panel were used to refine the idea into the form presented in this paper.

4. Conclusion

Technologies that have resulted from increased usage of mobile devices can be used to simplify development of low-cost applications aimed at tackling developmental problems. The case study we used resulted in developing a web application that can be used to improve health centre efficiency through better planning, more operational referral capabilities and effective resource distribution.

Such an application can be deployed in the 3000+ health centres in Uganda at a low cost. Improved efficiency will in turn greatly reduce delays at the health centre thereby reducing maternal deaths by ensuring timely medical treatment.

More generally, we believe leveraging advances in mobile web application development can reduce the technical debt involved in building and deploying e-Health solutions in Uganda, allowing more focus to be placed on the non-technical challenges that such solutions face.

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