Obstetric Emergency Supply Chain Dynamics and Information Flow in Amhara, Ethiopia: A Qualitative Study

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Abstract

This study aims to describe the obstetric emergency supply chain (OESC) dynamics and information flow in Amhara, Ethiopia as a crucial first step in closing stock-outs and gaps in supply availability. The research team performed semi-structured interviews with employees of the OESC at the federal-, regional-, and facility-level to gain an understanding of the system in the region, communication flow, and the current barriers and facilitators to consistent emergency supply availability. The interviews identified several locations within the OESC where barriers could be addressed to improve overall facility-level readiness. For example, barriers included gaps in communication about supply need and availability between healthcare facilities and regional supply hubs, and a lack of data transparency at the facility level. Ordering supplies through the integrated pharmaceutical logistics system was a well-established process, and a frequently noted strength. As a result of these interviews, we gained a nuanced understanding of information needs for various levels of the health system to maintain a consistent supply of obstetric emergency resources—and ultimately increase maternal survival. This study was primarily conducted to inform on future work to create customized strategies that increase supply availability in facilities and the region overall, specifically the development of electronic dashboards.

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ABSTRACT

This study aims to describe the obstetric emergency supply chain (OESC) dynamics and information flow in Amhara, Ethiopia as a crucial first step in closing stock-outs and gaps in supply availability. The research team performed semi-structured interviews with employees of the OESC at the federal-, regional-, and facility-level to gain an understanding of the system in the region, communication flow, and the current barriers and facilitators to consistent emergency supply availability. The interviews identified several locations within the OESC where barriers could be addressed to improve overall facility-level readiness. For example, barriers included gaps in communication about supply need and availability between healthcare facilities and regional supply hubs, and a lack of data transparency at the facility level. Ordering supplies through the integrated pharmaceutical logistics system was a well-established process, and a frequently noted strength. As a result of these interviews, we gained a nuanced understanding of information needs for various levels of the health system to maintain a consistent supply of obstetric emergency resources—and ultimately increase maternal survival. This study was primarily conducted to inform on future work to create customized

strategies that increase supply availability in facilities and the region overall, specifically the development of electronic dashboards.

Keywords: basic emergency obstetric care (BEmOC), supply chain, Ethiopia, Socio-technical model

1. Introduction

For the past several decades the Ethiopian Ministry of Health (MOH) has worked to decrease the maternal mortality ratio (MMR)—the number of pregnant mothers dying per 100,000 live births.(1) However, with the most recently reported MMR of 267, Ethiopia still ranks high in MM globally and needs additional interventions to lower the MMR to the sustainable development goal of 70.(2) For this reason, the Ethiopian MOH is focusing on improving "the health systems' capacity to offer quality care that meets women's needs (the supply side)".(3, 4) Toward this goal Amhara Regional Health Bureau in Amhara and Ethiopian MOH have identified the need for a real-time obstetric emergency readiness system, which will assist in measuring and monitoring facility-level readiness to manage the six most common basic emergency obstetric care needs (BEmOC) including a set of core drugs, commodities, and resources to identify emergencies, treat them and monitor-modify therapy as clinically indicated.(5)

Formative work to articulate the specific needs, barriers, and facilitators for the development and implementation of a real-time obstetric emergency readiness system is foundational to meeting required needs and ensuring that the system matches the environment in which it is deployed.(6) Thus, the aim of this study was to describe the obstetric emergency supply chain (OESC) dynamics and information flow through semi-structured qualitative interviews with key informants from different levels of Ethiopia's healthcare system. This information would be used to guide the design and eventual implementation of electronic dashboards as a component of the real-time obstetric emergency readiness system.

2. Materials and Methods

2.1 Theoretical Model

The Socio-technical Model for Studying Health Information Technology in Complex Adaptive Healthcare Systems guided this study (Figure 1).(7) The Socio-technical Model is a dynamic and interconnected model that provides a thorough picture of the process for designing, implementing, and evaluating health information technology (HIT) through eight inter-connected dimensions: *hardware and software, clinical content, human computer interface, people, workflow and communication, internal organization features, external rules and regulations,* and *measuring and monitoring* (Table 1).(7)

Table 1: Socio-technical Model Dimensions and Definitions

Model Dimension	Dimension Definition
Hardware & Software	The digital infrastructure and equipment that is used to operationalize the clinical application being explored
Clinical Content	The categorical or numerical data and images that make up the "language" of the clinical application

Human-Computer Interface	All aspects of the digital application that the user can see, touch, hear or manipulate
People	The application users from the developers of the HIT to the end-users
Workflow & Communication	The necessary steps that a user must accomplish to successfully and effectively complete the task at hand
Internal Organizational Features	The policies, procedures, and culture within the specific organization using the HIT
External Rules and Regulations	The policies, procedures, and culture within the larger geographical location that the HIT is located
Measuring & Monitoring	The evaluation process and method of measuring the effectiveness of the HIT change including both intended and unintended consequences

Figure 1: Socio-technical Model

Note. Socio-technical Model from (7)

2.2 Guiding Methodology

Guided by qualitative descriptive methodology, we conducted semi-structured interviews to further describe and contextualize the gaps in emergency supply availability discovered in an earlier quantitative analysis of facility-level obstetric emergency readiness in the region.(8) The interviews explored multifactorial causes of emergency commodity stockouts, the current health system approaches to restocking commodities (from the federal-, regional- and facility-level), and information flow gaps/dynamics that could contribute to emergency supply stockouts. Data collection and analysis occurred concurrently.(9)

2.3 Recruitment and Sample

We recruited a purposive sample of OESC experts from across the federal-, regional- and facility-levels of care in Ethiopia. This included federal MOH government officials, working in supply chain management and maternal survival in Addis Ababa, Regional Health Bureau officials with obstetric expertise, regional pharmaceutical supply system employees, and supply managers and pharmacists from individual healthcare facilities. To participate in this study, individuals had to be at least 18 years old, speak English and Amharic, and be full-time employees in one aspect of Amhara's OESC.

2.4 Ethics Approval and Informed Consent

The study was approved by institutional review boards at Columbia University (IRB-AAAU2006) and Emory University (MOD005-STUDY00005335) and received ethics approval from Amhara Public Health Institute (NoH/RfftT1D1o7144). All participants provided verbal consent prior to participate.

2.5 Data Collection: Semi-Structured Interviews

We created an interview guide with open-ended questions to explore the flow of information through the OESC including barriers and facilitators (factors that enhance or impede access and utilization) with paper-based systems and the computer-based Integrated Pharmaceutical Logistics System (IPLS) (Table 2 and Online Supplement). We conducted interviews in English (federal-level) and Amharic (regional- and facility-level). The interviews were audio-recorded and lasted approximately 60 minutes. Amharic is the national language, and individuals working in Ethiopia's healthcare field received their training and education in English. During the interviews, we performed member checks by summarizing the main concepts and ideas the participants voiced and asked for confirmation to ensure we accurately captured their perspectives.(10)

Table 2: Sample Interview Guide Questions

What do you see as the major challenges to having the right supplies on hand to deal with obstetric emergencies when they occur? *(Communication breakdowns, frequently unable to obtain certain items, computers available and/or consistent Wi-Fi)*
Can you describe your process for ordering (or shipping) obstetric emergency supplies? *(Barriers and facilitators in the process, how often it occurs, who does this task, was there any training, decision making process)*
What are your impressions of the paper-based supply request system? *(Likes, dislikes, barriers and facilitators for use, areas of improvement)*
Can you describe your experience using the integrated pharmaceutical logistics system? *(Likes, dislikes, barriers and facilitators for use, areas of improvement, training if it occurred)*
Is there anything else that you'd like me to know about the topics that we've discussed today that I didn't ask about?

2.6 Data Management and Preparation

We stored audio files in OneDrive, an encrypted, password-protected electronic site accessible only to research team members.(11) All interviewees were identified by a participant number linked to the OESC level in which that individual worked (i.e., federal, regional, or facility). The participant numbers were linked to their names and stored behind an encrypted, password-protected site. We checked the transcripts for accuracy against the audio recording in English or Amharic and de-identified them prior to sharing them with other research team members. We used ATLAS.ti to manage, code, and analyze all qualitative data.(12)

2.7 Data Analysis

We performed deductive and inductive analysis of the interview transcripts. The deductive analysis was guided by a codebook developed by KD and SB (Online Supplement) based on the *a priori* constructs of the Socio-technical Model dimensions.(7) During data analysis, we added codes to the *human-computer interface* dimension of the codebook to reflect the emergence of additional themes. KD independently coded transcripts, generated themes, and documented coding. SB reviewed the documentation and refined codes with KD to establish confirmability of the coding decisions. We created saturation tables concurrently with data analysis to document if and when data saturation, a measure of data adequacy that signals that no further data collection is needed, had occurred (Online Supplement).(13)

3. Results

We conducted 17 interviews (5 federal-, 5 regional-, 7 facility-level) from February 17th through March 17th, 2023. We relied on the qualitative research experience of the data collectors (KD and YA) and data saturation (Online Supplement) to guide the decision on when to stop participant recruitment. The sample was predominantly male (82%), with an age range of 30 to 60 years, and

two to 38 years of experience working within the OESC (Online Supplement). While we analyzed all 8 dimensions, in the main manuscript we focus on the five dimensions most pertinent to the development of dashboards for monitoring facility-level readiness to manage obstetric emergencies and report on the other three in the Online Supplement. Tables 3-8 summarize findings from the interviews including the key barriers and facilitators identified for the dimensions and provide quotes from study participants supporting these findings.

3.1 Hardware and Software

In 2014, Ethiopia launched IPLS which allows facilities to place orders for medical supplies either electronically or through paper forms. IPLS also enables the central Ethiopian Pharmaceutical Supply Service (EPSS) and regional hubs to see reports on supply availability at the regional and national levels.

Two software systems are used within the OESC to monitor the movement of medical supplies—*Vitas* and *Dagu*. *Vitas* is used by central EPSS, which supplies the country with medications and medical supplies. The director general of EPSS and input officers have access to *Vitas* dashboards, which allows them to check supply availability and track commodities at both the federal and regional hub levels. *Dagu* is the software used at individual healthcare facilities. *Dagu* is used at the facility level to monitor human resources and service availability, but it does not have dashboards for medical supply logistics and movement. Some software in the OESC has components that function offline while other features are fully dependent on live internet access. Barriers (e.g., unstable internet access, frequent electric power outages) and facilitators (e.g., some IPLS components available offline) and related quotes are summarized in Table 3.

Table 3: Hardware & Software Barriers and Facilitators

Component	Themes	Quotes
Hardware & Software *The digital infrastructure and equipment that is used to operational the clinical application being explored*	**Barriers**	*"Most health facilities lack a computer, a printer, or the training required to actively utilize the [current electronic system[s]." Regional #1* *"Updating our computers and laptops would be a good idea since we've been using them for a decade! It's tough to get them to work in this setting." Regional #4*
	-Lack of and/or outdated laptops, tablets, and phones	
	-Unstable and inaccessible internet	*"In general, 75% of the facilities have no internet access." Federal #2*
	-Technology is not tailored for use on mobile phones or offline	*"There are many things that need to be updated. Many systems have changed, but they are not keeping up with the change. For example, we have to find information on our mobile phones. But there is not much like that. It should be transparent." Facility #3* *"I want the IPLS system to be mobile application-based; if it is, then EPSS or other health offices should be checking the…hospital system." Facility #7*
	Facilitators	*"We distributed tablets to all health posts to track the workflow of health posts as well as any commodity-related issue activities" Federal #2*
	-Tablets provided to some facilities	
	-Most employees have access to mobile phones	*"Almost all health extension workers have a mobile phone and can easily see any piece of information" Federal #2*
	-Some IPLS components can work offline if source of electrical power is available	*"In some areas, the facilities are using solar panels." Federal #2*

3.2 Clinical Content

Respondents at all levels of the supply chain agreed that several pieces of information are critical to ensure facilities are ready to provide BEmOC and to prevent emergency supply stockouts. In many healthcare facilities, pharmacists hand-calculate the last month's consumption, average monthly consumption, and forecast future monthly and annual supply demands. In contrast, some healthcare facilities utilized components of the electronic IPLS to calculate expiration and current quantity of supplies automatically. These respondents stated that the automatic calculations assisted in their consumption calculations. Overall, participants reported a desire for an automated system at all healthcare facilities that will calculate consumption, waste, and medication expiration in real time.

Upon receiving orders from hubs, healthcare facilities must know and report the number of items they originally ordered, the number of items received, the number of items missing from the order, who sent and received the shipment, and the date the supplies arrived at the healthcare facility. These pieces of information are stored in various data sources, such as bin cards and stock record cards resulting in a fragmented, non-trackable, non-integrated reporting system.

Furthermore, when individual healthcare facilities are determining how much medicine and medical supplies to order, they must also know the disease burden in the population that they serve, and which items are available for ordering. For example, with obstetric emergencies, facilities should know the estimated size of their catchment population, how many mothers give birth at their facility for antenatal care service, how many pregnant women attend the facility, and the number of mothers who are typically referred to higher facility levels for more intensive treatment. These complex variables are implicitly factored into healthcare facility orders, but there is no system to formally account for those variables in creating orders from facilities. Respondent perceptions of barriers (e.g., lack of reliable, high-quality, real-time consumption data) and facilitators (e.g., integration of medical supplies into one place) as well as exemplar quotes are displayed in Table 4.

Table 4: Clinical Content Barriers and Facilitators

Component	Themes	Quotes
Clinical Content *The categorical or numerical data and images that make up the "language" of the clinical application*	**Barriers** -Lack of accurate, high quality consumption data	*"When we go to [look at] the health facility level, especially the primary centers like health posts and health centers, it is very difficult to visualize what they have or do not have." Federal #2* *"The expert tries to send information by speculation; this is also another problem because you may take more medication and supplies than you need, which will lead to expired medication and supplies and sometimes the institution also faces a shortage of medication and supplies because they send false information. Thus, using guessing information will create overstock and understock problems." Regional #1* *"Accurate and on time information is highly needed and very vital to get the right supplies on hand to deal with problems, but unfortunately, we don't gather reliable information and we are making mistakes." Regional #1* *"We are using the issue data as a proxy data [for] consumption and we usually use this data for the national quantification so it might exaggerate or decrease the national quantification." Federal #3* *"The IPLS does not take the average monthly consumption component into account, necessitating a review of these issues." Facility #7* *"There are also issues with the quality of data because there is no way for us to make sure the person sent a valid report with real information or not." Regional #2*
	Facilitators	*"Compared to the previous IPLS, the current IPLS manual system is highly*

	-High integration of medical supplies into one place	*integrated. The previous system was very scattered because the pharmacy sent requests by themselves, the laboratory sent requests by themselves, and others did the same thing, and it was very uncoordinated. As of right now, the integrated system is very good, and all requests are sent in the same direction and in a coordinated manner." Facility #2* *"Most of our facilities are integrated into IPLS, particularly most maternal commodities, which were integrated into IPLS after the 2009 Ethiopian calendar [2017 Gregorian Calendar]. Therefore, everyone can check what they have, what they do not have, what is nearing its expiration date." Federal #2* *"Following EPSS's establishment, the fragmented administration system completely stopped. For example, when we deliver medicines such as TB, HIV medicines, HIV examination kits, and mother-and-child-related medicines, we do so in an integrated way, not in fragments. When we deliver, we take all the HIV, TB, and medicines through one route because it is an IPLS system, which means we deliver integrated." Regional #4*

3.3 Workflow and Communication

In the Amhara region, there are 918 health centers, 103 hospitals, and 19 supply hubs. To determine the type and quantity of medical supplies to order, a facility must first determine its monthly consumption and average monthly consumption to forecast future needs. When requesting supplies, facilities can request up to a maximum of four months of stock. The head of each department/unit at the healthcare facility plans monthly consumption every two weeks and will submit an internal request and reporting forms (IRRF) to the central store or pharmacy in the facility. The pharmacist reviews and fulfills these biweekly requests from the facility's stock and also completes and submits requesting and reporting forms (RRFs) to their designated regional supply hub to refill facility-level supplies. Pharmacists submit these forms every one to two months depending on the size of the population they serve and may also submit an emergency RRF if they have less than two weeks supply of an item or experience a stockout. The RRFs are either submitted in paper form or electronically through the IPLS. A healthcare facility-level respondent describes the critical role of IPLS saying, "It acts as the system's brain and is crucial for having the right medication in the right quantity and of the right quality at the right time."

After receiving the RRFs through the IPLS, regional hubs will review the forms and if they have the stock on hand in the hub, they will create a stock transfer voucher and fulfill the request by providing the commodity to the facility. Additionally, the hub will consolidate the consumption reports and RRFs for the individual healthcare facilities under their jurisdiction and estimate overall consumption and forecasting for the upcoming months, which they will report in an RRF and send to the central/national office of the EPSS for fulfillment every one to two months.

Central EPSS reviews the RRFs from their hubs and fulfills the orders based on consumption reports and local and national forecasting numbers. The hubs receive the products from central EPSS and review the orders to see if they received the full or partial order. The hubs compare this information to the requests they have received from their facilities and send the supplies to the facilities every one to two months. After receiving the order from their designated hub, healthcare facilities then review what they have received and dispense it throughout the various departments/units at the facility. They track the new deliveries and existing inventory with bin cards and stock record cards that are paper-based. A summary of the various data sources, and communication systems present in this supply chain can be found in the Online Supplement. Figure 2 displays the procurement process. Barriers and Facilitators related to Workflow and Communication are presented in Table 5 with sample quotes from participants at various levels of the system.

Figure 2: Procurement Process

Table 5: Workflow and Communication Barriers and Facilitators

Component	Themes	Quotes
Workflow & Communication *The necessary steps that a user must accomplish to successfully and effectively complete the task at hand*	**Barriers**	*"The forecasting error at Ethiopia's health facility is not better than 35%, and you see 40%, very good facilities are forecasting at 50%. What does this mean, they are either over-quantifying or under-quantifying." Federal #1* *"The knowledge gap about capacity and forecasting error is evident." Federal #1* *"There is a [communication] barrier, the hub knows only the stock on hand issued data, so as a logisticians, the issue data is the proxy data [for] consumption, that is not the actual consumption but we use it as a proxy data as consumption and we usually use this data for the national quantification so it might exaggerate or decrease the national quantification and the forecasting that might occur." Federal #3* *"If we request medical equipment, we have to consider consumption, but currently, we request the amount of medical equipment by guessing, not based on consumption data, so this exposes us to medical equipment scarcity." Facility #2*
	-Inaccurate forecasting	
	-Outdated forms (both paper and electronic)	*"There is something that needs to be improved. I think it [IPLS] has not changed since the first format design. Therefore, the format must be adjusted, now the information network has grown." Facility #3*
	-Over reliance on paper-based methods	*"The other challenge is the system problem. Most of our health facilities use a manual method of requesting and ordering medical supplies and equipment." Regional #1* *"If it is paper based, it is like to be blinded. It's going to be difficult to find out the medicine that we are running out of stock, so it must be digital to analyze the data. Paper-based has nothing to show the expert how much demand there is today and what demand there will be tomorrow. Paper-based is not good. I think it should be updated." Facility #3* *"Paper-based systems are not appropriate for the 21st century; they are archaic, tedious, difficult to access, and unsuitable for auditing." Facility #7* *"In the current situation, the system between health facilities and us [regional hub] is still manual, so it's also possible for us to make several mistakes when it comes to requesting medicines due to this manual system." Regional #4* *"The paper-based or hard-copy system of supplying or requesting the information is very helpful, but it is very difficult to share information immediately." Regional #5*
	Facilitators	*"The integrated system is very good, and all requests are sent in the same direction and in a coordinated manner." Facility #2*
	-There is an established process for ordering medical supplies through IPLS	

3.5 Human-Computer Interface

Individuals interact with the OESC at the federal, regional, and individual facility levels of the system through a variety of human-computer interfaces. Table 6 describes the needs of the three

types of users as well as how they interact with the interfaces available at their level of the health system. In addition to the current interfaces, some respondents wanted the electronic IPLS to be accessible via a mobile application or on mobile devices so that they have greater access to the data —particularly when desktop/laptop computers were not available at the health facilities and alternative mechanisms were needed to use the electronic components of IPLS. Table 7 summarizes the barriers and facilitators identified for human-computer interfaces.

Table 6: Currently Available Human-Computer Interfaces

Interface Description	Central EPSS Office	Regional Hub	Facility
Bin Cards: Paper • Reports stock on hand, quantities issued/received, losses and adjustments, average monthly consumption, batch number and expiry date, product names, strengths and dosage, and product groups	• N/A	• N/A	• Reports changes in supply quantities • Views inventory data
Drug List: Electronic • Provides information related to drug names, unit of measurement, stock on hand, serial number, expiration date, lot number from its shipment, manufacturer, and price that should be available • Prints reports on the drug information	• Views information on the drugs that should be available	• Views information on the drugs that should be available at the hub level	• Views information on the drugs that should be available at the healthcare facility[1]
Drug Lists: Paper • Provides information related to drug names, unit of measurement, stock on hand, serial number, expiration date, lot number from its shipment, manufacturer, and price that should be available	• N/A	• N/A	• Views information on the drugs that should be available at the healthcare facility
RRF: Electronic • Reports stock initial balance, stock on hand, delivery reports, quantity received, losses and adjustments, reports of any additional drugs than an institution purchases from another institution, ending balance, overstock, date of stock out, ordered quantity, and products with a shelf-life less than six months • Supports entry of last month's consumption • Supports entry of calculated consumption days out of stock • Reports quantity needed to reach maximum stock status • Calculates average monthly consumption (AMC) • Prints paper copies of RRFs	• Views supply requests from regional hubs • Views the number of supplies consumed throughout the country • Views forecasted supply needs for the next several months • Tracks how much stock was shipped to each hub • Views AMC	• Views supply requests from individual healthcare facilities • Reports consumption rates • Reports calculated consumption days out of stock, and quantity needed to reach maximum stock status • Reports quantity ordered for the upcoming time period • Tracks how much stock has been shipped to	• Views supply availability[1] • Views expiration status of supplies • Reports consumption rates • Reports calculated consumption days out of stock, and quantity needed to reach maximum stock status • Reports quantity ordered for the upcoming time period • Views AMC

		individual facilities • Views AMC	
RRF: Paper • Reports stock initial balance, stock on hand, delivery reports, quantity received, losses and adjustments, reports of any additional drugs than an institution purchases from another institution, ending balance, overstock, date of stock out, ordered quantity, and products with a self-life less than six months • Supports entry of last month's consumption • Supports entry of calculated consumption days out of stock • Reports quantity needed to reach maximum stock status • Reports quantity ordered • Reports AMC	N/A	• Views supply requests from individual healthcare facilities • Views AMC	• Views supply availability • Views expiration status of supplies • Reports consumption rates • Reports calculated consumption days out of stock, and quantity needed to reach maximum stock status • Reports quantity ordered for the upcoming time period • Views AMC
Stock Status Dashboard: Electronic • Calculates expiration status and stock quantity levels • Prints reports related to supply availability and expiration status • Offers a color-coded view of stock availability (ex. overstock, normal, below minimum, emergency order point, and stockout)	• Views inventory data the central level • Views inventory data at the hub level • Views how much supplies have been ordered	• Views inventory data at the user's hub • Views inventory data at other hubs in the region • Views how much supplies have been ordered	• N/A
Stock Record Card: Paper • Reports stock on hand, quantity issued/received, losses and adjustments, unit price, expiry date, product name, strength and dosage, and product group	• N/A	• N/A	• Reports changes in supply quantities • Views inventory data

[1] Not available and/or used at all facilities

Table 7: Human-Computer Interface Barriers and Facilitators

Component	Themes	Quotes
Human-Computer Interface *All aspects of the digital application that the user can see, touch, hear or manipulate*	**Barriers**	*"Departments/units are unable to determine which supplies are in stock and which are not" Facility #1*
	-Gap in data visibility of supply inventory (especially between hubs and healthcare facilities)	*"Although they [current dashboards] are helpful, they also have problems with data visibility." Regional #3* *"There is no dashboard between health facilities and us. This means it is very difficult to access the health facility data because their data is not visible to us." Regional #4* *"One of the main supply chain challenges in our country is end to end data visibility." Federal #4* *"It is crucial to create and make available such a dashboard, especially for policymakers, decision-makes, and even health management and for health facilities at all levels. If it is available, everyone can view it and it encourages prompt action." Federal #5*
	-Perceived low ease of use	*"Most of them [facility-level employees], you know, are not doing good with DAGU2 [facility-level software] due to the complexity of the system and its needs like connectivity." Federal #4* *"We have a major problem with the way we use this dashboard, as well as the experience we have with it even though the dashboard is very helpful and useful." Regional #3*
	Facilitators	*[The current electronic system] "can provide the item's serial number, name, unit of measurement, and expiration date in addition to the quantity available and the average monthly consumption for this month." Federal #1*
	-Central EPSS and regional hubs, and some individual healthcare facilities can use electronic dashboards to view current inventory levels	*"We can browse the library [dashboard] and learn what is available in various hubs thanks to this tool [dashboard], and we can utilize the dashboard by making requests by checking the progress of other stocks. It also enables us to produce other reports, including those on expired and those that are waste. Therefore, it is without a doubt, really beneficial." Regional #2* *"There is a dashboard between the central and branch offices, we can view each other's data. To your surprise, we can also see the data of other branches, like Negele Borona [Oromia region] and Arba Minch [Souther Nations, Nationalities and Peoples Region]. The other branches can also see our data." Regional #4* *"This system [central and hub dashboards] is very important because we can show and see the products for all branches. For example, if there is a misdistribution of the products and the central EPSS sends all products to only three branches out of the 17 active branches by mistake, this dashboard shows where all the products go, and immediately the central office informs the three institutions to distribute the products to all 17 branches. Similarly, branches can also request products because they know where their products go thanks to this dashboard." Regional #4*
	-Perceived strong usefulness of the current technology	*"IPLS is a crucial system that helps developing nations like Ethiopia, it helps improve their supply chain management, reduce waste, and increase availability." Regional #3*

		"Certainly, it [the dashboard] is quite helpful [for task completion]. For instance, it may be used to transfer information, make decisions, check for medicine availability, and it also issues and gives us alarm by flashing a red light when a drug is about to expire." Facility #1 *"Without a doubt, it [the current dashboards] is very useful. It saves time, lowers labor costs, helps to determine when items pass their expiration dates, and lowers the rate of waste. In general, it is crucial for controlling." Facility #5* *The [electronic] IPLS system is capable of calculating and quantification of supplies more accurately and its capacity to minimize errors in the calculations." Facility #4* *"The [IPLS] system is very important because it makes it easier for us to complete our tasks and helps us to understand our responsibilities. If the data is stored clearly and is not blocked, we can easily access it and obtain the items we need, including those we receive, those we want to issue, the people to whom we issue them, and the data we issue. Knowing what is stocked out and what is to expire is helpful. It decreases waste as well." Facility #5*
	-Perceived high ease of use of the current technology	*"Other than a few amenities, IPLS is a user-friendly system." Federal #1* *"In the past, we have faced different challenges in using this electronic system, but currently it is very easy." Federal #2* *"Because the computer quantifies things on its own, if it is computerized, it makes things very simple." Facility #1* *"There are lots of benefits to using computer system [electronic RRFs], it's usually way easier to fill out a form using a computer than to do it by hand. Plus, since it's all done on a computer, the calculations are much more accurate." Facility #2*

4. Discussion

We used the Socio-technical Model to explicate participants' perceptions of barriers and facilitators to securing and managing supplies within the OESC in Amhara, Ethiopia, and to identify intervention targets to increase BEmOC supply availability at the facility level as a key step for reducing Ethiopia's MMR.(7) Changing one component within the OESC can influence the success of the system, but current barriers may impede or interact with the system in unique and unintended ways. An example of this would be if the EPSS increased the number of computers and tablets available to healthcare facilities but failed to explore users' usability and ease of use concerns. If the technology is still viewed as difficult to use and users continue to prefer paper-based forms, then EPSS as a whole will not see the full benefits of increasing access to the technology. To ensure the success of the electronic components of IPLS the researchers and individuals working within this field can build on the preexisting strengths found in the IPLS to rectify barriers and concerns for HIT-based real-time monitoring of BEmOC supply provision and availability.

The lack of access to computers and tablets led to lower utilization of the electronic components of IPLS; this is often the case at small, rural health posts. If facilities do not have the

equipment to access IPLS, then they will continue to rely on the paper-based method. However, when the MOH did provide tablets to individual facilities, they reported they were more likely to utilize the electronic components of IPLS. Additionally, even if facilities had the hardware available, if they did not have consistent access to the internet the electronic systems were still of little use because some features of the technology are not able to work offline. Creating dashboards and electronic components of the IPLS that work offline is crucial because internet access is not always consistent in all parts of Amhara. To encourage users to transition from paper-based forms and ensure facilities can leverage the benefits of the electronic system central EPSS and the MOH can ensure the hubs and individual facilities have the physical supplies necessary to access the government's technology infrastructure.

Users report the traditional, siloed process for ordering medical supplies for each health program or clinical condition was tedious and time consuming. Having all the supplies needed to manage obstetric emergencies in one place, along with supplies for other medical situations, makes the ordering process more streamlined. Furthermore, having all this information available in one place is useful when pharmacists and supply managers are trying to view inventory levels, determine their consumption, and forecast future needs. Pharmacists stated they enjoy having this information available to them electronically. As a developmental next step, the Ethiopian MOH could take steps to automate the electronic components of IPLS (online and hardware devices) at all healthcare facilities which will help with the calculation of monthly consumption, waste, and expiration so pharmacists can have these current, real-time data available when they are making supply requests to the regional hubs. Additionally, knowing what is available at various hubs can assist in making supply distribution decisions and advancing supply accessibility across hubs and the facilities they service. Without rich inventory data available facilities will continue to remain in the dark about their true readiness to manage basic obstetric emergencies, and central EPSS and regional hubs will not have the necessary information to provide essential emergency supplies prospectively—before stock-outs and maternal deaths occur.

Facilities reported using the same process for ordering and obtaining supplies was incredibly helpful. Using one system to order all basic emergency obstetric supplies created a uniform communication flow between individual facilities, regional hubs, and central EPSS. However, as the IPLS ages, it will benefit from ongoing updates and adaption to the evolving needs of the system's users at multiple levels. For example, providing space to justify seasonal differences in supply request quantities would allow facilities to explain the change in demand and would help hubs and central EPSS to both forecast future needs based on seasonal trends, and also help central planners make informed, strategic decisions even in cases where they must distribute a smaller number of supplies to multiple hubs.(14)

The greatest concern related to the workflow and communication of the OESC was an inability to accurately forecast future supply needs. This is a critical issue because inaccurate forecasting can lead to under-supplying and stockouts or oversupplying and waste of medication due to expiration. When individuals know their true consumption, they can trend their historic usage and forecast their future needs. Increasing data visibility is not only a concern at facilities for preventing maternal deaths but also crucial at every stage of the supply chain to ensure consistent, predictable emergency supply availability for reducing facility-based mortality at the population level in Amhara. Currently, the greatest communication breakdown occurs between regional hubs and individual facilities. Bridging the gap between these two areas will not only assist with forecasting but also provide an additional level of surveillance at the regional hubs

which can monitor inventory levels at facilities and prospectively send out supplies if they notice a facility is reaching critically low levels in order to prevent stock-outs in advance.

Technology updates and changes must be reviewed and monitored not only to measure their success but also to investigate if there are any positive or negative unintended consequences of the technology updates. This is seen in the *Dagu* 1 to *Dagu* 2 updates which improved data transparency within the system but also introduced barriers to efficient use of the system at the facility level. Based on user complaints from this update, it is imperative to a conduct formative assessment with end-users to ensure the technology updates cohere with the HIT's intended purpose and existing user workflow.(15) Furthermore, the *Dagu 1* to *Dagu 2* changes underscore the notion that usefulness does not always equal usability, and updates to technology should be reviewed by targeted end-users to ensure they will not have unintended negative consequences. This same problem occurred when electronic health records were widely integrated into hospitals in the United States in the 2010s.(16) Before implementing changes within the electronic components of IPLS those individuals who are leading these updates should establish a process to monitor and measure the impact of the changes.

The findings from these interviews highlight the need to bridge the data visibility gap present between facilities and regional hubs. Furthermore, facility-level participants stated that they would appreciate the ability to view inventory data electronically and that having that information available would assist in forecasting decisions and supply requests. The discussions with individuals at all levels of the supply chain underscore the importance of having data views that are tailored to the different job types. Providing health technology, such as dashboards with different views for the various stakeholders in the supply chain is helpful because it can provide a granular view for each stakeholder depending on their information needs and job functions. Different types of dashboards that could be useful would include those for individuals who work at facilities and regional hubs. The individual facility employees can use the dashboards to assist with performing accurate forecasting and supply requests, as well as monitoring their day-to-day inventory levels. In contrast, the dashboards for region hub employees could assist with the hub's ability to monitor the inventory levels of the facilities under their jurisdiction and provide supplies in advance of stockouts.

One facilitator of the current human-computer interfaces is that there is already strong buy-in from the users because they believe the technology is both useful for their jobs and easy to use. While some reported ease of use issues, the majority of respondents indicated the existing EPSS and IPLS systems were usable. New dashboards must maintain these existing usability strengths. Future steps can be taken to curate additional individualized dashboards that provide the information that is most pertinent for each stakeholder across the health system from facilities to regional hubs and the central EPSS. Additionally, if individuals continue to use the technology on tablets or mobile devices, then EPSS could ensure the technology is tailored for use on those devices instead of only computers. This incremental adaptation of the IPLS and EPSS interfaces to mobile technology can ensure the supply monitoring technology follows usability heuristics for mobile health.

4.1 Limitations

One potential limitation is that when transcripts were translated from Amharic to English there may have been unintended translation errors. However, to mitigate this concern a medical anthropologist who lives in Amhara and has over 14 years of experience performing qualitative data collection and translating data from Amharic to English performed the translations.

Additionally, while this work was designed for healthcare facilities in the Amhara region of Ethiopia, all regional- and facility-level participants worked in Bahir Dar city—the capital of the region. This limitation on sampling outside the regional capital was due to civil unrest which prevented team members from safely visiting other locations.(17) Despite this potential limitation, the study sample represents different healthcare facility levels and regional positions and still provides a rich understanding of the current OESC dynamics in Amhara. Finally, the sample was predominately male which may have unintentionally excluded the opinions and experiences of females working within the OESC. However, this male-dominated sample matches pre-existing HIT-user staffing in the region.

5. Conclusions

This study captured insight into the information and communication flow within Amhara's OESC. Participant responses identified several strengths and barriers related to the success of the current IPLS. A frequently noted strength was the high degree of integration of medications and supplies that can be purchased through the system. Common barriers include a lack of data transparency at the facilities, and also between facilities and regional hubs. The findings offer several recommendations for how future technology can be designed and tailored to meet the needs of current OESC employees. Additionally, the results of the interviews underscored the importance of conducting qualitative research early in the developmental process of HIT to ensure a rich understanding of the current environment and user tasks that the technology will need to accomplish. Although these data come from Amhara and national MOH informants, the EPSS and IPLS systems are common across Ethiopia's regions. Consequently, HIT-based innovations that come from this research can be readily adapted to the hubs and facilities in multiple Ethiopian regions.

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7. Disclosure of Interest

The authors report there are no competing interests to declare.

8. Abbreviations

Ministry of Health (MOH)
Maternal mortality ratio (MMR)
Basic emergency obstetric care needs (BEmOC)
Obstetric emergency supply chain (OESC)
Health information technology (HIT)
Integrated Pharmaceutical Logistics System (IPLS)
Ethiopian Pharmaceutical Supply Service (EPSS)
Internal request and reporting forms (IRRF)
Requesting and reporting forms (RRFs)

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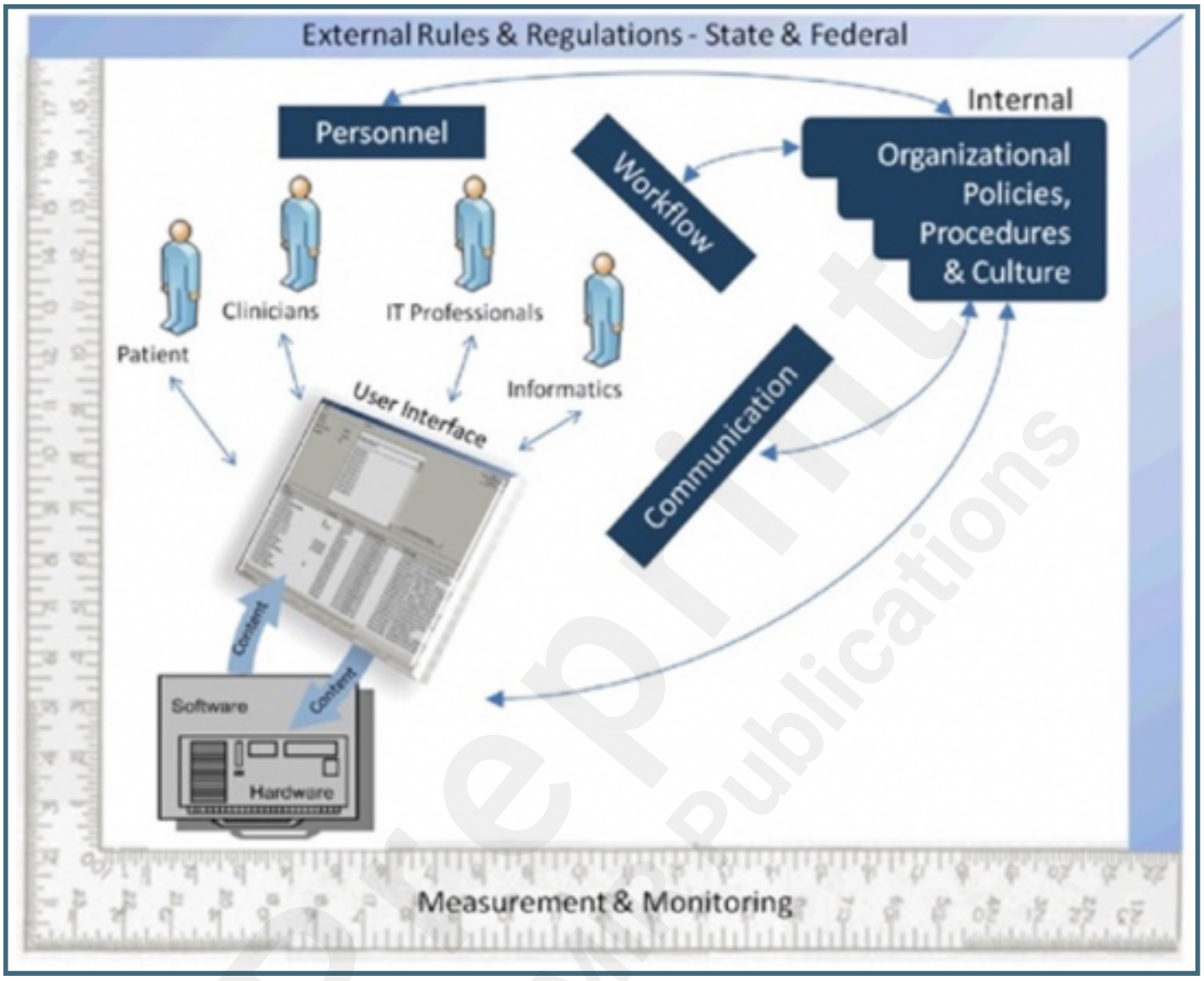
Supplementary Files

Figures

Socio-technical model.



Procurement process.