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# The Controversy of Responsibility and Accountability when Maintaining Automatic External Defibrillators

## Infrastructuring lifesaving technology with an IoT solution

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**Abstract.** This paper contributes to HCI with a foundation for exploring ways in which an Internet of Things (IoT) solution can support the maintenance of public automated defibrillators (AEDs) sustainably. AED is a critical lifesaving technology installed in non-medical environments. The technology places enormous demands on public engagement for its use and maintenance. Insights into how medical technology is maintained in non-medical environments can complement current innovations in lifesaving technology. This ethnographic study investigates the complexity around an IoT solution to remedy breakdowns in the maintenance of AEDs in a Danish context. We conceptualize maintenance as infrastructuring and identify how the diverse field of actors around an AED entails technical but primarily social dimensions revealing a controversy of responsibility and accountability. This article recommends that when developing an IoT solution for maintaining AEDs, technical, social, political, and ethical dimensions should be considered to address responsibility and accountability issues.

**Keywords:** Health, Public Automated External Defibrillators, Ethnography, Infrastructure, IoT

## 1 Introduction

In 2018, there were 5,400 incidences of out-of-hospital cardiac arrest in Denmark [1]. Chances of surviving an out-of-hospital cardiac arrest diminish minute by minute without intervention, giving a survival rate that remains below 10% [2]. In the event of an out-of-hospital cardiac arrest, immediate cardiopulmonary resuscitation (CPR) and early defibrillation by an automated external defibrillator (AED) are the most critical interventions. These interventions show survival proportions between 50% [2] and 74% [3].

An AED is a transportable and automated defibrillator driven by a battery. It can analyze a person's heart rhythm and provide an electric shock if necessary by using gel pads [4]. The gel pads are durable for up to two years but must be changed if the AED has been used. The battery can last between three to five years, depending on the brand of the AED [5]. The AED can also indicate if a technical error has occurred by turning off a little green light [5]. While lifesaving technologies are most often under the auspices of hospitals, AEDs can be placed in a community (Fig. 1) as part of a public access defibrillation program. The American Heart Association and the European Resuscitation Council support several public access defibrillation programs that encourage laypersons to use AEDs outside a hospital context [2, 6].



**Fig. 1.** Automated External Defibrillator.

For an AED to function as intended, it needs maintenance. AEDs need to be registered to be findable by a layperson [7, 8] and fully functional, with timely maintenance keeping the battery charged, sustaining the right cabinet temperature, and replacing dried-out gel pads [5, 8]. Studies from the United States [9, 10] and Singapore [8] and campaigns in Canada [11], the United States [12], and Denmark [7] raised awareness and educated the public about how to use and where to locate AEDs in case of an emergency [7]. However, these studies and campaigns do not focus on how and if the AEDs are fully functional over a more extended time. Therefore, when a layperson locates an AED in an emergency, a fully functional AED is not guaranteed [8]. In a Danish context, the owner is responsible for maintaining the AED, which in practice can be difficult for a layperson [13]. The lack of AED maintenance has been brought to both the Danish Parliament and Danish media attention several times [14]. In Denmark, where this study was conducted, no regulations are making the maintenance of AEDs compulsory, only a letter of recommendation from the Danish Health Authority stating that 1) all public sector owned AEDs must be registered on a free public online webpage, like Hjertestarter.dk, 2) there must be a standardized procedure when the AED has been used (e.g., registration of its location), and 3) a set procedure with an automatic electronic reminder that the AED needs maintenance [5].

Despite heightened focus on the awareness of maintaining AEDs, the controversy of who should maintain the AEDs and how remains.

In response to this controversy, a Danish non-governmental organization (NGO) has entered into a partnership with a Danish IoT Company to develop an Internet of Things (IoT) solution to help improve and support the maintenance of AEDs.<sup>1</sup> This IoT solution will become part of an insurance policy sold by the NGO to achieve fully functioning AEDs. The IoT solution aims to monitor AEDs in Denmark digitally, so errors in the AED can be detected and rectified. The NGO collaborates with a Danish IoT Company and a Danish Tele Company, which develops and provides the technical equipment. The development of this IoT solution was this study's point of departure, which led us to the broader investigation of the maintenance of AEDs in Denmark, opening the field to include an Administrative Organization and a Health Clinic. By analyzing the IoT solution and how it interacts with the other actors mentioned above, this study conceptualizes the maintenance of AEDs at an infrastructural level. This diverse field of actors shows that maintaining an AED does not just entail technical but also social dimensions. This diverse field inspired our theoretical perspectives on infrastructure and infrastructuring as an analytic lens to support an investigation of maintaining AEDs. As an AED is a public lifesaving technology, it places enormous demands on civic engagement. Understanding the complexity around an IoT solution is essential for future innovation of AEDs specifically and as a general insight into medical technology in non-medical environments.

While an infrastructure is conventionally considered a physical or technical foundation, Star and Ruhleder [15] proposed that infrastructure is socio-technical and relational. An infrastructure never stands apart from its designers, users, and people who maintain it [16]. The notion of infrastructuring emphasizes the processual qualities of creating and enacting infrastructures [17]. Maintaining AEDs in Denmark depends on public and civic engagement and voluntariness, with no compulsory regulations explained. Thus, the infrastructural circumstances regarding the responsibility can be arbitrary.

Given this socio-technical perspective, we argue that the infrastructuring of AED maintenance reveals a controversy of responsibility and accountability when the infrastructuring becomes connected and dependent upon multiple actors. In this paper, we differentiate between the notion of responsibility and accountability because responsibility is something that can be shared by various actors [44], and accountability is something only one actor can be attributed [42, 44]. We will further elaborate this in Section 2, 'Related Work.'

By investigating lifesaving technology outside the hospital setting, we further suggest that we can uncover why AED maintenance gets neglected by directing our attention to the infrastructural issues connected to AED maintenance. By adopting this infrastructural approach, we can explore how the proposed IoT solution could help sustainably maintain AEDs. In Section 5, we discuss why only focusing on the IoT

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<sup>1</sup> The name of the solution and names of the people involved have been pseudonymized.

solution as a technical dimension is problematic if wanting long-lasting upkeep and maintenance while critiquing the IoT technology as the answer to the controversy of responsibility and accountability. This study contributes to HCI by raising explicit attention to the discussion on responsibility and accountability in how AEDs are maintained and neglected.

## 2 Related Work

Previous research on AEDs in HCI has examined ways of technically optimizing AEDs by designing interactive systems with IoT-generated data [18, 19] and the training of laypersons [20, 21]. Furthermore, previous research on infrastructures of healthcare technology and IoT, primarily relates to medical applications such as fitness programs, health monitoring, and healthcare at home [22]. The research on infrastructure has attended to medication plans [23], electronic patient records [24], clinicians in hospitals [25], and how patients and caregivers make healthcare infrastructure work [16]. Research on infrastructuring and health information technology in the HCI literature presents a systematic perspective that supports a multifaceted approach. However, research on AEDs and infrastructuring is scarce, which means that researching AED maintenance with an IoT solution does not necessarily warrant an exclusive focus on the technical parts. It creates a space for investigating AED maintenance from a social, material, technical, political, and ethical perspective at the same time. For this study, exploring and analyzing the different perspectives in relation to each other enables a more holistic approach to an otherwise technical solution. As we discovered that the social and ethical concerns were vital, we realized that “maintenance” was not just technical. “Infrastructuring” helped us unpack the intertwining of the technical with the social and ethical and pointed us methodologically to ask about these connections [43].

As we will show, maintaining AEDs is a particular activity that needs social and technical infrastructure support. In studying infrastructuring, explicit attention to the ways people engage in the processes of infrastructure is required. Infrastructuring STS scholars Karasti and Blomberg (2018) argue that:

“The ‘ing’ terminology, including adapting, tailoring, appropriating, tuning, modifying, tweaking, making, fixing, monitoring, maintaining, repairing, hacking, vandalizing and instrumenting (...) shape infrastructures” [17].

Following this logic, we move beyond the hospital setting to the non-medical public, being “a particular configuration of individuals bound by common cause in confronting a shared issue” [26]. The issue in our case was out-of-hospital cardiac arrests. An infrastructure of volunteering [27] or infrastructuring civic engagement [28] may describe the AED as it is procured, used, and maintained by laypersons.

The social dimension of infrastructures makes them fundamentally relational, emerging in situ with organized practices and connected to particular activities [15]. Infrastructures are relational as they emerge in relation to other organized practices. They are not just stable objects of inquiry: “(...) the cook considers the water system as working infrastructure integral to preparing dinner, for the city planner it is a varia-

ble in a complex planning process, and for the plumber it is a target for repair” [17].

Just as infrastructures are relational, they are also connected. A relation depends on more than just itself. It requires other elements to be complete [17]. Star and Ruhleder [15] describe connectedness or scaling of infrastructures as reaching beyond a single event or a one-site practice. Connectedness as a characteristic of a phenomenon brings together things of different scales, extending the infrastructures’ social, material, technical, and political dimensions [17]. Star [29] underlines the importance of these dimensions when looking into infrastructures. It especially emphasizes the ethical dimensions: “Perhaps most important of all, what values and ethical principles do we inscribe in the inner depths of the built information environment [the infrastructure]?” [29]. Therefore, attention to the social, technical, political, and ethical dimensions is valuable. They can reveal controversies in the infrastructuring of maintaining AEDs when the infrastructuring becomes connected to multiple actors.

In addition to being connected, infrastructures are emerging and in the making. The stability of infrastructures is relative and is an ongoing development process [30]. Karasti and Blomberg characterize the emerging quality of infrastructure formation as “temporal complexities full of ups and downs, false starts, disconnects, dead ends and failures” [17]. Therefore, actors developing an infrastructure need to do regular repairs, monitoring, and upkeep when it does not perform as planned.

The emerging qualities of infrastructuring when developing the IoT solution for maintaining AEDs also demand actors attending to the long-term sustainability of the IoT solution. This long-term perspective on developing infrastructures relates to Ribes and Finholt’s focus on tensions between the short-term and the long-term vistas and their view of “the long now” [31]. The “now” of the IoT solution’s development may inscribe tensions to long-term needs within the infrastructuring for maintaining AEDs.

Regarding infrastructuring of AED maintenance, recognizing differences in infrastructuring approaches is essential when understanding different actors’ agendas. In this paper, infrastructuring AED maintenance is both seen through the lens of self-organized activities defined by individual willingness and an ad hoc approach, but also through the goal of creating a commercial IoT solution for maintaining AEDs. As described later in this paper, the tension between the different approaches of conceptualizing infrastructuring AED maintenance can cause controversies concerning responsibility and accountability.

Excellent and usable infrastructures disappear almost by definition: “the easier they are to use, the harder they are to see” [17]. By being out of the way, infrastructures gain their most significant effect when taken for granted and sometimes deliberately hidden [17]. However, making infrastructures invisible is an outcome of considerable work, effort, and investment [17]. The invisible becomes visible when the infrastructures break [15], which our study of maintaining AED will show. In healthcare infrastructure research, Gui and Chen [16] have shown that attending to breakdowns helps understand how patients and caregivers make healthcare infrastructure work. When infrastructures break down, the taken-for-granted logic and negotiations, needed to enable them to function, become visible. Therefore, attention to breakdowns that make infrastructures visible is relevant when looking into maintaining AEDs.

Scholarly work by Nissenbaum on accountability and responsibility [44] implies, “Responsibility, characteristically understood and traditionally analyzed in terms of a single individual, does not easily generalize to collective action” [44]. Going from self-organized maintenance to a commercially driven approach increases the number of actors involved, introducing more relations responsible for the maintenance to function. Nissenbaum draws on a moral-philosophical conceptual framework for understanding the interrelated concepts of liability, blame, and accountability in computerized systems [44]. This framework is used as a guideline when highlighting the increasing obscurity of accountability within computerized societies when, e.g., computerized systems are being built by “the hands of many” [44] or, in this study, connecting several actors in the development of an IoT solution to maintain AEDs. Nissenbaum emphasizes that labeling harm as accidents by the fault of the technology may produce further issues with the obscurity of accountability, highlighting that using “computers-as-scapegoats” may be tempting because “(...) computers present a curious challenge and temptation. As distinct from many other inanimate objects, computers perform tasks previously performed by humans in positions of responsibility. They calculate, decide, control, and remember” [44]. Holding computerized systems as “scapegoats” may, at first sight, be attractive, but as pointed out by Elish [42], that will not contribute to justice or serve the public good. Elish emphasizes the need for locating the responsible actor when a system fails and refers to the concept of ‘moral crumple zones’ deriving from ‘crumple zones.’ A crumple zone is intended to protect the human sitting in a car in case of an accident. The concept of a ‘moral crumple zone’ refers to cases where the aim is to protect a highly complex and automated system - the IoT solution for AEDs. However, the accountability for a fault often ends up being attributed to a human actor who had limited control of the failure in the automated and complex system. Thus, understanding the relational aspects of the different actors connected to maintaining AEDs may help untangle the obscurity presented by the many actors and differentiate between the social, technical, political, and ethical dimensions.

### **3 Methods**

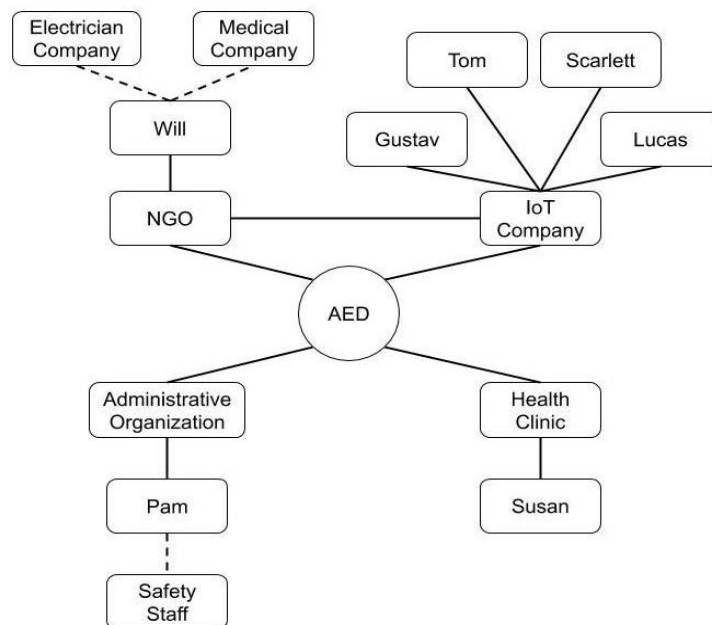
This section presents the ethnographic research methods used to investigate the infrastructuring of maintaining AEDs, constructed during our data collection.

#### **3.1 Constructing the Field**

We initiated our investigation by first contacting the Danish IoT Company that develops the hardware and software for the IoT solution. Here, Lucas, the CEO, a ‘gatekeeper’ [32], helped us extend our fieldwork to include the NGO that had initiated the IoT solution. The NGO pointed us to the Electrician Company responsible for installing the developed hardware on the AEDs. They also introduced us to the Medical Company that monitors the information in a software solution gathered from the hardware installed on the AEDs. To unfold the diversity of the infrastructuring of



maintaining AEDs, we included a health clinic in possession of one AED and an administrative organization that owns and maintains 96 AEDs. As our fieldwork developed, so did our field. We ended up with our constructed field of informants being the IoT Company, NGO, Electrician Company, Medical Company, Health Clinic, and Administrative Organization (Fig. 2).



**Fig. 2.** The constructed field in this study. The fully marked lines indicate direct contact with our informants, and the dotted lines indicate actors mentioned by our informants.

Ethnographically studying infrastructuring allows us to unfold the social, technical, political, and ethical dimensions present [17] within maintaining AEDs. Unfolding is a relational and situated job for ethnographers [33]. According to Karasti and Blomberg, we can understand the ethnographer's work as a fragmented process of creating options and possibilities when following connections and interactions between informants [17]. When studying the phenomenon, being the infrastructuring of maintaining AEDs, our field becomes constructed with this study's informants, the questions we ask, and how we understand the informants' answers. It is essential to be aware of the process of constructing the field when seeking to unfold and understand the dynamics that constitute the phenomenon of infrastructuring [17]. In our case, it is the infrastructuring of maintaining AEDs. When engaging in a field where actors are not all in the same place, multi-sited ethnography [17] is useful as it brings the possibility of constructing the field by following connections of the phenomenon, being the infrastructuring of maintaining AEDs, as they arise.

### 3.2 Data and Materials

This study began in February 2020 and ran until June 2020, and the methods used to gather data derive from the anthropological discipline, being ethnographic methods. The methods include participant observations [34, 35] and interviews [36]. We conducted participant observations at the IoT Company at the start and at the end of the study, where we gained knowledge about the IoT Company. Furthermore, we met different employees, extending our insights into the diversity in the IoT Company's ongoing tasks. We carried out our unstructured interviews during the participant observations where we spoke with different employees involved in developing the hardware and software for the IoT solution. These observations and unstructured interviews provided us with knowledge about the various challenges of developing the IoT solution. In total, we conducted 14 interviews, both unstructured and semistructured [36], with a duration ranging from 10 minutes to two hours. We carried out the interviews with employees from the IoT Company, the NGO, the Administrative Organization, and the Health Clinic.

### 3.3 Data Analysis

In our analytical process, initial patterns related to the informants' experience with the infrastructural properties of maintaining AEDs emerged. Following the data, we used the software program NVivo to categorize and code [39] the detailed descriptions of the dialogues from the interviews and field notes. We conducted coding in two rounds. The first round was open coding [38], where we kept an open approach and looked for categories by marking excerpts with codes. Based on the open coding, we went to the second round, focused coding [38]. Here, we looked for patterns among the many identified categories to identify overarching themes. Using this study's theoretical framework of infrastructure and infrastructuring [17], analytical points emerged that constitute our findings by analyzing these overriding themes. This iterative process involved going back and forth between the inductive notions and patterns from the field [38, 39] and the deductive understandings [40] from the theoretical framework. Growing out of this coding process, we used a thematic narrative approach [38] to present our findings below.

## 4 Findings

Our thematic narrative approach converts our data into a coherent story, using excerpts, where the emerging themes from the coding process structure the narrative [38]. When unfolding the infrastructuring of maintaining AEDs, we noticed, through the work with our informants, that the social dimension of responsibility becomes a matter of accountability, which leads to controversy across organizational levels. Will, from the NGO, acknowledges the controversy of responsibility and accountability when maintaining AEDs. He pointed out that the person responsible for checking up on the AED and, e.g., calling electricians to fix errors, could end up feeling accountable for a fully functioning AED, with life and death as a potentiality. This feel-

ing of accountability is one reason the NGO has initiated the development of an IoT solution. Will says:

“We sell the IoT solution as part of an insurance policy. You get everything. We take care of everything, all maintenance for the customer; there will not be any unexpected bills. You get the whole package. This is safety. We are selling, taking the responsibility (...) If that person vanishes, there is no one taking care of the AED. With our future service agreement, this will not be the case. The AED will be cared for”.

With the IoT solution, the NGO wants to take on the responsibility of accommodating the person who feels accountable for taking care of the AED. By taking the responsibility, they are ensuring that the AEDs will be maintained and stay fully functional. When we met Pam from the Administrative Organization, we found out that she is maintaining 96 AEDs. Pam is dedicated to maintaining the AEDs, but at the same time, she is what Will described as “that person” responsible for the maintenance, and if she “vanishes there is no one taking care of the AED”. Pam said:

“I don’t mind the responsibility, but it could be an advantage to have a technology that could support that the maintenance actually gets done. Right now, there are a lot of human factors that the maintenance depends upon”.

In the next section, we follow Will, Pam, and Susan, as we unfold the relational infrastructural landscape of maintaining AEDs, leading to breakdowns, which draws our attention to the controversy of responsibility and accountability.

#### **4.1 ‘The Wild West’ of Infrastructuring**

“As a private owner of an AED, you’re not bound to anything. You can install an AED that does not work. Many people think that it is something that the State is accountable for, but that is not the case! There are no rules about this! You can install all the AEDs you like and then just remove the batteries. That’s just how it is. It is the Wild West”.

In this quotation, Will links the lack of Danish regulation and private AED owners’ implicit accountability of maintaining AEDs to “the Wild West” – a state of lawlessness and low regulation with only the local sheriff trying to keep people safe. As a private AED owner, you cannot be held legally accountable for a non-functioning AED, which questions whether the purpose of the AED can be fulfilled in case of an emergency. With “the Wild West,” there is plenty of room for breakdowns in the infrastructure of maintaining AEDs, which relates to the controversy of responsibility and accountability, as it questions who will maintain the AEDs. Susan, the receptionist at the Health Clinic, is also confused about who is responsible for maintaining AEDs. She said the following about who is responsible for their AED maintenance:

“Hmm, I’m not sure. Someone comes and changes the battery; I think it is in 2022. But I really don’t know. We have it written on a note somewhere in the back office. It’s a part of a Danish campaign.”

Susan was not sure who was responsible for the maintenance, only that it was not the Health Clinic. She explained that she thought the maintenance was taken care of as part of the Danish campaign, wanting to distribute AEDs around the country. Ac-

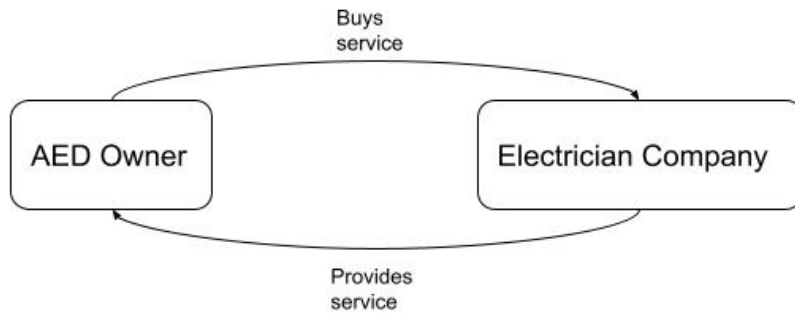
According to the Danish Health Authority, the responsibility of maintaining the AED relies on the actors that own the AED. Will explains how this is not always the case:

“(...) everyone can get an AED. Some owners invest in a service agreement having a firm do the check-up, but there are a lot of small firms selling it cheap. There is no control. Some firms have been in the media because they didn’t live up to the signed agreement. Others do it [the maintaining] themselves.”

When these relational infrastructures of maintaining AEDs become connected, reaching beyond just one actor, it becomes clear that the lawless dimension of “the Wild West” fuels the controversy of responsibility and accountability. Pam’s, from the Administrative Organization, description about how she became acquainted with the AEDs and in charge of the maintenance relates to the mentioned controversy:

“The question was who is in charge of the maintenance. There is no law, no mandatory inspection. I couldn’t find any regulation, but I needed to be sure the AEDs are taken care of.”

It was unclear to Pam who was responsible for keeping their 96 AEDs fully functional. Pam only knew that the physical maintenance was provided by an electrician company once a year, as seen in Fig. 3. Implementing new regulations, making the AED owner legally accountable for a non-functioning AED, may seem to be an effective step to address the lawless “Wild West.” However, such regulation could limit civic engagement in maintaining AEDs, as engaged people would feel hindered in acquiring AEDs. We will discuss this further in Section 5.1.



**Fig. 3.** Relationship of AED maintenance between the AED owner (*Administrative Organization*) and an Electrician Company.

## 4.2 Infrastructural Breakdowns

Breakdowns in the infrastructure of maintaining AEDs reveal the controversy of responsibility and accountability. Will described a breakdown, with an incident at a sports facility where an AED was not fully functioning and resulted in a man’s death. More so, Will draws attention to breakdowns caused by poor design of the AED cabinet, leading to someone stripping it together:

“People returning empty-handed because the AED is no longer there, or someone has stripped together the cabinet, making it impossible to reach the AED. Simply because the AED cabinet was poorly constructed, the battery has run flat, or the gel pads dried out, sometimes because the hard case has been opened or that there has not been a service check-up [maintenance] of the AED. All reasons for the AED not to function properly.”

The technical dimension of the infrastructure for maintaining AEDs stands clear when such breakdowns happen, where the battery runs flat or gel pads dry out. Breakdowns in the relational infrastructure of maintaining AEDs is also something Pam from the Administrative Organization has experienced:

“The AEDs kind of fell between two stools and got lost. The employee, who was very passionate about maintaining the AEDs, left his job, and no one knew, he was the one in charge of keeping an eye on the AEDs”.

What Pam describes as “falling between two stools” is what we understand, as when the job of maintaining the AEDs was not taken over by other employees, when the former employee left. The responsibility of maintaining AEDs got lost, until Pam noticed it. This situation shows a breakdown in an invisible infrastructure created by the former employee. As Pam unravels this invisible infrastructure, she found that: “All emails about when to check up on the AEDs went into the former employee’s mailbox.” The former employee had put time and effort into the task of maintaining the AEDs. He followed the recommendation from the Danish Health Authority about an electronic reminder, creating a well-working infrastructure at the time. Because the infrastructure worked and was invisible, it was taken for granted when he left. Pam said:

“When he left, it [emails] got lost. Somebody needs to get this reminder. Now, the emails go into our joint mailbox. We have 96 AEDs, I need to keep track of, so I created a local document on my computer, so I know what needs to be changed when.”

These breakdowns in the relational infrastructures underline the unclearness about who is responsible for maintaining AEDs, which all relate to the controversy of responsibility and accountability. These breakdowns and the controversy speak to the need for a sheriff in “the Wild West.” There is a need for someone to take on the responsibility of maintaining AEDs if they should continue to serve their purpose of being lifesaving technologies.

### **4.3 Breakdown Repair**

“(…) that’s [maintenance of AEDs] Alpha and Omega. But there is no standardized procedure. Somebody must take responsibility for the maintenance. Management agreed to put them [the AEDs] up, but not the maintenance. You don’t just install them. There are different types of maintenance, e.g., updates of different registers if the AEDs are moved around, doing the check-ups on AEDs, also making sure we have gel-pads in stock and keeping track of when to run a general status, which a company outside ours does. Management was like - that takes about five minutes - but it can’t be done, it’s unrealistic, it takes time. Someone has to feel passionate and

have a true commitment when it comes to the maintenance of AEDs. We had that [refers to the former employee].”

Pam’s initiative to avoid future breakdowns is by making a joint mailbox for electronic reminders and a personal, local document on her computer. In her local document, she decides on a fixed time, where all the batteries will be replaced. Pam tries to repair her experienced breakdown in the infrastructure of maintaining the AEDs. But the personal, local document makes the infrastructure fragile to future breakdowns, as she is the only person carrying the responsibility. Pam said that due to problems with her back, she needed to share the responsibility of maintaining the AEDs, prompting her to distribute the responsibility with the Safety Staff, a group of employees at the Administrative Organization. The distribution of the responsibility turned out to be a challenging task. Pam told how she used a lot of energy to make them see the importance of this task. The Safety Staff work day-to-day amongst the AEDs, making them able to detect if the AEDs send out alarms about errors, making the Safety Staff Pam’s “sensors in the field.” This was where Pam and the Safety Staff did not see eye to eye. As Pam said, “They didn’t want to be held accountable if something wasn’t working.” Suddenly, the Safety Staff’s work tasks were a matter of life and death, and they seemed uncomfortable with participating in the responsibility. “It’s not rocket science, but there are just a lot of emotions at stake. It’s not just about maintaining the AED,” Pam continued. Here, Pam mentions that maintaining AEDs is not rocket science, meaning that it is not a difficult job, but the problem is that social dimensions get entangled. This draws our attention to the importance of the social and technical dimensions when maintaining AEDs. The problem is not just to distribute the responsibility. Still, the Safety Staff concerns the potentiality of them being held accountable for the AEDs and, consequently, accountable for someone’s life. In this situation, the controversy of accountability and responsibility is apparent.

This section shows how Pam engages in developing an infrastructure for maintaining AEDs. Pam attempts to repair and avoid her experienced breakdowns and keep the AEDs from “falling between two stools.” In this infrastructuring, Pam sees a need to distribute her responsibility of maintaining the AEDs to the Safety Staff, which leads to an unwanted feeling of being accountable.

### **Repairing with the IoT solution**

Just like Pam trying to repair and avoid breakdowns in AED maintenance, the NGO also takes responsibility for maintaining the AED by developing an IoT solution. As pointed out by Will in Section 1, ‘Introduction,’ the NGO wants to sell the IoT solution as part of an insurance policy, which is why they have collaborated with the IoT Company, developing the software and hardware.

Gustav, a hardware engineer at the IoT Company, showed us the hardware, which “consists of a monitoring unit and an optical eye” (Fig. 4). The monitoring unit is a white box installed in the AED cabinet connected to the “optical eye,” the little black box at the end of the cord. The white box and the “optical eye” are designed to stay inside the cabinet. Gustav explained that they use magnets to make it easy for the Electrician Company to change the batteries in the monitoring unit: “If they are bolted into the cabinet, it takes too long.” The IoT Company tries to avoid future break-

downs in the maintenance of the AEDs by a design that makes it easy to access the monitoring unit. In this way, the IoT Company inscribes the Electrician Company's work practices into a technical solution.

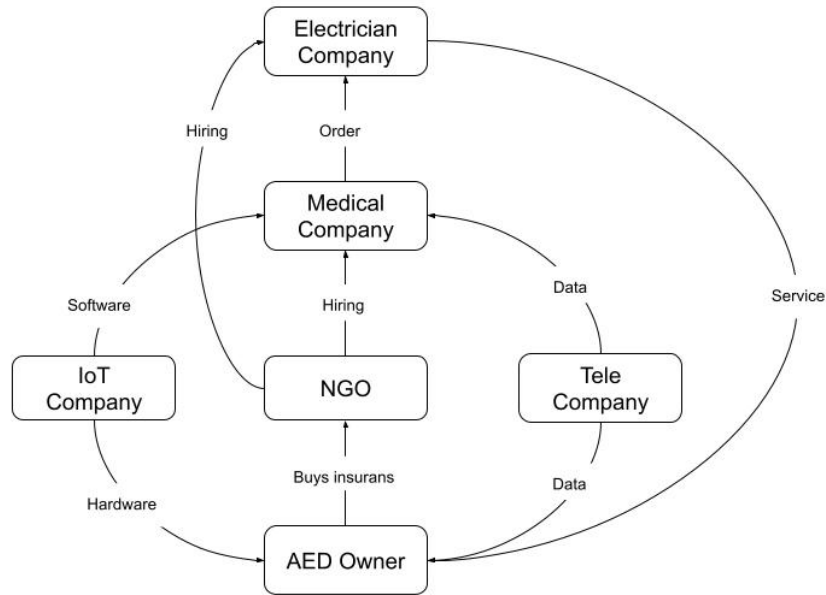


**Fig. 4.** Left: AED inside the cabinet. Middle: The monitoring unit and “optical eye.” Right: The monitoring unit.

Once every hour, the monitoring unit and “optical eye” harvest data about temperature, humidity, GPS location, and its online connection. Internally, the monitoring unit and “optical eye” monitor the mentioned parameters every hour and then once a day, every 24 hours, it sends these data to the Medical Company. The IoT solution functions as what Pam calls “sensors in the field.” But when the social dimensions come into play, the controversy of responsibility and accountability remains.

“The Medical Company will be given the screens [a dashboard]. They are in a better position to analyze the data. The Electrician Company is the one who is in charge of the practical stuff and needs to maintain the AEDs. The Electrician Company will be installing the monitoring units on the AEDs, but it will be the Medical Company that will monitor the AEDs. Then everybody does what they do best. We needed to feel comfortable in putting our trust in these companies in regard to the distribution of responsibility.”

Here, Will introduces the Medical Company and the Electrician Company. These actors are involved in the infrastructuring of maintaining AEDs with the IoT solution. Just like Pam, Will distributes the responsibility of maintaining AEDs to the Medical Company and the Electrician Company, to ensure fully functioning AEDs and to accommodate people feeling accountable for maintaining AED. However, implied in this infrastructuring with the IoT solution is the controversy of responsibility and accountability. Will foresees that the NGO will be held accountable if the AEDs do not work and cannot save lives. Therefore, the NGO is dependent on reliable actors to distribute their responsibility amongst. The distribution of responsibility for maintaining AEDs among the Medical Company and the Electrician Company had been rearranged during the development of the IoT solution so that “everyone does what they do best,” Will said. This reveals how the NGO seeks to distribute the responsibility of maintaining AEDs with the IoT solution (Fig. 5).



**Fig. 5.** Relationship between actors responsible for the IoT-driven maintenance of AEDs.<sup>2</sup>

## 5 Discussion

This study aimed to investigate the infrastructuring of maintaining AEDs. Unfolding the relational of the infrastructure of maintaining AEDs showed how the social, technical, political, and ethical dimensions are entangled herein. This study's informants experienced several breakdowns in the infrastructure, making them try to remedy these breakdowns with different solutions: a local document, a joint mailbox, and the IoT solution. These solutions aim to ensure that the AEDs are maintained, thus fully functioning and able to save lives, as an AED can be essential in the incidence of out-of-hospital cardiac arrest. However, this study revealed the controversy of responsibility and accountability when connecting the infrastructure of maintaining AEDs to other actors.

### 5.1 Civic Engagement in Lifesaving Technology

Investigating the infrastructuring of maintaining AEDs revealed several breakdowns, which resulted in AEDs not being able to fulfill their purpose as lifesaving technology (cf. Section '4.2 Infrastructural Breakdowns'). Social and political dimensions influ-

<sup>2</sup> The Tele Company provides the means of communication for the AED data to travel from the AEDs to the Medical Company.



enced these breakdowns, which show how the maintenance of AEDs is embedded into already existing structures and practices among this study’s informants. The political dimension of AED maintenance showed us a landscape like “the Wild West,” with no compulsory regulations, only recommendations (cf. Section ‘4.1 The Wild West of Infrastructuring’). A way to remedy these breakdowns could be to implement new regulations that would make the AED owner legally accountable for the AED maintenance. However, this could lead to civic engagement being minimized with the legal aspect as a judge. With less civic engagement, we take the risk of reducing the diffusion of publicly available lifesaving technology. The aim with the recommendations of AED maintenance relates to Korn and Volda’s infrastructure of civic engagement, being “those socio-technical substrates that support civic activities [and] (...) enable and support local practices” [28], where the purpose is to engage people to act. The hope with only having recommendations is to engage people in maintaining their AEDs, so they are capable of saving lives, instead of implementing new regulations, forcing the owner to do the maintenance by holding them accountable. Both Pam and Will decided to engage in maintaining AEDs to remedy the experienced breakdowns. In their engagement, they seek to upscale and connect the infrastructure [15] of maintaining AEDs by distributing the responsibility with other actors. They sought to develop infrastructures of civic engagement. However, as the infrastructure got upscaled and connected [15] to other actors, tensions occurred. The social dimension of accountability became evident in the breakdowns (cf. Section 4.2 ‘Infrastructural Breakdowns’) in the infrastructuring of maintaining AEDs. As Korn and Volda [28] put it:

“[These] moments of infrastructural breakdown can become moments of awareness, reflection, and questioning about the activities that infrastructures enable and the values inscribed in them” [28].

The social dimensions of accountability became entangled, and the task of maintaining the AEDs became a matter of life and death. This form of accountability speaks to a human-centered ethos, as humans watch the AED for humans. This raises the concern of who will participate in the responsibility of maintaining AEDs, and in the end, who will be held accountable for a fully functioning AED or, worse, a non-functioning AED.

## 5.2 Technological Repairs

“Perhaps most important of all, what values and ethical principles do we inscribe in the inner depths of the built information environment [the infrastructure]? We need new methods to understand this imbrication of infrastructure and human organization. One promising direction is to apply the tools of ethnography to this imbrication” [29].

In this quote, Star [29] underlines the importance and fruitfulness of applying ethnography to study infrastructures. By using the methods of ethnography, we saw how the social dimensions, or human organization [29], seem to be a struggle of coming to terms with the responsibility and accountability of maintaining AEDs (cf. Section ‘4.1 The Wild West of Infrastructuring’ and ‘4.2 Infrastructural Breakdowns’). With the IoT solution, the aim is for the mentioned breakdowns to be remedied (cf. Section

‘4.3 Breakdown Repair’). A technical IoT solution, the “optical eye,” is now watching over the AED. It tries to take on human-centered accountability with that of a technical one, leaving the IoT solution as the scapegoat. With 24-hour feedback on the AED status regarding humidity, temperature, and GPS location, everybody should rest assured that the AEDs are taken care of. Even though the IoT solution distributes responsibility, accountability will still be attributed to humans, just as Elish describes with the moral crumple zone [42]. This relates to the importance of looking at technical and social dimensions when investigating infrastructure and infrastructuring, raised by Karasti and Blomberg [17]. There is a need to understand these dimensions when unfolding the relational infrastructure, as “[the infrastructure] is embedded in, sunk into, other structure, social arrangement and technologies. This emphasizes the dense, socio-technical imbrication of infrastructure” [17].

The IoT solution can assist in maintaining AEDs on a technical level. Still, the social and political dimensions of accommodating accountability by distributing responsibility, as part of the infrastructuring, are not done by the technology itself. The technological dimension, and more specifically the IoT solution, cannot be held accountable if an AED cannot serve its purpose as a lifesaving technology. Ethical reflections need to be considered when developing infrastructures [29]. Suppose accountability is inscribed in the IoT solution. In that case, it can be held accountable for not saving lives, leaving the technology as a scapegoat to blame, and excuse the owner for not maintaining his/her AED [44]. However, based on this study’s findings, we believe that it will not be possible to hold the IoT solution accountable for not saving lives. As Nissenbaum pointed out, “computers perform functions previously performed by humans in positions of responsibility leading to the illusion of computers as moral agents capable of assuming responsibility” [44]. The IoT solution could help distribute the responsibility for maintaining AEDs. Human feelings of accountability become a driving force in taking care of lifesaving technology. Will seeks to accommodate feelings of accountability with a new technological solution but still claims the NGO will be held accountable.

### 5.3 A Sustainable Future for the IoT solution

Studying the infrastructuring of maintaining AEDs has drawn our attention towards the importance of negotiating strategic goals. A working infrastructure needs regular repairs, monitoring, and upkeep [17]. In our case, the IoT solution is also a work-in-progress, where different actors have their strategies and goals. For the IoT Company, the hardware and software of the IoT solution are, in the future, set out to become connected to new customers in different cases with different demands. For the NGO, the goal is to maintain as many AEDs as possible, meaning the hardware and software of the IoT solution need adjustment to fit different brands of AEDs. This risk of diverging strategic goals relates to Ribes and Finholt’s [31] emphasis on short and long-term vistas as a critical tension in an infrastructure. Designing an infrastructure for long-term maintenance of a lifesaving technology like the AED is a “varied compendium of work done today with an eye toward generating a sustainable future” [31], which Ribes and Finholt call “the long now.” Ribes and Finholt describe how new

technological platforms, like in the IoT solution in our study, often “do not match the extant needs of users, do not offer the functional stability that daily use demands, or lack the human resources to upgrade and maintain existing technology” [31]. Therefore, it is not enough for the two companies in our study to have one common goal of developing the IoT solution. They should have a joint responsibility to focus on a common sustainable future solution, where ongoing upkeep is in focus; otherwise, the IoT solution will only further lead to breakdowns in the infrastructure of maintaining AEDs.

## 6 Conclusion

In the case of out-of-hospital cardiac arrest, the use of an AED can be the difference between life and death. Thus, AEDs must be maintained to be fully functional and able to save lives. This study showed how a controversy of responsibility and accountability is present in the infrastructuring of maintaining AEDs. This controversy became clear as this study’s informants experienced different breakdowns in the infrastructure of maintaining AEDs, which caused the AEDs not to function as intended. The maintenance of AEDs is not compulsory. Thus, the political foundation is unclear - “a Wild West” - only based on recommendations. Implementing new regulations, making AED maintenance compulsory, can be challenging as civic engagement can be minimized. With less civic engagement, we take the risk of reducing the diffusion of publicly available lifesaving technology. The informants in this study describe how they have initiated different solutions: the IoT solution and a local solution involving a local document and a joint mailbox to repair and overcome the experienced breakdowns in the infrastructure of maintaining AEDs. In these solutions, the aim is to accommodate the controversy of accountability by distributing the responsibility of maintaining AEDs. However, the social dimension of potentially being held accountable for the AED and being the scapegoat when scaling up and connecting the infrastructure of maintaining the AED to other actors became visible. The IoT solution can technically participate in distributing responsibility for maintaining AEDs, but actors cannot avoid the social dimension of accountability. Therefore, our recommendation is that socio-technical perspectives should be taken into account when doing infrastructuring and developing new infrastructures to address possible controversies of responsibility and accountability. Future research on developing IoT solutions for technologies installed in non-medical environments dependent on civic engagement should pay attention to technical, social, political, and ethical dimensions. Furthermore, future research should focus on the importance of a graphical user interface (GUI) for lifesaving technologies to accommodate public engagement.

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