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Development of a stakeholder identification and analysis method for human factors integration in work system design interventions – Change Agent Infrastructure

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Abstract

In any work system design intervention—for example, a physical workplace re-design, a work process change, or an equipment upgrade—it is often emphasized how important it is to involve stakeholders in the process of analysis and design, to gain their perspectives as input to the development, and ensure their future acceptance of the solution. While the *users* of an artifact or workplace are most often regarded as being the most important stakeholders in a design intervention, in a work-system context there may be additional influential stakeholders who influence and negotiate the design intervention's outcomes, resource allocation, requirements, and implementation. Literature shows that it is uncommon for empirical ergonomics and human factors (EHF) research to apply and report the use of any structured stakeholder identification method at all, leading to ad-hoc selections of whom to consider important. Conversely, other research fields offer a plethora of stakeholder identification and analysis methods, few of which seem to have been adopted in the EHF context. This article presents the development of a structured method for identification, classification, and qualitative analysis of stakeholders in EHF-related work system design intervention. It describes the method's EHF-related theoretical underpinnings, lessons learned from four use cases, and the incremental development of the method that has resulted in the current method procedure and visualization aids. The method, called Change Agent Infrastructure (abbreviated CHAI), has a mainly macroergonomic purpose, set on increasing the understanding of sociotechnical interactions that create the conditions for work system design intervention, and facilitating participative efforts.

KEYWORDS
design changes, stakeholder analysis, stakeholder identification, stakeholder method, work system design

1 | INTRODUCTION

When a work system (WS) design intervention—for example, a physical workplace re-design, a work process change, or an equipment upgrade—is carried out from a participative ergonomics perspective, it is often emphasized how important it is to involve stakeholders in the process of analysis and design, to gain their perspectives as input to the development, and ensure their future acceptance of the solution. Ergonomics and human factors (EHF) authors from different fields often promote the *users* of an artifact or workplace as being the most crucial stakeholders in a design intervention, although there may be additional stakeholders who influence and negotiate the design intervention's outcomes, resource allocation, requirements, and implementation. This is particularly true in a work system context, where sociotechnical interactions tend to create the conditions for a design intervention's implementation.

In such complex processes, the power of multiple stakeholders over the outcome of the design intervention cannot be ignored, as sometimes non-users may have significant influence on the requirements and implementation of the change. It, therefore, seems prudent for anyone leading or participating in such an intervention to develop and share an awareness of which stakeholders may influence the outcome and process.

The endeavor of EHF integration is sometimes in need of a dedicated "champion" to drive the integration (Berlin et al., 2014). We can picture a scenario where a person with a moderate to high degree of EHF expertise becomes aware of an upcoming planned, tangible change to a work system. Either from their own conviction or by request, this person may decide to actively ensure that EHF considerations should be integrated into the intervention, in the form of requirements, goals, and methods from an EHF perspective. We will refer to the person with this ambition as the "EHF change agent" throughout the rest of this article, and to the work system change as the "design intervention."

It is not a given that the EHF change agent will be dealt significant influence over the design intervention; for one, not all EHF change agents are in a leadership position. As likely as being the intervention project manager, they may be an expert role, or even an external consultant, or even a worker who is about to be affected by the change—as such, they must orient themselves in who actually does exercise power and influence over the planning and execution of the intervention. Regardless of the organizational positioning of the EHF change agent, they may be successful in providing compelling and convincing arguments for the benefit of EHF integration, if they succeed in orienting their EHF goals alongside those of other stakeholders.

Integrating perspectives of EHF into WS design interventions is a scientific as well as a practical endeavor. On the practical side, (Stanton et al., 2013, p.27) list that EHF practitioners (among other things) address real-world problems; seek the best compromise under difficult circumstances; analyze and evaluate the effects of change; and communicate findings to interested parties. To succeed in all of these endeavors, it would seem that an EHF practitioner in general must have a clear idea of who or what else shapes the definition of the real-world problem, what makes a "best compromise," whom the change will affect, and who needs to be communicated with. In short, a stakeholder identification and/or analysis would quite obviously support the fulfillment of these endeavors. Regarding the scientific side, using rigorous methods for data collection and analysis and ensuring repeatability eventually contribute to a stronger case for EHF integration.

All of this begs the question—What tools exist for EHF professionals and researchers to facilitate stakeholder identification and/or analysis (SIA), and how are such methods used? How are stakeholders in EHF interventions typically identified, classified, and determined as important?

To address these queries, this article examines the use of SIA methods in EHF empirical studies, and then describes the development of a structured method for identification and analysis of stakeholders in work system design interventions. It describes the method's theoretical underpinnings, incremental development from use cases that have resulted in the current procedure, and discusses issues of validity, reliability, and usefulness. The method is carried out in steps, following a guiding template, and is (ideally) performed collaboratively together with other people in an intervention project team, and iteratively as the project progresses to update the common understanding of which stakeholders matter.

1.1 | Definitions of key terms

To clarify the scope of this article and method, some basic concepts that will be frequently referred to are defined as follows:

- **Human Factors (HF) Problem** – inspired by Stanton et al. (2013, p. 2, Figure 1.1) we define this as a sociotechnical problem that is (1) likely to have a negative impact on overall system performance, (2) involves humans and human behavior, (3) is not easily solved with purely technical interventions, and (4) may have a scope that renders existing methods insufficient to secure human well-being and system performance.
- **HF Method** – also based on Stanton et al. (2013, p. 2, Figure 1.1) and (Annett, 2002), this is an approach that adequately addresses one or more aspects of an identified *HF problem* to either increase understanding of the system at hand (analytic method), or provides a means to measure observable phenomena (evaluative). In our case, the CHAI method targets the early-phase goal of *Identifying needs*, through *understanding people and processes*.
- **Work system (WS) design intervention** – we define this as a planned change of work conditions within a limited, specific sociotechnical system. The changed work conditions can for example be a physical workplace re-design, a work process change, or an equipment upgrade. The WS design intervention includes the phrase "design" to imply that a change is planned and implemented based on a list of identified needs and requirements,

resulting in a decision to alter physical or organizational conditions. We consider this intervention to be finite in time, which is why we will assume that it is most often carried out in the form of a project.

- **Project** – defined by Project Management Institute as being "(…) temporary in that it has a defined beginning and end in time, and therefore defined scope and resources" and "(…) unique in that it is not a routine operation, but a specific set of operations designed to accomplish a singular goal." (Project Management Institute, 2021)
- **EHF change agent** – in line with the use scenario and persona we described earlier, we assign the moniker of "EHF change agent" to any person who wishes to influence a WS design intervention to integrate EHF perspectives into it, and to do so in a participative manner. We consider the EHF change agent as being in need of an increased understanding of how to navigate among and negotiate with the concerns of other stakeholders, and is therefore the target user of the CHAI method.
- **Analyst(s)** – this is the phrase we use in this article to signify the people who use the CHAI method to perform an SIA. Being an analyst may overlap with being the EHF change agent, but all participants and stakeholders who help to carry out the SIA are referred to as analysts.
- **Change infrastructure** – this phrase is borrowed from earlier works by Berlin (2011) and Berlin et al. (2016) where "infrastructure" is a metaphor for the various relational pathways by which an EHF change agent gets in contact with and convinces other stakeholders surrounding an intervention. An underlying assumption is that the EHF change agent must understand the convictions and priorities of other stakeholders to successfully navigate in an organizational setting, and persuade others to integrate EHF requirements into design interventions.

1.2 | SIA in EHF literature

To address the question of what SIA methods are available to guide the EHF change agent, Table 1 shows an illustrative (although not exhaustive) sample of EHF literary contributions that are SIA-related. These were found with a literature search in Scopus based on variations of the concept "Stakeholder(s)" and "Ergonomics" or "Human Factors" (See Appendix A for complete search strategy and results). The found EHF contributions, depending on their purpose, were assessed regarding whether they explicitly state that stakeholders are important to consider, name specific stakeholders (if applicable, primarily in empirical studies), use any kind of explicit method or approach for identifying stakeholders in a structured manner, and whether they reference any stakeholder analysis (SIA) literature (as far as made evident by the references' title, abstract, and keywords).

Although not an exhaustive table, one finding is clear: EHF literature about Stakeholder identification or analysis is not plentiful (see search results in Appendix A), and rarely appears to apply any

structured method for identifying and mapping stakeholders. Guiding literature on how to account for stakeholders from an EHF perspective appears sparse.

While only a few sources (notably from maritime ergonomics) describe an approach for how mentioned stakeholders were selected, about half of the examples include stakeholder analysis-related literature in their references (judging from titles, keywords, and abstracts). This ad-hoc approach contributes to great acceptance for arbitrarily identifying stakeholders in EHF literature.

At the same time, there is a possibility that EHF papers simply do not report the stakeholder identification step, regardless of whether one has been explicitly taken. It seems unlikely that most participative intervention studies can be done at all without some sort of stakeholder selection, for example, for interviews, observations, and other involvement. In other words, it is hard to learn the process and rationale behind a stakeholder list in literature, if a rationale for how it came about is not reported.

1.3 | SIA methods from other fields

Stakeholder identification/analysis methods stemming from other fields of scientific literature, on the other hand, appear relatively plentiful. Many appear to come from social science disciplines like business management, policy-making, and environmental studies. For example, Table 2 gives an illustrative overview of a number of available methods and "templates" for identifying and classifying stakeholders, which have shown to be mainly from non-EHF disciplines. Since a search for "Stakeholder Analysis method" in Scopus returns a vast number of results, many of which are not instructive, this list originates from a resource bibliography from one of the authors' lectures on the topic of SIA held for undergraduate students, which has been extended with a snowballing search (references found from the references of those sources).

The first part of Table 2 shows an overview of guidelines of a "cookbook" character that cover generic steps for stakeholder analysis and -engagement in different fields. Common denominators in SIA across different fields are the three steps of identification, characterization, and strategizing for involving stakeholders. It is however important to highlight that the stakeholder considerations for characterizing and categorizing are somewhat different across the fields (see Table 2). The second part of Table 2 shows conceptual frameworks, models, or typologies that focus on a specific aspect such as conflict resolution. These works are relevant for SIA and can be used together with a step-by-step guide depending on the application and its contextual conditions.

So why are these available methods from other fields (for lack of others) not commonly applied in EHF literature to structure and strengthen the case for the identification and involvement of appropriate stakeholders? The answer may lie partly in the original intent of many of the methods in Table 2: they are often purely from a *management* point of view, often with a goal to determine which stakeholders wield a certain degree of political power in enabling or

TABLE 1 An illustrative list of "Stakeholder"-oriented empirical EHF studies

Case description and source	States importance of considering stakeholders	Describes how (named) stakeholders were identified	Includes references related to SIA[a]
Main purpose: Identify stakeholder(s)			
Identifying stakeholders for Shore Control Center (Veitch et al., 2020)	Indirectly	Focus groups and Interviews	–
Identifying key stakeholders in maritime human factors (Österman et al., 2009)	Indirectly	Using a life cycle perspective	–
Main purpose: Understand an issue (empirical study)			
Interview study with ergonomists about their work (Theberge & Neumann, 2010)	Yes	(No stakeholders named)	Yes (3)
Perception of early identification of underperforming students in higher education through student data analysis (Sun et al., 2019)	Yes	Stakeholders named – No description how	–
Interview study with physicians to interpret survey data from patients in medical device design (Cajander & Grünloh, 2019)	Yes	Two stakeholders named – No description how	Yes (1)
Study communication between developers and clients during software development (Zhang & Pastel, 2014)	Indirectly	(No stakeholders named)	Yes (7)
Interview study to understand the constraints under which medical device development take place (Vincent et al., 2014)	Yes	(No stakeholders named)	Yes (1)
Understand the impacts of a ride-sharing platform on Uber drivers (Ma et al., 2018)	Yes	Based on which stakeholders had been mentioned in an internet forum	Yes (over 20[b])
Identify assembly training needs for operators in final assembly lines in automotive industry (Hermawati et al., 2015)	No (implied)	Through discussion between manufacturing representatives and EHF researchers	–
Main purpose: Propose theory/method			
Inclusion of stakeholder analysis methods and concepts in mental model theory (Searle & Todd, 2019)	Indirectly	(No stakeholders named)	–
Study collaboration between disciplines in software development (Kowalski et al., 2006)	Yes	(No stakeholders named)	-
Explore a possible Sustainable System-of-Systems Approach for Human Factors and Ergonomics (book chapter, (Thatcher & Yeow, 2018)	Yes	(No stakeholders named)	Yes (1)
Introduce applied methodological tool "Systems Scenarios Tool," with examples from healthcare and manufacturing industry (Hughes et al., 2017)	Indirectly	Stakeholders described in general, but no examples. Identified either through brief scoping interviews or more formally as in references	Yes (2)
Reveal user requirements of office layout and space planning (Brooks, 1998)	Indirectly	Stakeholders named, but only as examples (not an empirical study)	

Abbreviations: EHF, ergonomics and human factors; SIA, stakeholder identification and/or analysis.

[a]References were classed as SIA-related as interpreted from their title, abstract, and keywords.

[b]In this case, references were classed as SIA-related only as interpreted from their title due to a high number.

TABLE 2　A list of SIA methods found in other research fields

1. Step-by-step guides (source)	Field/application area	Stakeholder considerations
Stakeholder outline & commitment matrix (Jepsen & Eskerod, 2009)	Project management (hospital renewal case studies)	Interest, contributions, expectations, power, strategy, responsibility, commitment
Typology of SIA methods (Reed et al., 2009)	Resource management	Interest, power, influence, perception, relationships with other stakeholders
Stakeholder analysis (Golder & Gawler, 2005)	Conservation project management	Mandate, role, influence, importance, impact, strategies for engagement
Stakeholder identification and analysis techniques (Bryson, 2004)	Public and non-profit management	Power, interest, influence, ethics, problem frame, support, opposition, roles, capabilities, policy attractiveness, policy implementation, participation
SIA guidelines (Brugha & Varvasovszky, 2000)	Policy implementation in health care management	Involvement, interest, influence/power, position, impact of issue on actor
SIA guidelines (Schmeer, 2000)	Health reform policy or program implementation	Reason chosen/relation to policy, knowledge, position (stance), interest, strategies, alliances, resources, power
2. Conceptual frameworks, models, and typologies (source)	**Field/application area**	**Stakeholder considerations**
Agent-based simulation (Perišić et al., 2016)	Team/project management/PD	Role, competencies, availability, motivation, experience, behavior
Project-stakeholder relationship formation model (Karlsen, 2008)	Project management (engineering projects)	Relationship formations and underlying mechanisms
User typology (Janhager, 2005)	Product development	User types (primary, secondary, side- & co-users), use profile, user relations
Constructs in stakeholder identification and salience (Mitchell et al., 1997)	Management	Power, legitimacy, urgency, salience, types (expectant, latent, definitive)
Framework for stakeholder analysis and conflict management (Ramirez, 1999)	Natural resource management	Problem, boundaries, problem owners, power, urgency, legitimacy, roles, relations, knowledge, capacity, decision-making procedures,
Diagnostic typology of stakeholders (Savage et al., 1991)	Management	Factors affecting stakeholders' potential for threat or cooperation, strategies for managing stakeholders

Abbreviation: SIA, stakeholder identification and/or analysis.

hindering the change, and who are the most or least interested. Simply "managing" relations with these power-wielding stakeholders may not appear to be a concern of primary interest to the EHF change agent trying to map user requirements. Further, it appears uncommon that EHF specialists are trained in specific methods for stakeholder identification and analysis, although such knowledge could easily benefit perspectives of macroergonomics (which Hendrick and Kleiner (2005, pp. 3–4) characterize as *"(…) a top-down sociotechnical systems approach to the design of work systems"* that *"(…) most often requires employee participation at all levels of the organization"*).

Some takeaways from other fields come close to the EHF idea of *user-centered design*. Pacheco and Garcia (2012) review the stakeholder identification methods for requirements elicitation (RE) in software development perhaps comes closest. It states that three practices should be fostered to improve the stakeholder identification process (a) Using *"(…) an analysis of skills, behavior in group dynamics and personality tests"* to assign appropriate roles to stakeholders (although depending on the available time of the stakeholder), (b) enabling ways for all stakeholders to constructively interact with each other and the system during the RE process, *"to avoid conflicts and problems of communication"*; and (c) classifying elicited requirements *"according to an evaluation of their priorities in relation to the project goal, to define the interactions between the stakeholders themselves, and between the stakeholders and the project (…) to verify whether the initial project goal has been satisfied."* (Pacheco & Garcia, 2012, pp. 2178–2179)

Furthermore, macroergonomic perspectives are reflected in the more management-oriented SIA literature in many ways. Research by Jepsen and Eskerod (2009, in a project management context) identified a need for (1) guidelines for how to distinguish between important and not-so-important stakeholders based on desk research and prior knowledge, (2) increased clarification on how to approach and interview stakeholders, and (3) that SIA needs to be an iterative, dynamic and participative process involving stakeholders, *"focusing on what they can contribute and concerning their contributions and rewards"* (Jepsen & Eskerod, 2009, p. 342).

Chances are that the scope and credibility of an EHF-oriented intervention may benefit from a more tailored approach that can focus interventions and information towards user perspectives, rather than simply listing stakeholders who happen to be present in the picture.

1.4 | Structure of this article

The rest of this article is structured as follows. First, the theoretical underpinnings of the method and its development up to its present state will be briefly described. Then, the method procedure is explained step-by-step, detailing the set-up, execution and follow-up suggested for the method. Then, a number of use cases where the method has been tested in various scenarios and versions will follow, explaining how the method has been received by users and whether any gradual modifications occurred as a result of each use case. Finally, this article will highlight the relative benefits and drawbacks of the method as compared to other alternatives, discuss issues of validity, reliability, and usefulness, and directions for further development.

2 | THEORETICAL BASIS AND STRUCTURE

The Change Agent Infrastructure (CHAI) matrix has resulted from a body of work spanning several years of studies of how mainly ergonomists and industrial engineers act to successfully influence workplace changes to benefit EHF aspects, primarily in a manufacturing setting (Berlin, 2011; Berlin et al., 2014), followed by incremental development using Action research (Dick, 2002). Its focus has been influenced by the notions that "political reflective navigation" (Broberg & Hermund, 2004) and "organizational work" (Theberge & Neumann, 2010) are important for these professionals to pursue, to persuade other stakeholders and thereby secure attention, resources, and acceptance for interventions that have an EHF objective.

As a result of building on (Broberg & Hermund, 2004) which in turn relies theoretically on *Actor-Network Theory* (Latour, 1987; Latour, 2005; Law & Callon, 1992), a foundational idea of the CHAI method is to accept that both human and Nonhuman "actors" exist; or, as stated by Latour (2005, p. 71), *"anything that does modify a state of affairs by making a difference is an actor."* This acknowledges that technological change and persuasion occur as a result of dynamic relations between humans and artifacts, that for a limited time establish a *"negotiation space"* (Law & Callon, 1992). This implies that identifying stakeholders can very well include the recognition of a Nonhuman entity (such as a law, software, prototype, document, algorithm, code of conduct, etc.) as an actor in a change process. Many different outcomes are possible due to the varying interests, interpretations, and goals of all the elements in the actor-theory network, but the actors tailor their actions towards "stabilizing"

networks to support a particular outcome (Broberg & Hermund, 2004).

2.1 | Central concepts

Determining the CHAI of an intervention builds on three central concepts:

2.1.1 | The intervention proposal

In a CHAI analysis, it is foundational to explicitly phrase what the work system design intervention aims to achieve as a lasting effect. While it is recommended for workshop exercises that the intervention proposal be kept brief, there is no official limit to its length or scope. A basic "quality control" of the Intervention proposal statement is that it should:

(a) *state what will be intentionally different, on a tangible design-change level, compared to the current state; and*
(b) *be based on a legitimate problem or need, as experienced by one or more of the stakeholders.*

The above statements imply that the intervention proposal benefits from being a tangible suggestion rather than a simple problem statement, and that any actor who defines a legitimate problem or needs automatically gets counted as a stakeholder. If CHAI is used iteratively during the course of a project, the Intervention proposal may be refined for each iteration, as it may progress in clarity from an overall desired effect to concrete design parameter changes.

2.1.2 | Actors

Since a CHAI analysis builds "in spirit" on Actor-Network Theory (Latour, 1987; Latour, 2005; Law & Callon, 1992) it recognizes both humans and nonhuman artifacts as potential Actors (capitalized here when pertaining to the CHAI framework). Its output is relational, and it highlights the possibilities for influence and persuasive behaviors between Actors, chiefly based on shared perceptions of legitimacy. With regard to nonhuman Actors, their influence over change proceedings may be based on their perceived legitimacy and relevance among the human Actors, and on their static, consistent configuration of what process outcome or goal is desirable. For example, a law or prototype is a nonhuman Actor which may influence the persuasions of other Actors, until it is perceived as obsolete or a new one replaces it. If different human Actors perceive a nonhuman Actor as having more or less legitimacy, mismatches in that perception may cause conflict as it is no longer clear which entity has "authority."

An aspect of identifying human Actors is that they in some way display *agency*, which (consistently with social science parlance) is defined as an individual capacity to act on free will and

TABLE 3 The taxonomy of stakeholder "Roles" of the Change Agent Infrastructure (CHAI) framework for identifying crucial stakeholders

Role	Definition/behavior patterns relative to the intervention
Initiators	Bring attention to the underlying need for change and place the problem on the official agenda to be dealt with.
Sponsors	Sponsors are not directly affected by or active in the intervention but maintain and support the legitimacy of the intervention, morally or with resources, and keep it on the agenda.
Subjects	Actors who are recipients of the intervention, and whose operations are directly affected by both the original problem (if left unresolved) and the proposed change.
Documenters	Documenters document the problem formulation, requirements, decisions made, quality criteria and/or the design/execution of the intervention.
	A variety of actors may be responsible for different stages of documentation, which may lead to it being spread out in different formal and informal forums and mediums.
Convincers	Convincers use evidence (e.g., statistics, measurements, studies, reports) to convince other actors that there is a legitimate need for action and that change is required.
Change owners	Change owners are assigned legitimate ownership of the problem or intervention. They are assigned to ensure that the problem is resolved (i.e., that an investigation is made and the intervention is carried out). They have the mandate to determine when the intervention is sufficiently implemented.
Solution builders	Solution builders are made responsible for examining, advising on, and eventually solving the problem. They contribute wholly or partly to the design and implementation of the intervention, for example, with expertise, feedback, resources, or practical action.
	Their combined effort is assessed and approved by the Change owner who determines whether the solution proposed is sufficient.
Blockers	Blockers inhibit the proposed change. The intervention may involve a threat or conflict of interest for them. They may use arguments and power to hinder the intervention, or may withhold access, resources, or contacts needed to proceed.

Note: Adapted from Berlin et al. (2016) and informal workshop materials (Berlin, 2018).

independently of others. CHAI explores the ways in which that agency can be challenged, swayed, or reinforced due to characteristics held by each Actor. Perišić et al. (2016), in the context of agent-based simulation of development teams, propose that Agents have the following explicit characteristics: Role, Competencies, Availability, Motivation, Experience, and Behavior (although "role" in their framework pertains to the agent's operative working role). These characteristics are equally interesting and helpful to map when exploring the interactions and relative persuasions of "real" stakeholders in empirical intervention projects. (Importantly, the characteristic of "Role" is defined differently in CHAI.)

Nonhuman actors should not be overlooked as relevant to the sociotechnical interactions surrounding the intervention; particularly nonhuman actors that legally, practically, or cognitively constrain the available design choices for the intervention proposal. Sometimes, human actors will refer to limitations imposed upon their freedom to act by nonhuman actors. Examples of such actors are, for example, regulatory bodies, standards, laws, company policies, automated processes, software, IT frameworks, certification bodies, governmental authorities, documentation frameworks, or artificial intelligence. When humans go about their work operations in a workplace, it may be a matter of active training, reflection, and experience to actively recognize that a nonhuman entity is influencing decision choices and available alternatives; this particular aspect of CHAI may demand a bit of extra reflection work from analysts. A valuable probing question to find a nonhuman actor for a Role

might be: *"if there is a driving force for this role, has it been automated or put into policy somehow?"*.

2.1.3 | Roles

In CHAI, "Roles" are a pre-defined, a priori taxonomical categorization of how an Actor reacts or responds to the particular change or problem at hand; that is, their "Role" describes their expected way of relating to the change, once the intervention proposal becomes explicitly stated. These behavioral patterns may span from simply entertaining certain attitudes and beliefs, to engaging in concrete actions like co-operating in the change process or sabotaging it. In contrast, Roles are *not* to be equated with the title or task that is bestowed on an Actor.

The pre-defined roles originate from Jonker and Pennink (2010, pp. 7–8) framework of five "stakeholder/problem relation modes" plus some incremental refinements motivated by further theoretical and empirical exploration (Berlin, 2011; Berlin et al., 2014; Wells et al., 2013) that increased the number of roles to eight to become more relevant for an EHF improvement context. Their relevance and comprehensiveness are explored in the Use cases described later in Section 4.

What is most important to remember is that multiple Roles—that is, ways of relating to the change—can be engaged in by the same Actor. For example, a product user engaging in a participative

process may be both the Initiator of the change, the Subject, and the Solution builder (see Table 3). In another case, an office worker whose workplace is being renovated to become an activity-based flexible workplace may be the Subject as well as a Blocker. This possibility of taking on multiple roles is because their reaction(s) to the change may be informed by several differing—sometimes conflicting—motivations at the same time. Table 3 gives an overview of the eight pre-defined roles (or ways of relating to the change) that can be expected from actors in a design intervention process. Roles do not have any particular order or hierarchical relationship between them.

In particular, "users" of a product or workplace are most often found in the Role of Subjects to design intervention. Subjects may have limited influence, but winning their support and acceptance of the intervention may be crucial for implementing the change successfully, otherwise, resistance towards the change may continue among Subjects long after implementation and damage good-will relations (making them Blockers). It therefore becomes extra important to learn the motivations of Subjects for desiring or resisting a change in their operations.

In cases where a participative process or codesign is implemented to elicit user requirements participatively, the users are not only Subjects but also intentionally made Solution builders, and possibly also credited as Initiators of the change. In contrast, once an Actor has been recognized as a Blocker, finding out their motivations to oppose or resist the change can become valuable input towards initiating dialog, adapting the change solution to their needs, and gaining acceptance. An Actor may also become a Blocker inadvertently, by having insufficient time or resources to give to the intervention.

3 | THE CHAI ANALYSIS METHOD

Ideally, a CHAI analysis is carried out collaboratively in a workshop format, with a team of analysts and/or stakeholders, in relation to an intervention that creates a tangible change within a defined context.

For example, the change can be the creation or realization of a product, a layout modification of a workplace, the introduction of a new routine, planning an event, implementation of a new type of office, and so on.

A CHAI analysis may also serve as a fruitful team building activity, providing support for reflection at the following stages of a project (Table 4):

3.1 | CHAI method procedure

Table 5 details the procedural steps of carrying out the analysis (adapted from Berlin (2018) and Berlin et al. (2016)). The latter reference provides additional guidance regarding how a CHAI workshop can be organized and facilitated.

3.2 | Visualization aids – The CHAI matrix

Since the CHAI method has always been intended as a collaborative workshop exercise to be carried out by multiple people together, various visualization templates have been created to facilitate its use. Some details of earlier versions are described in the early Use cases in Section 4. Several iterations of the visual aids for carrying out a CHAI analysis have proven that the simplest version is often the most effective, in terms of user adoption. By placing the Actors in rows and the Roles in columns, forming a matrix (Figure 1), the process of identifying and analyzing which Actor adopts which Role and *Why*, becomes an easily visualized exercise of agreeing on Stakeholders' motivations at each intersection. The use of the matrix in Use cases is reported in Sections 4.3 and 4.4, respectively.

Although easily replicable in various other types of software, a spreadsheet version made in Microsoft Excel also exists (Figure 2). It is mainly meant to facilitate postworkshop documentation, but may also facilitate analysis by a solitary EHF agent, in cases where such an approach might be defensible.

TABLE 4 Opportunities for using the CHAI matrix at different intervention project stages

Project stage	Benefit	Requirements
The planning phase of an intervention	To determine initially which human and nonhuman "actors" may affect project planning, resource allocation, outcomes and/or criteria for approval	Access to/contact with central intervention project stakeholders, as far as the knowledge of the analyst (s) allows identification
In the middle of an intervention project	To re-evaluate whether certain actors' roles in relation to the intervention should be modified, expanded, or reduced to ensure inclusion and that legitimate doubts are captured; or to capture if their roles change as a result of new circumstances	Changes to the stakeholder picture resulting from updated project limitations and resources, or when additional perspectives are made available from user-centered approaches like user studies, shadowing, field observations, interviews, and so on
After completion of the intervention (potentially as a post-mortem)	To determine whether any success or roadblocks can be linked to the intervention's success or adversity. This step is aimed forward, so that important lessons learned can be carried on to future projects and secure the organization's learning	Sufficient documentation of decisions made during the intervention project and any rationale/data that could justify proposing an altered approach towards specific roles and actors

Abbreviation: CHAI, Change Agent Infrastructure.

TABLE 5 The steps of carrying out a CHAI analysis

Step 0	**Clearly formulate the intervention proposal**, that is, define the future "changed" state that is meant to be achieved as a result of the intervention project. The intervention should be worded in a concrete and unambiguous way, particularly with regard to how it affects Subjects.
	The participants carrying out the SIA together (the analyst/s) should be in agreement about the nature and execution of the intervention.
Step 1	**Brainstorm any actors who may be stakeholders in the intervention.**
	The analyst/s can list actors freely or use the eight different role templates as support in "brainstorming" who might fulfill each role.
	Actors can be either human (e.g., a manager, user, patient, purchaser...) or nonhuman (e.g., a law, authority, prototype, model, checklist, policy, algorithm, etc.).
Step 2	In the matrix cells, the analyst(s) should **write the reason why each actor takes on any of the different roles.**
	Answering the question "Why is [Actor X] a [Role]?" is the crucial exercise; this allows the analyst(s) to identify relationships between actors and the intervention, based on interests, motives, and influence.
Step 3	**Count the number of actors per role** and determine if there are any roles dominated by several or only a few actors, or if any are entirely "unpopulated."
	Having zero actors in any particular role may have an impact on the possibility of the intervention to be implemented, while having too many may indicate a difficult process of informing and gaining consensus.
Step 4	**Count the number of roles each actor belongs to** and determine if any single actor inhabits many different roles. Too many roles could mean that they are susceptible to conflicts of interest, and/or may require much more detailed decision support.
Step 5	The analyst(s) **discuss and determine whether the current distribution of roles among actors is ideal**, whether any roles should be modified to achieve the desired result of the intervention, and if so, how those modifications should be carried out in practice. The notes from that discussion could be appended to the CHAI matrix.
Step 6	The analyst(s) **determine whether a follow-up SIA analysis using CHAI is necessary at a future stage** of the intervention project.
	The purpose of follow-up sessions is to start from the already populated CHAI matrix and assess whether the intervention proposal itself should be re-phrased (in light of any changes in user needs or to the requirement specification) and whether any new actors have been identified and should be assessed.

Abbreviations: CHAI, Change Agent Infrastructure; SIA, stakeholder identification and/or analysis.

4 | DEVELOPMENT OF CHAI: ACTION RESEARCH

The CHAI method has for several years been used in different applied settings and with different visualization templates, leading to an incremental change process where the method has been streamlined and simplified into a "lightweight" visual guidance that has been optimized for collaborative workshop use. Its development has chiefly relied on an action research approach (Dick, 2002), that is, it has mostly been used in nonexperimental, real-life cases that led to a post-use evaluation and incremental changes to the CHAI method's scope, instructions, and visualization tool, to address found issues regarding usefulness and usability.

Its precursor, the original "Ergonomics Infrastructure" framework (Berlin, 2011), was a time-consuming and admittedly cumbersome exercise, intended for individual workplace change agents to do at their desk as an analytical reflection on possible
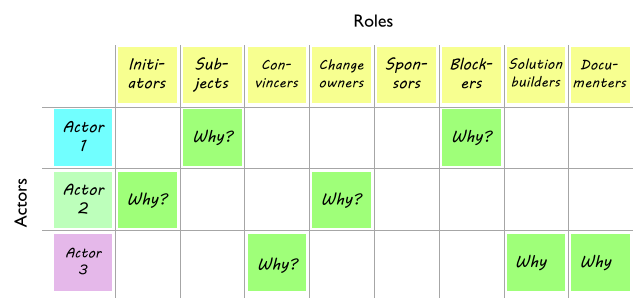
FIGURE 1 Schematic of the "tabletop" layout of the CHAI matrix with sticky notes in a grid, used in physical workshops. Essentially, the materials for a workshop are reduced to sticky notes, placed in a grid formation

ways they could influence important actors in change processes. For most practitioners, its comprehensiveness resulted in a too-high cost/benefit ratio; therefore, a series of incremental attempts

Template for the "Change Agent Infrastructure" method of stakeholder analysis, abbreviated CHAI								
ACTORS	**Initiators**	**Sponsors**	**Convincers**	**Change Owners**	**Subjects**	**Blockers**	**Solution builders**	**Documenters**
Actor 1 (change to appropriate name, function or title)								
Actor 2	[In each cell, answer WHY the actors fulfil a specific role; entered text will change the height and colour of the cell]							
Actor 3								
Actor 4								
Actor 5								
Actor 6								
Actor 7								
Actor 8								
Actor 9								
Actor 10								
Actor 11								
Actor 12								
Actor 13								
Actor 14								
Actor 15								
Actor 16								
Actor 17								
Actor ...								

FIGURE 2 Spreadsheet version of CHAI matrix made in Microsoft Excel; shared under a Creative Commons License CC-BY4.0 at Berlin (2018)

were initiated to tailor it better to practical cases and more collaborative workshop use. This resulted in a gradual elimination of several method steps—eventually resulting in the CHAI method and matrix. An important gradual change was the further elaboration of certain stakeholder categories (Roles), and that more focus was placed on the number and variety of stakeholders simultaneously occupying each role and the conflicts of interest that could arise from that.

The Use cases where CHAI was tested were a mix of educational exercises and industrial workshop applications. In the student context, it is of course easier to ensure that use of the method is carried out correctly since the instructional element is given more time and space, and the creator of the method was most often available to provide advice and support. This was of course true also in the industrial workshops, but there the focus was on time-efficiently gaining a result, rather than ensuring full understanding of the different elements of the method. What would have provided an interesting contrast would have been to have a "pure" in-house industrial case, where a company worked with CHAI in an internal team, and preferably also in iterations as the project progressed. The value perceived by participants from all the "one-off" use cases seems decently rewarding and useful, but the additional value of updating the SIA documentation further along the change process remains unexplored. In particular, this would be interesting to study if any Actors changed their Roles during the course of the project.

While a previous article by Berlin et al. (2016) describes one such use case in a software development project, this article adds to the scientific fortification of the method by providing multiple additional practical use cases. In all of the following cases, the first author was available as an instructor or guide for the SIA. In Cases 1 and 2, the first author taught the methods on-site and directly facilitated the SIA as a moderator. In Cases 3 and 4, the first author provided instructional material to the analysts who then carried out the CHAI analysis independently, only occasionally asking the first author for guidance.

4.1 | Case 1: Education (workplace interventions planned by students)

4.1.1 | Scenario

As part of an EHF project course at the Royal Institute of Technology (KTH) in Sweden, student groups were tasked with planning a workplace design intervention, acting as external EHF consultants. Each group was in contact with a "real-life" case company with some explicitly stated work environment or EHF problem to be addressed. The first author acted as guest lecturer and facilitated an SIA workshop where a total of 19 students in four project groups performed a CHAI analysis of their workplace intervention proposals, using an early visualization of the CHAI

analysis (Figure 3) that was a poster printout on size A2 paper showing the eight Roles.

They placed sticky notes with Actors' names and motivations near each Role on the poster, on either side of the oval demarcation lines signifying if a stakeholder was considered *External*, *Internal but passive*, or *Internal and actively involved* in the intervention. This segregation of actors into internal/external to the project organization was based on the nested Kirwan (2000) model that was present in the original framework by Berlin (2011), and was aimed towards identifying the organizational level of the stakeholders' agency (although reduced to three levels, instead of Kirwan's seven). If any Actor was identified as having several Roles, students drew lines by hand on the poster to connect the sticky notes. Some groups, but not all, identified nonhuman actors as part of the stakeholder ecosystem, for example, Swedish work environment regulations and a particular law, while one group identified a trust fund as an actor. Two groups ended up discovering that one Role was not engaged in by any actor. One group found that their project had no officially appointed Change owner, and surmised that this could be problematic for their implementation process.

4.1.2 | Evaluation

Three months after the workshop, students were asked on a voluntary basis to fill in an evaluation survey online. A total of four students anonymously responded to the survey, which unfortunately precludes drawing any numerical conclusions, but some tendencies are reported here. All respondents reported that they found the exercise useful. Each Role was rated (on a 4-step scale) with regard to how easy it was to understand them. The Roles that were found unanimously *"Very easy to understand"* were Initiators, Subjects, Convincers, Documenters, and Blockers. Sponsors were found to be very *"Very easy to understand"* by two students and *"Very hard to understand"* by the other two. Solution builders were deemed *"Very easy to understand"* (3), and *"Very hard to understand"* (1), while Change owners were deemed *"Very easy to understand"* (2), *"Fairly easy to understand"* (1), and *"Fairly hard to understand"* (1). In free-text responses, one student said that the CHAI analysis guided the discussion well and helped create a shared understanding for whom to influence to ensure success for the change. another student saw it as a good team-building exercise, but was apprehensive about whether the discussion could possibly be as relaxed if real company representatives would have participated.

Students were asked if they found it useful to count the ratios of Actors to Roles and vice versa. The responses there were mixed. One person stated that *"this gave good insights into how things are at the company, just the fact that there were eight Subjects but nobody that wants to be the Change owner"*, while another felt that it was difficult to practice this technique in a school setting without a sufficiently concrete example case. There were also mixed responses regarding whether CHAI analysis (1) stimulated a meaningful discussion (mostly positive), (2) helped identify the most important actors
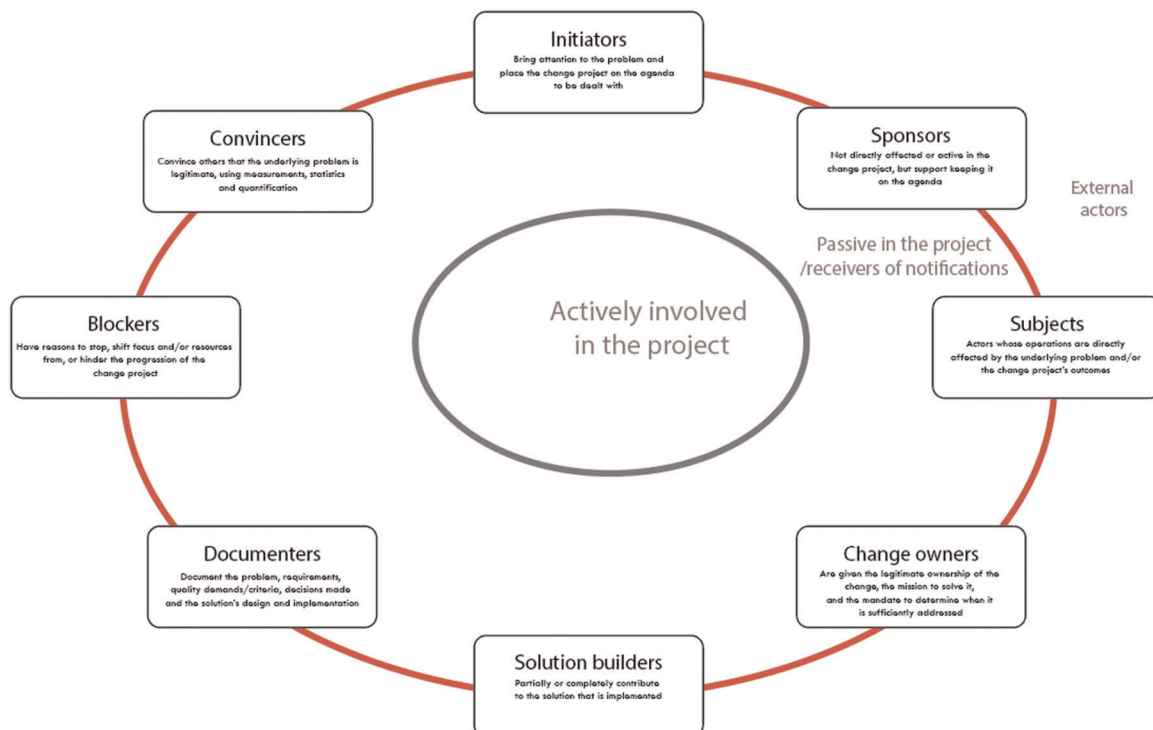

FIGURE 3 The CHAI "bubble" version, which was the first poster template used for in-person workshops with sticky notes. Each Role is described on the template with a similar explanatory text as that in Table 3

(mixed), (3) stimulated new solution ideas (mixed), and (4) stimulated a common understanding in the group (mostly positive).

When asked what their most important takeaway from the workshop was, students responded:

- "That nobody was driving the change problem in our case, apart from the project group, who are external to the company."
- "My takeaway is that [there are] more or less important people/positions in a company. I need to find the right ones if I am to help in the intervention or contribute to decision support."
- "Most important was to know who is most important in the project and who to talk to more. What approach you should take to achieve the goal in a better way."
- "Nothing regarding our project in particular, but the method is a good 'checklist' for interventions."

4.1.3 | Takeaways for improving the method

Although the workshop around paper templates was largely successful in helping student teams structure up their Stakeholder identification, it seemed that a limitation of the template was that the "central" demarcation oval for *Internal Actors* was too small to be useful, even when the poster was printed as a large size. The students solved this limitation in a creative way (Figure 4), by cutting the poster in half and spacing it apart so that the "inclusion lines" could be re-drawn and the sticky notes placed inside. However, the relative value of segregating the stakeholders in this way was deemed as less useful, so it was later abandoned.

Since there were mixed reviews of the clarity of each CHAI Role's definition, the wordings were altered in future instructions to clarify.

4.2 | Case 2: Dimension stone industry (SIA as a guide for selection of workplace interventions)

4.2.1 | Scenario

A workplace development project was carried out in 2015 by a consortium of several companies from the Swedish dimension stone industry and one university partner. An on-site work environment survey with worker interviews was carried out by the first and second authors (who are both EHF academic professionals) at six different dimension stone quarries, leading to a generation of 20 different workplace intervention proposals targeting the found HF problems. These proposals were ranked by consortium members in a workshop, and the chosen three projects that were considered for implementation were evaluated with the CHAI method as described in Section 3.1.

Intervention proposal 1 concerned *Knowledge enhancement* and proposed increased knowledge transfer, training for the quarry workers, and creating skills redundancy to make sure there was always

sufficient staffing. Intervention proposal 2 concerned *Implementation of technology to improve communication in the quarry*. Intervention proposal 3 concerned *Translating the Swedish Work Environment Authority's legal requirements into quarry-specific best practices*.

Each project proposal was evaluated, one after the other, using CHAI. The workshop participants represented all the dimension stone companies and the university, and both the first and second authors were present at the SIA workshop to facilitate. Participants were asked to use the online voting software Mentimeter (Figure 5) to fill in their proposed Actors for each role as free-text entries, and were allowed to do so as many times as they wanted until the next Role was discussed.

After the workshop, a graphical summary using "Boxes and arrows" (Figure 6) was used to convey the workshop results. The workshop participants were not involved in co-creating the visualization. As seen in the figure, the idea was to emphasize the "number of Actors per Role" and "number of Roles per Actor," similar to that achieved in the previous "bubble" poster visualization (Figure 4) where arrows were hand-drawn and counted. The graphic also employed specific code colors to indicate whether each Actor was Company-internal, External or "Nonpersonal" (which mostly included nonhuman Actors, but also associations, organizations, and so on, who were not an individual.)

4.2.2 | Evaluation

Since the workshop was digitalized using Mentimeter as its input interface, it was partially limited by the functionality offered. This meant it was not possible to discuss multiple Roles and Actors at the same time—instead, each Role had to be addressed in turn, with participants entering free-text answers into the interface.

FIGURE 4 Example of students' analysis of their workplace change project (in Swedish). To fit all their Actor sticky notes inside the "Internal and involved" border, they cut the template in half (dashed lines) and extended the space by drawing a new oval. The low number of arrows overall indicates a low number of Actors per Role in this project, except as "Subjects"

FIGURE 5 The Mentimeter voting interface where Actors were suggested, Role by Role, by participants using free-text answers (In this case, Blockers were discussed in Swedish)

Some participants found that they wanted to explain the "Why" of the Actor motivations with more than the interface's character limit allowed, and so resorted to continuing on separate entries. This was found to be slightly bothersome by participants, who were all using the interface and method for the first time. Also, several participants receiving the postworkshop documentation found the "Boxes and Arrows" visualization hard to understand. This was largely due to a large number of irregularly curved arrows and crossing lines. Participants relied heavily on the attached detail descriptions that accompanied the visualization to understand the implications of the SIA discussion. Still, the visualizations were incorporated in the official workshop report and the participants appreciated the conclusions drawn from the comprehensive SIA.

4.2.3 | Takeaways for improving the method

After this workshop, the "Boxes and Arrows" visualization was more or less abandoned. It required too much postworkshop effort from an analyst with both time and graphics software skills, and the result was also considered more confusing than enlightening. The changes after this version removed the focus from the quantitative counting of Actor, Roles, and connections, and instead focused on qualitative aspects, especially the question of *"Why?"* and how actors engage in each Role.

4.3 | Case 3: Workshop with industrial companies evaluating possible interventions

4.3.1 | Scenario

In 2018, a workshop about production-related EHF was organized by an interest group for industrial development, with 13 participants from three different Swedish industrial companies (Aerospace, Machining, and Special-purpose automatic machine manufacturing). The first author was invited as a speaker and workshop facilitator. After a 1.5-h lecture about EHF, socially sustainable workplaces and change processes, the company representatives participated in an SIA workshop using the tabletop grid-and-sticky notes version of the CHAI matrix in groups of 3–4 people for about 60 min. Each company group chose an intervention relevant to their work environment that would directly impact the operations of their employees: the Aerospace company analyzed the implementation of a digital e-learning tool in their offices, while the two other companies analyzed the possible acquisition of new industrial equipment. The two latter interventions were primarily system performance-oriented, but the overall workshop theme (and the facilitator) made sure that the EHF perspective was present in their choice of intervention scenario.

In discussions, the participants were able to identify and elaborate a wide variety of stakeholders who would both support and oppose their suggested interventions. Some mid-workshop discussions made the participants realize that the intervention proposal in some cases had to be refined and clarified, to agree on what kinds of reactions could be expected from the identified Actors. Initial vagueness in the intervention proposal wording was quickly revealed to give an inconclusive common view of which Roles stakeholders would inhabit.

4.3.2 | Evaluation and takeaways for improving the method

In a postworkshop survey, the participants all rated the lecture and workshop contents as very interesting and relevant for their operations. Three participants mentioned in free-text entries that the active workshop part, the analytical structure, and the eight stakeholder roles were particularly interesting. After this workshop, the

Actor map: implementation of communication tool in the quarries
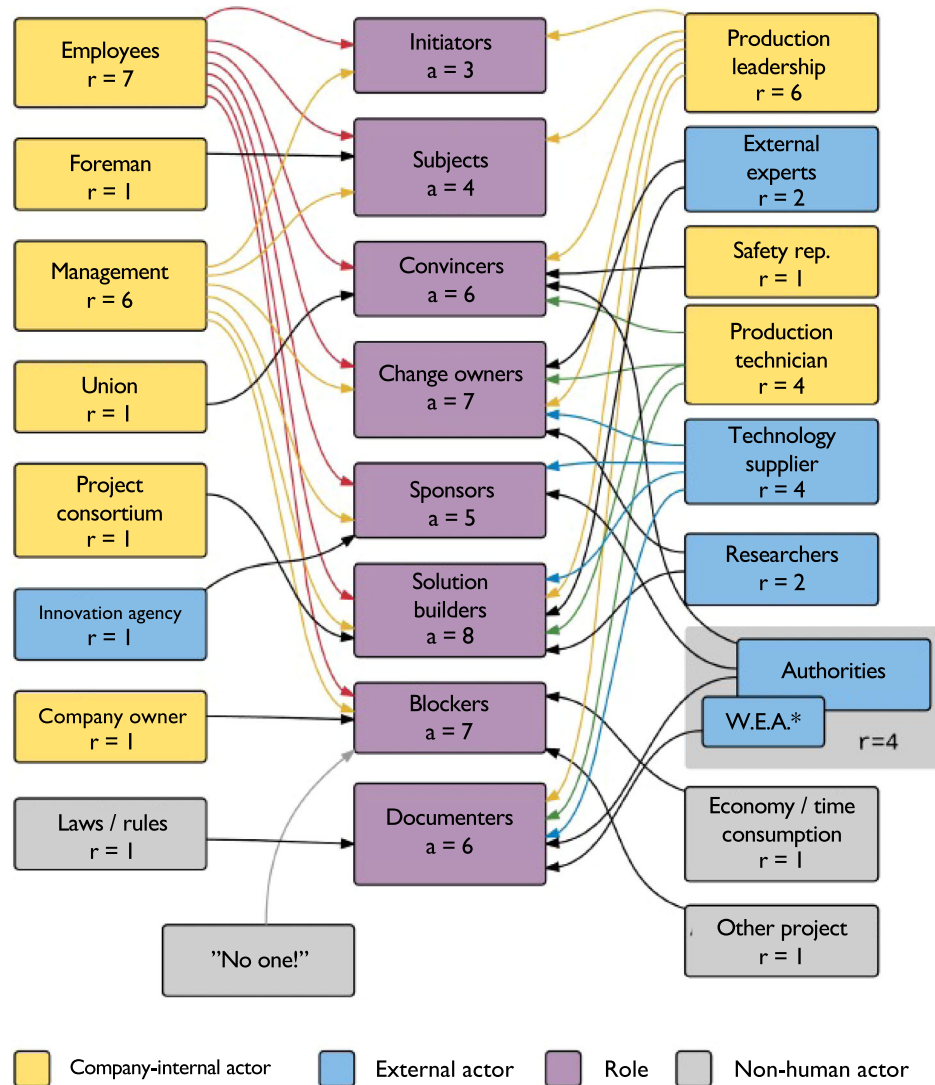
FIGURE 6 The finished CHAI visualization for one of the project proposals. Actors are yellow, blue, or gray, while Roles are purple.

CHAI workshop template and instructions were updated to emphasize the importance of the method's *Step 0*, Formulating the Intervention proposal clearly.

4.4 | Case 4: MedTech user interface development (remote use of CHAI under COVID-19 pandemic restrictions)

4.4.1 | Scenario

In early 2020, the medical innovation center *Hälsoteknikcentrum Halland* in Sweden started a user interface development Master thesis project within the "Virtual Hospital" (VH) concept, where a self-care digital tool for elderly COPD patients to monitor their own health statistics from home was developed. Henning and Thörn

(2020), referred to from here-on as the UI developers, planned to carry out user studies and the ensuing industrial design engineering work, focusing on EHF aspects of the interface (in particular cognitive aspects) and it is fit for the different stakeholders who would interact with it. The UI developers had both had substantial EHF training as part of their MSc coursework, and the first author acted as their thesis supervisor.

When the COVID-19 pandemic broke out during the spring, many of their user study plans and their access to healthcare professionals and patients alike were endangered. As part of salvaging the data collection stage of their project, they decided to carry out an online SIA mapping workshop together with healthcare professionals, using the CHAI matrix as described in Section 3.2 and Table 5. They formulated the intervention proposal as: "*Implementation of a digital system that connects healthcare providers within region and municipality with patients at home, and relieves the*
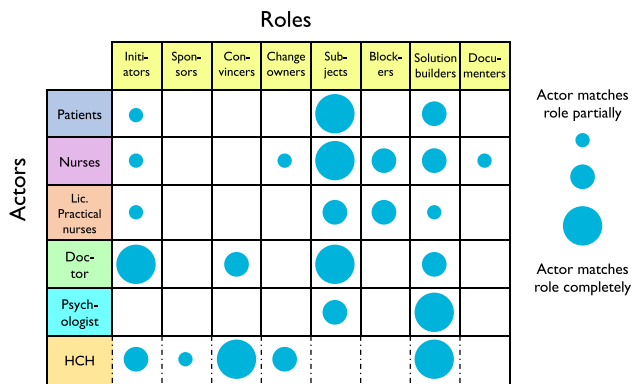
FIGURE 7 Illustration based on Henning and Thörn (2020, p. 46) depicting part of the digitalized CHAI matrix that was used in the online workshop. The UI developers added the visual component of differently-sized circles to indicate relative "degree of match" for each Actor to each Role.

healthcare sector through remote monitoring and support of self-care" (Henning & Thörn, 2020, p. 45).

The UI developers prepared a virtual "workshop template" using the *mural.io* online interface for collaborative design. The template consisted of a Conventional CHAI grid (Figure 1) with static sticky notes denoting the eight Roles. In an online video meeting, participants would be able to access the template and be able to fill in and move around virtual sticky notes on their respective screens.

4.4.2 | Evaluation

According to feedback from the UI developers (Personal communication, March 26, 2020), the CHAI analysis was mostly successfully carried out online thanks to the prepared online template made possible by the mural.io interface that allowed remote interaction from all six participants. They were given a quick walkthrough of the functionality before the actual workshop began, with the UI developers as discussion leaders and moderators. Participants of this workshop commended them for a well-prepared workshop and for facilitating a shared, holistic understanding of the project.

One difficulty was that the changed behavior of participants in the online meeting setting (compared to being in the same room) may have affected the discussion, since they were slightly more apprehensive than usual about interrupting each other. To facilitate, the UI developers let participants vote (using an online voting tool) which of the listed Actors best fit each Role (similarly to Case 2) and moderated the discussion so that all participants had a say. However, they felt that this seemed to "thin out" the discussion somewhat. Also, the allotted time ran out (possibly due to the participants needing to wait their turn to speak), so the last two steps in the CHAI procedure (Table 5) were not completed, however, this was not considered detrimental to the overall SIA.

The UI developers felt that although the CHAI analysis did not really reveal any unexpected new facts about the stakeholders

compared to what they had learned in previous interviews, it was successful in stimulating *"many valuable insights and discussions, and the populated matrix is a useful visualization of the distribution of responsibility within a complex project like VH."* (Henning & Thörn, 2020, p. 54)

4.4.3 | Takeaways for improving the method

At their own initiative, the UI developers created a CHAI matrix visual template in *mural.io*, with one functional amendment: as seen in Figure 7, the visualization departs from the conventional matrix by not displaying the reasons for each Actor-Role match; instead, the visualization focuses on displaying the relative "degree of match" for each Actor to each Role using three different sizes of circle, since most Actors had multiple Roles (the largest indicated the greatest fit). The motivations for each Actor-Role match were instead extensively reported in writing (Henning & Thörn, 2020, pp. 45–55). In their feedback regarding CHAI as a method, the UI developers pointed out that the CHAI workshop procedure could benefit from a more decisive conclusion step, to wrap up the exercise for the participants and offer closure.

5 | DISCUSSION

In terms of offering EHF agents a structured method for performing an SIA, rooted in research from a macroergonomic EHF perspective, CHAI in its present form fulfills its purpose. The method (1) enables and systematizes identification of stakeholders using a taxonomical approach; (2) goes through each Role begging the question *"Who or what could relate to the change in this way?"*; and (3) provides a visual support for analysts to gain an overall perspective of how different motivations and persuasions may influence the outcome. This makes it easy to identify particularly important Actors (who engage in. several overlapping Roles, or highly influential ones), conflicts of interest, resource allocation imbalances, change implications for psychosocial aspects, and more.

5.1 | Validity, reliability, and added value

According to Salmon et al. (2020), if EHF methods are to be adopted and taken seriously, developers must provide some judgment of their methods' reliability and validity—that is, whether the methods "actually do what they aim to do (validity)" (Salmon et al., 2020, p. 7) and whether their application produces a consistent, repeatable result, either when they are used by multiple users (intra-rater reliability), or on several occasions with a time interval in-between.

Annett (2002) makes a widely adopted and helpful distinction between EHF methods, separating them into two categories: *Analytic* versus *Evaluative*. Methods in the *analytic* category aid the EHF change agent's understanding of complex systems (see Read, in

Salmon et al., 2020) and rely on data collection, often from observations of complex "live" phenomena. In contrast, *evaluative* methods aim to measure observable, specified parameters consistently, for the purpose of evaluation. Annett (2002) makes a point that evaluative methods more readily conform to criteria of validity and reliability in a manner similar to psychometric measurements, while the case is not as clear-cut for analytical methods—he further proposes that a method's *purpose* should be what dictates the suitability of quality criteria to judge whether methods work as intended and are scientifically reliable.

Discussing reliability and validity is not clear-cut when it comes to CHAI, as its purpose and ideal result deviate from some previous expectations of what an EHF method is and should do. Table 6 below summarizes the method's main characteristics and limitations, which serves as a basis for continued discussion of its reliability, validity, and usefulness.

The way CHAI has been developed to date, using an Action research approach to make incremental changes after being tested on real-life-occurring design interventions, the opportunity to test reliability has been minimal, for two important reasons: (1) no design intervention scenario was uniform; they were all on-going situations in existing project or educational contexts, with their own timelines. In that sense, the testing of the method was in each case opportunistic, rather than experimental; and (2) no design intervention scenario was repeatable; each workshop was contingent on the participants, the scenario, and time period they occurred in. This is particularly true for Case 4, which was affected by the ongoing COVID-19 restrictions. This means that there has been very little chance of seeking consistency and repeatability in the CHAI analysis results. As suggested in Table 6, it may be possible to design an experiment to test the consistency and repeatability between individual analysts' results; however, our view is that this would run counter to the method's core purpose. Also, the CHAI method's proposal to repeat the analysis as the WS design intervention progresses, is specifically aimed at *changing* the analysis results to reflect the additional learning that comes from the analysts carrying out EHF integration work within the intervention, *and* by adding the perspectives of additional stakeholders as new insights are gained. In other words, a consistent, repeatable result is not a desirable result.

The issue of CHAI's reliability conundrum echoes an insight in Salmon et al. (2020, p. 7) where Salmon comments on systems analyses or risk analyses across entire sociotechnical systems: *"(…) the analyses are always richer and more comprehensive if we use multiple analysts from different parts of the system (…) they produce entirely different analyses based on their own view and experience of their own part of the system in which they work, and when these analyses are combined it becomes extremely comprehensive. This of course represents low inter-rater reliability; however, the outputs are more valid as a result."* (p. 7). This is precisely the challenge for CHAI: is it even desirable to aim for greater (inter-rater) reliability? Exactness and repeatable results do not offer new insights. Possibly, this aspect is intertwined with that of *construct validity*; that is, can all analysts interpret the

Roles consistently enough to gain equivalent guidance when carrying out an SIA?

Regarding the validity of CHAI, judging its merit is a question of whether its theoretical background is credible to the analyst, and whether the resulting taxonomy of Roles "hits the mark" of helping analysts identify relevant stakeholders. Since the method is analytical and qualitative, much of its success is contingent on whether the analysts are able to adequately answer the question *"Why is [Actor X] a [Role]?"* in step 2 of CHAI. This analytical exercise and having a sufficient diversity in the team of analysts, are essentially the "gatekeepers" for the method's validity; the method provides a valid and relevant stakeholder-system description only (1) if the Roles are correctly interpreted, and (2) if the team's collective knowledge of other stakeholders is comprehensive and diverse enough to not omit crucial ones. An important validity consideration is that the method has not necessarily "failed" if not all Roles have helped to identify Actors; having an "empty" Role is more of an indication of either a lack of information about particular stakeholders, a need for recruiting an additional analyst to add new perspectives, or that the nature of the intervention project is such that nobody responds to the intervention that way.

Ultimately, the crucial question is whether using the CHAI method returns value to the EHF change agent, in relation to the time spent carrying out a structured SIA. This returns the discussion to the beginning of this article where we drew a conclusion based on a cursory literature search that "no method" seems to be the current norm of SIA for determining who matters in EHF-related design interventions. We are not convinced that this should be regarded as "best practice" simply because it is common, and have therefore offered a way to structure and systematize the mapping of which stakeholders matter.

It should be mentioned that the method entirely leaves it up to the analyst(s) whether to actively engage stakeholders in the CHAI analysis itself, or in other participatory activities, or to simply map their influence for the common understanding of the intervention team. It is not entirely uncommon in EHF interventions that certain stakeholders are "spoken for on behalf of" other Actors who may have closer personal access to the project change team. For instance, in both Case 4 (Henning & Thörn, 2020) and in Broberg and Edwards (2012), patients were not present to speak for themselves, but were represented indirectly in the change processes by medical staff (although in the former case, this was due to COVID-pandemic restrictions that hindered contact with COPD patients). This practice leads to a "filtered" view of that Actor group's needs and motivations, which may risk informing the CHAI analysis with incorrect perceptions, leading to an inadequate representation of perspectives. A possible remedy to this would be to employ CHAI iteratively and gradually involve stakeholders actively in the analysis to confirm whether the basis for their relationship to the change (Roles) is correctly understood. At the same time, it can sometimes be practically difficult to recruit certain stakeholder groups to inform a design intervention process (particularly patients, who are in a

TABLE 6 Summary of CHAI's purpose, characteristics, and issues of validity and reliability, including potential future work to address identified threats

	Current state	Success factors/Caveats
Purpose and intent	To maximally broaden the analysts' scope of alternatives regarding who might be a potential stakeholder. The method is to be used "creatively" to elicit differing viewpoints from different analysts.	As the intent is to *increase and enrich awareness*, the work should ideally be carried out collaboratively, and preferably with users who have differing insights. Multiple users of CHAI should then ideally suggest as many different stakeholders as possible for each Role.
Type (Annett, 2002)	Analytic; to provide understanding of a complex system. CHAI is a Data Collection technique that relies on qualitative input. The focus is to understand sociotechnical systems, but more so on the relationships between actors (human and nonhuman) than on more traditional human–machine interface analysis.	Correct use requires that analysts have consensus on how to interpret the eight Roles, as this is the guiding factor to which stakeholders are considered.
Validity	Construct validity: should be based on an acceptable model of the system being studied. The theoretical constructs that form the basis of the taxonomy of "Roles" are based on the research described in Section 2, Theoretical basis and structure. Since the main underlying constructs come from research about how EHF change agents can successfully pursue "political reflective navigation" among other stakeholders to advance EHF integration in a multitude of production environments, this also justifies its suitability for being used to investigate EHF perspectives, as opposed to being regarded as a "purely generic" SIA method.	Assessing the validity of the underlying theories and empirical studies that CHAI has been developed from may be a question of whether the EHF change agent accepts the theoretical combination of Actor-Network Theory with the gradual, Action-research based modification of the CHAI method into its current form.
Threats to validity	The risk of identifying a stakeholder "incorrectly" as belonging to one of the eight Roles (false positive) is currently counteracted by the requirement to justify "Why" each stakeholder is considered active in such a role (step 2). The risk for an omission, i.e. failing to identify a stakeholder as active in any role (false negative) may increase if the analysts are few or if their viewpoints of the design intervention are too similar. In either case, lack of information or insight may affect the validity and quality of the SIA.	Caveats: The risk of identifying a false positive stakeholder is currently counteracted by the requirement to justify "why" each stakeholder is considered active in such a role. The remedy to false negatives (omission) is to combine broader recruitment of more analysts (including potential stakeholders) with iterations of the CHAI analysis as the intervention progresses; these steps are already recommended in the current method version.
Future work to address validity	Revisiting and revising the underlying theory and empirical evidence that creates the basis for CHAI's eight roles may be required to secure greater validity.	
Reliability	The eight "Roles" provide some structured guidance to the identification of stakeholders, compared to an ad-hoc approach.	
Threats to reliability	The results of a CHAI analysis are highly likely to vary greatly between individuals—as eliciting their (hopefully) different viewpoints is the method's purpose and intent. Reliability has not yet been tested with several analysts attempting to perform an SIA on the same, identical case.	Caveat: Since the method is meant to capture a current state of the sociotechnical system with a focus on the
Future work to address reliability	An experiment could be set up to investigate whether the eight roles of the CHAI analysis could allow different analysts to identify the same stakeholders, given the	Caveat: Although "high reliability" might strengthen the case for letting a single analyst perform a CHAI analysis independently. such a result from an

(Continues)

TABLE 6 (Continued)

	Current state	Success factors/Caveats
	same description of an identical work system design intervention case.	experimental assessment would run counter to the method's original intent and purpose of combining as many varying insights as possible and working collaboratively on SIA.
Usefulness	As indicated by user tests in Cases 1–4, most users would not have used any specific alternative method for SIA had they not been introduced to CHAI. Therefore, the time spent on SIA was not necessarily asked for.	Most users reported an increased understanding of the perspectives, needs, and requirements of the identified stakeholders, as well as potential implementation enablers and obstacles present in the sociotechnical system. This in turn led to better support for design and stakeholder management decisions.
	However, most users who were analytical drivers of the SIA were able to make concrete use of the results by deciding to engage with some identified stakeholders.	
Threats to usefulness	Cost/benefit aspects of using CHAI have not been particularly explored, but the predominant alternative (according to empirical studies) is ad-hoc, unstructured SIA, which may mean that the perceived time requirement for ad-hoc SIA is vague and the identified stakeholders may be seen as sufficient.	**Caveats:** No user has stated that the effort involved in carrying out a CHAI analysis has been excessive in relation to the obtained results, but in all use cases they have agreed to try the method at the suggestion of the first author, rather than seeking out the method themselves.
	Some users may have trouble remembering that nonhuman actors are also important to identify, since the terms "stakeholder" and "actor" may inadvertently imply human agency.	Some additional support may be possible to introduce to the method guidance to remind users to also consider nonhuman actors.
Future work to investigate usefulness	Additional real-life trials to investigate the usefulness of *iterative* CHAI analysis (i.e., several times during the intervention project) would fill a knowledge gap regarding what benefits the additional analyses could bring, and at what cost (in terms of invested time and the possible perception among analysts of "re-doing" completed work.	

Abbreviations: CHAI, Change Agent Infrastructure; EHF, ergonomics and human factors; SIA, stakeholder identification and/or analysis.

vulnerable state), meaning that representation by others aware of their motivations may be better input than nothing.

CHAI's practical origins stem from *workplace* intervention research, meaning that the point of departure is sociotechnical, and the expectation of the method context is that there will be several stakeholders, all of whom have different operative goals (in the workplace) and that an intervention will have an impact on several of them. Applying CHAI to a product design case may result in a departure from the typical direct user focus and expand the view of whose needs matter to a broader spectrum, which may beg the question of whether this leads to a desirable scope shift increasing the anticipation of possible conflicting needs and requirements, or whether it shifts focus away from the user-centered perspective. This is a consideration that should be weighed by the intervention project team.

5.2 | Future testing and development of CHAI

We have previously suggested some ways to further the development of CHAI, particularly with regard to Validity and Reliability, in

Table 6. However, we have also presented some caveats there regarding whether it is desirable to extend the method's reliability. Its validity and usefulness can be tested in the future by comparing the ability of the method to elicit a diverse, "rich" stakeholder map, in comparison with another SIA method or compared to ad-hoc identification.

The CHAI method has not (to the knowledge of the authors) yet been applied in multiple iterations within the same project. The prospect for doing so in an opportunistic manner (as in the Action research development carried out to date) would require a long-term commitment on the part of real-world intervention project participants and would require a structured timeline in which the SIA updates would need to be planned. Until such an opportunity presents itself, the assumption is that the procedure of a CHAI analysis is certainly repeatable thanks to its Role-based structure, but it remains unestablished whether the results will differ much between each analysis session; whether any new Actor-Role relationships will be revealed; whether participants find the exercise different if they no longer start from a blank slate; or whether previous results will influence the thinking of new analysts brought in at later stages. Therefore, conducting one

or more trial cases "in the wild" featuring iterated use of the method would be a suggested future avenue to explore. Doing this in a purely experimental setup (where the researchers exercise greater control over the intervention parameters) seems likely to be a purely academic pursuit where recruitment of participants may be difficult, as no other practical added value is evident.

6 | CONCLUSION

This article has proposed a structured procedure for carrying out and visualizing a Stakeholder Analysis for EHF intervention projects—ideally in a collaborative workshop format, to combine the differing perspectives of the analysts into a more comprehensive system description. The method's theoretical underpinnings combine social science influences with participative EHF perspectives, essentially guaranteeing that stakeholders in an intervention project are identified in a way that is structured, useful, and relevant for integrating EHF perspectives into work system design interventions. What distinguishes this SIA method from others is that it initiates the identification of stakeholders on predetermined relational categories—*Roles*—that are based on previous literature and empirical studies of what can facilitate or hinder EHF integration in a design intervention. Instead of ad-hoc identification of stakeholders, the eight Roles allow for a "creative elicitation" of which human or nonhuman actors may be relevant to the intervention, by virtue of how they relate to the change that the intervention brings to their own operations.

The value of the method lies in making it possible to make the SIA process participative in and of itself, encouraging a pluralistic view of how actors may relate to an intervention in multiple ways, and formalizing the procedure and analysis in a repeatable way. Even though the method is a framework to stimulate and elicit the situational understanding of every analyst in the room, results and coverage may vary with the knowledge-maturity of participating individuals. The relational emphasis and visualization turn the discussion towards the question, *"How does each actor relate to the change that this intervention brings?"*, in terms of the possible gains and threats they perceive. The end goal is to make SIA methodology less ad-hoc, more transparent, easier to visualize, more iterative (if used several times in a design process), and (most importantly) more grounded in a sociotechnical EHF perspective.

Also, the increased understanding of which stakeholders matter provides a chance for the intervention team to be more deliberately empowering towards stakeholders. Judging from the results and feedback from the use cases, the method offers a systematic overview of identified stakeholders in a way that method users find accessible, useful, and acceptable as a basis for moving onward with requirements elicitation and design decisions. Eventually, clarifying which stakeholders matter (and why) is likely to pave the way towards lasting acceptance for design interventions that benefit EHF perspectives.

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