White paper

The HUMANE typology and method – supporting the analysis and design of human-machine networks

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Abstract	This white paper presents the HUMANE typology and method, intended to support the analysis and design for human-machine networks (HMN). The typology serves to characterise HMNs on dimensions pertaining to the actors of the network, the relations between the actors, network extent and network structure. The method supports profiling HMNs along these dimensions, to analyse implications of the network characteristics, identify similar networks, and enable the transfer of design knowledge and experience in the form of design patterns. The application of the typology and method is exemplified a summary presentations of one of the HUMANE case studies (eVACUATE).
Key-words	Human-machine networks, typology, method, implications, design patterns, eVACUATE.

Disclaimer

Definitions and abbreviations

Abbreviation	Definition
DSS	Decision support system
HCD	Human-centred design
HMN	Human-machine network
ICT	Information and communication technology

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1 Introduction

In the networked society, the people and the technology (machines) we rely on for our working and civic lives are moving rapidly towards a pattern of always on, always connected. Machines are taking increasingly active and visible roles in both personal and professional networks, e.g., recommending friends and purchases, detecting and stopping online vandalism, and processing vast quantities of data to assess risk in order to provide support to humans. Machines are not merely a means of achieving scalability of data processing and analysis that humans cannot achieve; we observe a more complex and synergistic relationship between humans and machines forming what we call Human-Machine Networks (HMNs) (Pickering, Engen, & Walland, 2017; Tsvetkova et al., 2017). Such networks are capable of generating value that would not be possible by humans or machines alone (Tsvetkova et al., 2017).

The EC H2020 HUMANE project [1] set out to develop a typology and method to support the development of HMNs. Through traditions such as socio-technical systems design (Mumford, 2006) and human-centred design (Maguire, 2001) we are provided with frameworks needed to analyse the context of technology design, and processes for involving users and stakeholders in the design process to ensure effective and efficient work support. However, designing for networks of humans and machines remains challenging. Examples include online innovation platforms that fail to strengthen innovation capabilities (Lüders, 2016), how procedures for including and excluding people in online collaboration may work against their intentions (Rudas, Surányi, Yasseri, & Török, 2016), and how the excessive use of bots in a network for collaboration may change or, at worst, challenge collaborative culture (Tsvetkova, García-Gavilanes, & Yasseri, 2016). Failing to design for purposeful participation and interaction within HMNs may threaten the value of investment in a design, but also potentially represent lost opportunities to improve on the quality and competitiveness of European society (Guerrieri & Bentivegna, 2011).

To address the challenges of designing HMNs, we have created a typology to better understand and characterise these networks, and a method for how to use that understanding to gain insight into ways of building or modifying networks so that they are better able to deliver the stated objectives or goals of the people who use them.

The target audience for the HUMANE typology and method include practitioners within ICT development and design, as well as researchers within fields approaching the phenomenon of HMNs. While we focus on the use of the HUMANE typology for HMN design in this white paper, we note that it can be used more broadly. For example, within the HUMANE project, the typology has been used as part of a roadmapping process for future HMNs. Interested readers are referred to HUMANE D4.4 (Jaho et al., 2017) and the HUMANE website: https://humane2020.eu/2017/01/16/humane-roadmap-process/

This white paper is based on work conducted in the HUMANE project, for which more details can be found in reports referenced throughout. In particular, readers should make a note of the following HUMANE reports on the typology and method: D2.1 (Følstad et al., 2015), D2.2 (Følstad et al., 2016)

[1] https://humane2020.eu/

and D2.3 (Følstad et al., 2017). For a background on HMNs, please refer to the HUMANE review of literature on this topic (Tsvetkova et al., 2015, 2017).

Below, we present the HUMANE typology in Section 2, which allows us to characterise HMNs. Based on the characteristics, Section 3 discusses how we can analyse the consequences for how users perceive, behave, or collaborate within the network. This analysis informs the design decisions, taking into account, e.g., privacy, trust, motivation and infrastructure. Further, HUMANE has followed a design pattern approach to help share HMN design knowledge by means of what we refer to as 'design considerations' here. This is discussed in Section 4.

The HUMANE method is presented below in Section 5, which describes how to apply the HUMANE typology to the design process of a HMN. The method comprises five steps, which we have aligned with the ISO standard on Human-Centred Design (ISO, 2010). As introduced above, the method includes implication analysis (which serves to identify areas of concern) and design considerations (which serves to identify possible solutions). An example of how the HUMANE typology and method can be applied is provided in Section 6.

To make it easy to use the HUMANE typology and method in design and development projects, we have developed an interactive tool to support HMN profiling and transfer of design knowledge and experience. This tool, the HUMANE Network Profiler, is available at the following URL:

https://networkprofiler.humane2020.eu/

2 Typology

The HUMANE typology was first introduced in D2.1 (Følstad et al., 2015) for the purposes of being able to characterise and analyse HMNs during a design process intended to supplement the ISO standard on Human-Centered Design (ISO, 2010). The typology is structured according to four layers, each with two dimensions to describe the actors, their interactions, the network extent and structure. An overview of the typology is provided below in Table 1.

Table 1: The layers and dimensions of the HUMANE typology.

Layer	Dimension	Description
Actors	1. Human agency	The degree to which human actors may have impact or cause change through open and diverse activities. *High levels of human agency mean:* People in the HMN typically can engage in many open and diverse activities towards self-decided goals, possibly aiming to influence others.
	2. Machine agency	The degree to which machine actors may have impact or cause change through open and diverse activities, as well as the extent they enable agency in human actors. *High levels of machine agency mean:* The networked machines typically can perform many open and diverse tasks, aiming to influence other actors in the network, possibly appearing human-like, and allowing human actors to do things they otherwise could not.

Layer	Dimension	Description
Relations	3. Social tie strength	The strength of typical relations between the human actors as nodes in the network. *High levels of social ties strength mean:* The social relations in the network typically hold characteristics of closeness such as intimacy, extended duration, and reciprocity.
	4. Human-machine relationship strength	The strength of the relation between humans and machines as nodes in the network. *High levels of human-machine relationship strength mean:* The human actors in the network typically are trusting, dependent, and reliant on the machine actors.
Network extent	5. Network size	The number of actors as nodes in the network. *High network size mean:* The network has a large number of members and a dominant position in its market segment. A broad uptake of the network is required for intended network effects to be realized.
	6. Geo-graphical reach	The geographical extension of the network. *High levels of geographical reach mean:* The network covers large geographical areas, and in consequence typically have a character of transnationality and cultural diversity.
Network structure	7. Workflow inter-dependence	The levels of coordination and interaction required between the actors of the network. *High levels of workflow interdependence mean:* The desired results of the activities within the network typically require substantial interaction, coordination, and possibly also collaboration between its actors.
	8. Network organisation	The character of the network organisation with implications for predictability and emergence; specifically contrasting top-down vs. bottom-up organisation. *High levels of network organisation mean:* The network is characterised by a top-down organisation, often with a hierarchical structure and centralized control. In contrast, low levels of network organisation indicate a flat organisational structure and substantial self-organisation.

The first two dimensions describe the actors in the HMN, both human and machines. Machines can include a wide array of actors or agents, such as sensors, software systems, autonomous cars and social robots. Each type of agent can have different levels of agency, ranging from the passive sensors (low agency) to more active machine actors, such as social robots (high agency). Agency provides a framework to describe the capacity for what the actors can do in the network, will relates to, e.g., their motivation for participating in the first place (can they do what they want/need?) and their potential behaviour (do they have a lot of freedom, e.g., to interact and influence other participants? Or are they constrained to fixed and predictable activities?).

The next layer includes two dimensions describing the nature of relationships that may be observed within the HMN. Firstly, between humans, and secondly, between humans and machines. The human-to-human relationships are characterised by, e.g., whether they are close affiliations or not, and whether they are reciprocal (mutually supportive). In terms of human-to-machine relationships we characterise these in terms of trust (do people trust in the machines?) and reliance/dependency (do people depend on the machines? If the machines failed, could people do what they need to do through alternative means?).

The third layer is the network extent, which represents the scale of the HMN, which considers both the network size and the geographical distribution of the network. Network growth is considered a key objective of many HMNs (Følstad et al., 2017), and the two dimensions may be correlated in cases where increasing the network size is achieved by expanding the geographical distribution of the network. Furthermore, as discussed in other HUMANE reports (Eide et al., 2016; Følstad et al., 2017), increasing the network size or geographical distribution may have implications for other dimensions, such raising a need to increase machine agency.

In the final layer, we describe the network structure at a higher level in terms of the HMN being organised top-down or bottom-up. A bottom-up structure implies self-organisation, which may provide opportunities for flexibility, robustness and sustainability (Juris, 2012), as well as a greater potential for emergent behaviour (Heylighen, 1989). There is, therefore, also a link between this dimension and agency (in terms of the capacity for what the actors can do in the network). Workflow interdependence describes relationships between actors at a higher level than in the 'relations' layer; by describing the nature of interactions that may need to take place within the HMN. That is, can actors do things independently, or do they do particular activities that depend on other actors? What is the communication/activity workflow like?

To determine values to attribute to the different dimensions, we have identified several statements for each dimension that can be assigned a value to indicate a level of agreement. This can then be aggregated to provide a value for each dimension and illustrated as a spider diagram. See Appendix A for further information.

Example: Within the HUMANE project we developed a roadmap for HMNs within the sharing economy (Jaho et al., 2017). Here, an envisioned HMN may be characterised as shown in Figure 1. Human agency is low to strengthen process and quality control in the HMN, whereas intelligent matching of supply and demand is supported by high levels of machine agency. Social tie strength is low, as mainly strangers are matched in the HMN, and only for the duration of a specific transaction, whereas the relation to the technology and service platform is strong. Network extent (size and reach) is typically important in sharing economy HMNs to benefit from network effects and achieve sustainability. Finally, while the overhead associated with coordination and communication between actors (workflow interdependence) should be as low as possible, a relatively centralized and policy-driven network organisation is required to obtain predictability and trust for users.

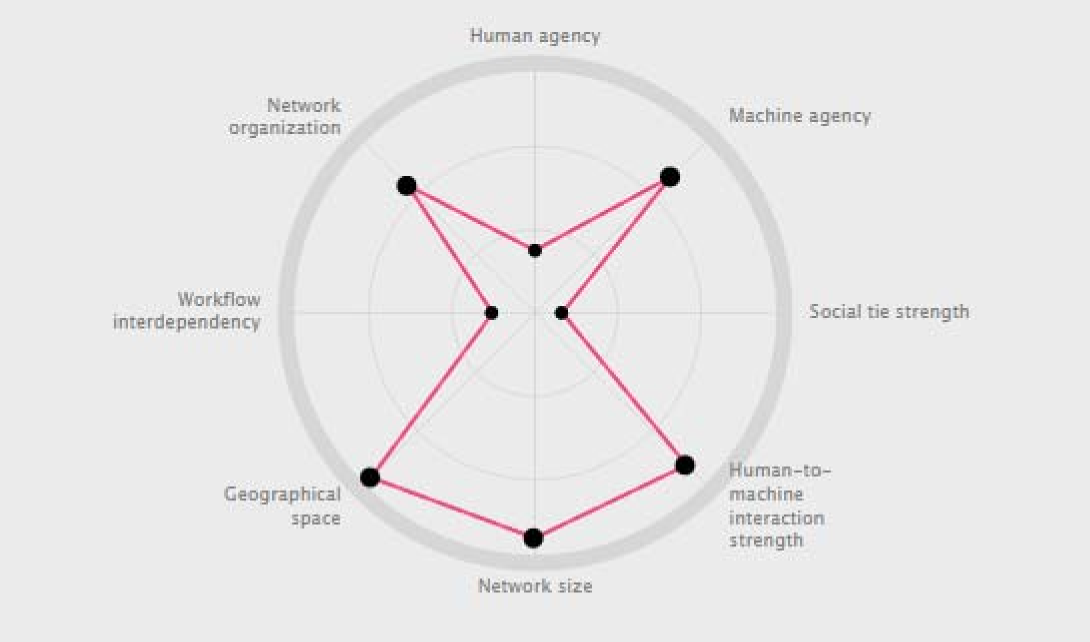

Figure 1: Example profile - envisioned sharing economy HMN.

In the final two layers we have made references to implications, which is a key part of the HUMANE typology and method. Being able to characterise an HMN is only the beginning and should naturally start raising questions about what it means for dimensions to be at certain levels. For example, what does it mean if humans depend on the machines? What if the machines fail? We will give an overview of implication analysis in the following section.

3 Implication analysis

The characteristics of a HMN have consequences for how users perceive, behave, or collaborate within the network. We refer to such consequences as network *implications*. We have identified five groups of implications that typically need to be considered for a HMN (Følstad et al., 2016, 2017).

- **Motivation and experience**, that is, implications of HMN design for how users perceive, experience, and respond to HMNs. May, in particular, concern motivation, user experience, attention, or reputation.
- **User behaviour and collaboration**, that is, implications of HMN design for how users behave and collaborate in the HMN. May, in particular, concern collaboration, behaviour change, patterns of interaction, shared responsibility, or sociability.
- **Innovation and improvement**, that is, implications of HMN design that affect the capacity for renewal and change in the HMN. May, in particular, concern sustainability, flow of ideas, knowledge integration, learning within industrial and societal contexts.
- **Privacy and trust**, that is, implications of HMN design for how users sense of privacy or trust in each other, in the machine components of the network, or in the HMN at large.

- **Underlying technical infrastructure**, that is, implications concerning aspects of the underlying infrastructure and machine components of the HMN, such as flexibility, scalability, or resilience.

The implication analysis can be done on the basis of the profile of the network, ala that seen above in Figure 1 representing sharing economy HMNs, or network diagrams depicting the actors and their relationships. We will discuss this further below in Section 5.

For more information on the theoretical basis for the implications, interested readers are referred to HUMANE D2.3 (Følstad et al., 2017).

4 Design considerations

HUMANE has followed a design pattern approach to help share HMN design knowledge by means of what we refer to as 'design considerations' here. Whereas the implication analysis (introduced above) serves to identify areas of particular concern, the design pattern approach serves to identify possible solutions in response to those concerns.

Each design consideration follows a structured presentation as per Table 2, below:

Table 2: Template for HUMANE design considerations.

<Reference number> <Descriptive title> HMN type: *<if relevant, the most salient dimension associated with the pattern; otherwise "N/A")* Implication: *<the type of implication associated with the pattern>* Design Pattern Group(s): *<the sections in this chapter covering H2H, H2M, M2H and M2M interactions)*
Problem: a brief description of the issue which the design consideration is intended to address. **Background**: information about the typical situation in which the problem might occur and, thus, when this design consideration may be appropriate. **Solution**: a brief overview of the proposed design consideration. **When to use**: typically the development or deployment stage when this may be used. **Sources**: if appropriate, where the design consideration was derived from or what it is related to.

Within the HUMANE consortium, over 40 design considerations have been identified and associated with the groups of implications introduced above. For example, under 'privacy and trust' we have addressed problems such as users losing control over their own data, and under 'motivation and experience' we have addressed problems such as information overload.

For more information, interested readers are referred to HUMANE D2.2 (Følstad et al., 2016) or the online HUMANE Network Profiler tool: https://networkprofiler.humane2020.eu/patterns.

5 Method

As noted above, one of the aims in HUMANE is to provide ICT design support as a supplement to the ISO standardised methodology on human-centred design (HCD) for interactive systems (ISO, 2010). This methodology is depicted below in Figure 2, which aims at including a human-centric perspective into the software development process. This HCD process comprises four main cyclic phases[2] (Maguire, 2001):

- **Context analysis:** understanding the environment for which the HMN will operate, identifying stakeholders, surveying existing users and establishing characteristics the HMN should support. This forms the basis for identifying requirements in the following phase.
- **User requirements:** requirements elicitation and analysis for the HMN, which includes *inter alia* stakeholder analysis and cost-benefit analysis, and establishing clear statements of design goals and benchmarks that the designs can be tested against.
- **Design:** an iterative process of producing design ideas, including mock-ups and possibly simulation of the system with the aim to rapidly seek feedback to progress the designs.
- **Evaluation:** prototypes from the previous phase are evaluated against the benchmarks established in the user requirements phase. The prototypes may be paper-based or software-based. The purpose is to measure and demonstrate how well the objectives have been met, as informing potential re-designs.

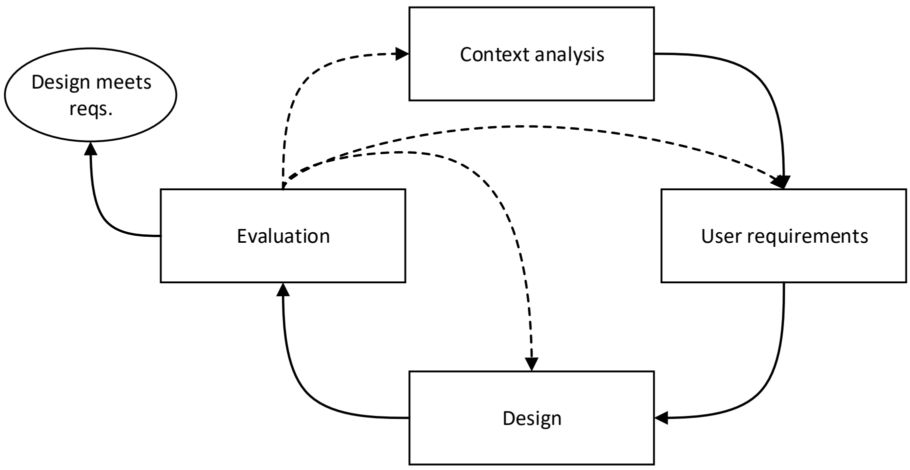

Figure 2: Human-centred design process (ISO, 2010).

The HUMANE method starts with a similar step as the HCD methodology introduced above, with context analysis. There are actually three steps of the HUMANE method that address the context analysis, which is illustrated below in Figure 3. The five steps of the HUMANE method are outlined at the top of the diagram, and the phases of the HCD method at the bottom.

[2] We omit the initial phase of 'planning'.

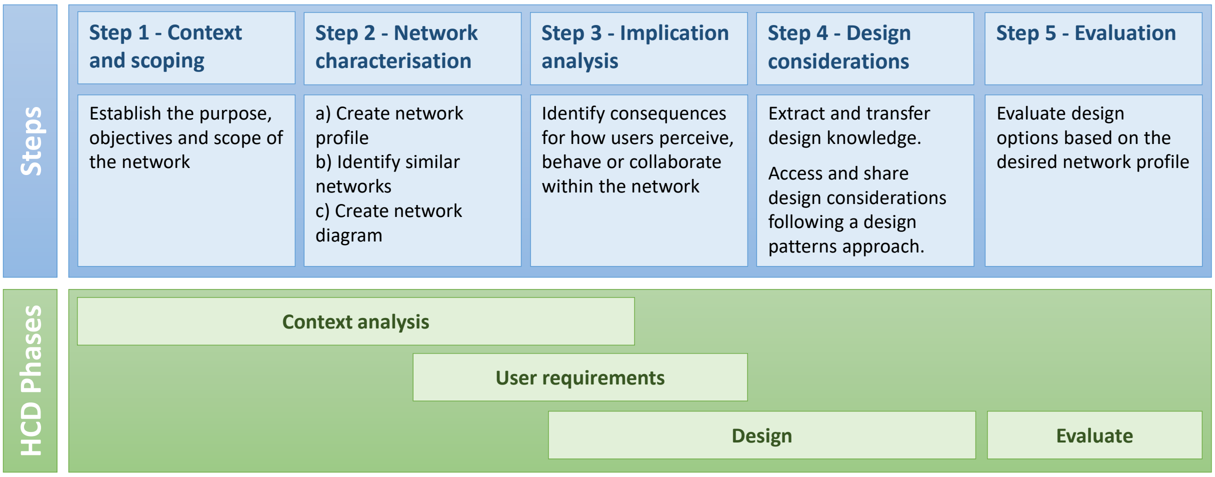

Figure 3: The HUMANE method mapped to HCD methodology.

As described in HUMANE D2.3 (Følstad et al., 2017), the five steps of the HUMANE method are summarised as follows:

Step 1: Identify and describe the purpose of the HMN, broken down into objectives that can be used when assessing implications of design options, as well as evaluating the design(s) against. This step also includes a scoping exercise, to clarify who the actors are who are to be considered a part of the HMN. This can be particularly important for HMNs that may link with other networks.

Step 2: Characterising the HMN, primarily by creating a network profile using the HUMANE typology, potentially via the HUMANE Network Profiler Tool[3]. Using the aforementioned tool, this is also the step in which similar networks can be identified, from which design knowledge can be extracted. In this step, a more structural view of the network can be created, by producing an initial network diagram depicting the known actors and how they are connected to form the HMN. The step overlaps with the two first phases of the HCD methodology.

Step 3: Analyse the implications with respect to consequences of the network design based on the HMN profile and network diagram from Step 2. We have identified five categories of implication: motivation and experience; user behaviour and collaboration; innovation and improvement; privacy and trust; and underlying technical infrastructure.

Step 4: Extract and transfer design knowledge by analysing similar networks to the HMN under design (or re-design) with regards to potential design solutions they have implemented that may be of benefit. This involves accessing design patterns the similar networks have used.

Step 5: Evaluate the design options against the desired network profile identified as a benchmark earlier in the method.

The steps are seen as supporting a creative or exploratory design process, and cannot be expected to be applied mechanically to achieve the desired results. Rather, the steps facilitate discussion and reflection pertaining to e.g. implications of the HMN and transfer of knowledge and experience from successful HMNs. This is discussed further below.

[3] https://networkprofiler.humane2020.eu/

5.1 Step 1: Context and scoping

In this step, the purpose and objectives of the HMN should be identified. The objectives are used directly in the latter steps of the HUMANE method, for interpreting implications and evaluating designs against.

To clarify the distinction between these two, you can, for example, define the purpose by answering ***why*** the network exists (or should exist, if it is a new network being designed). The key means of achieving (i.e., ***how***) the purpose can thereafter be broken down into objectives. The objectives are typically more tangible and should ideally be measurable. Moreover, the purpose of a network is likely to remain the same over time, while the objectives, business models and the HMN itself are likely to change.

If we take Wikipedia as an example, we could, for example, define the following purpose: *providing a free-access, free-content, Internet encyclopaedia*. In order to achieve that, we can, for example, define the following objectives:

- Facilitating cross-cultural synergy towards collaborative work.
- Advocating the free sharing culture.
- Developing infrastructure for fostering large-scale collaborative work.

A second activity that should be performed in this step is to scope the HMN. Minimally, this involves identifying the type of actors, both human and machine, and establishing their functions and capabilities in the network. Results from the HUMANE case studies demonstrated that people are prone to have different scopes of their respective network in mind, leading to inconsistencies when performing the profiling exercise part of Step 2 (Følstad et al., 2017). Depending on the nature of the HMN, the scoping should clarify boundaries of the network, especially if it interconnects with other networks (e.g., social media platforms or other Internet services). For example, although a particular HMN connects with Twitter users, it would be inappropriate to extrapolate the HMN to include Twitter in its entirety.

5.2 Step 2: HMN characterisation

Characterising a HMN is done through a) creating a profiling of the respective HMN, b) identifying similar HMNs and c) creating a network diagram.

5.2.1 Create network profile

When the scope of the HMN is clarified, the HMN can be characterised using the HUMANE typology, as discussed above in Section 2. This could be done as a manual exercise, using the statements included in Appendix 1, or with tool support via the HUMANE Network Profiler:

https://networkprofiler.humane2020.eu/networks/new

The profiling of a relatively homogeneous HMN is relatively straight forward. More challenging is the profiling of HMNs with great variations in their actor groups and how these different actors relate to each other. Whereas for homogeneous HMNs, it may be appropriate to make aggregations across the different actors in the system. However, in HMNs characterised by substantial variety in actors and relations, it may be necessary to reflect this by creating multiple profiles for the different key stakeholders that should be analysed. Also, as shown for the application example in Section 6, some HMNs have important variations in state, which may also need to be reflected by creating multiple profiles.

For new networks, this characterisation may represent the expected profile. In addition, which is also relevant for existing networks that may be updated, a profile of the future desired characterisation may be created as well. This can be used as part of the evaluation in step 5.

5.2.2 Identifying similar networks

A basic assumption in HUMANE is that analysis and design for HMNs may be supported by transferring design experience and knowledge from successful HMNs. For this purpose, it is useful not only to profile the HMN but also to use this profile to identify other HMNs with similar characteristics.

When considering similarities in HMNs, the HUMANE typology and method open up for two approaches:

- **Similarity in purpose**: This is typically found for HMNs within the similar domain. Typically, development teams are well aware of other HMNs with a similar purpose, for example, from competitor analyses. Learning from HMNs with a similar purpose is critical for owners of HMNs in competitive markets. At the same time, such learning typically will only imply innovation that is new to the specific service or network but not new to the market.
- **Similarity in profile**: This may be found for HMNs belonging to different domains, and may provide a gateway to insight and design knowledge not immediately associated with the envisioned HMN. Learning from HMNs with similarity in profile is assumed to support transfer of design knowledge across domains, potentially leading to design suggestions potentially new to the domain of the envisioned HMN.

The basis for identifying similar networks in terms of the HUMANE typology, is the HMN profile. Here, the profile scores may be used to identify other HMNs with similar profiles; that is HMNs belonging to the same type of HMNs. In the online profiling tool, each HMN profile is associated with the most resembling HMNs already profiled, as shown in Figure 4.

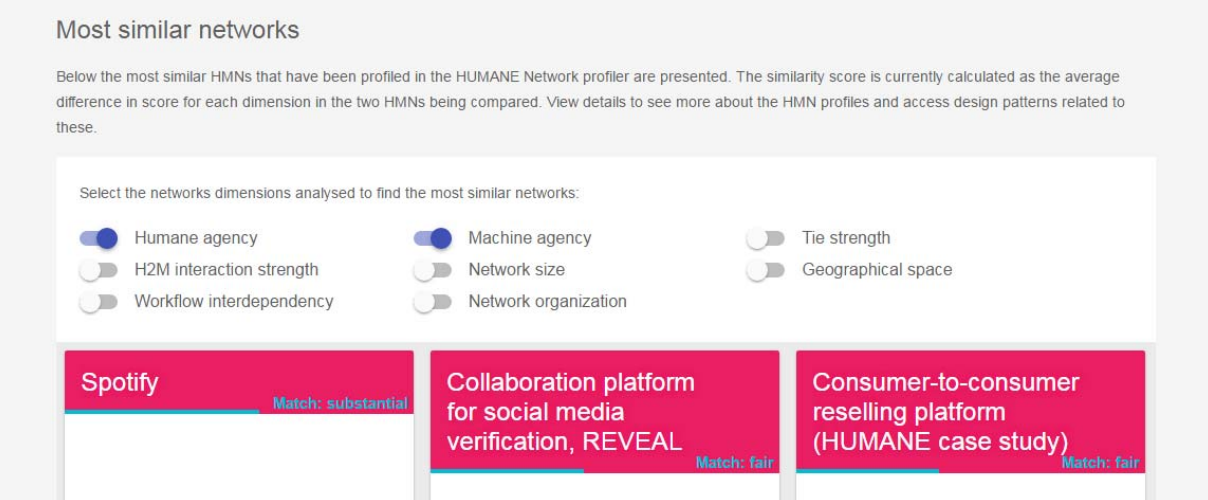

Figure 4: List of similar HMNs in the HUMANE Network Profiler tool.

5.2.3 Creating network diagram

For some cases, it may be beneficial to provide a detailed characterisation of the network organisation. In particular for HMNs consisting of a wide range of actors which may serve different purposes, as the HMN here may be insufficiently diagrammed elsewhere.

Such a detail characterisation may be provided through the drawing of a network diagram for the HMN, comprising the different actors (both human and machine) and depicting how they are connected. In the HUMANE background publications (Tsvetkova et al., 2015, 2017), a set of primitives were identified which can be used for such diagrams. An example diagram for the eVACUATE[4] case study is provided in Figure 5, below. However, also an informal approach may work well, especially as it may be more intuitive for different stakeholders involved in the design process who are non-technical. See an example of this in Figure 6, which we will build upon in the following steps.

[4] eVACUATE will be discussed further in Section 6.

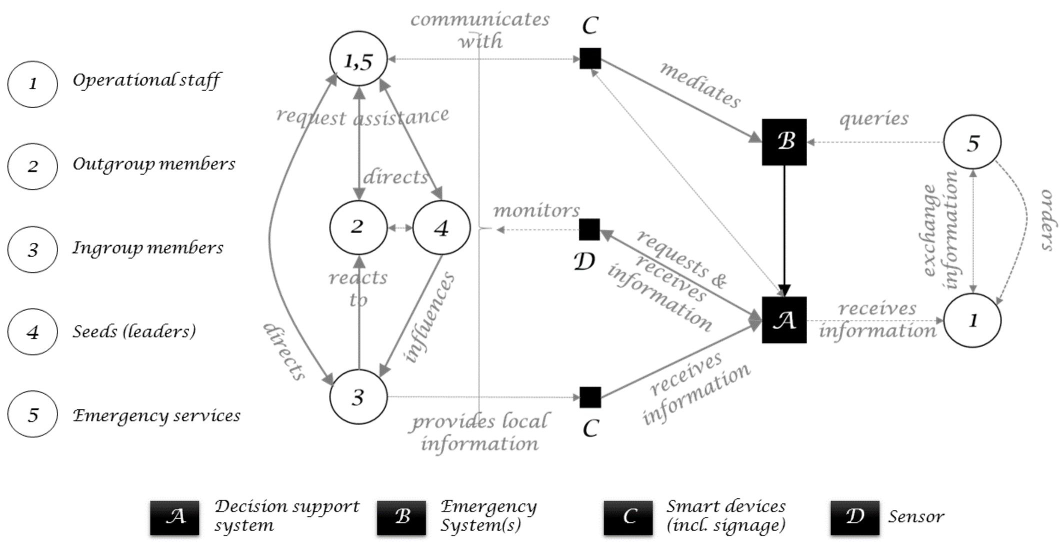

Figure 5: eVACUATE network diagram for context analysis using primitives (Tsvetkova et al., 2017).

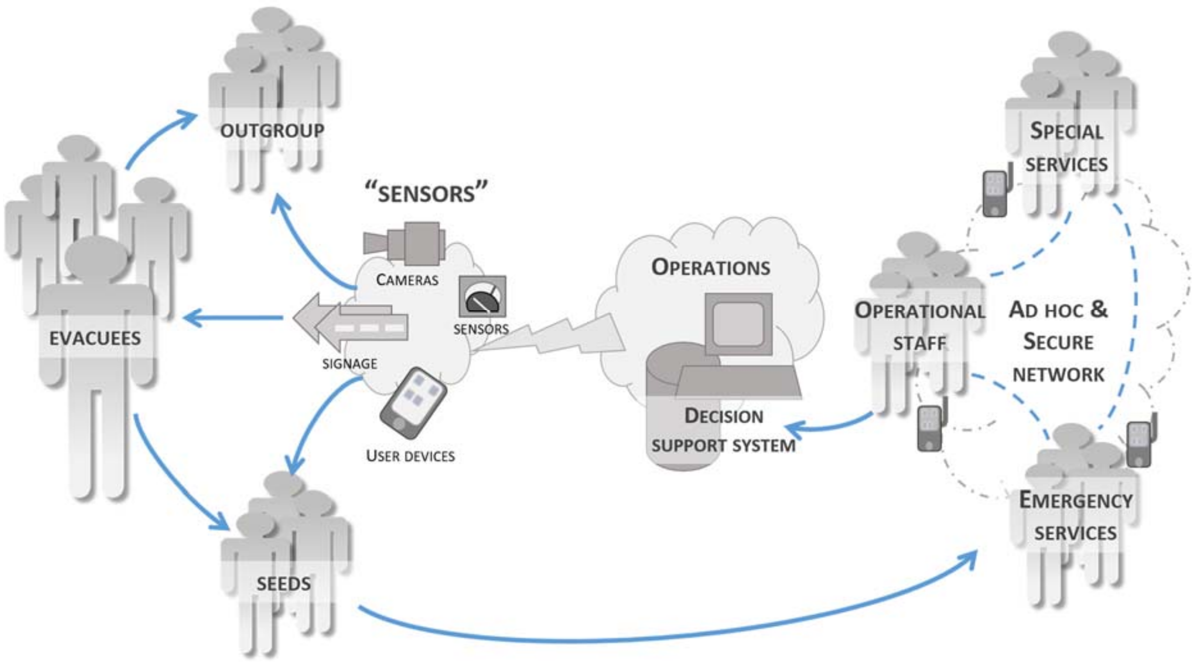

Figure 6: eVACUATE network diagram for context analysis using informal approach.

5.3 Step 3: Implication analysis

As discussed above in Section 3, we have identified 5 groups of implications in the HUMANE project. When applying the HUMANE method, we assume that implications within these groups may be identified and analysed on the basis of the HMN profile and network diagram established in Step 2.

The role of the implication analysis is to identify and discuss consequences of the network characteristics that are of particular concern for a successful implementation of the HMN (i.e., having a positive impact on the objectives defined in Step 1). Solutions to potential challenges that are identified may then be sought through a design pattern approach in the subsequent method step (Step 4).

5.3.1 Implication analysis from HMN profiles

Using the HMN profiles to identify and analyse network implications may be done through a process of reflecting on the dimensions from the perspective of relevant implication groups. We have outlined key groups of implication in Section 3 that could be used to facilitate a brainstorming exercise. We do note that this exercise would benefit from people with specialised expertise and a mixture of technical and non-technical participants. Further, in order to focus the analysis, it may be scoped to a smaller subset of implications that are considered particularly relevant for the respective HMN.

The implication analysis can be scoped in terms of the dimensions considered. For networks that have different states, the analysis can be focused on the dimensions that change, rather than assessing all. Similarly, for existing networks that are updated, a profile of the desired HMN characteristics may be defined in Step 2. In this case, the analysis can be focused on the dimensions that need to change in order to achieve the desired profile.

It should be noted that while the implication analysis aims to support the discovery and analysis of implications that may otherwise not have been covered, the implication analysis is not assumed to provide a comprehensive identification of all potentially relevant implications. However, if well conducted, the implication analysis should enable a design or development team to systematically consider important implication groups in light of the HMN profile.

In principle, all groups of implications may be relevant for any of the dimensions or their combination. However, the case experiences with implications analyses within the HUMANE project suggest some implications to be particularly relevant for some dimensions, which is depicted below in Figure 7. Here, the associated coloured implication groups are highlighted for those dimensions for which more than 1/3 of the implications for a particular implication group has been identified across the HUMANE cases.

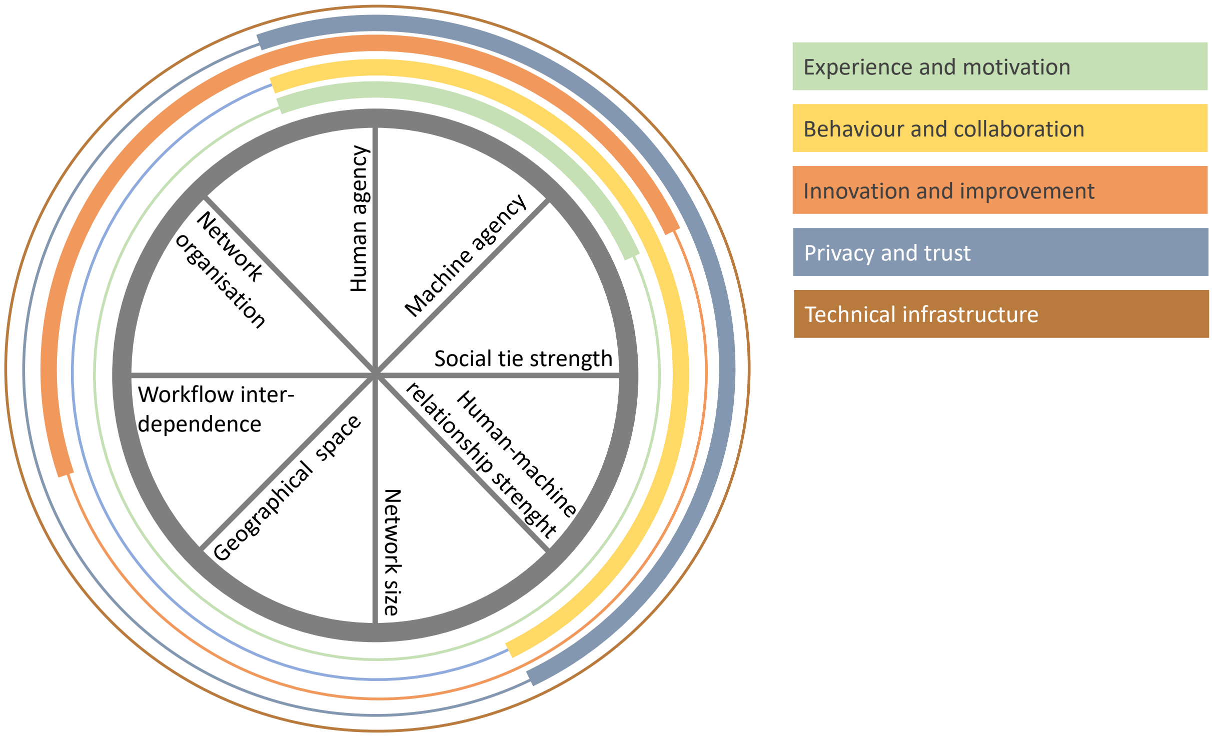

Figure 7: Typology dimensions and frequently associated implication groups in the HUMANE cases.

For example, in a HMN characterised by high human agency and social ties, it would be relevant to brainstorm these characteristics from the perspective of user behaviour and collaboration, and for privacy and trust. For further detail on implications associated with the HUMANE typology dimensions, interested readers are referred to HUMANE D2.3 (Følstad et al., 2017).

5.3.2 Implication analysis from network diagrams

Having drawn a network diagram in Step 2, this can facilitate a more specific analysis of both technical and non-technical implications for the connections (relationships) between the actors. One of the benefits of discussing specific connections in this manner is that the context of the entire HMN is retained, as wider considerations will then be more obvious, unlike the isolated approach to use case analysis in UML (for each stakeholder), for example.

At this stage, it should also be possible to assert some key information pertaining to each connection. As illustrated in Figure 8, for the eVACUATE HMN, we have noted things like operational staff being suspicious of the decision support system and the strength of the ties between the evacuees. This information should be clearer after profiling the HMN, as discussed above.

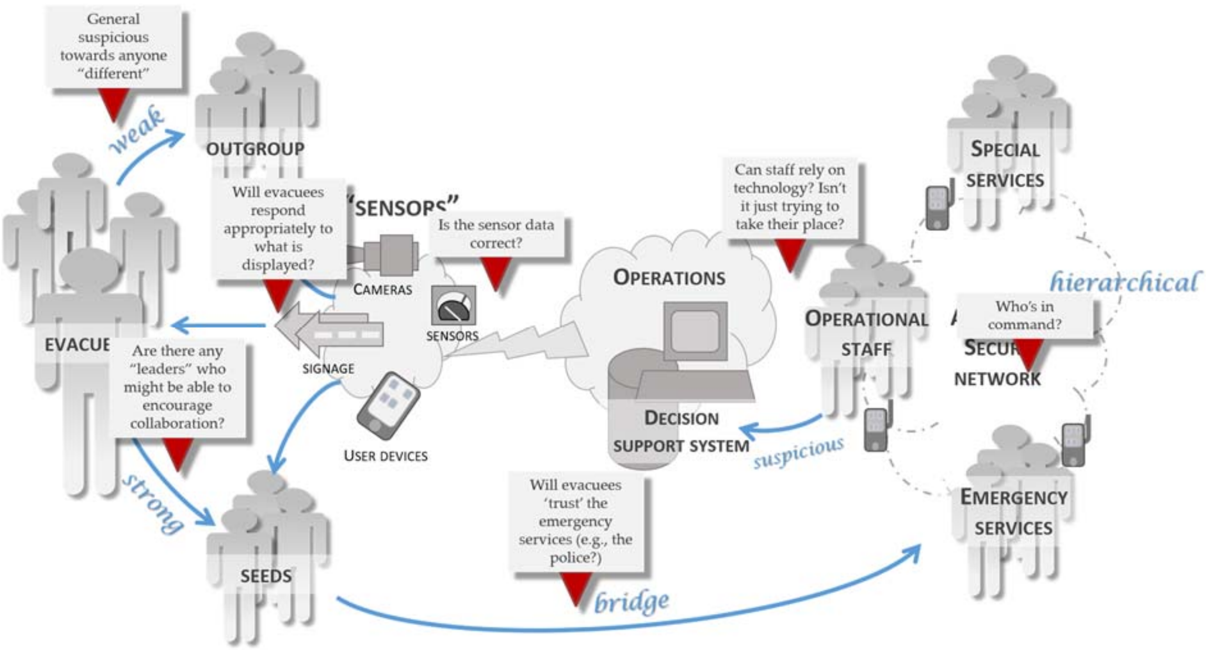

Figure 8: eVACUATE network for design implications.

For each implication group (see Section 3), each connection between actors in the HMN should be assessed. Figure 8 provides an example of an analysis of the trust implications in the network. Potential implications can be phrased as questions, for which possible design solutions may be sought. For example, can the operational staff rely on the decision support system? It has been identified that they are suspicious of the technology, governed by fears that it may replace their job. The designs should consider these aspects, as it will influence the uptake and use of the system.

5.4 Step 4: Design considerations

The HUMANE typology and method is intended to support the extraction and transfer of design knowledge from other successful HMNs and from the state-of-the-art on which these are based. This is to be conducted on the basis of characteristics of the HMN (identified in the profiling of Step 2), and in response to challenges identified in the implication analysis (Step 3).

Ideally, when having identified a challenge through the implication analysis, design suggestions should be available from the work of others. As discussed above in Section 4, we have extracted over 30 design considerations. These form the basis of a library of design considerations which is provided in the project's online profiling tool: https://networkprofiler.humane2020.eu/patterns

As a first step in the extraction and transfer of design knowledge, the analyst may explore the suggestions already available. The relevance of the suggestion will depend on the profile of the envisioned HMN. Hence, design considerations are suggested on the basis of these already being associated with HMN profiles that share the characteristics of the HMN in question.

For simplified exploring of design considerations, existing suggestions are characterised in terms of the group of implications they address (user experience and motivation, behaviour and collaboration, innovation and improvement, privacy and trust, and underlying infrastructure). This grouping allows for filtering according to the implication of interest. Furthermore, the individual design considerations are presented both in terms of the problem these address, as well as the suggested solution.

As an example, existing design considerations filtered on the implication group *Innovation and improvement* are listed in Figure 9.

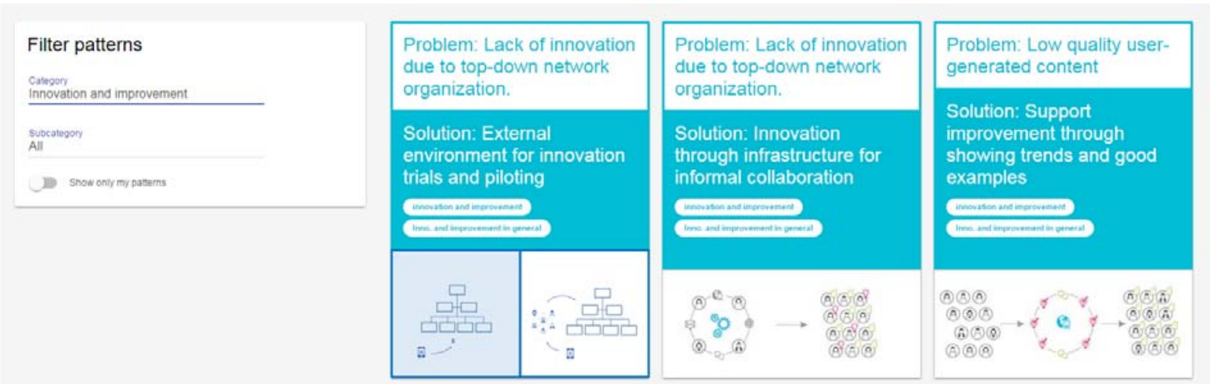

Figure 9: Example listing of design considerations

When identifying relevant design considerations, the analyst may associate these with the HMN profile, allowing for easy reference and also for improving the recommendation of design considerations for other HMN profiles.

The HUMANE profiling tool also support users in adding new design consideration.

5.5 Step 5: Evaluate

Evaluation is a key phase in HCD. The HUMANE method may support such evaluation through a process of reflecting on the HMN profile as well as relevant implications and design suggestions for a given HMN. The use of the output of the previous steps of the HUMANE method for evaluation purposes, will need to be adapted for the specific case context.

In the following we suggest three approaches that may be considered. It should be noted that the suggested evaluation approaches have not been verified in HUMANE case trials. We expect the approaches to correspond to relevant potential uses of the output of the HUMANE method, but its verification will need to be considered future work.

Reflecting on the HMN profile: When analysing or considering possible overall designs for an HMN, the envision future HMN may be characterised in a HMN profile. The profile may then be augmented with the characteristics of the current state of the HMN, as described for Step 2. The divergences between the current and envisioned future HMN profile may constitute areas of particular interest when evaluating designs throughout the HCD process. In particular, considering how suggested designs may affect the overall HMN profile and whether the suggested design may contribute to narrowing the gap between the profile of the current HMN and the envisioned future HMN.

Reflecting on implications: The implications identified in Step 3 can be used as topics for evaluation work. During the implication analysis, key challenges for the envisioned HMN are identified. These challenges may in turn be used to guide evaluation efforts, serving to validate the identified challenges are relevant for the envisioned HMN and serving as guidance on evaluation topics.

Reflecting on design considerations: The design considerations identified through the design pattern approach in Step 4, may be used to guide evaluations in a similar vein as for identified implications. The relevance of design suggestions for the envisioned HMN may be validated through evaluation. Furthermore, the topic of the design considerations may guide evaluation effort. It should also be noted that the format of the design considerations is set up so as to facilitate analytical evaluation or critical discussion of suggested HMN design. For each design consideration, a possible solution is contrasted to a background situation illustrating a potential counterproductive situation. Hence, the design suggestion may also motivate reflection on design alternatives, and the degree to which these serve to address the counterproductive situation accentuated in the design suggestion.

6 Application of the HUMANE method to eVACUATE

This example is based on one of the case studies in the HUMANE project on an EC FP7 project called eVACUATE[5], which is about getting people out of dangerous situations. We will describe the network further below as part of the context and scoping step. Note that step 5 of the method (evaluate) is omitted as this example is based on an existing network used as a case study. As such, the final step of the complete design process could not be conducted.

[5] http://www.evacuate.eu/

6.1 Step 1 - context and scoping

In the short description of the eVACUATE network, above, we have already made a note of the purpose of the network as being about getting people out of dangerous situations. In other words, the purpose of the network is to keep people safe and facilitate large-scale evacuations should dangerous situations occur.

The context of the network in the case of eVACUATE is confined to a particular venue in a geographical sense. In eVACUATE, there are four different venues: an airport, a cruise ship, a metro station and a football stadium. Although each venue may have variation in objectives and network set-ups, we focus on the generic and common aspects here. Example objectives include:

- Monitor and detecting dangerous situations as soon as they unfold.
- Real-time analysis of monitoring data.
- Adapt evacuation plans dynamically to current conditions.
- To provide clear, easy to use, set of safe evacuation instructions.
- To support civil protection authorities in the formation and validation of safety procedures.
- To comply with regulations.

In terms of scoping the network according to its actors, we note that the main participants of the eVACUATE evacuation scenarios are: operational staff who are responsible for making sure people get out safely; the people to be evacuated; and the emergency services who are quasi autonomous but responsible for the safe evacuation of the site(s). There are two different types of machine "actors": 1) the site itself, which is often equipped with various sensors (especially the cruise ship and airport cases), characterised by equipment with no particular autonomy in terms of execution, and 2) a Decision Support System (DSS) developed in the eVACUATE project to assist the operational staff, which by contrast to (1) supports the operation of software components which act on and interpret the information coming from the non-autonomous equipment. Thus, we see this as a HMN where the 'machine' actors are both active and passive elements.

The eVACUATE HMN is used under two main circumstances: (i) during monitoring (normal operation) where the emphasis is on periodic checking by operational staff based on default input from sensors, that individuals act appropriately and safely; and (ii) during evacuation, where the HMN changes to accommodate tighter interaction with sensors, even the recruitment of additional sensors, and the possible involvement of emergency services such as paramedics, the police, or special forces.

6.2 Step 2 – network characterisation

The HUMANE consortium created the profile of the eVACUATE HMN, which was presented to and validated by members of the eVACUATE project. Using the HUMANE Network Profiler, the profile is depicted below in Figure 10, representing the two states of operation: grey dotted line for monitoring; pink solid line for evacuation.

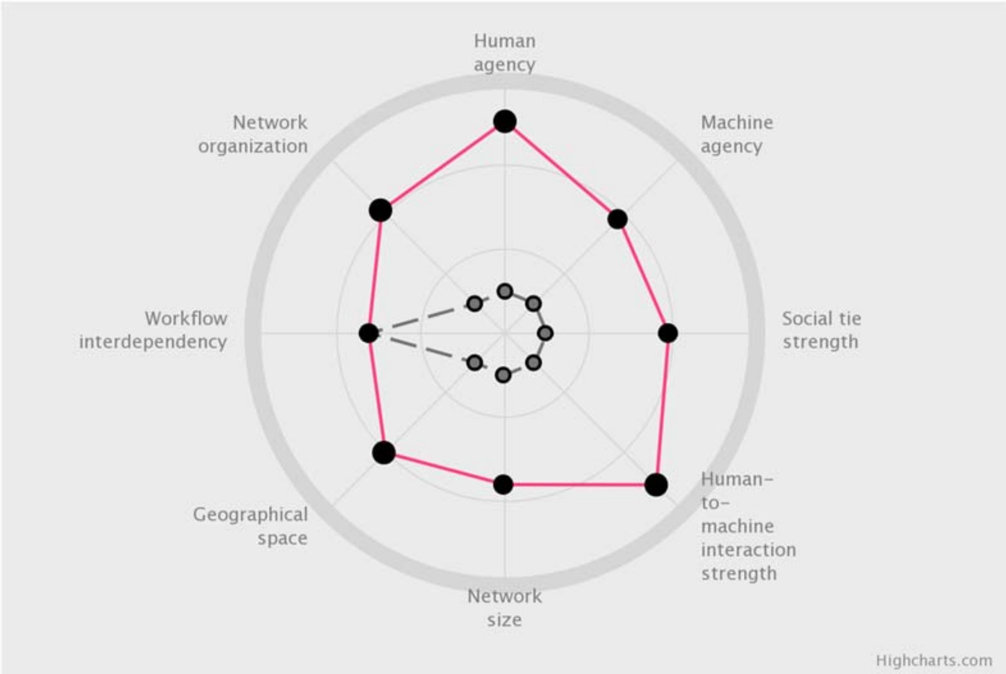

Figure 10: eVACUATE profile. Dotted line = monitoring; solid line = evacuation.

There are a number of general features and characteristics which are worth picking up on in the eVACUATE profiling. As previously stated, the eVACUATE case does not simply refer to a single situation. Instead, there is a default network, involved in the day-to-day monitoring of the specific venue(s). This is not a particularly complex network of humans and machines, interacting to check output or, in the case of potential evacuees, as passive subjects being monitored. With the exception of *workflow interdependence*, the associated HMN occupies the space towards the centre of the spider chart. However, the moment an evacuation is required for whatever reason, values become more extreme approaching, if not attaining, the outer edges of the chart. This is now effectively a short-lived, bespoke configuration in response to the specific requirements of the evacuation.

The significant changes in the profile of the two states raises several interesting questions that could be explored in the consecutive steps of applying the HUMANE method. For example, what transformations does the network have to go through to switch from one state to the other? Is the transformation uniform across all dimensions? Or are there one or more dimensions which may dictate where the others lie? Clearly, some dimensions such as *geographical size* are subject to other, external, factors and we could here expect variation between the four different venues considered in the eVACUATE project (airport, cruise ship, metro station and football stadium).

At this stage, what the spider graph indicates is a need to 'design for flexibility' (Clark, Wroclawski, Sollins, & Braden, 2002). The changes around *network size* and *geographical size* are externally dictated, and are really just a matter of scalability or elasticity. However, any dependencies such as between *human agency* and *network organisation* would need to be called out to the architect, along with any other consequences for *workflow interdependence* and *social tie strength* for instance. For the sake of brevity, we provide an example analysis of two of the eight dimensions below.

Social tie strength *(Monitoring: low. Evacuation: intermediate)*: There are significant differences in the relative strength and relationship of interactions between individuals. Further, there will be different levels of interdependency depending on participant role: they may be citizens / potential evacuees, operational staff, or members of the emergency services. Their relationships will change as situations change; further the social tie strength is not necessarily bidirectional.

During monitoring: Social tie strength will tend to be latent during normal operations: although being monitored by operational staff, neither group is particularly concerned with or dependent on the other. There may be strict guidelines and hierarchical dependencies between them as the situation changes, of course.

During an emergency: Social tie strength will increase during evacuation not least as dependencies increase: natural groupings are likely to form between evacuees with a view to mutual support if possible, and involvement of emergency services may introduce other relational dynamics between those responsible for the safe evacuation of participants. *Note* that in Figure 10, the value indicated represents an aggregate across all human participant types.

H2M interaction strength (*Monitoring: low. Evacuation: high*): H2M interactions will remain fairly low-key, with low levels of reliance and dependency on machines for citizens / potential evacuees and for operational staff. However, we do note that operational staff do have a greater reliance on machines to perform monitoring activities. This will change, though, as different situations arise, with occasional override by operational staff if they decide to check or have checked specific details and issues.

During monitoring: The overall strength of H2M interactions is relatively low, though the operational staff will tend to relinquish responsibility for monitoring to automated processes using data provided from sensors.

During an emergency: During evacuation or other emergencies, however, dependence on machine processing will to some extent reduce: potential evacuees, operational staff, and if involved, emergency staff may well make extensive use of the outputs of sensors and warnings and alerts from any decision support platforms, but they will typically retain overall responsibility for the synthesis of immediate and historical facts.

6.3 Step 3 - implication analysis

Following the previous step, we can make certain observations pertaining to implications when the network changes state. For example, we observe that agency increases differentially with greater real-time processing and two-way sensor control as well as increasing human decision making. As noted before, this has implications for the architecture, requiring flexibility and scalability.

We can also observe implications that lead to the desire to control certain dimensions, such as human and machine agency, both of which we see increase in the previous step. For example, the introduction of the DSS has implications pertaining to trust and reliability as the staff need to rely on the information for their decision making that they are ultimately responsible and accountable for. Hence, for safety reasons, the staff seek to control the agency of evacuees so that they follow instructions in order to safely evacuate; and for ethical reasons, the agency of machines so that their processes are transparent and decisions are left with operational staff rather than being fully automated.

In a focus group with five participants, discussing potential opportunities and implications for the eVACUATE network (Pickering et al., 2016). At a higher level, in terms of the objectives of the HMN, the increased agency introduced by the DSS (in particular), can increase safety levels while keeping the same number of staff. However, the participants also noted that the HMN owners may alternatively chose to save costs while maintaining the same safety levels.

In the aforementioned focus group, trust implications were explored. It was established that the trust relationship between the DSS and operational staff is important, as the staff need to rely on the information for their decision making that they are ultimately responsible and accountable for, as noted above. As such, using a network diagram approach (as discussed in Section 5.2.3 – see Figure 8 on page 18), we summarise the following implications and potential mechanisms for maintaining or building trust that were identified by the participants:

- ***Trust:*** transparent reporting of history and state might engender trust; i.e., the system should provide evidence about the recommendations it makes.
- ***Reliability:*** continuous service and fault tolerance essential as operational staff become reliant on the DSS and may be concerned with how the system's performance may impact on their job performance.
- ***Report state:*** the current state of the system should be made available to support the perception of reliability as well as trust.

6.4 Step 4 - design considerations

On the basis of the implications discussed above, existing design considerations identified in HUMANE apply, e.g., "increasing trust of users through transparent algorithms"[6], though not necessarily for all actors in the network. To build trust in the operational staff, the participants considered information transparency to be important. However, for the evacuees, different strategies were considered more appropriate, e.g.:

- ***Schema patterns:*** lighting used in support of information presented on signage, e.g., by turning off lights in hallways for paths evacuees should not follow.
- ***Informative displays:*** adding too much detail could potentially delay the processing of information and, therefore, an evacuation.

[6] https://networkprofiler.humane2020.eu/patterns/aztzZQQtyKmRoY2Wi

Put more generally, any information presented to users should be appropriately structured in order to ensure that they can understand and process the information fully under the circumstances where it will be used.

Specific to the DSS capabilities in the eVACUATE network, a design solution was proposed to retain browsable records of historical performance (correct as well as incorrect decisions made). In a similar vein, a possible design solution is to provide regular reports highlighting the accuracy of the system's performance. Both of these relate to the design solution noted above, about increasing transparency in order to maintain trust.

7 References

Clark, D. D., Wroclawski, J., Sollins, K. R., & Braden, R. (2002). Tussle in cyberspace. *ACM SIGCOMM Computer Communication Review*, *32*(4), 347. http://doi.org/10.1145/964725.633059

Eide, A. W., Pickering, J. B., Yasseri, T., Bravos, G., Følstad, A., Engen, V., … Tsvetkova, M. (2016). Human-Machine Networks: Towards a Typology and Profiling Framework. In *HCI International*. Toronto, Canada: Springer.

Følstad, A., Eide, A. W., Pickering, J. B., Tsvetkova, M., Gavilanes, R. G., Yasseri, T., & Engen, V. (2015). *D2.1 Typology and Method v1*.

Følstad, A., Engen, V., Mulligan, W., Pickering, B., Pultier, A., Yasseri, T., & Walland, P. (2017). *D2.3 The HUMANE typology and method*.

Følstad, A., Engen, V., Yasseri, T., Gavilanes, R. G., Tsvetkova, M., Jaho, E., … Pultier, A. (2016). *D2.2 Typology and Method v2*.

Guerrieri, P., & Bentivegna, S. (Eds.). (2011). *The economic impact of digital technologies: Measuring inclusion and diffusion in Europe*. Edward Elgar Publishing.

Heylighen, F. (1989). Self-organization, Emergence and the Architecture of Complexity. In *Proceedings of the 1st European Conference on System Science* (pp. 23–32).

ISO. (2010). *Ergonomics of human–system interaction — Part 210: Human-centred design for interactive systems*. Geneva, Switzerland: International Organization for Standardization.

Jaho, E., Klitsi, M., Følstad, A., Lech, T. C., Walland, P., Pickering, J. B., & Meyer, E. T. (2017). *D4.4: Final roadmap of future human-machine networks*.

Juris, J. S. (2012). Reflections on# Occupy Everywhere: Social media, public space, and emerging logics of aggregation. *American Ethnologist*, *39*(2), 259–279.

Lüders, M. (2016). Innovating with users online? How network-characteristics affect collaboration for innovation. *Journal of Media Innovations*, *3*(1), 4–22.

Lüders, M., Pickering, J. B., Engen, V., Bravos, G., Yasseri, T., & Tsvetkova, M. (2016). *D3.2 Report of first set of case-studies*.

Maguire, M. (2001). Methods to support human-centred design. *International Journal of Human-Computer Studies*, *55*(4), 587–634.

Mumford, E. (2006). The story of socio-technical design: reflections on its successes, failures and potential. *Information Systems Journal*, *16*(4), 317–342. http://doi.org/10.1111/j.1365-2575.2006.00221.x

Pickering, J. B., Engen, V., Jaho, E., Sarris, N., Yasseri, T., Tsvetkova, M., … Følstad, A. (2016). *D3.3 Report on second set of case-studies*.

Pickering, J. B., Engen, V., & Walland, P. (2017). The Interplay Between Human and Machine Agency. In *HCI International*.

Rudas, C., Surányi, O., Yasseri, T., & Török, J. (2016). *Understanding and coping with extremism in an online collaborative environment* (No. 1607.08127). *arXiv*.

Tsvetkova, M., García-Gavilanes, R., & Yasseri, T. (2016). Dynamics of Disagreement: Large-Scale Temporal Network Analysis Reveals Negative Interactions in Online Collaboration. Computers and Society; Physics and Society. Retrieved from http://arxiv.org/abs/1602.01652

Tsvetkova, M., Pickering, B., Yasseri, T., Walland, P., Lüders, M., & Engen, V. (2015). *D1.1 Systematic Literature Review*.

Tsvetkova, M., Yasseri, T., Meyer, E. T., Pickering, J. B., Engen, V., Walland, P., … Bravos, G. (2017). Understanding Human-Machine Networks: A Cross-Disciplinary Survey. *ACM Computing Surveys (CSUR)*, *50*(1).

Appendix 1 – typology dimensions and aspects

Each of the dimensions of the HUMANE typology are detailed in the form of a small set of key aspects. In Table 3 below, all aspects are presented. The aspect descriptions are formulated so as to reflect a high level of the dimension in question.

Table 3: Typology dimensions refined through characterizing dimension aspects.

DIMENSION/ASPECT	DESCRIPTION
D1. Human agency	**The degree to which human actors may have impact or cause change through open and diverse activities.**
D1.1 Varied activities	People can perform a diverse range of activities in the HMN
D1.2 Influence	People are able to interact freely and influence other participants in the HMN, whether human or machine
D1.3 Open activities	The activities people can perform allow them to express their personalities, behave diversely, freely, creatively and even use the HMN unpredictably
D1.4 Self-decided goals	People can use the HMN to help them achieve goals (set by themselves) that they may otherwise not be able to achieve, e.g., via other people or technology in the HMN
2. Machine agency	**The degree to which machine actors may have impact or cause change through open and diverse activities, as well as the extent they enable agency in human actors.**
D2.1 Varied activities	Machines (technological actors/agents) in the HMN can perform a diverse range of activities
D2.2 Influence	Machines can interact freely with - and may influence other participants in the HMN, and may help human agents achieving goals they cannot achieve on their own
D2.3 Open activities	The activities the machine agents can perform are open, giving opportunity for dynamic and perhaps unpredictable behaviour
D2.4 Human-like	The behaviour of the machines in the HMN can be seen as intelligent and autonomous, with human-like appearance or behaviour
3. Social tie strength	**The strength of typical relations between the human actors as nodes in the network.**
D3.1 Intimacy	People in the network are typically connected to one another by friendship or other close affiliation
D3.2 Duration	Relationships between people in the HMN typically last a long time
D3.3 Reciprocation	People in the HMN are typically mutually supportive

DIMENSION/ASPECT	DESCRIPTION
4. Human-machine relationship strength	**The strength of the relation between humans and machines as nodes in the network.**
D4.1 Trust	People strongly trust the machines in the HMN
D4.2 Reliance	People tend to accept what the machines of the HMN do and would only rarely intervene
D4.3 Dependency	People depend on the machines in the HMN to achieve their goals
5. Network size	**The number of actors as nodes in the network.**
D5.1 Uptake	The HMN includes a broad range of users
D5.2 Number of users	The HMN includes a large number of users
D5.3 Growth rate	The HMN has grown, or is expected to grow very rapidly
6. Geographical space	**The geographical extension of the network.**
D6.1 Transnationality	The HMN includes members and sites in many countries or states
D6.2 Cultural diversity	The HMN includes members or sites across different cultural groups
D6.3 Geographical reach	The HMN spans large geographical areas
7. Workflow interdependence	**The levels of coordination and interaction required between the actors of the network.**
D7.1 Coordination	Activity in the HMN require that people interact in a highly coordinated manner
D7.2 Interdependence between actors	The actions and communication between people in the HMN very much depend on the actions and communications of others
D7.3 Collaboration	There is extensive collaboration between the people in the HMN
8. Network organisation	**The character of the network organisation with implications for predictability and emergence; specifically contrasting top-down vs. bottom-up organisation.**
D8.1 Top-down organisation	The organisation of the HMN is highly centralized or predetermined
D8.2 Stability	The HMN has a stable organisation that does not easily adapt to different conditions
D8.3 Regulation	The HMN is regulated by thorough and detailed policies