Empirically-driven social networks: using survey data to specify social influence in agent-based models

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1 Introduction

Social networks - actors and the relation(s) among them [1] - are crucial elements for understanding dynamics of social systems. Agent-based models (ABMs) often include some representation of a social network to model social influence and interactions among agents [2].

Social influence is the process of individuals adjusting their opinion or behavior under the influence of others, in other words, because of social interactions. The strength of the influence depends on the relationship between the individuals, the network distance, time, and other characteristics of networks and individuals [3]. There are various theories for modelling social influence, for example the opinion dynamics model proposed by Degroot [4], and others used in ABMs [5].

The structure of a network is crucial to how the social influence unfolds. We know that context matters and shapes the structure of social networks [6]. Social networks in ABM are often categorized as random, scale-free or small-world, but these are not necessarily a good proxy for empirical social networks [2][7]. While these approaches are a good start, they cannot fully replicate real-world social network structures [9].

In this paper, we use an existing ABM to show the influence of social network structure and interaction on the model results. Based on that, we propose a methodology on collecting empirical data using surveys to build context-specific dynamic networks in ABMs. The survey questions are grounded in tested survey items on social networks developed in various fields of research (e.g., psychology, sociology) and are built on different theories for explaining social influence.

2 Case Study

To illustrate our methodology, we use an ABM of households' flood adaptation decisions in Harris County, Texas, USA.

Figure 1 shows a conceptual overview of the model: On a micro level, households decide on taking adaptation measures using Protection Motivation Theory (PMT) [10]. The adaptation decision is parameterized based on a household survey [11]. The empirical data suggests that individual intentions to invest in adaptation are largely

driven by social influence, even stronger than by information on perceived probability and damages by our respondents [11].

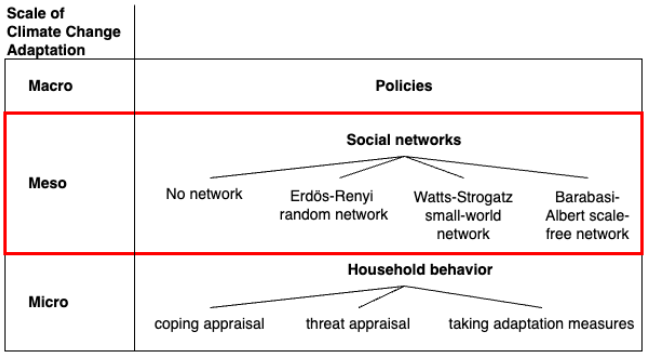

Figure 1: Conceptualization of the household flood adaptation ABM. The focus for this work lies on the meso-level – the interaction of household agents within a social network.

In our ABM, household agents are connected within a social network and exchange their perceptions regarding threat and coping appraisal (meso level). So far, we have compared how the network structure and what information household agents exchange influences the adaptation uptake (see Figure 2). In this case, we compared the model results for no network interaction and interaction within standard networks (Barabasi-Albert scale-free network [12], Watts-Strogatz small-world network [13], Erdös-Renyi random network [14]) and based on the Degroot's opinion dynamics model [4]. Furthermore, we investigate the impact of household agents exchanging different aspects of their adaptation decision: worry, coping appraisal (perceived costs and effectiveness of measures), and threat appraisal (perceived flood damage), individually or combined. Lastly, we observed how these interactions also influence the effectiveness of policies (macro level) and eventually decrease damages.

As we only have a stylized representation of the social network and influence the household agents have on each other, we do not know to what extend this represents real-world social network of households in this context. This highlights the need for empirical data on social networks and interactions within these.

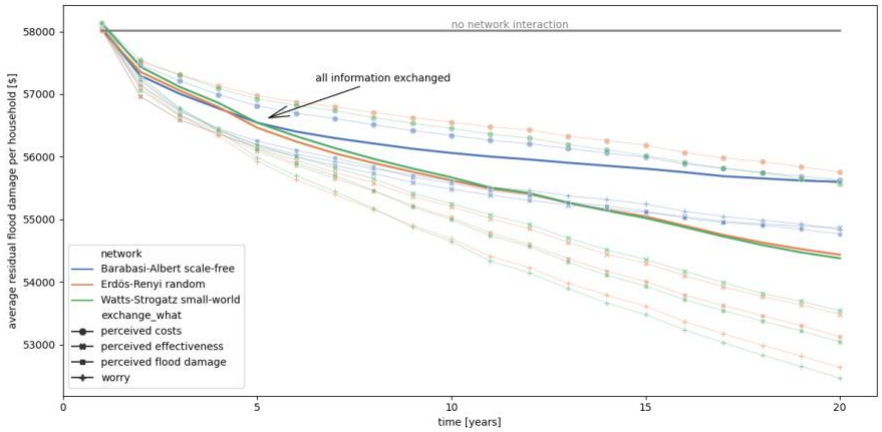

Figure 2: ABM results for influence of exchanging different perceptions (costs and effectiveness of measures, worry and perceived flood damage) in different network structures (Barabasi-Albert scale-free network, Watts-Strogatz small-world network, Erdös-Renyi random network) on the average per household residual flood damage for a flooding as experienced after hurricane Harvey in 2017.

3 Measuring social networks and social influence via surveys

3.1 Collection of data on social networks

To generate a social network for an ABM from empirical data, we take inspiration from social science and how data on social networks is collected there.

There are various ways to get information on social networks. Empirical foundations that include both structure and influence are often done through extensive data collection. This means all network members are asked about their relations with each other to remap a real-world network meticulously (e.g., [15], [16]). However, this approach can only consider a snapshot of a limited social network in a specific context and is very time-consuming. Another option is to use social media network data, but that does not necessarily represent the actual social environment of people [17].

Another possibility is to ask people on their influence for example, utilitarian, value-expressive or informational influence [18], [19] or via the process theory of power [20]. Descriptive and injunctive norms are also commonly used, for example in [21], [22]. Furthermore, for the ABM presented, risk is a key concept. Therefore, frameworks such as the Social Amplification of Risk Framework developed by Kasperson et al. [23] are of interest. For example Binder and colleagues use it, to consider interpersonal discussions as amplifiers of risk [24].

To elicit data on close ties, the name generator is a widely used approach. Instead of asking general questions about the entire social network of a respondent, the close contacts are retrieved through questions like "Who are your three closest friends?" or "Who would watch your home when you are away?" [25]. We select a set of survey

questions from this literature that can capture data requirements for building data-driven social networks in ABMs.

3.2 Proposed survey questions for collecting social network data for ABMs

We propose a set of questions for constructing surveys to derive social networks from small samples of respondents (only a fragment of the real social network), while defining rules on how the network connections could evolve based on the reported channels of social influence.

The name generator approach is used next to more general questions drawn from the social amplification of risk framework and other social influence theories. Below, we propose questions to capture various aspects of a social network that are relevant for ABMs: 1) number of connections or ties for each node in the network [26], 2) frequency of interaction (i.e., information exchange) [11], 3) characteristics of close connections [24], 4) influenceability (how one agent is affected by its connection) [19].

We formulated these questions in application to the flood adaptation ABM with the main topic of peer-to-peer discussions around flooding; here we list the questions referring to [Topic X] which should be replaced with the specific issue at hand when applied to different cases.

1- **Number of connections or ties.** The goal is to get a general idea of the network size concerning a specific topic (inspired by [26]).
Survey question*:* With how many people in your social network do you ever talk about [Topic X]?

2- **Frequency of interactions.** From these questions we want to know how often people generally are in exchange about the topic of interest (inspired by [11][24]).
Survey question 1: In the last year, approximately how many times have you been involved in a conversation or contributed to a discussion (in person or on social media) involving the subject of [Topic X]?
Survey question 2: Approximately how many of these conversations took place with someone who lived in your local area?
Survey question 3**:** How often do you have discussions with other people in your social network about [Topic X]? (inspired by [24], to ask about specific elements of Topic X)

3- **Characteristics of close connections.** To identify the characteristics of the close connections of a person to deduce the likelihood of two people / nodes being connected with the name generator approach (inspired by [26]). Three general types of characteristics are asked: relationship to this person, similarity in terms of specific attributes, and spatial relation.
Survey question 1: Who is this person to you? Please select all applicable: Family / Friend, Neighbor, Colleague / business partner, Online acquaintance

(e.g., through TikTok, Facebook, Instagram, Twitter etc.), Governmental official, Other.
Survey question 2: Do you consider yourself to be similar to each of those people, in terms of the following characteristics...? Please tick all those you consider to be similar for each person: [Characteristics relevant for Topic X].
***Survey question 3*:** How far away from you does this person live?

4- **Influenceability – weight attached to other nodes' opinions.** From these questions we want to know how easily the person is influenced by others (inspired by [19], [20], [26]).
Survey question 1: To seek a second opinion about [Topic X], people tend to consult with others to receive additional information about the process, the effectiveness or whether the costs are worth it. If you are to consider [Topic X-related aspects], what will you chose? Please select one option that describes your position the best:
   - I always consult with others regardless of …
   - I consult with others even when …
   - I would never seek additional information from others about [Topic X].

Survey question 2: How much you agree or disagree that each of this person has valuable experience when it comes to [Topic X]? (name generator)
***Survey question** 3:* The people around me seek my advice or support when considering to …
Survey question 4: The people around me get influenced by my opinion when it comes to …

The questions outlined above provide the basis for the network generation within the ABM. They also serve as the empirical foundation to operationalize social influence when defining social interactions in the ABM. These questions are collected as part of a bigger survey and can be connected to other socio-demographic data (age, level of income and education, ...) as well as the core behavior we are measuring for our case study - individual climate change adaptations.

4 Conclusion and further work

Based on literature on survey instruments, we proposed a set of questions that can be used to gather empirical data about social networks for ABMs. The questions can be adapted to different contexts. Currently, we are running the survey in four different countries with the approach outlined above. Although the implementation within the ABM still needs to be tested, we hope with the survey responses the social network in the ABM becomes a better approximate of real-world social networks. At the Social Simulation Conference, we will discuss further how to build social networks from empirical data.

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