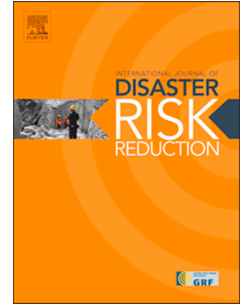


# Journal Pre-proof

Towards using agent-based modelling for collaborative translation of crisis information: A systematic literature review to identify the underlying attributes, behaviours, interactions, and environment of agents

R.I. Ogie, S. O'Brien, F.M. Federici



PII: S2212-4209(21)00678-6

DOI: <https://doi.org/10.1016/j.ijdr.2021.102717>

Reference: IJDRR 102717

To appear in: *International Journal of Disaster Risk Reduction*

Received Date: 21 July 2021

Revised Date: 2 December 2021

Accepted Date: 3 December 2021

Please cite this article as: R.I. Ogie, S. O'Brien, F.M. Federici, Towards using agent-based modelling for collaborative translation of crisis information: A systematic literature review to identify the underlying attributes, behaviours, interactions, and environment of agents, *International Journal of Disaster Risk Reduction* (2022), doi: <https://doi.org/10.1016/j.ijdr.2021.102717>.

This is a PDF file of an article that has undergone enhancements after acceptance, such as the addition of a cover page and metadata, and formatting for readability, but it is not yet the definitive version of record. This version will undergo additional copyediting, typesetting and review before it is published in its final form, but we are providing this version to give early visibility of the article. Please note that, during the production process, errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

© 2021 Published by Elsevier Ltd.

# Towards using agent-based modelling for collaborative translation of crisis information: a systematic literature review to identify the underlying attributes, behaviours, interactions, and environment of agents

R.I. Ogie<sup>\*1</sup>, S. O'Brien<sup>2</sup>, F.M. Federici<sup>3</sup>

<sup>1</sup> *Smart Infrastructure Facility, University of Wollongong, Northfields Ave, Wollongong NSW 2522, Australia*

<sup>2</sup> *School of Applied Language & Intercultural Studies, Dublin City University, Glasnevin, Dublin 9, Ireland*

<sup>3</sup> *Centre for Translation Studies, University College London, London, WC1H 0AG, United Kingdom*

\* Corresponding Author

Email: [rogie@uow.edu.au](mailto:rogie@uow.edu.au)

Phone: +61 (0) 2 4239 2546

## **Towards using agent-based modelling for collaborative translation of crisis information: a systematic literature review to identify the underlying attributes, behaviours, interactions, and environment of agents**

### **Abstract**

Collaboration in language translation has a long history and continues to develop in the form of crowdsourced and community translation. More recently, efforts in collaborative translation for crisis communication have been noted. These efforts are far from being mature in nature. We propose that Agent Based Modelling (ABM) for crisis translation could have significant benefits for the field of disaster response. A systematic literature review reveals how little consideration has been given to the topic to date. We review the limited literature from the perspective of agent's attributes, behaviours, interactions, and their environmental and operational factors. These are useful as a list of observations to be considered in the future modelling of collaborative translation. The complexities of ABM for collaborative translation are also highlighted and we propose some theoretical underpinnings that could be used to further enhance ABM for collaborative crisis translation. Based on the new knowledge generated to support accurate modelling of collaborative translation, we conclude that ABM may offer an opportunity to verify if, and how, translation crowdsourcing can be best optimised to support multilingual communication across the different phases of a disaster or crisis lifecycle. ABM could offer opportunities to assess rules, attitudes, behaviours, and interactions of multiple actors, from professionals to bilingual volunteers in rare, non-commercial language combinations, with the view of identifying positive rewarding mechanisms, including both financial incentives and the opportunity to broaden one's translation experience.

Keywords: translation, disaster, crowdsourcing, collaborative, agent-based modelling, ABM

### **1. Introduction**

Effective communication with the public is an essential part of disaster risk reduction because it influences how ordinary people take actions to plan, prepare, respond to, and recover from disasters. In multicultural societies and in multilingual regions where one language of communication does not effectively serve the entire population, it is vital to translate crisis information into multiple languages as required for effective communication between members of the public and the disaster management agencies. Translation is typically done by professional translators, where the profession is well-established, but translation in a crisis will sometimes require other types of contributions, from volunteers who speak multiple languages, and/or via translation technology such as machine translation (MT). In the worst settings, no dictionaries or translation resources may be available to volunteer bilinguals in supporting communication. The huge volume of translation work, its somewhat unpredictable nature, and the associated cost and time constraints demanded by past disasters such as the 2010 Haiti earthquake have necessitated the need to explore other translation models such as crowdsourced translation.

Crowdsourced translation is a growing practice that harnesses the multilingual skills within a large virtual crowd of internet users to obtain translations (O'Hagan 2011). It is not always agreed what exactly the term 'crowdsourcing' means in the domain of translation, but as Jiménez-Crespo (2017, p. 194) argues, its most important feature is that it depends on collaborative, web-mediated environments. Jiménez-Crespo (2017) argues for a differentiation between 'crowdsourcing' – when an explicit call is made to a 'crowd' and related forms of activity such as online (volunteer) collaborative translation. Collaborative translation is when “two

or more agents cooperate in some way to produce a translation” (O’Brien 2011, p.17; Khosravani and Dastjerdi 2013). The crowdsourcing model of translation was adopted in the Mission 4636 initiative to translate more than 40,000 messages from Haitian Kreyol to English within the first six weeks of the 2010 Haiti earthquake (Munro 2010; Hester, Shaw and Biewald 2010). To provide a sense of perspective to help highlight the importance of this work, it has been reported that 80,000 text messages were translated and processed in response to the earthquake in Haiti (Munro 2013). Besides the cost savings associated with this volume of crowdsourced translation (80,000 SMS), it is worth noting that it would have been a lot more difficult to rely solely on professional translators without compromising on the turnaround time, which is so critical in crisis relief.

Crowdsourced translation share similarity with other concepts such as community translation, citizen translation, and user-generated translation because they all rely on members of the public who are either volunteers or paid translators, irrespective of whether the translators are professional or untrained linguists (Flanagan 2016; O’Brien and Cadwell 2017; O’Hagan 2011; O’Mathúna et al. 2020; Federici and Cadwell 2018). A unique form of crowdsourced translation known as the collaborative translation of emergency messages (Co-TEM) requires two or more individuals to work together remotely or face-to-face to translate emergency messages (Ogie and Perez 2020). When individuals work constructively together to translate or review the outputs of crowdsourced translation, the quality typically improves. This reiterates results from a previous study by Persaud and O’Brien (2019), which indicated that the quality of crowdsourced translations can be equivalent to professional translations and far better than raw (i.e., unedited) MT outputs. Furthermore, the absent or insufficient data to train MT engines presents limitations for widely used yet low-resourced languages with millions of speakers (Magueresse, Carles, and Heetderks 2020; Shikali and Mokhosi 2020). Dialects and languages in the Indian sub-continent, in Africa, and in mainland China are obvious examples (Magueresse, Carles, and Heetderks 2020; Shikali and Mokhosi 2020). Therefore, crowdsourcing translation could be an absolute necessity to accommodate the needs of culturally and linguistically diverse (CALD) communities that use rare, lesser-used, low-resource languages.

This does not mean, though, that crowdsourced translation has reached a maturity level in terms of its reliability to support communities in preparing, responding to, and recovering from disasters. As Guazzini et al. (2015) noted, the full potentials of crowdsourcing systems are currently underexplored because of poor understanding of these systems. There is therefore the need for research to gain a deeper understanding of systems used for crowdsourced translation. The study of these systems should not only shed light on how to optimise their performance and reliability but should also improve understanding of their overall behaviour under different conditions, including the social, technical, and environmental factors that could interact to either worsen or improve system performance. System performance could be measured in terms of the user participation rate, quality of translation, speed of translation, behaviour changes, participants’ interactions, and the stickiness of the system in relation to the producers and consumers of the translated contents. For example, user participation rate could be investigated under different reward policies to determine the most appropriate incentive mechanism for attracting and sustaining the participation of the crowd (Ogie et al. 2020; Yang et al. 2019). Some users may require a monetary reward to participate, particularly considering that translation takes time and effort, not to mention the cost incurred through internet data. There may be however many other people who are motivated by altruistic reasons to contribute to building the resilience of humanity to disasters (just as some volunteer their construction skills in reconstructing damaged buildings, or others volunteer time in search and rescue missions, linguists volunteer their translation skills). Others may be motivated by a need to increase their experiential learning. The monitoring of performance could be instrumental in assessing learning as behaviour change – revising practices, reviewing outcomes, reassessing workflows based on

other participants' feedback as part of individual learning and improved system performance. Going beyond rating systems will be necessary as their effectiveness in some crowdsourcing systems has not proven to be trustworthy or acceptable (Morschheuser et al. 2017; O'Hagan 2017). Administering the most appropriate incentive mechanisms is therefore challenging, but it remains just one of many factors that need to be well understood to guarantee the viability of any crowdsourced translation project. An appropriate solution should therefore aim for a methodological approach with inherent capability for investigating a broad range of factors or conditions that could worsen or improve the performance of systems used for crowdsourced translation.

Agent-based modelling (ABM) provides a veritable ground to investigate how a broad range of factors could interact to worsen or improve the performance of crowdsourced translation systems. ABM is a class of computational models that is great for examining complex systems and determining their emergent behaviour. While cellular automata (CA) and social force model (SFM) can be used as alternative modelling approaches, ABM is computationally more superior for modelling social phenomena such as collaborative translation (Clarke 2014; Yang et al. 2014). ABM is preferred when dealing with social phenomena or complex adaptive systems for which the basis of the model is a behavioural unit, such as a person or organisation (Clarke 2014). Whereas CA are best used for modelling spatial processes, SFM are best for modelling pedestrian dynamics (Clarke 2014; Yang et al. 2014). It should be noted, though, that ABM does have its limitations, including high computational requirements for complex systems and challenges in determining the right level of abstraction for the model (Crooks and Heppenstall 2012). If the right level of model abstraction is not observed, the model might be too simple to provide practical value or too complicated to run due to excessive constraints (Crooks and Heppenstall 2012). However, ABM remains a robust modelling approach, considering that the above limitations are also common to most modelling techniques (Crooks and Heppenstall 2012). ABM can help to improve understanding of the overall system behaviour under different conditions and scenarios by simulating the actions and interactions of autonomous agents (e.g., individuals or organisations) contained in the system (Islami et al. 2017). For this reason, several studies have explored the use of ABM for understanding crowdsourcing and collaborative problem solving (Axelrod 1997; Bergner et al. 2016; Zou et al. 2014; Guazzini et al. 2015; Yang et al. 2019). However, none of them have focused on crowdsourced translation of crisis information.

In the absence of any existing ABM for crowdsourced translation of crisis information, the first challenge would be to determine the appropriate elements to include in the model. According to Jeong and Khouja (2013), an agent's behaviour, motives, and interactions are the key elements required to develop a realistic model for examining the overall behaviour of the system to be investigated. The task of identifying these key elements is a vital initial step that is often downplayed in the ABM process. This issue has been previously highlighted by Islami et al. (2017), who noted that a major weakness in ABM is the identification of the agents, their characteristics, behavioural rules, and interactions. Recognising that not many studies address the preliminary step of systematic identification of key elements, the authors call for greater transparency in how future ABM studies identify the agents, their attributes, behavioural rules, and interactions (Islami et al. 2017). Hence, the present study contributes by performing a systematic review of the relevant literature, with the aim of addressing the following research questions:

1. What attributes and behaviours of actors characterise the collaborative translation of crisis information?
2. What are some of the interactions of agents who participate in the collaborative translation of crisis information?
3. What are the environmental and operational factors that characterise the collaborative translation of crisis information?

## 2. Method

This study follows a systematic literature review process, which is depicted in Figure 1. The systematic approach is considered most appropriate for the study as it allows the researchers to address well-developed research questions based on a robust search strategy and screening process. The literature search was conducted using academic databases such as Scopus, Web of Science, IEEE Xplore, and ScienceDirect. The cut-off date for the search was October 10, 2021. Based on a combination of keywords (see Figure 1), a total of 233 articles were retrieved after removing duplications and conference reviews, which often do not have an author or scientific contribution. The 233 retrieved articles were those written in the English language and published in the last decade. This focus on current literature is vital given that web 2.0 technologies and the proliferation of social media would have changed the way collaborative translation is approached.

Upon screening, 58 of the retrieved articles were found to be irrelevant to the study because they have not actually reported about collaborative translation. From the remaining 175 articles, 34 were screened out because these articles did not provide any relevant description of the activities of collaborative translation to warrant inclusion. For example, articles were excluded if they only mentioned collaborative translation as a translation technique without further description of the translation process, or if they solely proposed software algorithms for implementing collaborative translation. The remaining 141 articles were scrutinised to ensure that they are primary research articles that report empirical findings based on observed and measured phenomena, that is, one that derives knowledge from actual experience rather than from theory or belief. Consequently, 112 articles were excluded, which were not empirical research. This left 29 articles from which we excluded two articles that were not peer reviewed. The remaining 27 peer reviewed articles were thoroughly examined and included in the study. These 27 articles include 9 that focus specifically on humanitarian crisis or disaster relief and 18 that relate to other application areas such as bilingual reading in classrooms and schools, legal translation to support societal needs and human rights provision, translation on Chinese video-sharing websites (Bilibili), etc.

The small number of included articles is not unusual, given the specific focus of the research questions and the stringent methodological inclusion criteria imposed in the interest of high-quality evidence (Yaffe et al. 2012). Reviews with small includable studies is not an uncommon phenomenon in research, neither is it new to publication in high quality journals. In fact, a study conducted in 2010 found that 9% of systematic reviews published in the Cochrane Database of Systematic Reviews (the leading journal and database for systematic reviews in health care) were 'empty reviews', that is, systematic reviews with no includable studies that meet the inclusion criteria (Yaffe et al. 2012). The robustness and systematicity of the review protocol are critical to finding high-quality evidence and should not be compromised in order to increase the number of included studies. Afterall, a scanty or empty review, in itself, is still useful evidence showing that there are few high-quality studies in the research field, evidencing a research gap, or the existing studies cannot be found through a systematic process.

**Keywords** = ( "collaborative translation" OR "citizen translation" OR "volunteer translation" OR "crowdsourcing translation" OR "crowdsourced translation" OR "translation crowdsourcing" OR "user-generated translation" OR "community translation" OR "social translation" ) AND PUBYEAR > 2009 AND ( LIMIT-TO ( LANGUAGE , "English" ) )

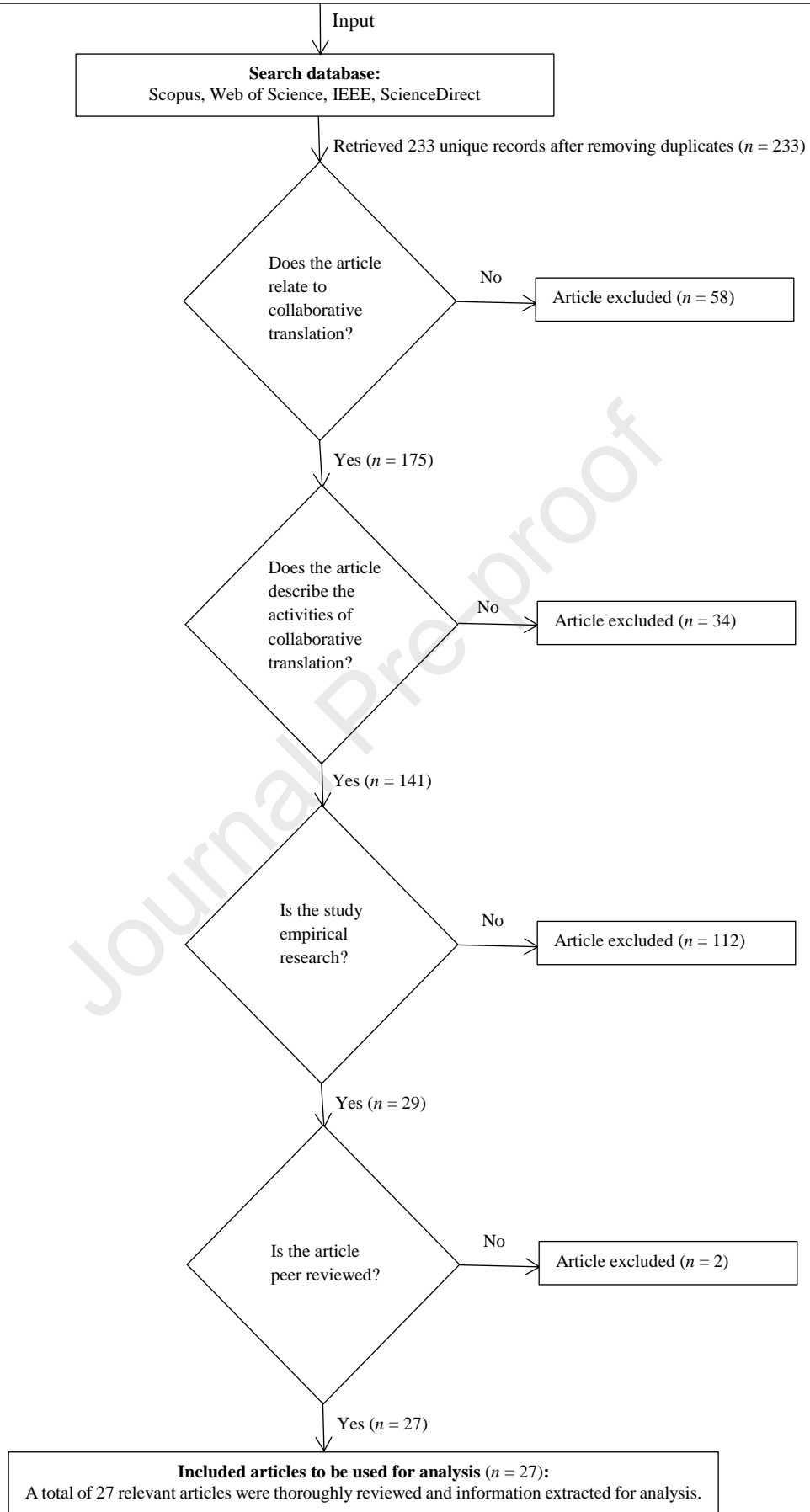


Figure 1. Flow diagram for systematic literature review



### 3. Results

In this section, we present the results of the systematic literature review. In presenting the results, consideration is given to the typical structure of ABM, which includes (1) the attributes and behaviours of agents, (2) the interaction of agents, and (3) the environment in which the agents operate (Macal and North 2014). Hence, Section 3.1 focuses on agents' attributes and behaviours. Section 3.2 summarises agents' interaction while section 3.3 presents some notable environmental and operational factors to be considered when creating an ABM for the collaborative translation. Agents could be volunteer translators, members of CALD communities who need translated information during crisis, emergency agencies, etc. The list of observations about agents' attributes, behaviours, interaction, and environment should form the basis for developing future ABM models to improve understanding of the collaborative translation of crisis information. The implications of the results are also discussed in this section.

#### 3.1 Attributes and behaviours of agents

##### 3.1.1 Summary of agents' attributes

1. *Volunteer translators are often well educated.* This has been observed in an online collaborative translation project aimed at supporting multilingual logistics communication in COVID-19 disaster relief (Zhang and Wu 2020). The study noted that several volunteer translators had multiple university degrees related to language (Zhang and Wu 2020). Other studies, which are not specifically focused on humanitarian or disaster relief, have also reported the same to be true, with volunteer translators often educated to bachelor's or master's degree level (De Wille, Exton and Schäler 2015; Marin-Lacarta and Vargas-Urpí 2020; Ding et al. 2021).
2. *Volunteer translators are resourceful in helping with the translation process.* Volunteer translators can act as cross-lingual mediators (i.e., linguistic and cultural mediators) to translate crisis information (Zhang and Wu 2020). By working collaboratively, bilingual members of CALD communities can potentially translate emergency messages (Ogie and Perez 2020; Khaefi et al. 2018). In response to the COVID-19 crisis in Wuhan China, volunteer translators were said to have multilingual repertoires, social resources (e.g., social networks - a type of social capital), intercultural communicative competence, and humanitarian spirit to help in the translation process (Zhang and Wu 2020; van Rooyen and van Doorslaer 2021; Paradowska 2021). Yu (2019) also discussed the concept of shared repertoire, which is a set of resources that participants possess and employ in the meaning negotiation process of collaborative translation. Moreover, volunteer translators often possess local knowledge of locations, regional slang, abbreviations and spelling variants, which they can employ to localise translations for disaster-impacted communities (Munro 2010). In relation to social capital, Ogie and Perez (2020) added that community translators have local knowledge and established networks of trusted relationships that they can potentially draw on to help increase community participation and to connect other members of community to translated resources. Partnership with local translators and other local community organisations is therefore very helpful to facilitate community participation (Ogie and Perez 2020).
3. *Volunteers may be professional or non-professional translators.* It is not uncommon to have both non-professional and experienced professional translators with full-time jobs participate as volunteer translators for online collaborative translation projects (Marin-Lacarta and Vargas-Urpí 2020; Ding et al. 2021). This has been observed in several studies, including those focusing on translation for humanitarian (Flanagan 2016; Ding et al. 2021) and non-humanitarian issues (Yang 2021; Dolmaya 2012).
4. *Volunteer translators possess unequal levels of skills and experience to influence the translation output.* Some volunteer translators are more efficient than others in terms of the quality of translation or peer review, and the response time to complete tasks (Khaefi et al. 2018). Yu (2019)



reported that there are hierarchies in the Yeeyan translation platform, including a formal recognition of different levels such as novice (less than two years' experience), experienced (more than two years' experience) and senior members (a special group a.k.a Translation Senators). Volunteer translators may also have low or no experience with computer-aided translation technology (O'Brien 2019).

### 3.1.2 Agents' behaviours

#### 3.1.2.1 Summary of agents' behaviours that are broadly applicable to most domains

1. *Some participants in collaborative translation are motivated by personal reasons.* Some community members are motivated to consistently provide translation because they feel it can help them improve their language skills or avoid language attrition (García 2020; Ogie and Perez 2020; Olohan 2014; Dolmaya 2012). Some newly qualified translators use collaborative translation platforms to gain work experience so they can then go and use the experience to promote their own services or improve job opportunities (Flanagan 2016; Dolmaya 2012; García 2020). However, experienced professional translators do not have the same motivation to gain translation experience (Flanagan 2016). Olohan (2014) and Dolmaya (2012) noted that there is also a motivation that is hinged on gaining translation skills. Others may volunteer to translate just to gain intellectual stimulation (Olohan 2014; Dolmaya 2012). Monetary concerns and additional income have also been identified as possible motivation for participation in collaborative translation projects (Dolmaya 2012). However, Flanagan (2016) noted that most non-professionals want to translate because of their personal interest in the topic, and not for payment. Few people engage in volunteer translation because of "warm glow" (Olohan 2014). Warm glow is impure altruism, which represents a feel-good factor or the sense of satisfaction associated with altruistic behaviours (Olohan 2014). It is also possible to have volunteer translators who participate for the purpose of personal fun and enjoyment (Olohan 2014; García 2020; Dolmaya 2012; Ding et al. 2021; Marin-Lacarta and Vargas-Urpí 2020).
2. *Some participants in collaborative translation are motivated by social reasons.* Motivation is crucial because it determines the degree of involvement of participants and the extent to which they want to collaborate (Marin-Lacarta and Vargas-Urpí 2020; Hester, Shaw and Biewald 2010). Some volunteer translators are motivated to translate because it enables them to develop friendship and multiple trusted social networks in their field of interest (Zhang and Wu 2020; García 2020; Dolmaya 2012; Marin-Lacarta and Vargas-Urpí 2020). Some are motivated to join volunteer translation because of a shared sense of responsibility to support a social cause (Zhang and Wu 2020; García 2020; Olohan 2014; Dolmaya 2012). The motivation to participate could also be due to a desire for gaining reputation or recognition within the community (Dolmaya 2012; García 2020). Hence, a translation leader board is sometimes used as a form of non-monetary incentive to motivate participation in volunteer translation (Flanagan 2016). With the myriads of personal and social motivating factors highlighted, how to determine the most appropriate incentive mechanisms to attract and ensure sustained participation in collaborative translation can be challenging (Ogie and Perez 2020). However, the consensus seems to be that people often engage in collaborative translation due a combination of reasons, which may be personal or social (Olohan 2014; Dolmaya 2012).
3. *Volunteer translators often participate from different parts of the world.* During their spare time, volunteer translators may translate for projects outside their country (Zhang and Wu 2020). In the context of supporting disaster relief efforts, Hester, Shaw and Biewald (2010) noted that while members of the disaster-impacted community contribute to the translation of emergency information, volunteers and workers living outside the crisis region tend to dominate the translation tasks. For this reason, crowdsourced translation projects must aim to harness the "cognitive

surplus”, which is the free time amongst translators located in different parts of the world (Marin-Lacarta and Vargas-Urpí 2020).

4. *Volunteer translators may exhibit undesirable behaviours that could be counter-productive, if not well managed.* Some volunteer translators may display undesirable behaviours such as negative comments and constantly disagreeing with others’ translation (Ding et al. 2021; Khaefi et al. 2018). This is more likely when volunteers have not undergone translator training and so have different, sometimes misguided, perceptions of what is required in translation. For example, it is not uncommon for untrained commentators to criticise a translation if it does not reproduce the original sentence in a very literal manner. Studies have reported how such behaviours could sometimes result in conflicts and frustrations (Yu 2019; Cerezo 2017). There could also be negative behaviours such as language-related frustrations associated with self-perceived linguistic incompetence (Beauvais and Ryland 2021). However, Cerezo (2017) noted that the mutual support inherent in collaborative translation projects can help to manage frustrating moments by creating less struggle or at least a sense of struggling together.
5. *Some professional translators have reservations towards other volunteer translators who provide free translation services.* Non-professional translators, who work for free without any formal training, have been considered the biggest threat to labour market structures and the livelihood of translation professionals (Flanagan 2016). Professional translators may hold negative sentiments or behaviours if they believe the use of volunteer translators on pro bono basis is devaluing their work (Gigliotti 2017). This can potentially cause tension between volunteers and professionals (Gigliotti 2017). A recent study focusing on translation in the university classroom has reported that while the trainee translators had an overall positive attitude towards non-professional translators, there were concerns as to whether it was ethical to provide free services (Sanchez Ramos 2021). A previous study also noted that although many professional translators would like to volunteer with non-profit translation crowdsourcing projects that are centred on humanitarian goals, professional translators do have ethical questions and would not like to extend free professional translators’ services to non-profit translation crowdsourcing projects, if they suspect that there are conflicting humanitarian and commercial agendas (Flanagan 2016). There is currently a lack of clarity as to how divided the translator community is regarding professionals translating for free, even when it is for a non-profit organisation (Flanagan 2016). However, it is expected that this issue would be more problematic in profit-based translation projects, but less of an issue when translating for a social or non-profit humanitarian cause such as disaster relief (Flanagan 2016).
6. *Low paid translation projects could turn off interest from professional translators.* Some professional translators would rather volunteer with a non-profit translation project than to work for the “impossibly low rates,” because at least volunteering would give them personal satisfaction and the great feeling of knowing that their work would be appreciated (Flanagan 2016).
7. *A few translators may attempt to cheat in a monetary reward system.* When translators are provided with point-based rewards, some (minority) may try to cheat the system just to earn points (Khaefi et al. 2018).
8. *Translators desire transparency in online collaborative translation projects.* When organisations and communities are not fully transparent about their activities, their motivation and the processes involved in the translation work, this fuels anger and division rather than a close-knit crowdsourcing community (Flanagan 2016).
9. *Volunteer translators may be demotivated to participate by the workload involved.* Some volunteers may feel hopeless and discouraged, if they realise that the information requiring translation or review is too much (Hester, Shaw and Biewald 2010). Marin-Lacarta and Vargas-Urpí (2020) explained that professional translators prefer short length translation tasks because they can afford to complete them in their free time without interrupting their professional commitments. Whereas other volunteers are motivated when they have clear transparency of the pending workload,

regardless of the volume of work (Hester, Shaw and Biewald 2010). The time flexibility (deadline) and the freedom on how the translation should be done can also affect whether volunteer translators would take up the translation task. If translation tasks are pre-populated with a Google Translate version, this can help to reduce the workload of the translators, thereby speeding up the translation process and reducing volunteer's frustration about workload (Hester, Shaw and Biewald 2010). In other words, volunteers would be motivated to help if they simply need to validate or correct the results from machine translations such as pointing out any missing details or editing to improve translation quality (Hester, Shaw and Biewald 2010). However, machine translation technology can lead to misleading translation, which requires training and skill to spot and fix. This can be highly challenging for untrained individuals.

10. *Not all translators are open to collaboration on chat rooms.* Some volunteer translators would not collaborate in the chat room because they are either professional translators who are more used to working alone or they are simply not comfortable interacting in an online environment (Munro 2010). However, volunteer translators who do not collaborate in a chat room still find the chat room useful because it gives them a sense of belonging to a larger community of volunteers that they can reach out to for help, if needed (Munro 2010).

### 3.1.2.2 Summary of agents' behaviours that are specific to humanitarian or disaster relief

1. *Some volunteer translators are driven by a sense of community and the humanitarian spirit to help those in crisis.* In times of disasters, individuals and groups become more cohesive, working together to overcome disaster-induced challenges (Ogie and Perez 2020). A few volunteer translators tend to be consistently active in their participation due to a strong sense of community (Munro 2010). Some other volunteer translators see their contribution as a way of giving back to a worthwhile community (Flanagan 2016).
2. *Volunteer translators may be motivated by shortage of translators in the wake of emergency needs.* Some volunteer translators are motivated to join volunteer translation when they become aware that the language skills they possess are urgently required and there are currently insufficient foreign language human resources to support emergency multilingual services in the crisis-impacted community (Zhang and Wu 2020). This is consistent with a previous study by Olohan (2014), who noted that some people may choose to translate just to ensure critical information is available in a lesser-used language.

## 3.2 Summary of agents' interaction

1. *The interaction between participants in collaborative translation often follow a typology with specific dialogue acts.* The interaction of agents in collaborative translation can be thematically classified into five dialogue acts, namely general interaction, information, maintenance, status, and miscellaneous (Yang 2020). General interaction relates to acts that promote dialogue flow, fulfills the need of social networking between peers, or involves general comments (e.g., the essence of the project) that are not directly related to the substance of the translation. Information covers any dialogue act involving the discussion or provision of information that is directly related to the delivery of the project (e.g., translation requirements, platform usage, project schedule) or the substance of the translation (e.g., clarifying the meaning of a term, providing revision comment, or asking someone to revise a translation) (Yang 2020). Maintenance refers to dialogue acts that involves acknowledgement. This could be an acknowledgement to peers that a piece of information has been received. It could also involve the compliment of one's work or a show of appreciation for others' comments or contribution to a task (Yang 2020). Status covers acts that involves requesting or responding to a request for

- the status or progress of the translation project. Miscellaneous is any dialogue act, which does not fit any of the above categories (Yang 2020).
2. *Participants in collaborative translation are often connected through social networking sites.* Social networking platforms (e.g., ProZ or TranslatorsCafé) and other user-generated content sites (e.g., YouTube, Wikipedia) provide both a communicative function and online social connections for various agents involved in collaborative translation projects (Yang 2020). This social networking opportunity helps the participating agents to build friendship and a trusted network of like-minded professionals in the translation industry (García 2020; Dolmaya 2012).
  3. *Mutual engagement in collaborative translation results in improved efficiency and speed.* Collaborative translation that involves inputs from multiple volunteers is a socially distributed production that benefits from mutual engagement and joint decision making (Ogie and Perez 2020). As Cerezo (2017) rightly noted, this type of collaboration often helps to increase the comprehension of the source text and improves both the efficiency and speed of translation.
  4. *Collaborative translation involves meaning negotiation between the participants.* In collaborative translation, personal insights are put forward and the best ideas are adopted to translate the message while others are either fine-tuned for use or rejected by the group (Ogie and Perez 2020; David and Cole 2021). This phenomenon has been referred to elsewhere as meaning negotiation (Hirvonen and Tiittula 2018; Yang 2021; Yu 2019) or joint meaning making (Puzio et al. 2013). Hirvonen and Tiittula (2018) provides further information about the possible problem-solving sequences, including the proposal/acceptance sequence and the proposal/negotiation/acceptance sequence.
  5. *The interaction and meaning negotiation in collaborative translation is characterised by several discourse units, including questioning, disagreement, and acceptance.* In collaborative translation, participants may take turns in conversations about how best to translate a message by using several discourse units such as questions, acceptances, disagreements, and repairs (Ogie and Perez 2020; Yang 2020). One individual naturally takes the lead, often dominating the conversation during collaborative translation (Ogie and Perez 2020). Temporary moments of disagreements may ensue as individuals try to negotiate their own ideas during the process of collaborative translation (Ogie and Perez 2020; Yang 2020). This is common to most collaborative translation projects, including those on the Yeeyan platform (Yu 2019; Yang 2020). According to Puzio et al. (2013), participants sometimes disagree and use questioning to contest the opinions of others, with the aim to co-construct a more complete, accurate, and better translation (Puzio et al. 2013). In fact, Puzio et al. (2013, p. 342) noted that “in many cases, questioning, debating, and arguing showed a higher level of participation than cooperation and agreement”.
  6. *Collaborative translation can be a self-organising process.* Collaborative translation is considered a self-organising process wherein the community translators are able to self-manage the translation process without significant intervention from an external moderator (Ogie and Perez 2020). This self-organisation has been acknowledged in several collaborative translation research studies across different domains, including online collaborative translation on the Yeeyan platform (Yu 2019; Yang 2020). According to Yang (2020, p.327), participants involved in the collective problem-solving of translation can “self-organise and resolve various kinds of issues through collaboration”. Similarly, Zhang and Wu (2020) noted that volunteer translators can self-organise to carry out urgent translation and relief tasks.
  7. *Volunteer translators often work constructively together.* When translators have great respect for the shared work of translation, disagreements are quickly repaired through the use of interpersonal and social communication skills to achieve and consolidate shared understanding and to re-establish mutual intelligibility of the collaborative problem-solving activity (Ogie and Perez 2020). The participants often encourage mutual consultation to work towards a shared

- understanding or agreement on what needs to be done (De Wille, Exton and Schäler 2015; Sanchez Ramos 2021).
8. *Volunteer translators share knowledge amongst themselves.* When a participant in collaborative translation is confused, the others or another participant often helps to explain (Ogie and Perez 2020; Cano and Ruiz 2020). According to Yang (2020, p.329), “peer interaction in online collaborative translation may include a process of multi-agent knowledge transfer that contributes to participants’ learning”. In general, the participants tend to share knowledge and learn from each other’s experience (De Wille, Exton and Schäler 2015; Dolmaya 2012; Beauvais and Ryland 2021; Sanchez Ramos 2021). Puzio et al. (2013) noted that in such an environment of collaborative translation, help seeking and help giving is common. The online chat room helps newbies and other volunteer translators to ask questions and obtain quick answers to issues requiring clarification during the translation process, especially regional slang (Munro 2010; Hester, Shaw and Biewald 2010).
  9. *Collaborative translation is a positive social experience.* Collaborative translation is considered a positive social experience for communities because it brings community members together, allowing for socialisation, development of personal networks, and exchange of opinions through a shared language and a similar cultural lens (Ogie and Perez 2020). Puzio et al. (2013) view collaborative translation as a sociocultural tool for joint meaning making while Paradowska (2021) highlighted intercultural skills as vital to a positive social experience for translators. This positive social interaction has been acknowledged in several studies that employ collaborative translation (Hirvonen and Tiittula 2018; Yu 2019).
  10. *The interaction in collaborative translation leads to synergistic outcomes.* Collaboration between professionals and non-professional translators working on translation projects exceeds that of any one individual (Flanagan 2016). Non-professional translators tend to have higher confidence and self-efficacy to translate when working collaboratively than when working individually (Ogie and Perez 2020). Collaboration among translators leads to improvement in data quality, motivation, and community contacts, enabling richer value adding in the translation than would have been possible from any one person (Munro 2010; Flanagan 2016; Cerezo 2017; García 2020). In other words, the joint knowledge of volunteer translators exceeds that of any one individual translator (Munro 2010). Similar synergy has been reported in non-humanitarian settings such as translations in classrooms (Puzio et al. 2013; Beauvais and Ryland 2021).
  11. *Participants in collaborative translation projects play different roles.* Besides the role of translators, participants assume several roles such as project initiator or project manager (Yu 2019; Dolmaya 2012), editor (Hirvonen and Tiittula 2018; Yu 2019; Dolmaya 2012; van Rooyen and van Doorslaer 2021), reviewer or revisor (De Wille, Exton and Schäler 2015; Yang 2021; Hirvonen and Tiittula 2018; Yu 2019; Dolmaya 2012; van Rooyen and van Doorslaer 2021), proof-reader (Yu 2019), and commenter or publisher (Yu 2019). Volunteer translators who act as reviewers provide evaluations and help to refine the translated information from other volunteer translators, thereby improving quality (Zhang and Wu 2020; Khaefi et al. 2018).
  12. *The interaction between agents creates a beneficial value network.* In online collaborative translation projects, particularly those with humanitarian focus, volunteer translators contribute in ways that create benefits, which extend beyond the translation work. For example, volunteers cannot only translate crisis information but can also provide categorisation and geo-tagging for them (Hester, Shaw and Biewald 2010; Khaefi et al. 2018). Volunteer translators can sometimes choose to take up a role of “sourcers” of relief materials to support the needs of crisis-impacted communities. In other words, volunteer translators can act as “crowdsourcers” of on-the-ground disaster relief efforts to help organise material donations to crisis-impacted communities (Zhang and Wu 2020). In essence, the participation of volunteer



translators can directly or indirectly complement official disaster relief efforts (Zhang and Wu 2020). The output from collaborative translation is beneficial enough to be disseminated to multiple agencies and actors to facilitate disaster response, relief, and recovery (Hester, Shaw and Biewald 2010). Relief workers, emergency agencies, NGOs and other actors involved in the humanitarian sector find the translated crisis information to be useful in directing assistance to where it is needed the most (Hester, Shaw and Biewald 2010). Through translation activities, volunteer translators can also facilitate direct contact between overseas donors, aid workers, and the recipients of emergency supplies/aids, which then accelerates the distribution and use of the relief materials (Zhang and Wu 2020). To further illustrate the expanded role of collaborative translation, a study of content typically translated by one of the main not-for profit translation organisations working in crisis and humanitarian response confirmed that most content types being translated were somewhat unexpected and included educational materials, training materials, and surveys (Cadwell, O'Brien and DeLuca 2019).

13. *Participants in collaborative translation often need to agree on the language form to be used.* When volunteers, who are working collaboratively to translate a message, speak different dialects or regional slangs, the result of the translation could potentially reflect inconsistency in language use, unless there is an agreement amongst the participants to consistently maintain one form of the language (Ogie and Perez 2020).

### 3.3 Environment and operational factors

#### 3.3.1 Summary of environmental and operational factors that are broadly applicable to most domains

1. *Finding translators can be difficult with rare, lesser-used, low-resource languages.* There can be a critical shortage of volunteer translators for less common languages, making it difficult to find volunteer translators who can review and refine translated information submitted by their peers (Zhang and Wu 2020). Hence, both word of mouth and viral online marketing are important for recruiting participants from a global pool of volunteer translators (Hester, Shaw and Biewald 2010).
2. *Clarity in translation requirements is vital for online collaborative translation projects.* When project owners or project initiators do not provide clear directions and standards that should be observed in the translation task, this can cause confusion to volunteer translators who want to assist (Zhang and Wu 2020). This is particularly true in disaster relief work, where volunteer translators expect clear direction from the government or responsible emergency authority (Zhang and Wu 2020). Moreover, volunteer translators would be encouraged when they receive some cooperation from the government and know that the government supports what they are doing in crisis relief (Zhang and Wu 2020).
3. *A robust translation management platform is essential for effectively coordinating collaborative effort.* In the absence of a robust system with an effective mechanism to assign workload, coordinate tasks, and organise the division of labour in crowdsourced translation projects, volunteers may repeat the same translation task already being done by other volunteers, thereby resulting in a waste of human resources (Zhang and Wu 2020). In designing the platform for crowdsourced translation, the display of the pending workload queue should be made available as an optional feature, so that volunteers who derive motivation from this information can activate the feature while volunteers who feel discouraged by this workload transparency can deactivate it (Hester, Shaw and Biewald 2010).
4. *Computer-aided translation (CAT) tools and other communication technologies play vital roles in supporting translation activities.* Technological competence has been highlighted as a vital skill required for modern day translation work (Paradowska 2021; Sanchez Ramos 2021).

Technological tools such as online dictionaries (e.g., Youdao Translate, UNTERM, IATE), online corpora (e.g., Linguee), machine translation tools (e.g., Google Translate, DeepL) are used by volunteer translators to provide a supportive role in overcoming some of the translation challenges that they might encounter (Ding et al. 2021; Ogie and Perez 2020; Atabekova and Gorbatenko 2017). These tools are not available in equal measure (or supporting similar levels of quality) for many languages, especially those used in regions more highly exposed to disaster risks. Chat rooms can act as a parallel stream of communication to help online workers to facilitate collaboration and clarify issues during the translation process (Hester, Shaw and Biewald 2010). Moreover, volunteer translators use social media as a way of networking and communicating translated information to those who require it (Zhang and Wu 2020).

5. *Online collaborative translation projects require appropriate incentive mechanisms.* Community translators and the mobilisers of collaborative translation spend their time and sometimes incur costs (e.g., telephone, transport) in contributing to the translation project (Ogie and Perez 2020). This suggests a need to consider incentive mechanisms, which may be social incentives, not necessarily monetary reward.
6. *Error checking or a quality control mechanism is vital to any collaborative translation project.* Without adequate peer reviewing or proofreading of translated text, there is a possibility of errors from translations done by non-professional volunteers (Gigliotti 2017). Besides, systems designed for crowdsourcing the translations of information can deliver misleading results if a mechanism is not put in place to allow the inclusion of vital contextual or cultural information. There needs to be a feedback mechanism to correct misconceptions (Sutherlin 2013). The use of multiple judgments or reviews per message can prevent mistakes that may not be detectable by an individual translator (Hester, Shaw and Biewald 2010).
7. *The level of responsibility and accountability associated with volunteer translation is still an open issue.* There is currently a lack of clarity as to whether non-professionals should take responsibility for their translations and if so, what are the implications of this shift of responsibility for the translation profession, including for professional and non-professional translators working collectively in translation projects (Flanagan 2016). The key issue, which still requires further clarification, particularly in the context of the acute phase of an emergency, is whether there is a greater or lesser acceptance to have an imperfectly translated information as compared to having no translated information at all (Hester, Shaw and Biewald 2010; see also Hunt et al. 2019).

### 3.3.2 Summary of environmental and operational factors that are specific to humanitarian or disaster relief

1. *In humanitarian and crisis contexts, translated information is desirable in multiple formats.* Both text and voice translations are essential in crisis situations as not everyone has adequate literacy skills (Ogie and Perez 2020).
2. *Emergency warnings and messages from government authorities are sometimes convoluted or have jargon that are difficult to translate.* Written information from government authorities or emergency agencies are often very difficult to translate because of the technical nature and complexity of the writing (Ogie and Perez 2020). Research has shown that community translators face difficulty in translating messages issued by emergency agencies when the messages are ambiguous or lack clarity (Ogie and Perez 2020).
3. *Translated resources are more meaningful to people from CALD backgrounds.* There are several members of CALD communities who cannot comprehend emergency messages that are communicated in the official (English) language (Ogie and Perez 2020). Members of CALD



communities are more likely to find messages that are translated into their languages to be more meaningful, understandable, and relevant as compared to the corresponding version of the messages in the formal language (Ogie and Perez 2020).

4. *Translation in response to humanitarian and disaster relief is often constrained by accuracy and time pressures.* During the emergency response phase there is an urgency, which creates tension between speed and accuracy of translation (Hester, Shaw and Biewald 2010). The urgent nature of disaster response means that it may not be feasible to improve accuracy by relying on multiple judgements from several volunteers. Nevertheless, some messages warrant review by more than one human judge (Hester, Shaw and Biewald 2010).
5. *The time to complete the translation of disaster-related messages varies.* In relation to the emergency response following the earthquake in Haiti, Hester, Shaw and Biewald (2010, p.3) stated that “the average response time to filter, translate, map/geocode and categorize a message did not exceed two minutes”. However, a different account of the emergency response in Haiti has reported that “the average turn-around from a message arriving in Kreyol to it being translated, categorized, geolocated and streamed back to the responders was 10 minutes” (Munro 2010, p.1). In a later publication, Munro (2013) reported the median turnaround time to be less than 5 minutes. Given this discrepancy, it is safe to say that the average time to translate emergency messages could vary, depending on the efficiency and speed of the translators. The exact average time could be clarified through future research. However, the present focus is on the immediate response stage only and translation has a role to play in all other parts of a disaster cycle (Alexander and Pescaroli 2020; O’Brien and Federici 2020).

### 3.4. Relevance of research findings

This research has synthesised evidence from literature indicating that collaborative translation holds a huge potential for minimising crisis communication issues associated with language differences in multicultural communities. Volunteer translators often possess the multilingual skills and the humanitarian spirit to help in translating crisis information. The information translated by these volunteers have been found to be more meaningful and understandable to members of CALD communities as compared to the corresponding versions of the same information conveyed in the formal language (Ogie and Perez, 2020). However, some issues (e.g., incentive mechanism, quality of translation, time pressure etc.) have been identified that could potentially threaten the success and sustainability of collaborative translation in crisis situations. This is where agent-based modelling can be helpful to simulate various scenarios of these issues in order to understand the response or behaviour of the system, including the overall impacts in the short and long terms. Importantly, this study has provided some evidence in the form of a list of observations to be considered in supporting future modelling of agents’ attributes, behaviours, and interactions of actors, including the environmental and operational factors that characterise the collaborative translation of crisis information. This is a significant contribution given the lack of research focusing on collaborative translation of crisis information. The remainder of this section would discuss the implications of these findings for agent-based modelling of collaborative translation, including some theoretical perspectives.

### 3.5 Implications for agent-based modelling of collaborative translation

A suitably designed agent-based model (ABM) can potentially reveal valuable information about the dynamics of collaborative translation, including any emergent complex behaviour patterns (Bonabeau, 2002). The findings conveyed in this paper could form the basis of developing an ABM to ensure that the right amount of detail is incorporated to suit the purpose of the model. In the ABM design, agents could be treated as autonomous and heterogenous entities, meaning that they are capable of making decisions based on the rules and parameters of the environment, and are characterised by diversity in terms of their behaviours, intercultural communicative competence, multilingual skills, spatial boundaries, motivations,

and other demographic characteristics. An agent can either be an individual (e.g., volunteer translator, professional translator, etc.) or an organisation comprising of individuals (e.g., emergency agency, community organisation, professional associations of translators, etc). In determining the rules of the ABM, the attributes, behaviours, and interaction of actors should be considered along with the environmental and operational factors that characterise the collaborative translation of crisis information (see Section 3). The established rules will govern what agents can and cannot do, not to say that agents cannot adapt their rules and behaviours based on experience and information gathered from their interactions.

As agents interact with one another within the environmental and operational constraints specified in Section 3, this could have either positive or negative impacts on both the process and outcome of collaborative translation. A negative impact, for example, could be an increase in the average turnaround time to translate emergency messages. This could be associated with a gradual decline in participants' motivation to contribute to the process of collaborative translation. A positive impact could be an increase in the quality of translated messages, in terms of accuracy, as well as an increase in speed of production. Given the subjective choices and complex psychology that characterise human interactions (Crooks and Heppenstall, 2012), agents can be expected to exhibit both rational and irrational behaviours, which could either be beneficial or detrimental to the collaborative process. Agents may, in fact, evolve in response to changes in the participatory environment as they strive to attain personal or collective goals, potentially resulting in the emergence of unanticipated behaviours. An ABM for collaborative translation of crisis information should therefore incorporate opportunities for learning and adaptation, including through the integration of other sophisticated techniques such as neural networks and evolutionary algorithms. An ABM model could also be applied and designed to solve a translation problem that helps creating resources deployable in the response and recovery phases of a crisis: using crowds to compile bilingual or monolingual corpora to support crisis messaging efforts.

The findings of this research provide opportunity for the development of ABM to help understand a wide range of issues associated with collaborative translation in crisis situations. These issues would most likely pertain to the quality of both the process and outcomes of collaborative translation (Bergner et al. 2016). For example, how can we determine the conditions under which collaborative translation of crisis information is most effective? How sensitive are the outcomes to different rules or initial conditions? Another specific issue relates to incentive mechanisms. It is often advised to avoid financial incentives when collaborative translation contributes to a humanitarian or social cause (Flanagan 2016, p. 151). As O'Brien and Schäler (2010) noted, online collaborative translation communities control what they give and make choices based on their belief in the 'cause'. Agreeably, it is typical to see increased interest from individuals wanting to contribute voluntarily to support emergency agencies in meeting the needs of affected communities during emergency conditions such as the response or recovery phases of earthquake or flood disasters (Yang et al. 2019). However, in the normal day-to-day duties of emergency agencies to improve disaster preparedness (e.g., the translation of messages for creating disaster awareness resources for CALD communities), the people's motivation to provide free translation is nowhere comparable to the high level of voluntary participation received from the global pool of volunteers during the response and recovery phases of disasters. Hence, to guarantee improved participation in all phases of disasters (not just response and recovery phases), it is important to have an in-depth investigation into the roles of incentive mechanisms in enhancing collaborative translation of crisis information (Yang et al. 2019). This is where ABM can be relevant to investigate this issue. For example, how does the provision of rewards to participants affect the quality and rate of participation and how does that change with the types of incentive including financial (e.g., money), social (e.g., public recognition, translator leader board), and material (e.g., gift tokens) compensation? Importantly, how sensitive are these reward policies to changes in other parameters of the model, and how does that impact on the overall performance and sustainability of the system? These are just some of the myriads of questions that the ABM can allow researchers to investigate.

### 3.6 Some key challenges in agent-based modelling of collaborative translation

It is important to acknowledge some limitations that the modeller might face in developing an ABM for the purpose of collaborative translation. A robust ABM needs to account for complexity in language use and how that might affect how we model translation done mainly by non-professionals. What level of abstraction is permissible in this process without making the model less realistic or useful? We provide a brief overview of some of the distinctive complexities that may need to be considered but acknowledge that this is not a complete list: communication type, time pressure, source language complexity, modality, and technology use.

First the ABM system would probably need to be able to differentiate between different kinds of communication types, where a risk factor is associated with the communication. When the risk factor is high, a poor or inaccurate translation might result in a negative outcome for the recipient, or even loss of life. As an example, a message to stay indoors or leave the building during an earthquake, if incorrectly translated could have devastating outcomes. The system would need to be able to categorise content so that high risk content might only be translated with the assistance of a professional translator. A trustworthy ABM may also need to differentiate messaging needs over time in relation to the disaster cycle, as translation cannot happen only in the early phases of the response. For example, the COVID-19 experience of a prolonged crisis requiring translation shows that translated messages, including crowdsourced and outsourced collaborative translation, lost credibility when translations did not update in real time alongside the changes and updates to mitigating measures provided in the main language. Looking at behaviour changing, attitudes, and interactions in crowdsourcing projects simulating the involvement of professional translators as mentors, and reward systems based on scoring mentors and mentees, could prove to be a novel approach to differentiate which rewarding approach may replace financial rewards in the absence of a budget.

The ABM would need to also consider the urgency of the message. Some content may need to be published immediately, while other content could wait for 24 hours or longer. As noted already, it is possible for collaborative translation, even with non-professional translators, to result in a better translation quality. However, if urgency is high and there is no time for discussion and negotiation of meaning, then the system might decide to have only one 'agent' involved. At the same time, the risk factor would need to be assessed and counterbalanced against urgency.

To some extent, this points to an ABM system being more appropriate for translation of preparedness content. Yet, as already mentioned, the level of motivation to translate urgent content in response to a crisis will most likely be higher. Thus, ways of effectively communicating the contribution of agents to preparedness content would need to be considered.

Crisis communication should be accessible, in all senses of the term. In particular, the source language (from which the translation is generated) should be clear and unambiguous. However, when content is created rapidly, in response to an urgent situation, and when information needs to be updated at a rapid rate, the likelihood of ambiguity, or lack of clarity, is very high. Ambiguity can cause problems for translation under normal circumstances and is even more problematic in a crisis response cycle. As the global COVID-19 pandemic has demonstrated, crises can also give rise to neologisms, which are difficult to understand. One example is the concept of 'social distancing' – an inaccurate way of communicating the concept of keeping *physical* distance during the pandemic – which was 'borrowed' from English into many other languages, but which made little sense to so many non-English language communities. A final point about accessibility is the role of specialised terminology in certain types of crises. For example, the pandemic required knowledge of virology terms such as the 'reproduction rate' and, in the 2011 Great East Japan Earthquake, the communication eventually also required knowledge of nuclear radiation. Non-professional translators may

not have access to such specialised terminologies and so the ABM might need to be able to identify subject matter 'experts' if required (e.g., an Arabic and English-speaking nuclear scientist).

It was mentioned previously that literacy levels may be low in communities that are targeted with (translated) crisis messages. In this context, written messages may need to be translated and recorded as spoken messages, in dialects and accents that are appropriate to the targeted communities. Furthermore, the deaf community may need renditions in the appropriate sign language. The ABM system should also be able to identify when voice recordings or sign language renditions are required.

As a last addition to this list of complex aspects, machine translation systems such as Google Translate can assist, especially with speed of production, but also to help those who are not trained as professional translators. The decision to include MT, or not, in a crisis translation solution would depend on multiple factors such as the language pairs that are involved (MT is better for some and worse for others) and whether the agents had any specific training in MT literacy and editing of MT output (for further discussion on these topics see O'Brien 2019 and Bowker and Buitrago 2019).

## 4. Discussion: Theoretical perspectives

It is necessary to reflect on two theoretical perspectives that best inform how to design ABMs that are robust enough to enable assessment, monitoring, and evaluation of successful crowdsourcing efforts, while remaining streamlined and effective. Capturing the interactions, agent behaviours, outcomes, rules, a myriad of other factors would be easy to do with a sophisticated ABM, but the issue will be whether such complexity would hinder its value at implementation level. It might be worth considering two ABM approaches. On the one hand, an ABM could test the complex and detailed crowdsourcing efforts with a view of identifying weaknesses in the workflows and target those with specific interventions. On the other hand, an ABM could focus on interactions, actors, and attitudes to generate the blueprints for crowdsourcing translation systems involving all possible stakeholders that can be integrated in disaster management processes.

Two theories ground our belief that systematic applications of ABM are needed not only to study translation crowdsourcing phenomena in crises per se, but to view them as a resource. By this, we mean a resource to guide future crowdsourcing efforts towards harnessing competences, volunteerism, and activist practices in effective and efficient ways.

### 4.1 Socio-technical systems theory

There has been a growing interest to improve the theoretical understanding of crowdsourcing systems that are designed to harness the power of social networks in mediating crisis communication and supporting online communities to perform collaborative work such as the translation of disaster-related information. One of such theoretical standpoints views these collaborative systems as socio-technical systems (Ogie et al. 2019; Perez et al. 2015). The socio-technical systems (STS) theory postulates that all work systems comprise of interdependent technical and social subsystems, which must be jointly optimised to maximise the system performance (Pedram et al. 2021). These social and technical subsystems often operate under the influence of environmental forces. Hence, STS literacy requires an appreciation of the social, technical, and environmental factors. In other words, the overall behaviour of STS derives from the interactions between the social, technical, and environmental components, rather than their individual properties (Saurin and Patriarca 2020).

The rationale for considering this theoretical perspective lies in the findings in the systematic review from the reports and data concerning large-scale crowdsourcing efforts. The 2010 Haiti messaging efforts were an efficient form of crowdsourcing because they combined geolocation data in language combinations not

available on the field. The 2020 COVID-19 crowdsourcing in China showed the risk of excluding social needs from crisis communication strategies (the use of Korean, Arabic, and other languages among large non-Chinese speaking communities). An STS perspective would enable to distinguish which systems should be created as part of regular expectations of crisis and emergency risk communication practices (translation as risk reduction) from workable crowdsourcing workflows that deal with entirely unexpected language combinations (translation as mitigation).

A rational modelling of STS such as a system for the collaborative translation of emergency messages would therefore require a holistic approach that considers the interactions and dependencies between all three dimensions - the social, technical, and environmental factors. The social factors relate to language and communication, human behaviour, regulation, organisational policies, culture, and politics (Wu et al. 2015). The technical factors relate to hardware (e.g., mobile devices), software (e.g., ease of use of software application, usefulness of software application, graphical user interfaces), internet data for users, security infrastructure, and electrical power to recharge mobile devices (Wu et al. 2015). Environmental factors relate to the absence or otherwise of major ecological disturbances such as fires, heat waves, flooding, storms, etc (Wu et al. 2015). These factors are only suggestive as it may not always be possible to capture all the fine-grained elements in a single model without running into issues with model complication and the lack of real-world data to validate the results (Dugdale 2013). The modeller must therefore aim to find the right balance between the levels of abstraction in what is included in the model and the plausibility of reality attained as generalisable for the social phenomenon (collaborative translation) under investigation (Dugdale 2013; Saurin and Patriarca 2020).

The modelling of the interactions between the included factors can be explored in a what-if analysis to understand the overall performance of the system, including any emergent behaviour (Wu et al. 2015). Emergent behaviour is any system behaviour or characteristics that is not expected or explicitly intended (De Bruijn and Herder 2009). Emergent behaviour is possible in STS because the overall behaviour of the system is not a function of the sum of the performance of all its subsystems (Walker et al. 2008). In other words, STS do not maintain linear relationships as changes in one subsystem do not necessarily cause a proportionate reaction in another subsystem (De Bruijn and Herder 2009). The modeller is therefore tasked with investigating the possible system performance or behaviours that might emerge unexpectedly from simple individual interactions in the collaborative translation of emergency messages, including relationships that tend to foster or hinder the emergence of cooperation and collective actions.

The realistic nature of any STS model can be further improved by using human agents that are aware of the context of their interactions. Context is the background information that is vital for human beings to make informed decisions. The contextual awareness of human agents can influence how they reason, interact, and behave. For example, a human agent may change its course of action once it becomes aware of the actions of other agents or some changes to the prevailing social, technical, or environmental factors. Hence, a more realistic model can benefit from developing contextually aware artificial agents as proposed by Dugdale (2013), including a framework to assess the degree of contextual information required for informed decision making by such agents.

#### *4.2 Structuration theory*

Giddens's structuration theory is one of the several theories of social processes that provide a lens to understand how best to model an ABM for collaborative translation of crisis information. The structuration theory enables us to conceptualise the ABM system for collaborative translation as comprising human agents with relevant behaviours such that these agents interact to realise their intentions or accomplish their goals through rules and resources (Islami et al. 2017). According to Giddens (1984; 1991), rules are important for the legitimation of agent's actions. Rules define acceptable procedures and govern the conduct of agents. Rules would often exist as stocks of knowledge in the agent's memory to guide their actions and interactions within the system. Resources, on the other hand, relate to means of exercising power to accomplish goals. Resources can be said to be 'authoritative' if they allow agents to control other agents. An example of authoritative resource is the power that the system admin possesses to block a user



or volunteer translator who is found to have repeatedly abuse the use of the online platform for collaborative translation of crisis information. At another level, authoritative resource could also be the power of a volunteer to indirectly influence the reputation of another volunteer translator by providing positive or negative rating for the quality of translation work done by that volunteer translator. Resources can be said to be 'allocative' if they allow agents to control material objects. An example of allocative resource is the power of a volunteer translator to delay or refuse the completion of translation tasks. Giddens (1984; 1991) used the term, *structure*, to describe all of these rules and resources, whereas the interface at which an agent meets a structure, he described as *structuration*.

Structuration theory therefore aids planning and preparedness when it comes to reassessing crowdsourcing benefits in the overall communicative practices. Given language diversity, cultural implications, and issues with human and technical resources, this approach is particularly important focusing on translation as a risk reduction tool. In fact, the success of deploying translated texts in response to a disaster depends on having speakers of the languages being able to translate into that language and having access to resources to evaluate the quality of the translation. The development of relationships and resources to support relationships among agents is key. Through the analysis of past relationships that resulted in weak and inefficient interactions (Mulder et al. 2016), structuration represents the theoretical angle that enables to assess the limitation of translation crowdsourcing in relation to digital inequalities (e.g., the exclusion of actors due to temporary or consistent lack of broadband access). As a result, the agent participating are not necessarily representatives of their communities as a whole.

Structure exhibits a property known as the *duality of structure*. The duality of structure stipulates that structure is both a medium for shaping the actions of agents and an outcome of reproducing those actions (Chang, 2014). In other words, agent's autonomy is constrained by structures, in that agents draw upon structures to perform social actions but then structures themselves are preserved or modified through the actions of agents. The actions of agents can reproduce structure through memory traces wherein the actors in the system maintain awareness of the nature of behaviours and patterns that have been acceptably undertaken under the structure and can therefore draw on those to embark on future actions that respect the structure. However, if for some reasons, certain agents believe the structure is a hinderance to achieving their goals, the agents can choose to embark on a major intervention that would influence behavioural change or lead to modification of the structure. For example, agents could choose to be more assertive in calling for a change to the rules using the (authoritative or allocative) resources in their disposal. This means that as agents in the system act and interact, they are invariably shaping the working arrangement of the system (Islami et al. 2017). In the context of designing an ABM for collaborative translation, it is therefore important to incorporate opportunities for learning and adaptation of structure (rules and resources) based on the action of agents. This way, structure will continuously be produced and reproduced by the individual actions of agents.

## 5. Conclusion

This study has reported the results of a systematic review of current literature focusing on translation crowdsourcing in multilingual crisis settings. The article addressed three research areas. Firstly, it considered features that characterise collaborative translation in relation to the attitudes of agents involved. The behaviours of the agents are also highlighted in relation to collaborative translation in general and specifically for humanitarian or disaster relief. Secondly, the paper scrutinised the existing literature concerning the interaction of agents who participate in collaborative translation. Thirdly, it highlighted the environmental and operational factors that characterise collaborative translation projects in general and specifically for humanitarian or disaster relief. The paper then discussed the complexities of agent-based modelling (ABM) for collaborative translation. Finally, theoretical perspectives on collaborative translation are put forward through the lens of socio-technical systems theory and the structuration theory. All these aspects of agents' attributes, behaviours, interaction, and environmental factors are presented as relevant and useful list of observations to inform appropriate design and modelling of collaborative translation in

crisis settings. The systematic review indicates a maturity and necessity for adopting an ABM approach to study collaborative translation of crisis communication.

Whether directed to enhance translation as a risk reduction tool or to assess applicability of protocols to the response phase in the disaster lifecycle, an ABM approach would provide a simulated environment to monitor the effectiveness of the interactions, behaviours, attributes, skills, and workflows that underpin the translation of crisis communication. From this perspective, exploring the viability of translation crowdsourcing through an ABM promises improved chance of succeeding in future translation crowdsourcing initiatives aimed at supporting multilingual crisis communication. Modelling could help to determine trigger factors for disaster managers to consider which conditions do and which do not warrant the additional logistical challenges created by crowdsourcing language skills. Even though we do not envisage ABM as a real-time operational tool, it will support decision making at operational level. Our expectations are that we would gain novel insights on collaborative translation done through crowdsourcing. These must be based on improved understanding of what does (not) work, which stakeholders need to be involved more, which workflows need to be preserved, improved, or replaced. Furthermore, we believe an ABM approach will get us closer to answer why and under what circumstances translation crowdsourcing has proven crucial, rather than a marginal improvement to the complexity of circulating and obtaining information in real-time.

One limitation of this study is the focus on only articles published in English. We acknowledge that the effects of English as the scientific lingua franca may be excluding original contributions in other languages, especially in Japanese and Chinese that have used crowdsourcing solutions respectively in the 2011 Tōhoku earthquake and tsunami, the Great East Japan Earthquake, and in 2020 COVID-19 initial response. Future research could further extend this work through the inclusion of non-English publications in the systematic review process.

## References

- Atabekova, A. and Gorbatenko, R., 2017. Multilingual community and translation: Focus on information processing to enhance quality. *International Information Institute (Tokyo). Information*, 20(7A), pp.4677-4691.
- Axelrod, R., 1997. *The complexity of cooperation: Agent-based models of competition and collaboration* (Vol. 3). Princeton university press.
- Alexander, D. E. and Pescaroli, G. 2020. The role of translators and interpreters in cascading crises and disasters. *Disaster Prevention and Management: An International Journal*, 29(2), pp. 144-156. <https://doi.org/10.1108/DPM-12-2018-038>.
- Beauvais, C. and Ryland, C., 2021. 'We actually created a good mood!': metalinguistic and literary engagement through collaborative translation in the secondary classroom. *Language, Culture and Curriculum*, 34(3), pp.288-306.
- Bergner, Y., Andrews, J.J., Zhu, M. and Gonzales, J.E., 2016. Agent-Based Modeling of Collaborative Problem Solving. *ETS Research Report Series*, 2016(2), pp.1-14.
- Bonabeau, E., 2002. Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the national academy of sciences*, 99(suppl 3), pp.7280-7287.
- Bowker, L. and Ciro, J.B., 2019. *Machine Translation and Global Research: Towards Improved Machine Translation Literacy in the Scholarly Community*. Bingley, Emerald Publishing.
- Cadwell, P., O'Brien, S. and DeLuca, E., 2019, More than tweets: A critical reflection on developing and testing crisis machine translation technology. *Translation Spaces*, 8 (2), pp. 300-333.



- Cano, J. and Ruiz, N.T., 2020. "Wait! I don't get it! Can we translate?": Explicit collaborative translation to support emergent bilinguals' reading comprehension in the intermediate grades. *Bilingual Research Journal*, 43(2), pp.157-177.
- Cerezo, L., 2017. Always together or alone first? Effects of type of collaborative translation on Spanish L2 development. *Journal of Spanish Language Teaching*, 4(2), pp.152-167.
- Chang, C.L.H., 2014. The interaction of political behaviors in information systems implementation processes—Structuration Theory. *Computers in Human Behavior*, 33, pp.79-91.
- Clarke, K.C., 2014. Cellular automata and agent-based models. *Handbook of regional science*, pp.1217-1233.
- Crooks, A.T. and Heppenstall, A.J., 2012. Introduction to agent-based modelling. In *Agent-based models of geographical systems* (pp. 85-105). Springer, Dordrecht.
- David, S.S. and Cole, M.W., 2021. Jostling Isaac: dynamic configurations of bodies and objects during a language problem solving event. *Classroom Discourse*, 12(1-2), pp.101-120.
- De Bruijn, H. and Herder, P.M., 2009. System and actor perspectives on sociotechnical systems. *IEEE Transactions on systems, man, and cybernetics-part A: Systems and Humans*, 39(5), pp.981-992.
- De Wille, T., Exton, C. and Schäler, R., 2015, September. Before Knowledge Management: Quality Expectations in Volunteer Translation. In *European Conference on Knowledge Management* (p. 920). Academic Conferences International Limited.
- Ding, N., Yang, Z., Li, S. and Zhang, A., 2021. Where translation impacts: The non-professional community on Chinese online social media—A descriptive case study on the user-generated translation activity of Bilibili content creators. *Global Media and China*, p.20594364211000645.
- Dolmaya, J.M., 2012. Analyzing the crowdsourcing model and its impact on public perceptions of translation. *The Translator*, 18(2), pp.167-191.
- Dugdale, J., 2013. *Human behaviour modelling in complex socio-technical systems: an agent based approach* (Doctoral dissertation, Université Joseph-Fourier-Grenoble I).
- Federici, F.M. and Cadwell, P., 2018. Training citizen translators: Design and delivery of bespoke training on the fundamentals of translation for New Zealand Red Cross. *Translation Spaces*, 7(1), pp.20-43.
- Flanagan, M., 2016. Cause for concern? Attitudes towards translation crowdsourcing in professional translators' blogs. *The Journal of Specialised Translation*, 25(1), pp.149-173.
- García, L.D.M., 2020. Researching the motivation of Spanish to Chinese fansubbers: A case study on collaborative translation in China. *Translation, Cognition and Behavior*, 3(2), pp.165-187.
- Giddens, A., 1984. *The constitution of society: Outline of the theory of structuration*. Univ of California Press.
- Giddens, A., 1991. Structuration theory. *Past, Present and Future*. In: Bryant, C. and Jary, D.(eds.). *Giddens' Theory of Structuration. A Critical Appreciation*. London: Routledge, pp.55-66.
- Gigliotti, G., 2017. The Quality of Mercy: A corpus-based analysis of the quality of volunteer translations for non-profit organizations (NPOs). *New Voices in Translation Studies*, (17).
- Guazzini, A., Vilone, D., Donati, C., Nardi, A. and Levnajić, Z., 2015. Modeling crowdsourcing as collective problem solving. *Scientific reports*, 5(1), pp.1-11.
- Hester, V., Shaw, A. and Biewald, L., 2010, December. Scalable crisis relief: Crowdsourced SMS translation and categorization with Mission 4636. In *Proceedings of the first ACM symposium on computing for development* (pp. 1-7).
- Hirvonen, M.I. and Tiittula, L.M., 2018. How are translations created? Using multimodal conversation analysis to study a team translation process. *Linguistica Antverpiensia, New Series: Themes in Translation Studies*.

- Hunt, M., O'Brien, S., O'Mathúna, D. and Cadwell, P., 2020, Ethics at the Intersection of Crisis Translation and Humanitarian Innovation. *Journal of Humanitarian Affairs*, 1 (3), pp.23-32.
- Islami, I., Sadoddin, A., Barani, H., Asgharpourmasouleh, A. and Akhbari, M., 2017. Modeling socio-ecological structure of local communities participation for managing livestock drinking water using the agent-based approach. *Applied Ecology and Environmental Research*, 15(3), pp.1173-1192.
- Jeong, B.K. and Khouja, M., 2013. Analysis of the effectiveness of preventive and deterrent piracy control strategies: Agent-based modeling approach. *Computers in Human Behavior*, 29(6), pp.2744-2755.
- Jiménez-Crespo, M.A., 2017. Translation Crowdsourcing: Research Trends and Perspectives, in Anthony Cordingley and Céline Frigau Manning (Eds) *Collaborative Translation: From the Renaissance to the Digital Age*, Bloomsbury Advances in Translation Studies, London: Bloomsbury, pp. 192-211
- Khaefi, M.R., Idzalika, R., Amin, I., Pramestri, Z., Jutta, P., Riyadi, Y., Hodge, G. and Lee, J.G., 2018, August. Estimating the quality of crowdsourced translations based on the characteristics of source and target words and participants. In *2018 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM)* (pp. 151-158). IEEE.
- Khosravani, Y. and Dastjerdi, H.V., 2013. Back translation vs. collaborative translation: A comparative study of Persian subtitles in English movies. *Lebende Sprachen*, 58(2), pp.366-378.
- Macal, C. and North, M., 2014, December. Introductory tutorial: Agent-based modeling and simulation. In *Proceedings of the Winter Simulation Conference 2014* (pp. 6-20). IEEE.
- Magueresse, A., Carles, V. and Heetderks, E., 2020. Low-resource Languages: A Review of Past Work and Future Challenges. *arXiv preprint arXiv:2006.07264*.
- Marin-Lacarta, M. and Vargas-Urpí, M., 2020. Translators as publishers: exploring the motivations for non-profit literary translation in a digital initiative. *Meta: journal des traducteurs/Meta: Translators' Journal*, 65(2), pp.459-478.
- Morschheuser, B., Hamari, J., Koivisto, J. and Maedche, A., 2017. Gamified crowdsourcing: Conceptualization, literature review, and future agenda. *International Journal of Human-Computer Studies*, 106, pp.26-43.
- Munro, R., 2010, October. Crowdsourced translation for emergency response in Haiti: the global collaboration of local knowledge. In *AMTA Workshop on Collaborative Crowdsourcing for Translation* (Vol. 77).
- Munro, R., 2013. Crowdsourcing and the crisis-affected community. *Information retrieval*, 16(2), pp.210-266.
- Mulder, F., Ferguson, J., Groenewegen, P., Boersma, K., and Wolbers, J. 2016. Questioning Big Data: Crowdsourcing crisis data towards an inclusive humanitarian response. *Big Data and Society*, 3(2), pp. 1-13.
- O'Brien, S., 2011. Collaborative translation. In *Routledge Handbook of Translation Studies*. Edited by C. Millán, and F. Bartrina, 17–20. London: Routledge.
- O'Brien, S. and Cadwell, P., 2017. Translation facilitates comprehension of health-related crisis information: Kenya as an example. *Journal of Specialised Translation*, (28), pp.23-51.
- O'Brien, S. and Schäler, R., 2010. Next Generation Localisation: Users are taking charge. *Translating and the Computer Conference*, 32, 17-18 November, London, UK. Available at: <http://doras.dcu.ie/16695/>
- O'Brien, S., 2019. Translation Technology and Disaster Management. In: Minako O'Hagan (eds). *Routledge Handbook of Translation and Technology* (pp. 304-318). London: Routledge.
- O'Brien, S. and Federici, F. M. 2020. Crisis Translation: Considering Language Needs in Multilingual Disaster Settings. *Disaster Prevention and Management*, 29(2), pp. 129-143. <https://doi.org/10.1108/DPM-11-2018-0373>.
- O'Hagan, M., 2011. Community Translation: Translation as a social activity and its possible consequences in the advent of Web 2.0 and beyond. *Linguistica Antverpiensia*, 10(2011), pp.11-23.

- O'Hagan, M., 2017. Deconstructing translation crowdsourcing with the case of a Facebook initiative: a translation network of engineered autonomy and trust? In: Dorothy Kenny (ed.). *Human Issues in Translation Technology* (pp. 43-62). London: Routledge.
- Ogie, R.I. and Perez, P., 2020. Collaborative translation of emergency messages (Co-TEM): An Australian case study. *International journal of disaster risk reduction*, 50, p.101920.
- Ogie, R.I., Clarke, R.J., Forehead, H. and Perez, P., 2019. Crowdsourced social media data for disaster management: Lessons from the PetaJakarta. org project. *Computers, Environment and Urban Systems*, 73, pp.108-117.
- Olohan, M., 2014. Why do you translate? Motivation to volunteer and TED translation. *Translation Studies*, 7(1), pp.17-33.
- O'Mathúna, D.P., Escartín, C.P., Roche, P. and Marlowe, J., 2020. Engaging citizen translators in disasters: Virtue ethics in response to ethical challenges. *Translation and Interpreting Studies. The Journal of the American Translation and Interpreting Studies Association*, 15(1), pp.57-79.
- Paradowska, U., 2021. Benefits and Challenges of an Intra-University Authentic Collaborative Translation Project. *New Voices in Translation Studies* 24 (2021), pp.23–45.
- Pedram, S., Ogie, R., Palmisano, S., Farrelly, M. and Perez, P., 2021. Cost–benefit analysis of virtual reality-based training for emergency rescue workers: a socio-technical systems approach. *Virtual Reality*, pp.1-16. <https://doi.org/10.1007/s10055-021-00514-5>
- Perez, P., du Chemin, T.H., Turpin, E. and Clarke, R., 2015, September. Citizen-driven flood mapping in Jakarta: a self-organising socio-technical system. September (Ed.), In Self-Adaptive and Self-Organizing Systems Workshops (SASOW), 2015 IEEE International Conference. pp. 174-178
- Persaud, A. and O'Brien, S., 2019. Quality and acceptance of crowdsourced translation of web content. In *Crowdsourcing: Concepts, Methodologies, Tools, and Applications* (pp. 881-897). IGI Global.
- Puzio, K., Keyes, C.S., Cole, M.W. and Jiménez, R.T., 2013. Language differentiation: Collaborative translation to support bilingual reading. *Bilingual Research Journal*, 36(3), pp.329-349.
- Sanchez Ramos, M.D.M., 2021. Integrating collaborative localization into professional translator training. *Translation and Interpreting*, 13(1), pp.38-50.
- Saurin, T.A. and Patriarca, R., 2020. A taxonomy of interactions in socio-technical systems: A functional perspective. *Applied ergonomics*, 82, p.102980. <https://doi.org/10.1016/j.apergo.2019.102980>
- Shikali, C.S. and Mokhosi, R., 2020. Enhancing African low-resource languages: Swahili data for language modelling. *Data in brief*, 31, p.105951. <https://doi.org/10.1016/j.dib.2020.105951>
- Sutherlin, G., 2013. A voice in the crowd: Broader implications for crowdsourcing translation during crisis. *Journal of information science*, 39(3), pp.397-409.
- van Rooyen, M. and van Doorslaer, L., 2021. News translation as collaboration in multilingual community radio stations in South Africa. *Language and Intercultural Communication*, 21(3), pp.411-425.
- Walker, G.H., Stanton, N.A., Salmon, P.M. and Jenkins, D.P., 2008. A review of sociotechnical systems theory: a classic concept for new command and control paradigms. *Theoretical issues in ergonomics science*, 9(6), pp.479-499.
- Wu, P.P.Y., Fookes, C., Pitchforth, J. and Mengersen, K., 2015. A framework for model integration and holistic modelling of socio-technical systems. *Decision Support Systems*, 71, pp.14-27.
- Yaffe, J., Montgomery, P., Hopewell, S. and Shepard, L.D., 2012. Empty reviews: a description and consideration of Cochrane systematic reviews with no included studies. *PLoS one*, 7(5), p.e36626.
- Yang, J., 2020. Participatory, self-organising, and learning: The patterns and influence of peer communication in online collaborative translation. *Target. International Journal of Translation Studies*, 32(2), pp.327-357.

- Yang, P., Ng, T.L. and Cai, X., 2019. Reward-Based Participant Management for Crowdsourcing Rainfall Monitoring: An Agent-Based Model Simulation. *Water Resources Research*, 55(10), pp.8122-8141.
- Yang, X., Dong, H., Wang, Q., Chen, Y. and Hu, X., 2014. Guided crowd dynamics via modified social force model. *Physica A: Statistical Mechanics and its Applications*, 411, pp.63-73.
- Yang, Y., 2021. Danmaku subtitling: An exploratory study of a new grassroots translation practice on Chinese video-sharing websites. *Translation Studies*, 14(1), pp.1-17.
- Yu, C., 2019. Negotiating identity roles during the process of online collaborative translation: An ethnographic approach. *Translation Studies*, 12(2), pp.231-252.
- Zhang, J. and Wu, Y., 2020. Providing multilingual logistics communication in COVID-19 disaster relief. *Multilingua*, 39(5), pp.517-528.
- Zou, G., Gil, A. and Tharayil, M., 2014, December. An agent-based model for crowdsourcing systems. In *Proceedings of the Winter Simulation Conference 2014* (pp. 407-418). IEEE.

**Declaration of interests**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Journal Pre-proof