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The applicability of the 3C model for understanding the use of technology in emergency management scenarios.

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Abstract:

The nature of emergency is intensive, imposing challenges related to the way co-agencies collaborate. The 3C model consists of the combination of three elements, namely communication, coordination, and cooperation, connecting in a cycle, illustrating the nature of collaborative work for accomplishing certain tasks. Very few studies considered the use of the 3C model for improving collaboration in domains other than emergency management. This paper presents a scoping review of the literature in the domain of emergency management, focusing on how the 3C model can help us understand the use of technology for improving collaboration. The paper identifies the commonalities between the elements of the 3C model for improving our understanding of collaboration in emergency management scenarios, and indicating the inter-relationships among the elements of the 3C model that are applicable for understanding the topology of technology use in emergency management.

JEL Codes: D83, L86, Q54

Keywords: 3C model, communication, coordination, cooperation, collaborative, emergency management

1 INTRODUCTION

Emergency management is considered a top priority in almost every nation when it comes to the safety and security of the people, their properties, and operations in emergency situations. In the context of an emergency, collaboration among co-agencies (either regional or international) can be difficult, depending on the nature of the emergency. Collaborative systems are models and techniques that are used to classify and organise various features where co-agencies engage in using technology in a shared activity to accomplish certain goals (Medeiros et al., 2012). According to (Oh et al., 2014), without effective collaborative systems for an emergency, response services such as the development of plans and the delivery of trainings for ensuring the safety of the people and properties can easily fragment and fail, causing much loss of life and property.

An evaluation of the status of collaboration by the United Nations and Economic and Social Commission for Asia and the Pacific (2016) indicates the need to improve the level of collaboration between national and subnational levels of government for emergency management. This indicates the need to improve collaborations among co-agencies, and also the need to understand how technology is being utilised to support communication, coordination, and cooperation in an emergency. To realise better collaboration, a relationship between communication, coordination, and cooperation must exist, and the combination of these elements as defined by Fuks et al. (2005) is referred to as the "3C model". This is based on a similar model, proposed by Ellis et al. (1991), which has some terminology differences whereby cooperation sometimes referred to as collaboration. The relationship between the elements of the 3C model have proven useful for analysing the developments of collaborative systems particularly.

Due to the diverse range of literature in the domain of emergency management, this study focuses on carrying out a scoping literature review to find out what has been covered about the use of the 3C model. The model has rarely been used in the literature about improving collaboration in the domain of emergency management. Understanding the interdependencies between the elements of the model can help uncover essential relationships between the elements. Even though the literature covered some elements of the 3C model for different purposes, carrying out a scoping literature review in the domain of emergency management will help identify the inter-relationship among the elements of the 3C model that are most useful for understanding the use of technology in emergency management scenarios. The outcome of this research will showcase the potential contribution of the 3C model to improving co-agency collaboration in emergency management.

2 THE 3C MODEL

The elements of the 3C model are built on top of each other as outlined by Ellis et al., (1991). According to Fuks et al. (2008; 2009) and Steinmacher et al. (2010), the model present a collaboration phenomenon that extend using a variety of collaboration forms for the purpose of improving awareness support. The literature focused more about the application of the model in the area of software and groupware development, purposely for understanding the use of Virtual Reality (VR) technologies in remote locations (De Oliveira & Gerosa, 2011; Medeiros et al., 2012; Modi, Abbott, & Counsell, 2013). In particular, Medeiros et al. (2012) used the 3C collaboration model as a methodology to analyse the applicability of the model for defining collaborative tools for helping VR improve the support of collaborative tasks. The evaluation of these tools proved a fluid interaction between participants which support communication, coordination, and cooperation as core elements of the 3C collaboration model. Even though the study's emphasis was more on the context of collaboration, but without one key elements of the 3C model, understanding the interactions between participants is rather difficult.

The application of the 3C collaboration model in Emergency Management has only been researched once in the literature by Martin et al. (2016) and with the inclusion of collaboration as an additional element. This study highlighted a number of issues in regard to disaster response, including the delays in recovery response, inefficient response between the co-agencies, and ineffective solutions in response to various emergencies. These problems occurred because of a lack of collaboration and coordination among co-agencies. Therefore, understanding the application of these elements is crucial to this study.

2.1 ELEMENTS OF THE 3C MODEL

This subsection presents a more contextual overview of the three elements of the model.

2.1.1 Communication

Communication in this context is the key component of the 3C model covering most of the literature in this domain. It can be understood as a general conversation where a message containing information is transmitted between a sender and a receiver. Ghiuță and Prelipcean (2014) defined communication as the process of information transmission between a transmitter to a receiver. However, Helfer and Orsoni (2005) added that communication exceeds simple informing in the context of emergency management, where those who emit the message not only they want to inform the target audience but more on influencing their behaviour. Due to the nature of this scoping review, all these definitions will be used to understand what has been covered in the literature about the use of communication in an emergency scenario.

2.1.2 Coordination

Most of the literature consider coordination as a means for providing awareness support, where members of a group or a team become aware of the work of others who are interdependent with the task being carried out. Malone and Crowston (1994) stated that coordination is the process of managing dependencies among activities. The operational definitions vary depending on the types of agencies involved. Coordination, as presented by the majority of studies in this domain, focuses on disaster or emergency response management and preparedness (Shen and Shaw (2004)., Purohit et al. (2014)). The challenges outlined by these studies indicate that to achieve better coordination, we need to encourage the effective use of communication in an emergency shared environment.

In an emergency, the coordination effort mainly requires people at a different hierarchical level in different organisations. Chen et al. (2008) stressed the importance of effective coordination as an essential ingredient for Emergency Response Management (ERM). Given the uncertainty and rapid decision-making within the temporal and resource constraints of an emergency, proper and effective coordination may become a challenge.

2.1.3 Cooperation

Characterising certain kinds of group work as "cooperative" or "collaborative" has been done mainly in the area of management science community (Oravec, 1996). Cooperative work is considered a less general term than collaborative work. As defined by Sorgaard (1987, p. 3), "to collaborate is to work together or with someone else, and to cooperate is to work or act together for a shared purpose". According to Saab et al. (2008), cooperation in humanitarian ICT usually manifests between organisations as primarily verbal dialogue, which takes place in informal settings and commonly occurs at a field level where an employee from other agencies share resources online, therefore skipping any formal procedures. The results of these studies presented some imperative implications for designing tools for managing communities, and the sharing of information across and within community groups.

2.2 UNDERSTANDING THE INTER-RELATIONSHIP BETWEEN THE 3C ELEMENTS IN A COLLABORATIVE GROUPWORK SETTING

The conceptual framework in *Figure 1* was adopted from Fuks et al. (2005) and extended to reflect the concept of the 3C collaboration model. The figure illustrates the relationship between the three elements in a cycle showing the iterative nature of collaboration. One of the important use of the 3C collaboration model outlined by Steinmacher et al. (2010) is for improving awareness support in Global Software Development (GSD). This study only focuses on analysing the use of the three elements of the model in the domain of emergency management, however, the importance of awareness support is addressed otherwise in our discussions.

Communication in an emergency requires people to negotiate and make critical decisions. The complexity of an emergency varies from the geographically dispersal of affected areas to difficulties in communicating with supporting bodies. However, with the availability of technology such as the internet and social media, co-agencies can exchange and share information among themselves. In the action of communicating to make decisions and negotiations, it also fosters and mediates awareness between co-agencies and anyone involved. A study by Antunes et al. (2010) also indicates the importance of the use of the SHELL[1] model as a conceptual framework for analysing the interaction between human factors in a complex collaborative setting. The study shows that even slight changes in an environment can have a significant impact in a collaborative work setting.

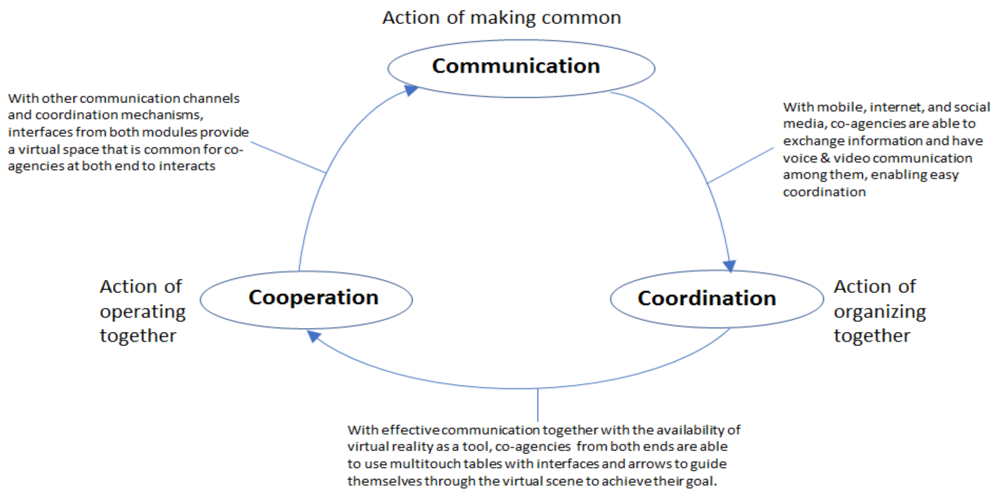

Figure 1: 3C Collaboration model instantiated for co-agencies in an emergency context.

Effectiveness in communication enables smooth and easy coordination among agencies, allowing them to deal with problems that may arise. The geographical dispersal of co-agencies from emergency locations can put pressure onto co-agencies who struggle to operate as a team, and the capability of virtual reality with extensive features, such as multitouch surfaces, helps agencies from distinct locations to guide and organise their activities in a uniform manner without the fear of losing communication and cooperation efforts. Again, with the advancement in technology, such as virtual reality and mobile devices, together offer the capability to deploy a

[1] A Software-Hardware-Environment-Liveware-Liveware (SHELL) model for understanding the interaction between human factors (liveware), computer (software and hardware), and the environment.

common virtual space for co-agencies to interact with each other in real-time. This allows them to work cooperatively to accomplish their goals. In the same manner as outlined by Fuks et al. (2009), co-agencies who are involved in this groupwork collaboration obtain feedback for their decisions and grant actions, and then feedthrough from actions of others, using awareness information as a result of their interactions with each other.

3 EMERGENCY MANAGEMENT

The concept of emergency management dates back to the late 1930s and is based in the context of rebuilding confidence in the national banking system in the US (Preston, 1993). During the late 1960s and 1970s, the Disaster Emergency Relief Act was passed, putting the focus on emergency management. As defined by Arranz and Danalache (2015), emergency management refers to the managerial functions responsible for the creation of a framework that helps reduce vulnerability to hazards and allow communities to cope with disasters. A recent study by Liu et al. (2016) described emergency management as a decision making process intended to mitigate the severity of harm from the destructive, uncertain, and critical nature of a disaster, crisis, or emergency. The methodology prospective of an emergency management technical support problem indicates that without the use of technology advancement, it is easy to make wrong judgments, resulting in dire consequences.

Three stages of an emergency are highlighted in this study including the *pre-event*, *during-event*, and *post-event* stages. These three stages have their corresponding emergency management functions, such as mitigation and preparedness for the *pre-event*, response for the *during-event*, and recovery for the *post-event*. A number of elements involved in each stage of an emergency including planning, communities, technology infrastructure, training and exercises, managing people, health and social services, collaboration, communication, coordination, and cooperation. However, the 3C model covers in this paper focus mainly on communication, coordination, cooperation, and collaboration.

4 RESEARCH METHODOLOGY

This study adopts the scoping literature review method presented by Paré et al. (2015). The method has the ability to clarify working definitions and conceptual boundaries of collaboration, thus, improves the understanding of the use of technology for emergency management. The scoping review method was originated from Arksey and O'Malley (2005) and later enhanced with additional features by Colquhoun et al. (2014) and The Joanna Briggs Institute (2015). Both versions were used interchangeably in this study. Other researchers used terminology such as "scoping study" which refers to the same methodology. A later study by Colquhoun et al. (2014, p. 9) aimed at establishing a consensus on standardising the terminology and definitions and agreed to use both "scoping review" and "scoping studies". The methodology became increasingly popular and influential for research and practice, and its popularity increased rapidly over the years.

Looking at different versions of this methodology, the enhanced version of the original scoping review by Arksey & O'Malley (2005) was found useful in clarifying and enhancing each stage of the framework. Aiming at mapping the key concepts underpinning this research area and identifying the distinct types of sources and evidence extant in this area of study. One of the key strengths of this framework, also highlighted by Davis et al. (2009), is its ability to extract the essence of a vast body of evidence giving meaning and significance to a topic that is developmental and intellectually creative. Both Davis et al. (2009) and Colquhoun et al. (2014) believed that the approach could be used to synthesise what has been covered in different areas of the literature in a study domain. Due to the strengths outlined here, this study will use the enhanced methodology to help synthesise the literature in this domain. The scoping review framework used for this paper offers both the original framework by Arksey and O'Malley (2005) together with enhancement features proposed by Levac et al. (2010).

As noted in *Section 2*, the study domain has not yet been comprehensively reviewed, particularly from the perspective of collaborative work, and the 3C model gives a viewpoint for analysing the literature. Therefore, by using the 3C model, we can emphasise the key elements of the model, allowing the ability to put more stress on the inter-relationships between the elements. Both the elements and the relationships between them will provide an understanding of the collaborative nature of an emergency context. Since the review focuses mainly on the breadth rather than the depth of the literature, it is considered feasible as a strategy for identifying research foci and knowledge gaps for the past 20 years. The method also allows us to achieve clarity about the state of knowledge and evidence that exists on the applicability of the 3C model in the domain of emergency management.

4.1 PAPER SELECTION PROCESS

The ACM Digital Library, Science Direct, and Information System for Crisis Response and Management (ISCRAM) Digital Library were used to search articles published between the year 1998 to 2016 (20-year period). At this early stage of the study, peer-reviewed journals and conference proceeding articles were used. The selection of papers was based on the following keywords, shown in *Table 1* below:

Reference	**Category**	**Keywords**
C1	Emergency Management	[“Emergency”, “Crisis”, “Disaster”] management
C2	3C Model	“Collaboration”, “Collaborative”, “Communication”. “Coordination”, “Cooperation”, “Cooperative”

Table 1: Keyword Search

The keywords in category C1 from *Table 1* were considered because the coverage of the domain of Emergency Management is prominent in the literature and is sometimes referred to as either "emergency management", "crisis management", or "disaster management." To map category C1 with the elements of the 3C Model (C2) with the inclusion of “Collaboration”, each of the keywords from C1 with each one of the keywords in C2 were searched separately. Using the logical connectors “AND” and “OR”, C1 and C2 were combined in our search query strings as shown below:

- (Emergency Management) AND (“Collaboration” OR “Collaborative” OR “Communication” OR “Coordination” OR “Cooperation” OR “Cooperative”)
- (Crisis Management) AND (“Collaboration” OR “Collaborative” OR “Communication” OR “Coordination” OR “Cooperation” OR “Cooperative”)
- (Disaster Management) AND (“Collaboration” OR “Collaborative” OR “Communication” OR “Coordination” OR “Cooperation” OR “Cooperative”)

The paper selection process depicted in *Figure 2* presents the process of extraction, sifting, charting, and sorting the results of the papers. According to Levac et al. (2010), there is still an unclear viewpoint on the nature of data extraction from the included studies, therefore, for this study, a thematic analysis was used to embrace field diversity instead of reducing it. A total of 451 papers were extracted from all database searches attempted. After identifying duplicates, anonymous, and non-English papers, a total of 76 papers were removed. The remaining 375 papers were used in a two-stage reviewing process conducted independently of each other. Given the remaining sample of 375 papers, a first stage screening, which involved the screening of titles and abstracts was used to determine inclusion status, and a total of 273 papers were excluded from the sample. A second stage screening was used to screen the full-text of each paper to ensure that each paper covered the content of the 3C model elements and emergency management. The remaining sample of 102 papers was then used in the second stage of screening, and as a result, a total of 17 papers were identified and excluded. The remaining 85 papers were the final sample size used for analysis.

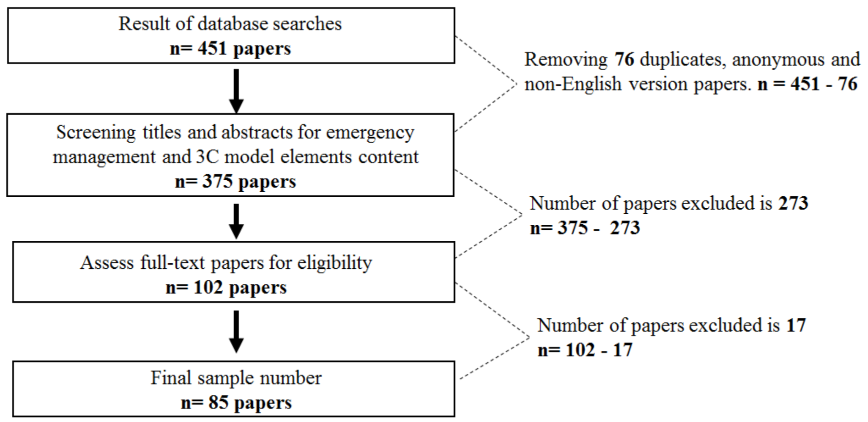

Figure 2: The paper selection process

4.2 SORTING OF KEY STUDY ELEMENTS

The final sample of 85 papers was sorted according to years of publications and the type of publications used. Using the EndNote software, the sample papers were grouped into four periods of five years. The first period consisted of papers found between the years 1997 and 2001 inclusive, the second period covered the years 2002 to 2006, the third from the year 2007 to 2011, and the fourth period from the year 2012 to 2016. In addition, advanced functionalities of the EndNote software were employed to extract all paper details from the selected online databases. The details were used to sort papers according to the types of publications used, including journal articles and conference proceedings papers. In terms of eligibility, a full-text assessment was conducted to determine how each component of the 3C model has been applied in the literature regarding the use of technology for emergency management.

The next step involves the assessing of the full-text for sifting the core elements of the 3C model used in the area of emergency management. The result was sorted according to the three elements of the model (*communication, coordination, and cooperation)* with the inclusion of *collaboration*. Another thorough analysis of the full-text was performed to identify the key concepts covered in each paper, followed by identifications of papers according to their implication in all the three stages of an emergency. Each paper was again assessed to find out the common relationships between the elements of the 3C model. For the final assessment of the full-text, the papers were sorted according to the types of technology used in each study.

5 RESULTS AND FINDINGS

The quantitative results and findings from this study are calculated in percentages rounding to one decimal place. The total number of papers shown in *Table 3* is greater than the sample size because some of the papers used more than one element of the 3C model. Also, a paper can be applicability to more than one emergency stage.

5.1 STUDY PROFILE

Figure 3 shows the distribution of 85 papers of the study sample from the past 20 years. In the first period, 5.9% of papers from the study sample were found using the elements of the 3C model. An increase in the number of studies was evident from the second period, with a total of 15.3% paper coverage, and dominated by conference proceeding papers, as shown in *Table 2*. In the third period, the increase was more than double with 32.9% of paper coverage. Another increase occurred in the last period with a 45.9% of paper coverage. The trendline shows the rate of increase in the number of studies for the past 20 years, which implies the increasing relevancy in the domain of emergency. Not only that emergency management is confined to one particular study area, but the concepts and techniques are applied to multiple study areas such as health, education, disasters, and many more. Therefore, it is predicted that more research will be done on and around the domain of emergency management in the future.

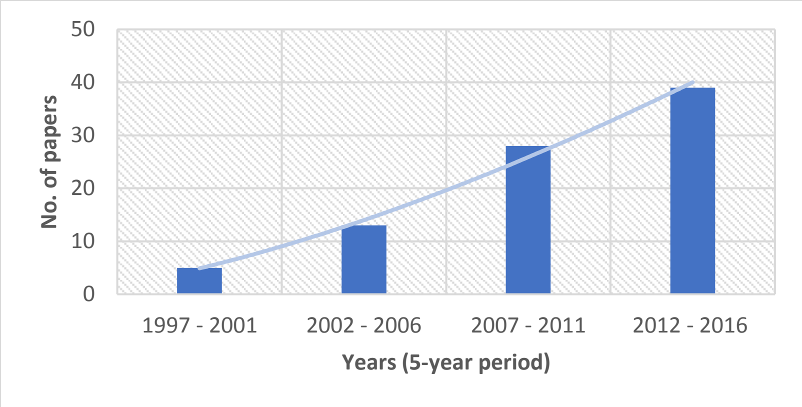

Figure 3: Distribution of sample papers for the past 20 years

Table 2 presents the sample study profile for different items in each category and descriptions. The papers are distributed into two types of publications namely journal articles and conference proceedings. *Table 2* also shows the distribution of papers amongst the elements of the 3C model with the inclusion of collaboration. A total of 39 papers were published in peer-reviewed journals, and the remaining 46 papers were conference proceeding papers. Most of these conference proceeding papers were extracted from the Information Systems for Crisis Response and Management (ISCRAM). The results extracted from ISCRAM online databases are more recent and up to date, reflecting the consistency and increase of research interest in the area of emergency management. From the total sample of 85 papers, more than half are conference proceeding papers covering 54.1%, and the remaining 45.9% are journal articles.

Category	**Descriptions**	**Number of Papers**
Publication	Journal Articles	39
	Conferences papers	46
3C Elements & Collaboration & Awareness	Communication	49
	Coordination	25
	Cooperation	17
	Collaboration	29

Table 2: Sample study profile

Under the category for 3C Elements & Collaboration & Awareness, one paper can be found useful in more than one component. Therefore, the total number of papers under this category exceeded the total sample of 85. The analysis shows that apart from *communication* as the dominant component with a total of 49 papers, *collaboration* represented the second most common paper coverage, with a total of 29 papers followed by *coordination* with a total of 25 papers, and 17 papers for *cooperation*.

Many of the papers under the *coordination* category are papers that require improvements in frameworks, models, approaches, and prototypes used for coordination purposes (de Greef & Oomes, 2008; Edrissi et al., 2013; Purohit et al., 2014). Papers by Abramson et al. (2007), Shen and Shaw (2004), and Yi and Özdamar (2007) highlighted the important relationship between *communication* and *coordination* in a multi-disciplinary concept of emergency response and preparedness. According to Steigenberger (2015), the involvement of a single organisation in disaster response operations is not enough, more than one organisation is needed for rapid response in order to improve facilitation response, leading to effective coordination among the organisations.

Cooperation had the least amount of paper coverage, with a total of 17 papers. Papers under this category include a paper by de Koning et al. (2011) that emphasised on the importance of effective coordination efforts for improving multidisciplinary *cooperation* for emergency management teams. Similarly, Floch et al. (2012) argued that exploring the use of smart technologies such as smart spaces is vital for improving cooperation among co-agencies during emergencies. A study by Sabino and Rodrigues (2011) also highlighted the usefulness of using cooperative workspaces for extracting information about how people cooperate with each other and their relationship to that information. Therefore, with the use of technology such as smart spaces, real life and emergency activities can help define cooperation strategies for improving plans in an emergency.

5.2 THEMATIC ANALYSIS

This section of the paper outlines and discuss the main themes identified from our sample papers.

5.2.1 The 3C Model in all stages of an emergency

The three stages of an emergency, namely *pre-event, during-event, and post-event*, were used to identify papers targeted for each emergency stages. *Figure 4* illustrated how the elements of the model are used in each stage of an emergency, and what elements are common to more than one stage. The result indicate that almost half of the total sample of papers were found important in the *during-event* category, covering a total of 40 papers. Interestingly, 18 out of the 40 papers were from recent conference proceedings, reflecting up-to-date developments in emergency management (Eleftherakis et al., 2015; Hassan & Chen-Burger, 2016; Hughes et al., 2014; Oh et al., 2014; Ooms & Jan van den Heuvel, 2014; Purohit et al., 2014; Vivacqua et al., 2016).

Under the *post-event* category, only 9 papers were covered including some most recent studies by Paul et al. (2016) and Takahashi et al. (2015). Both papers emphasised about the use of technology such as mobile applications containing map interfaces for improving conventional communication channel, and the use of social media such as Twitter for strengthening communication from user perspectives.

In the *pre-event* category, 11 papers were found applicable concerning the use of the 3C model for the purpose of training and preparedness. Most of the papers under the *pre-event* category were published no later than the year 2010, including studies by Andersen et al. (1998); Bertolli et al. (2010); Hoard et al. (2005); Johnson and Calkins (1999); Keselman et al. (2005) and Klappenbach et al. (2004).

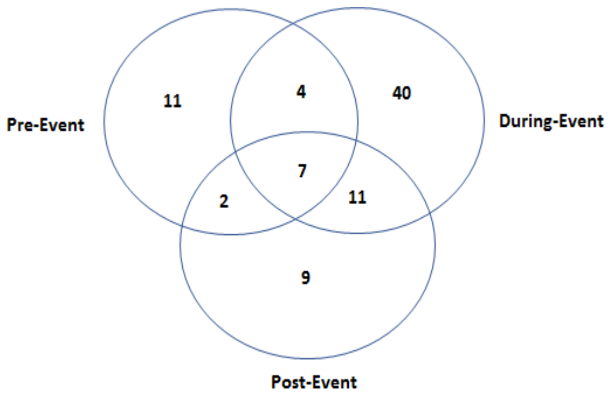

Figure 4: Categorising studies in all stages of emergency

Apart from studies that fell directly into each stage of an emergency, other studies were targeted and useful in more than one stage. Firstly, a total of 7 studies were found common in all stages of an emergency, with studies that used distinct types of technologies for improving awareness support among co-agencies and different communities. Studies like Abramson et al. (2007) focused on enforcing tiered peer-to-peer agent-based systems for supporting coordination, while Trnka et al., (2005) on the other hand highlighted the use of ICT and GIS infrastructure for enhancing emergency management and inter-organisational cooperation in addition to improving communication between them. Other studies like Abramson et al. (2007); Eleftherakis et al. (2015); Shen and Shaw (2004); Törnqvist et al. (2009) and Yao et al. (2010) used computerized systems such as social networks, multi-agent and peer-to-peer systems as communication means for improving coordination in all stages of an emergency.

A total of 11 papers were found for the *during-event* and *post-event* combination, which represented the most papers in comparison to studies that are common to other combinations such as *during-event* and *prevent-even*, and *pre-event* and *post-event*. Included in these 11 papers are studies like Iapichino et al. (2009), Tarchi et al. (2009), and Wiedenhöfer et al. (2011) that utilised the advancement of mobile communications, wireless communications, and CSCW for improving mobility, security, reliability and interoperability during and before an emergency. Studies like Busa et al., (2015), Olteanu et al. (2015), and Temnikova et al. (2015) utilised social networks to help understand the communicating of information in the *during-*

event and *post-event* of an emergency, noting that it would be different in different crises, even though co-agencies have long recognised the importance of clear communication regarding the readability of text documents. Moreover, social media, as argued by Busa et al. (2015), represents a digital space that can be used by co-agencies during a disaster to disseminate accurate and more ethical sourced data. Therefore, sharing this information across will reinforce trust between these co-agencies even at the aftermath of a disaster.

A total of 4 papers were found common for both the *pre-event* and *during-event* categories. These studies used one of the most shared and foundational elements of the 3C model, communication. Communication has been useful in all stages of an emergency, and Cinotti et al. (2010) believed that developing software tools such as QoS Management Architecture (QMA) would help improve communication and also allow co-agencies to cooperate effectively before and during a disaster event. Studies by Epley et al. (2006) and Terpstra and Vreugdenhil (2011) both used early warning and monitoring systems like Flood Warning Communicator (FWC) to help professionals communicate effective flood warning systems with others, and MedCom as a system that combined a communication centre and organised systems to improve patient flow in a trauma centre. As a result, the improvement in the flow of communication between these co-agencies promoted effective cooperation, thus saving a lot of lives. Catarci et al. (2008) also stressed the idea of collaboration in terms of using mobile devices such as PDAs for coordinating tasks among co-agencies from their operational centres to the back-end centre. These portable devices can be used in all stages of an emergency. However, the author argued that these portable devices are most useful in the before and during stages of an emergency.

Interestingly, the results show only a small portion of papers useful in both the *pre-event* and *post-event* stages of an emergency. Out of the two papers found under this combination, the paper by Kapucu (2006) indicated the importance of the use of information technologies (IT) for achieving effective inter-organisational communication and decision-making. The study did not implicate any use of technology, but the theoretical framework drawn from the literature of emergency focused on the use of communication and decision-making in rare cases of uncertainties such as emergencies, indicates that establishing effective frameworks can lead to the use of appropriate communication, resulting in effective interagency coordination during an emergency.

5.2.2 The inter-relationship between the 3C elements

This section of the paper discusses the inter-relationship between the 3C elements. This analysis covers 32 papers in total.

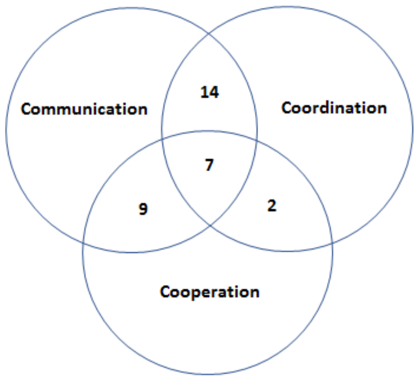

Figure 5: Inter-relationship between the 3C Model elements

5.2.2.1 Communication and Coordination

The combination of these two elements represent the most common papers in comparison to the other two combinations of 3C elements, with a total of 14 papers. In an emergency context, analysis indicated that communication plays a key role in reaching and maintaining excellent coordination among the co-agencies. Studies like those by de la Torre et al. (2012), Hassan and Chen-Burger (2016), Hoard et al. (2005), Meissner et al. (2006), Paul et al. (2016), Takahashi et al. (2015), and Temnikova et al. (2015) indicated the importance of using social media and mobile technologies for improving not only communications but also effective coordination. In reference to the types of technology used, *computerised systems* were found to be common in all the elements of the 3C model, including collaboration. These studies focused on the use of virtual reality, multi-agency stimulators, unified modelling language (UML), and CSCW for improving communication and coordination in an emergency.

5.2.2.2 Coordination and Cooperation

Surprisingly, only two studies were found applicable in this combination. The result is puzzling because commonly in a group work environment, *coordination* arranges tasks for *cooperation* used mainly for supporting computational work (Fuks et al., 2008). Most papers under this combination are papers that did not use any type of technology, and were excluded from the sample. Studies under this group discussed the importance of a situation where people from different organisations at different hierarchical levels must deal with emergencies that require coordination effort. According de Koning et al. (2011), to improve multidisciplinary cooperation in an emergency context, there is a need for developing e-learning tools that can help guide and improve the way agencies coordinate with each other. In addition, a paper by Steigenberger (2015) highlighted the importance of improving *cooperation* in disaster response, where disaster response operations usually exceed the capacities of a single agency or organisation, therefore requiring multi-agency *cooperation*, which in turn needs effective *coordination* among the agencies.

5.2.2.3 Cooperation and Communication

Most of the studies under this group used communication networks and the internet to improve *communication* and *cooperation* in the context of an emergency. For instance, Cheikhrouhou (2016), Cinotti et al. (2010), O'Dell (2008), and C. Ribeiro and Ferworn (2010) employed technologies such as QoS Management Architecture (QMA) for improving *communication* infrastructure, allowing different operators to cooperate better during rescue procedures. The use of various wireless networks for analysing technical aspects among provincial police and response teams was also cited as effective for helping agencies communicate effectively and work cooperatively in their shared space to perform well-defined tasks. Additionally, Klappenbach et al. (2004) and Trnka et al. (2005) specified the usefulness of deploying early warning systems for promoting heterogeneous and flexible *communication* among various actors. The system enables Public Safety Organisation (PSO) *cooperation* by standardising data structure for data exchange. Trnka et al. (2005) also emphasised on the importance of the use of GIS and GSD at the local and regional level for improving organisational *cooperation*. Studies such as Törnqvist et al. (2009) highlight the challenges of collaboration within multi-organisational when trying to quickly form networks for post-disaster response, where they rely more on emerging ICT infrastructures for *communication* and *cooperation*.

5.2.3 The 3C model and technology use in emergency management

Figure 6 represents the distribution of papers addressing the use of all the elements of the model and the use of technology in emergency management. The papers were allocated according to the identified types of technology used in the literature for emergency management, including *mobile communication, social networks, communication networks & internet, Computer Supported Collaborative Work (CSCW), early warning systems, remote sensing & GIS, computerised systems*, and the remaining are labelled as *non-tech* papers. Non-tech papers represent studies that use collaboration frameworks, models, approaches, and prototypes instead of a specific type of technology.

Referring to *Figure 6*, the category of *non-tech* papers has a total of 24 papers from our sample papers of 85. Some of these papers used more than one component of the model, while others used only a specific component in their studies. The most prominent component used under this category is collaboration with a total of 33.3% paper coverage (Arrieta et al., 2008; Ferdinand, O'Brien et al., 2012; Kessler et al., 2012; Ley et al., 2013; Oh et al., 2014; Pipek et al., 2012; Tamura & Cao, 2012; Vivacqua et al., 2016). The second most common, *non-tech papers*, were found under *coordination*, including papers by Ainuddin et al. (2013), de Greef and Oomes (2008), Edrissi et al. (2013), Malešič et al. (2015), Purohit et al. (2014), Saab et al. (2008), Steigenberger (2015), and Su et al. (2016) with a 29.2% of paper coverage. *Communication* represents the third most common category for non-tech papers with 25.0% coverage (Arpan & Pompper, 2003; de la Torre et al., 2012; Fekete, 2012; Kapucu, 2006; Keselman et al., 2005; Kim et al., 2008). *Cooperation* covered the least number of papers with only 12.5% coverage, including studies like Messemaker et al. (2013), Münzberg et al. (2013), and Rencrantz (2012).

The following subsections discuss the use of technology in emergency management scenarios using specific elements of the 3C Model.

5.2.3.1 Communication vs. Technology Used

The distribution of papers as illustrated in *Figure 6* shows that *communication is* represented in all the 8 types of technologies from our sample of 85 studies in comparison to the other four elements. Communication is represented in 46.1% of the total papers. The most dominant technology used from the sample was *communication networks & internet*, covering 28.6%. This category consists of paper discussions about the use of wireless communication, wireless sensing, wireless social networks, and web-based solutions such as Dynamic Team Management (DTM), and Integrated Systems for emergency (Cheikhrouhou, 2016; Iapichino et al., 2009; Park et al., 2005; C. Ribeiro & Ferworn, 2010; Tarchi et al., 2009). Also, the use of the internet and web-based technologies such as IPv6 micro-mobility management presented an advantage for improving mobility, security, reliability and interoperability in domains like emergency management.

The second most common technology used in all the elements of the 3C Model is *social networks*, covering 14.3% of the total 42 papers under this category. The majority of papers under *social networks* are recent studies such as Busa et al. (2015), Hughes et al. (2014), Olteanustillo et al. (2015), Reuter et al. (2013), Takahashi et al. (2015) and Temnikova et al. (2015). These studies addressed the use of social media such as Twitter for the dissemination of second-hand information in coordinating relief efforts. Others believed that by systematically investigating further on different crises like natural hazards and human-induced disasters, social media could provide anecdotal evidence which could allow the identification of several types of crises causing different reactions from Twitter users. Understanding these interactions enable co-agencies to cooperate more efficiently in emergency situations.

Moreover, the third most common technology used was *mobile communication* and *computerised systems* with the same number of paper coverage (11.9% of the total 42 papers) for each communication category. These studies used mobile devices and mobile messaging as tools for improving communication in more than one stages of an emergency. Included under the *mobile communication* category are studies by Krasovec (2004), Kung et al. (2008), and Meissner et al. (2006), who proposed and designed mobile applications, integrated mobile information and other mobile communication systems for emergency response and in healthcare emergencies for reducing referral time for patients. More recent studies by Hassan and Chen-Burger (2016) and Paul et al. (2016) highlighted the key reason behind poor decision making and lack of coordination among the co-agencies involved in an emergency, which is the non-availability of crisis information from the field. Therefore, the development of key mobile applications containing map interfaces and mobile messaging could help these co-agencies to communicate the right information and enable proper coordination among them.

Early warning systems account for 9.5% of the total paper coverage under this category. According to Zacarese (2013), communication between students, faculty, and staff during an emergency requires careful planning and proper dissemination of information. Even though the study did not emphasise the potential of communication as a component, with effective communication, coordinating common tasks among co-agencies could be improved. Other related studies by Terpstra and Vreugdenhil (2011) indicated the idea of developing a software tool such as the Flood Warning Communicator (FWC). The tool, as reported, was a success regarding constructing messages for websites and SMS which provided smooth and effective communication among the co-agencies. As a result, improvement in cooperation with public authorities at the local level was a success. In terms of health emergencies, improvements to the level of communication in Emergency Medical Services (EMS) was a priority during small mass incident areas, especially in most frequent and unmanaged disasters (Johnson & Calkins, 1999).

Under the *computerised systems* category of technology used, a total of 14 papers addressed the use of elements for understanding various *computerised systems*, and 7.1% of paper coverage was found useful for the purpose of *communication*. Included under this category are studies by Hale (1997) and Tufekci and Wallace (1998), which emphasised the role of advanced communication and computing technologies for providing a system view of emergency management at both the pre-event and post-event stages. Moreover, the organisation of a response system requires crisis communication architecture (CCA) to enumerate communication functionality. The enumerated functionalities help support response teams in communicating effectively during an emergency. Even though these papers only outlined the use of this communication architecture for improving communication, it is important to address the usefulness of coordination and cooperation in an emergency also. Obviously, with effective communication, there is no doubt that the use of coordination and cooperation in this context should be stressed.

The least number of papers in this context fell under *CSCW*, with only 2.4% coverage. Interestingly, the only *CSCW* paper that uses communication as a component of the model was a study by Wiedenhöfer et al. (2011). The paper highlighted the challenges faced by firefighters, police, suppliers, and the public during electrical power breakdowns. During such events, these co-agencies faced difficulties in inter-organisational communication, and the information and coordination process. The challenge could be overcome through the support of social practices, like the collaborative interpretation of emergency situations and ad-hoc coordination.

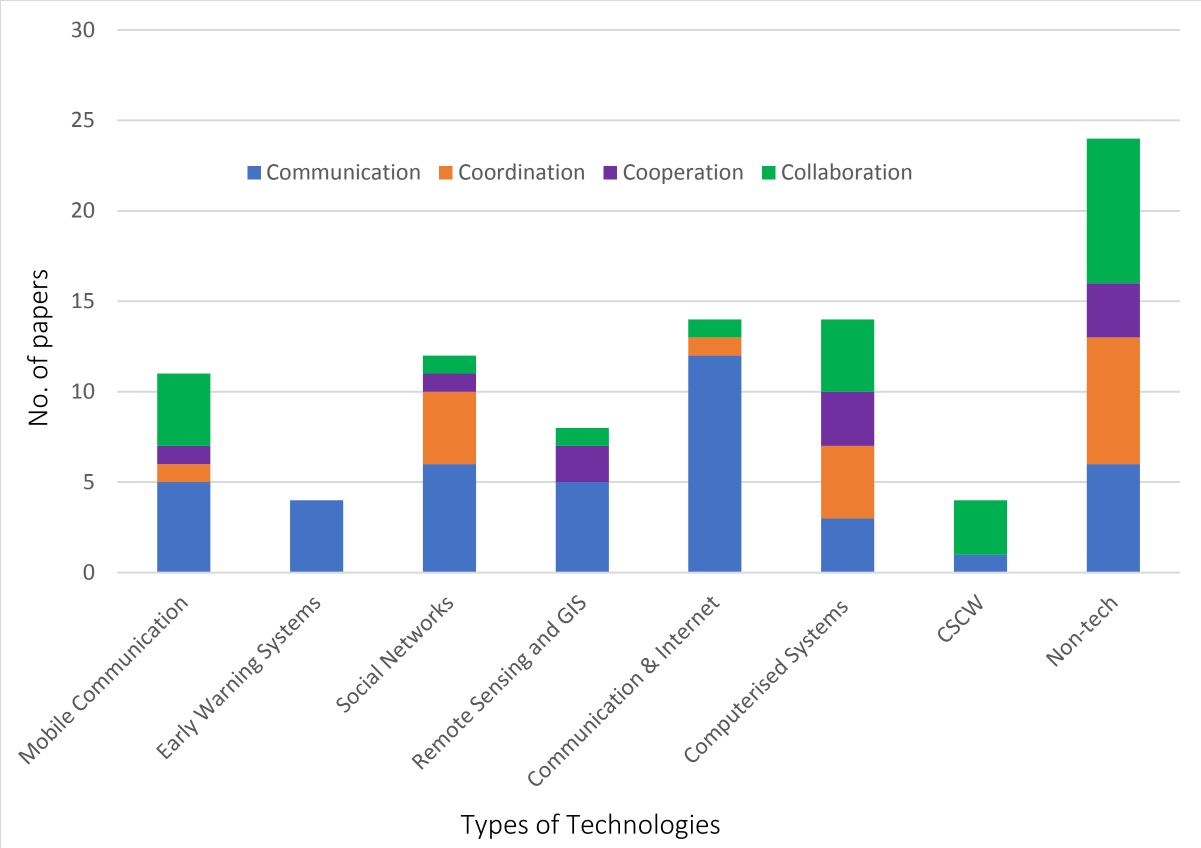

Figure 6: 3C Elements and Collaboration vs. Technology Used

5.2.3.2 Coordination vs. Technology Used

The distribution of papers under the coordination category shows a total of 17 papers and none were found useful for the purpose of *remote sensing & GIS*, *early warning systems*, or *CSCWD*. However, almost half of the papers included under this category were found common for the *non-tech* category.

Technology such as *computerised systems* & *social networks* are the second most common technologies used under this category, covering 23.5% papers for each. In the case of *computerised systems*, Chen et al. (2008) demonstrated how the US at the federal level of the National Incident Management System (NIMS) prescribes institutional response guidelines of what should be done during an emergency. A framework was formulated for analysing response coordination patterns capable of enabling effective emergency response operations across co-agencies. According to Abramson et al. (2007), there are three separated levels of coordination that need to be combined using a tiered peer-to-peer system architecture for addressing the changing needs of disaster management. The three levels include communication and transportation infrastructure, monitoring and assessment tools, and collaborative tools and services for sharing information.

*Social network*s appear to have the latest papers published in the years 2012 to 2016. Social media such as Twitter and crowdsourcing are the two most used social networks found in this study. For instance, a recent study by Callaghan (2016) argued for the useful insights of crowdsourcing R&D and social media, for solving societal problems through the increase in coordination among co-agencies in disaster situation. Cameron et al. (2012), on the other hand, addressed the important use of a platform, namely the Emergency Situation Awareness-Automated Web Text Mining (ESA-AWTM) system, which demonstrates the relevancy of Twitter messages in identifying and informing situation awareness during an emergency incident. Social communication networks are the most complex systems when it comes to emergency response, due to their dynamic environments and technical constraints, where coordinating among actors can be a problem. That is why studies such as Shen and Shaw (2004) are valuable in terms of identifying dependencies in the system to compensate the complexity of coordinating tasks in an emergency.

The least coverage of technology papers in this category is the use of *mobile communication* and *communication network & internet*, covering only 5.9% of papers respectively. In regards to mobile networks, a study by Andersen et al. (1998) highlights the main features of an electronic communication system that was designed to support coordination and the exchanging of information. So, at predefined stages of an emergency, users can monitor the current state of Multimedia Messaging Services (MMS) message to provide a preparedness plan for emergency management organisation as a contingency plan and procedure. Another study by Kumar and Havey (2013) suggested that by maintaining the relationship and trust between communities and Non-Government Organisations (NGOs), building a robust communication plan and system would become convenient. Thus, allowing an effective coordination among all groups, with improved response at all stages of an emergency.

5.2.3.3 Cooperation vs. Technology Used

Cooperation as the last component of the 3C model has the least number of papers in this domain. The total number of papers in this category represent a 10.9% coverage of the overall sample papers. The use of coordination for understanding the list of technologies outlined here is not complete, and out of the seven technologies used, only four technologies considered cooperation as a useful component in an emergency. These four technologies are *mobile communication*, *social networks*, *remote sensing & GIS*, and *computerised systems*.

Firstly, the use of *mobile networks* accounted for 10.0% of the total number of papers for mobile networks alone. Romano et al. (2014) was the only study that used cooperation for understanding the use of mobile applications. The study was based on the domain of health emergencies, focusing on common citizens in the emergency management process, where their participation was based strictly on their experience from previous emergency events. Based on the identified roles of the agents who were selected from the community of so-called common citizens, a mobile tool was proposed to allow agents to receive information from operation centres. The information was visualised through advanced visualisation modality. It is expected that with the use of the mobile tool, cooperation between organisations and citizens could help rescuers and emergency operators to provide more efficient and effective response.

Secondly, the use of cooperation as an element of the model for understanding the use of *social networks* such as Twitter in emergency management accounted for 10.0% of all papers in the social network category. The nature of an emergency or a crisis is crucial, and a call for improvement in collaborative resilience is vital in terms of fostering the collaboration potential of co-agencies and the public. A study by Reuter et al. (2013) discussed the impact of a tornado, with the focus on analysing the use of Twitter during the devastating impact. Through social media, real and virtual volunteers were considered to detect conditions of cooperation among these groups. The study looked at patterns and aspects from Twitter messages to help merge groups of volunteers in the virtual space. They found out that virtual teams are easy to form and collaborate, and as a result, the engagement of real volunteers started to decrease. Despite the decrease in real volunteers, the study considered the use of a software prototype to support the collaboration of both types of volunteer groups.

Remote sensing & GIS technologies are the third technology used under the *cooperation* category and covered 20.0% of the total number of papers for *remote sensing & GIS* in overall. Previous studies have highlighted the important part that remote sensing and GIS played in emergency management. Included in these studies is a study by Sabino and Rodrigues (2011) discussing the representation of internal information that should follow a spatial approach. The approach defined the need for understanding the structure of the cooperative workspace, where the information is extracted based on how people are cooperating. Also, the study included their relationship with the information they had been working on, such as real-life plans for emergency management. In a similar context, Floch et al. (2012) emphasised the potential for cooperating smart spaces in disaster management. The smart space helps to improve and increase the efficiency and effectiveness of rescue teams in a real-life emergency. To support and manage smart space management and community collaboration, both pervasive and social computing are combined and extended based on disaster scenarios. As a result, initial user evaluation conducted by disaster management experts lead to the designing of a cooperating smart space platform for improving collaborations among the rescue relief teams.

The last technology used item in this category is the use of *computerised systems.* Conversely, this last item represents the most paper coverage under the *cooperation* category, with a 30.0% of papers covering technologies such as *computerised systems* that include technologies like virtual reality, application software, and model and framework simulators. The inclusive identification of threats and emergencies requires a wide range of co-agencies such as authorities and actors to get involved in the process regardless of whether each authority had their model and framework to follow. Honkavuo et al. (2015) argued that a single application was required to integrate all separated models to help improve contingency planning for inter-authority and stakeholder cooperation. An Agent-Based Simulation Model (ABSM) was developed to provide support to authorities in contingency planning, especially in extreme winter condition scenarios. A study by Ooms and Jan van den Heuvel (2014) took an engineering approach to the Civil-Military Interaction (CMI) which corresponds to most behavioural-oriented research in the domain of CMI. The study highlights the essential need for effective cooperation and information exchange between military and civil actors in an emergency response situation. Given the military nature of the work, information exchange during a state of emergency is complex. Therefore, proper investigation should be done to enable understanding of different model requirements needed for the development of the CMI.

5.2.3.4 Collaboration vs. Technology Used

Collaboration has been widely used in studies from different domains, but in this paper, the focus is on the use of collaboration as an additional component for understanding the use of technology in the context of emergency management. A total of 22 papers is distributed across the six technologies used, as depicted in *Figure 3*. From the 22 papers, two technologies namely, *mobile networks* and *computerised systems* have the same paper coverage of 18.2%. Out of the 4 papers for *CSCW*, 3 papers focused on collaboration alone, which is the second largest of paper coverage under this category covering 13.6% of the papers. *Social networks, remote sensing & GIS,* and *communication network & Internet* have the least number of papers with a 4.5% coverage for each.

Under *mobile networks*, Catarci et al. (2008) and Luqman and Griss (2010) suggested the use of devices such as PDAs and mobile devices for supporting collaboration and task management in distributed dynamic teams during an emergency. PDAs are equipped with capability features of gateway communication technologies, allowing a better flow of communication and collaboration with other actors. According to Catarci et al. (2008), the workpad, i.e. PDA, consists of both the front-end and the back-end layers, and the front-end layer consists of first responder teams whereas the back-end layer is an integrated peer-to-peer network that allows a good flow of collaboration through the exchanging of information. Fundamentally, mobile device as highlighted by Luqman and Griss (2010), uses an agent-based system called Overseer to exploit content information for facilitating collaboration and task allocations among the dynamic formed teams. Clearly, these studies implicate the capability of mobile devices for improving not only collaboration but use the device as a means of communication, allowing smooth collaboration among the teams.

Moreover, Reuter et al. (2014) and Törnqvist et al. (2009) highlighted the practical challenges to multi-organisational collaborations during post-disaster response, and with high complexity and unpredictable emergencies, proper collaboration is needed with the help of mobile networks. For instance, the use of a mobile geo-collaboration system suggested by Reuter et al. (2014) was implemented using an Android application located on-site and in control centres to support and facilitate ad hoc participation of units for situation awareness. On the other hand, Törnqvist et al. (2009) emphasised more on how the challenges within multi-organisational relied strongly on the use of ICT infrastructure for communication and cooperation. In today's growing trend of ICT, mobile networks can extend footprints, reaching affected areas and victims of disasters that were never reached before, thus enabling better collaborations between response teams and those impacted in an emergency.

6 DISCUSSION

The literature coverage of emergency management as a domain alone is dynamic, however, to our knowledge no studies have covered the use of the 3C model for understanding the use of technology for improving collaboration in an emergency context. The analysis in *Figure 3* shows that the increasing trend of studies in this domain over the past 20 years indicates the rate of increase was more than double from the period (1997-2001) to (2002-2006), and from the period (2002-2006) to (2007-2011). Many of these studies consist of recent conference proceeding papers in comparison to journal articles. The increase in the number of publications in conference proceedings may signpost the increasing number of emergency occurrences around us, which are then associated with the growing need for improvement in the use of technology solutions for helping people at all stages of an emergency. Therefore a rapid increase in the number of journal publications in this study domain is expected for the future.

Most of the studies conducted in the first period (1997 to 2001) focused on the use of communication as a tool for improving communication across co-agencies and the public in all stages of an emergency (Garshnek, Shinchi, & Burkle, 1998; Hale, 1997; Tufekci & Wallace, 1998). From the 85 sample papers, only one study that was found applicable for the domain of emergency management, and used the 3C model to understand the inter-organisational coordination of agencies involved in an emergency (Martin et al., 2016). An indication showing an under-researched study area , or that the model has been used before for understanding the use of technology for emergency management purposes but has never been acknowledge in the literature. Clearly, the use of the 3C model in the domain of emergency management needs to be strengthened. Our study shows that the inter-relationship between the 3C elements can be strengthened by using technologies such as mobile communication, virtual reality, and early warning systems for improving collaboration among co-agencies in any emergency collaboration settings.

Interestingly, the results showed a substantial amount of papers that were useful for *during-event* management, but a very small number of papers were found useful for the *post-event* stage. This implies that most paper discussions seek to develop more innovative technologies for anticipating the various types of emergency. On the other hand, the *pre-event* stage presented almost the same number of papers as *post-event*, but only two papers were found common to both events. The combination of *during-event* & *post-event* indicated the same amount of papers as in the *pre-event* stage alone, and this combination had the most represented papers in comparison to the other two combinations (*during-event & pre-event*, and *pre-event & post-event*). Eventually, technologies like *mobile communication*, *wireless communications, social networks*, and *CSCW* are the common used technologies for both the *during-event* and the *post-event* stages of an emergency (Busa et al., 2015; Iapichino et al., 2009; Olteanu et al., 2015; Tarchi et al., 2009; Temnikova et al., 2015; Wiedenhöfer et al., 2011).

The result of the thematic analysis shows some remarkable indications when the elements were graphed against the commonly used types of technology. Clearly, *mobile communications, social networks*, and *computerised systems* were found common across all the elements in comparison to other technologies. *Mobile communications* were widely used for communication and collaboration purposes, whereas *computerised systems* were largely useful for coordination and collaboration purposes. *Social networks* were investigated more in relation to communication and coordination, and less to cooperation and collaboration.

Other technologies, such as remote sensing and GIS were dominated by communication, and fairly distributed in both cooperation and collaboration, but not present in coordination. Conversely, *communication networks & internet* are widely useful for communication purposes and less for the purpose of coordination and collaboration, but without any support for cooperation. All papers using early warning systems were only found useful for communication purposes. Even though *mobile communications* were found common in all the elements, it had the least number of paper coverage under *communication network & internet*. It was also notable that despite the considerable number of papers under the *non-tech* category, the coverage of these papers clearly emphasised the application of different frameworks, models, and approaches for understanding the applicability of 3C model in different types of collaborative settings. Out of the seven technologies identified in this study, *social networks* appeared to have the latest paper published.

To understand the inter-relationship of 3C elements in a collaborative groupwork settings further, the adapted conceptual framework in *Figure 1* helps strengthen our understanding of the model. Also, it shows us how technologies are being used by co-agencies to collaborate and obtain feedback from other agencies' decisions and actions and then feedthrough from their actions through awareness information. This reflects the iterative nature of the model, as shown by the directions of arrows that implicate the collaborative nature of the work done in an emergency. Since *computerised systems*, *mobile communications*, and *social networks* were the three most commonly used technologies in all the elements of the 3C model, their use together with the usefulness of the 3C model makes it more invaluable to understand the interdependencies and inter-relationships between the elements.

Overall, the results draw out an understanding that both the domain of emergency management and the 3C model contribute to each other in both ways. For instance, by analysing the stages of an emergency we are able to draw a topology of the types of technologies that have been studied in this domain, thus indicating the three most common technologies namely *computerised systems* such as virtual reality, *mobile communications*, and *social networks.* These technologies, together with understanding of the inter-relationship between the 3C elements as shown in *Figure 1,* allow us to improve our understanding of collaboration in an emergency context. Also, the results can contribute to the developments and improvements of new technologies.

7 CONCLUSION

The nature of emergency requires collaborative work among the co-agencies and people involved. It is appropriate to adopt a methodology such as the 3C model for understanding the use of technology in an emergency collaborative setting. This paper presents a scoping review on the applicability of the model for understanding the use of technology in emergency management scenarios. It can be considered a starting point for researchers to extend their research on key issues, such as strengthening the relationship between coordination and cooperation in this domain. Our results also provide a pathway for practitioners to consider investing in the types of technologies that are more effective and have successfully been used in an emergency context. A lot of research has been done in the area of communication with a reasonable amount on coordination. However, almost half of the papers supporting coordination are non-tech papers, which signpost the need for more research development on the use of technology for improving coordination. It was notable from the results that support for cooperation is very poorly explored, and this could be a potential area for future research.

The classification of studies for all stages of emergency indicated that the literature focussed more on the *during-event* stage, with almost half of the studies are from conference proceedings. However, in the *pre-event* stage more than half of the papers were for the purpose of training and preparedness, and a small number of papers were found useful for the *post-event* stage. *Figure 4* also present the lack of studies that support the combination of *pre-event* and *post event*, whereas the majority of papers were found common to the *during-event* and *post-event.* A considerable number of papers supported all stages of an emergency, indicating a positive increase of research focusing at each stages of an emergency.

Conducting a scoping review in this domain enabled us to identify the types of technologies used for improving collaboration among the co-agencies and people involved in an emergency. From the seven common technologies used, *computerised systems*, *mobile communication*, and *communication network & internet* appeared to be the most used technologies for all elements of 3C including collaboration. The conceptual framework in *Figure 1* also gave directions for determining the inter-dependencies of the elements of 3C. A much stronger relationship was witnessed between *communication & coordination* and *communication & cooperation* than the weak relationship between *coordination & cooperation*. One reason that might have contributed to this weak relationship is the fact that most of the papers that are found useful in both *coordination & cooperation* fell under the *non-tech papers* category and were excluded from our classification in *Figure 5.*

Given the complex interactive nature of emergency management, understanding the interdependencies and the inter-relationship between the 3C elements will help researchers and practitioners focus their attention on small improvements in the development of their collaborative systems. Co-agencies and those involved in emergency management may also be benefit in terms of improving their decision making for choosing the most effective technology for collaboration in an intensive collaborative environment.

As a result of our review and for future research, we seek to carry out a case study to establish patterns of how the three most used technologies, namely *computerised systems* such as virtual reality, *mobile communications*, and *early warning systems* are used in an emergency collaborative setting. In this way, we can acknowledge the applicability of the 3C model by employing a mind-map using the

SHELL conceptual framework to understand the interdependencies of the 3C elements for improving awareness in an emergency collaborative setting.

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