Improving Heterogeneous Team Collaboration in Disaster Risk Management: Lessons from Innovation

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A comparative analysis of concepts and experiences in heterogeneous team collaboration, between the fields of disaster risk management and innovation.

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Abstract

Heterogeneous team collaboration is a fundamental component of Disaster Risk Management (DRM). However, DRM teams face complex-dynamic situations characterised by high disruptions, distributed locations and other factors, which create persistent problems for team collaboration. In these contexts, even the smallest improvement to our understanding has the potential to yield enormous benefits to DRM objectives. Innovation is a highly complementary field to DRM, facing similar complex-dynamic situations, requiring inter-disciplinary team collaboration while under significant pressure. This research proposes that the field of technology-based innovation might offer insights for DRM in how heterogeneous teams collaborate.

Using a combined methods approach, primary and secondary data was generated to compare concepts and practical experiences between DRM and technology-based innovation. The two fields being highly complementary and therefore ideal for comparative analysis. Complexity theory was an essential component in the analysis, to allow for emergent themes across various team-types and contexts. Insights emerged on team themes such as: new team perspectives, management and leadership, and related variety. Related variety was the most challenging finding, as it proposes that not all diversity or heterogeneity is beneficial and therefore must somehow be managed. Additionally, related variety recognises that dissent and divergence are essential in collaboration; however, no findings were made on how to structure this, leaving the door open for further research in this space.

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Abbreviations

AI	Artificial Intelligence
CSCW	Computer Supported Co-operative Work
DRM	Disaster Risk Management
H-MI	Human-Machine Interactions
LUBsearch	Lund University Biblioteket Search database
MSB	Swedish Civil Contingencies Agency (In Swedish: Myndigheten för Samhällsskydd och Beredskap)
TBI	Technology-Based Innovation
UNDP	United Nations Development Programme
UNISDR	United Nations International Strategy for Disaster Reduction
WFP	World Food Program

Contents

1. Introduction

1.1 General background of research

This research began as an investigation into the effects of heterogeneity in teams operating in extreme conditions. My interest in collaboration had led me to co-found the *Lund Inter-Faculty Sustainability Network* (LISN) in 2016, as a way to foster interdisciplinary collaboration among students. Separately, I participated in *EIT Climate-KIC* entrepreneurship summer training in 2016, where I experienced how heterogeneous teams were regularly more adaptive, creative and effective in performance than their homogeneous counterparts.

Hence, the research started as an idea to merge two interests, collaboration and innovation, into Disaster Risk Management. What the findings ultimately showed was unexpected: that heterogeneity comes with costs, as well as benefits, and a risk of dysfunctional collaboration; and therefore, obligations exist to both participants and leadership to manage heterogeneity. How these factors might be balanced and potentially improved is investigated below.

Disaster Risk Management (DRM) is highly reliant on heterogeneous team collaboration, and in these complex systems, "it is fundamentally impossible for any actor to grasp the complete working of the system as a whole" (Bergström, Uhr, & Frykmer, 2016, p. 6). The field is characterised by increasing complexity and uncertainty (Becker, 2014; Bergström et al., 2016; Coppola, 2011). Globalisation and digitalisation have led to dramatically increased inter-dependencies, increased social and economic complexities and a rapid acceleration of change (Coppola, 2011; Lechner, Jacometti, McBean, & Mitchison, 2016). Therefore, a heterogeneous range of DRM actors and organisations are required to somehow collaborate in difficult conditions, with different organisational systems, to effectively achieve DRM objectives (Ergun, Gui, Heier Stamm, Keskinocak, & Swann, 2014; Ginige et al., 2014).

Understanding heterogeneous team collaboration is therefore a fundamental component of DRM.

1.2 Persistent issues in DRM team collaboration

Despite being essential to DRM, heterogeneous team collaboration faces persistent problems. In complex-dynamic environments, teams must constantly establish and maintain the awareness of one another's intentions, actions and results in order to remain effective (Endsley, 2015; Klein,

Feltovich, Bradshaw, & Woods, 2004; Van de Walle, Brugghemans, & Comes, 2016). When collaborating remotely, as is often required in DRM, teams face additional difficulties. Diminished interactions, rapid situational changes and a low priority for maintaining common ground create significant difficulties for maintaining common situation awareness (John M. Carroll, Rosson, Convertino, & Ganoe, 2006; Gregorio Convertino, Helena M. Mentis, Aleksandra Slavkovic, Mary Beth Rosson, & John M. Carroll, 2011a). This presents the international community with persistent challenges: an ongoing need for coordination and an understanding of how key players should collaborate (Jahre & Jensen, 2010, p. 658).

1.3 Why innovation?

Owing to persistent challenges, an improved understanding of heterogeneous team collaboration can present significant opportunities for DRM. Even small improvements to systems of collaboration have the potential to yield enormous impacts on DRM objectives (Ginige et al., 2014). Rapidly advancing technologies are driving new understandings of how teams can harness technology such as IT systems and human-machine interactions, to improve shared team awareness and intentionality (Tenenberg, Roth, & Socha, 2016). Finally, heterogeneity is worth improving, because "if managed properly, team heterogeneity can create significant operational synergy, whereas mismanaged team diversity can become a major operational impediment to optimal functioning" (Horwitz, 2005, p. 219).

Innovation is a highly comparable field to DRM, and the management of team heterogeneity and collaboration could provide insights into the persistent collaborative challenges identified by Jahre and Jensen (2010). Teams in competitive innovative industries face accelerating changes, high uncertainty and complexity, and high demands for the coordination of processes and the adaptation of knowledge interfaces (Berggren, 2011). Trends in collaborative processes are emerging, based on the need to rapidly develop new products or technology in a systematic way. Berggren (2011, p. 4) notes that these emergent trends have profound implications for the innovation process, making it more interdisciplinary, collaborative, inter-organizational, and international; with trends that imply an increasing need to integrate knowledge across disciplinary, organizational, and geographical boundaries. Accordingly, these emergent trends in innovation hold intriguing relevance and promise to the context of DRM.

Technology-based innovation (TBI) holds a particular relevance to DRM. Research is now occurring into how technology can be better utilised to improve collaborative systems and

information management, in complex and remote contexts (John M. Carroll et al., 2006; Ergun et al., 2014; Ginige et al., 2014; Van de Walle et al., 2016). TBI shows strong congruence with collaborative concepts in DRM. Tenenberg et al. (2016) argue that *awareness* and *shared intentions* are central concepts to computer-supported-cooperative-work (CSCW), which resonate strongly with concepts of *common ground* and *situational awareness* that often appear in DRM terminology (Convertino et al., 2011a; Klein et al., 2004; Uhr, 2017).

Technological advances in human-machine interactions (H-MI) and CSCW are re-examining notions of heterogeneous team collaboration; by questioning what it is to collaborate effectively, or develop *common ground* and *shared intentionality* in dynamic systems of human-machine interactions (John M. Carroll et al., 2006; Ergun et al., 2014; Tenenberg et al., 2016). Accordingly, this research project has identified TBI as a sub-set of innovation, and an ideal focus for comparative analysis.

This research project will therefore compare collaborative concepts between DRM and TBI, using combined research methods to generate secondary data and primary data on which to draw comparisons. To achieve this, a research aim and objective were identified.

1.4 Research aim and objective

Collaborative processes continue to present persistent challenges to the international DRM system (Jahre & Jensen, 2010), and every small improvement to collaboration can yield an enormous impacts on lives saved (Ginige et al., 2014). Therefore, this research aims to improve the performance of heterogeneous collaborative teams in DRM, through a comparative analysis with innovation.

To achieve the aim, the research adopted two objectives, for comparing concepts and experiences between the two fields of DRM and TBI. The first objective is to compare underlying concepts of heterogeneous team collaboration, between DRM and TBI, seeking insights from research occurring in fields such as CSCW and human-machine interactions. Insights are the new knowledge, understanding or practices that could emerge from a comparative analysis; such as conceptual variances, different practices or new research developing so rapidly in innovation that it might not yet be present in DRM. The second objective is to compare concepts with the practical experiences of DRM and TBI practitioners, seeking insights from how core concepts align with real-world experiences of collaboration. Examining how concepts map onto the experiences

of practitioners might yield new insights, which could help to improve collaborative team performances in DRM. To achieve the aim and objectives, a series of research questions were established.

1.5 Research Questions

The research aim was divided into sequential research questions, designed to facilitate combined methods (desk-based study and interviews). The first over-arching research question (**RQ1**) was created to facilitate a comparison of concepts and experiences between two fields. The following sub-questions **(SQ1-3**) were designed to generate qualitative data for a comparative analysis. The questions were:

Research Question 1 (RQ1) – *What -if any- insights concerning how to improve team performance can be drawn from the concepts and experiences of heterogeneous team collaboration, by comparing TBI to DRM?*

Sub research questions were created, to feed into RQ1:

- ***Sub Question 1 (SQ1)*** *– What are the core concepts of heterogeneous team collaboration in a DRM context?*
- **Sub Question 2 (SQ2)** – *Can our understanding of heterogeneous team collaboration in DRM be improved by comparing core concepts between DRM and TBI?*
- **Sub Question 3 (SQ3)** – *Can our understanding of heterogeneous team collaboration be improved by comparing collaboration concepts with practical experiences?*

This research used combined methods to perform a comparative analysis between two fields – DRM and innovation– with a specific focus on heterogeneous team collaboration. The methods used were a desk-based study on collaboration concepts and literature across both fields; and semi-structured interviews with experienced practitioners in both fields, to generate primary data.

At a broader level, this is intended to be an investigation into the benefits of diversity and collaboration. With all its associated challenges, and in the difficult context of DRM, is heterogeneity in collaborative teams ultimately a worthwhile endeavour?

1.6 How does a team collaborate? Background concepts and terms

This section outlines general concepts and terms in heterogeneous team collaboration, selected from initial background research. Further information on this process is outlined in section 2.2 (Research design) and section 3.0 (Conceptual framework). Terms outlined here include *shared intentions; common ground; joint activity*, identified in literature provided by supervisor C.Uhr, being prerequisites for joint activity in a team system (Klein, Feltovich, Bradshaw, & Woods, 2005). *Situational awareness* is also presented here, being relevant to all levels of team and organisational systems, and identified in literature spanning over 20 years of research (Cuevas, Jones, & Mossey, 2011; Endsley, 1995; Tomasello & Carpenter, 2007). Finally, *knowledge transfer* is presented, for its role in adapting teams to complex-dynamic systems, and maintaining common ground (Convertino et al., 2011a). However, before considering these concepts, we must first define collaboration and how it relates to DRM.

1.6.1 Collaboration, cooperation or coordination?

The terms *collaboration*, *cooperation* and *coordination* have many definitions in different fields, and tend to be used interchangeably (Amici & Bietti, 2015; Ergun et al., 2014), creating an important consideration for how to search and analyse terms. All three terms have relevance when discussing team collaboration, yet they retain subtle but important differences.

- *Coordination* refers to the alignment of operational activities in a way that increases efficiency or effectiveness (Ergun et al., 2014);
- *Cooperation* has roots in game theory (Ergun et al., 2014) whereby actors might temporarily set aside divergence to work together to achieve their individually held goals (Klein et al., 2005);
- *Collaboration* describes the process of shared creation, where actors with complementary skills interact, to create a shared understanding that none had previously possessed on their own (Schrage, 1990, cited in Dennis, 1999, p. 3).

While all three terms have unique objectives, *collaboration* was selected for the specific principle of seeking "new, shared understanding" through the "interaction of complementary skills". Collaboration is about using information to create something new (Denise, 1999). Ergun et al. (2014, p. 1003) gives a working statement for collaboration in DRM, being: "the relationships between organisations whose operations are coordinated"; yet this statement lacks something

important. Perhaps Denise captured best this important factor, in saying: “unlike coordination, collaboration seeks *divergent insights* and spontaneity, not structural harmony. And unlike cooperation, collaboration *thrives on differences* and requires the *sparks of dissent*” (my italics) (1999, p. 3).

This thriving on differences, divergence and the spark of dissent should be noted for the importance it plays in later findings. The function of promoting creativity as an emergent property, thriving on differences and absent of structural harmony strongly articulates why collaboration was used to frame this research; and also illustrates the links between DRM and TBI. With collaboration defined, we can move to general concepts in team collaboration.

1.6.2 Shared intentions

Teams can be distinguished from individuals via the *shared intentions* of team members (Searle, 1990; Tuomela & Miller, 1988). “There is broad agreement in philosophy, artificial intelligence and cognitive science that the collective, joint activity of a group is more than the simple sum of the actions performed by the individuals in that group” (Grosz & Hunsberger, 2006, p. 259). Collectively held intentions are not the same as the summation of individual intentional behaviours; and therefore, teams require different concepts from simply aggregating the individual intentions – what are considered here as *shared intentions*.

The s*hared Intention* of a team is: “the collaborative interactions in which participants share psychological states with one another” (Tomasello & Carpenter, 2007, p. 1). It is more than simply an agreement, but rather it is a joint commitment, in which sociality and an important form of obligation come together (Gilbert, 2009). It is referred to by Klein et al. (2005) via the *basic compact* in a team: “an agreement (often tacit) to facilitate coordination and prevent its breakdown” (p.2); the commitment of aligning multiple goals, and to support the process of shared coordination (2005).

Shared intentions therefore show a team as a distinct entity from the individual members; whereby members mutually intend to coordinate effectively towards an agreed purpose or joint activity. The *shared intention* is supported by a *common ground* being held among team actors.

1.6.3 Common ground

Common ground was proposed by Clark (1996) to conceptualise the coordination requirements for language and conversation; whereby people work to establish and maintain a shared

background of understanding. Klein et al. (2005, p. 4) extended the concept from conversation to team collaboration, arguing that the level of coordination needed in teams is similar to a conversation. Klein et al. defines *common ground* as "the relevant pertinent knowledge, beliefs and assumptions that are shared among the involved parties"(2005, p. 1); while Xiao (2013) describes it as "mutual understanding in interpersonal communication" (p. 1732).

Interestingly, the original definition developed by Clark (1996), that *common ground* should be established and maintained, is noteworthy for DRM teams. It illustrates that *common ground* between actors is not static but dynamic, requiring ongoing maintenance; highly relevant for the dynamic and uncertain contexts faced by DRM teams. *Common ground* assists the team in adapting and maintaining the effectiveness of its tasks as situations unfold, when undertaking their *joint activity*.

1.6.4 Joint Activity

Joint activity is the activity a team undertakes mutually, to complete a jointly shared purpose or task. It can be defined as "the extended set of behaviours that are carried out by an ensemble of people who are coordinating with each other" (Clark, 1996, p. 3; cited by Klein et al., 2005). Interestingly, Klein et al. proposed two criteria for joint activity in teams, being that: 1) parties have to intend to work together; and 2) their work has to be inter-dependent (p. 6).

This proposal of mutuality and inter-dependency in team activities corresponds with earlier research published by Bratman (1992) who suggested three fundamental requirements of a shared cooperative activity, what can also be called *joint activity*. These three requirements being: 1) mutual responsiveness (where actors attempt to respond to the intentions and actions of the other; 2) commitment to the joint activity, of each actor; and 3) commitment to mutual support (where involved actors are committed to playing their role in the join activity (Bratman, 1992). These three notions of mutual intent and inter-dependence also resonate with earlier concepts of *common ground* and *shared intentionality*. The relevance of a team's *joint activity* to its *shared intention*, particularly in dynamic contexts, requires ongoing *situation awareness* of changes occurring in the system or context.

1.6.5 Situation awareness

Situation awareness can be referred to as a team's collective awareness, and the component individuals' awareness, of a situation or context for the team's activities. Endsley (1995) in

researching dynamic systems, proposed *situation awareness* as an actor's "understanding of the situation as a whole, forming a basis for decision making" (p. 34). It is a state of knowledge; or more specifically it is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1995, p. 36).

In researching distributed cognition, Artman and Garbis (1998) proposed *situation awareness* as "an intermediate state in the decision-making process of dynamic systems where one should be able to comprehend the situation in order to make an appropriate decision for future development" (p. 1). This illustrates that *situational awareness* is not static or fixed, but 'intermediate' – in other words it requires constant adaptation to the team's dynamic and uncertain contexts. In this regard, it accords with earlier concepts such as the need to maintain *common ground* through ongoing commitment and communication.

To uphold this communication such that the *situation awareness* of a team and its members can remain current and accurate, requires *knowledge transfer*.

1.6.6 Knowledge transfer

An integral part of effective team collaboration, in dynamic contexts, is the function of *knowledge sharing*, also referred to as *knowledge transfer*. In research on common ground among DRM planners, Gregorio Convertino, Helena M Mentis, Aleksandra Slavkovic, Mary Beth Rosson, and John M Carroll (2011b) defined *knowledge sharing* as: "the development of shared knowledge as integral to transactive memory, common ground, and strategic knowledge" (p. 22:3).

Knowledge sharing among collaborators is critical for situational awareness and for continually improving group performance; because, "one needs to know many things about one's collaborators regarding their activities, intentions, evaluation criteria and a range of other factors" (John M Carroll, Neale, Isenhour, Rosson, & McCrickard, 2003, p. 606). Indeed, "people working collaboratively must establish and maintain awareness of one another's intentions, actions and results" (p. 606).

Knowledge transfer is therefore a critical activity for teams in dynamic contexts. It ties together a team's *joint activity;* serves to establish and maintain *common ground*; ensures the team's *situation awareness* remains current; and regularly aligns or re-aligns the *shared intentions* of

team members. This is important to note, for the role *knowledge transfer* plays in findings and recommendations.

With background concepts and terms outlined, it is necessary to discuss the methodology designed to implement the research aim.

2.0 Methodology

This chapter outlines the methodological approach taken for developing research, gathering data, assessing the reliability and validity of data, and the associated limitations and assumptions.

2.1 Research philosophy

This research adopted a hermeneutical philosophical approach common to social sciences, whereby interpretation is given to the cause and consequences of human behaviour. This differs from a naturalist approach in physical sciences, which emphasises measuring or uncovering causes that produce effects (Flowerdew & Martin, 2005). A hermeneutical research philosophy was considered more appropriate due to the transdisciplinary nature of disasters (Becker, 2014; Coppola, 2011), and the inter-disciplinary nature of comparing two related but different fields. Indeed, a hermeneutical social sciences approach fits well with DRM, because the management of vulnerabilities in this field is increasingly being demanded through social ventures; such as partnerships, policies, procedures and cooperation at all levels of governance (ISDR, 2005).

The research philosophy is therefore anti-naturalist, in that it asserts that human actions can be reasonably interpreted for meaning and significance (Flowerdew & Martin, 2005), based on evidence. Anti-naturalism is the assertion that humans are swayed by reasons or rules, not by causally determined forces of nature (Flowerdew & Martin, 2005, p. 18). Evidence was therefore required to justify interpretations, which was gathered through the desk-based study and semi-structured interviews. The research process has attempted to mitigate against potential opaqueness of a social sciences philosophy, by upholding principles of *the scientific method*: using a research methodology, and respecting the centrality of empirical evidence, when providing interpretations (Flowerdew & Martin, 2005). The interpretations and conclusions drawn are based on evidence obtained through the research process, while attempting to recognise biases or the absence of falsifiability.

2.2 Research design

Following from the research philosophy being rooted in social science, a combined methods approach was adopted, combining a desk-based review of literature with an analysis of primary data gathered through interviews. The combined methods approach was considered appropriate as it provided flexibility and breadth, needed to facilitate the development of a conceptual framework and background, from which a comparative analysis could be made between the concepts and theories from two separate fields.

2.2.1 What makes a "core" concept?

An important question in determining a methodology for answering SQ1, to then facilitate comparisons in SQ2 and SQ3, is to first establish what makes a concept *core* to a field? Concepts and terminology in DRM remain open to debate, what Uhr (2017) refers to as a *semantic fog*. Therefore to seek robust results, an initial background reading was conducted on texts considered fundamental to DRM – requiring a qualitative judgement from the outset. Concepts (and synonyms) important to team performance were identified in the background research were then compared to DRM and TBI via a targeted concept review, interviews, and supplementary readings from further discussions. This facilitated the emergence of *core concepts*, motivating a discussion on **SQ1-3** and into **RQ1.**

2.2.2 Data collection

i) Desk-based study

Initial background readings were conducted on key articles provided by supervisor C.Uhr in the field of 'Direction and Coordination in Disaster Management'; and articles taken from the reading list of 'Humanitarian Logistics' at Lund University (course MTTN45, 2016/17). These readings yielded the terms *common ground*, *shared intentionality* and *joint activity situation awareness* and *knowledge transfer* (Klein et al., 2005; Tomasello & Carpenter, 2007; Uhr, 2017); along with ongoing issues in collaborative team management in the international cluster system (Jahre, Tatham, & Jensen, 2010); and novel collaborations occurring in TBI (Berggren, 2011).

After the research aim was identified, the desk-based study was undertaken beginning with a broad (un-targeted) search of literature and a backwards review of references from the earlier key articles. This was intended to assist in building the research concept and conceptual framework. The terms *heterogeneous*, *collaboration* and *innovation* were generated from the

research aim, and were searched in various combinations on LUBSearch. Boolean search operators were used to direct the search towards either DRM or TBI (Appendix A); synonyms were then used to capture variations and semantic differences in the common concepts (Appendix B); inclusion and exclusion factors used to filter results (Appendix C); and a final qualitative judgement made using titles and abstract to obtain a reading list (Appendix D).

ii) Targeted concept review

Following the background research, a more systematic approach was required to begin comparing central concepts in the fields of DRM and TBI. The method chosen for the concept review was a 'general literature review' - one of 14 potential methods outlined by Grant and Booth (2009). The 'general literature review' format was chosen for its breadth, allowing for the summation and consolidation of previous material, the identification of potential gaps in literature, and the discussion of innovative developments in the field (Grant & Booth, 2009).

To answer the research questions systematically, the concept review began by identifying a suitable database (Scopus) and building up search term queries to seek literature relating to the research questions. The search queries were designed from concepts identified in the research aim.

Following the initial structure of the literature search, recurrent issues emerged that required adaptation. Specifically, high numbers of unrelated search results were returned when using terms *emergency* (relating specifically to medical, health and surgery fields), or *crisis OR disaster* (relating to financial and banking fields). To reduce this noise, synonyms became limited, as evident in the table of search results.

iii) Supplementary literature:

Additional supplementary literature on team collaboration in DRM contexts was sought through discussions with Tove Frykmer, a doctoral student at Lund's Division of Risk Management and Societal Safety. Literature obtained was used to analyse the concepts of *multi-team systems*, *common ground* and *situation awareness* in specific DRM contexts.

A further discussion was conducted with professor Cristina Chaminade (Professor in Innovation Studies; Faculty of Economics and Management, Lund University). Prof. Chaminade introduced concepts for team collaboration specific to the field of innovation, such as *compositional diversity*, *related variety*, *knowledge networks*, '*co-opetition'* and *combinatorial knowledge*

dynamics; with specific literature provided for these terms. These concepts were eventually merged into a singular concept, *related variety*, which is discussed further in section 4.2 and in Appendices D & E.

iv) Interviews

Primary data was collected through eight qualitative interviews, averaging 29 minutes each, conducted using a semi-structured method. Interviewees were sourced equally from two fields – four from DRM and four from TBI – with the limiting factor from both fields being that interviewees were experienced in heterogeneous teams operating somehow in environments of uncertainty and complexity. The justification for this limiting factor for interviewees was that this was the common factor between the two fields, necessary for a comparative analysis. Specific to TBI, interviewees were sourced from teams operating in new product development; because of effects that can occur when teams operate in environments of dynamic innovation (Berggren, 2011).

Specific criteria for targeted interviewees were:

1) Previous experience in either DRM (preparedness, response or recovery) or TBI:

developing new products, software, methodology or techniques: such that the practitioners were operating at the front-edge of their profession;

2) Previous experience in a heterogeneous team –either as a leader or subordinate– diversity in gender, language, culture or professional skills and background;

3) Willingness to be recorded; and

4) Willingness or ability to discuss the topic. No distinction was drawn between team subordinates, leaders, or those operating in nested teams (multi-team systems).

No distinction was made for age, ethnicity, location of experience, or specific field. A balanced gender was initially sought but with a low interview response this proved difficult to achieve.

Interviewees were initially sourced through private or departmental connections, from which further interviewees were snowballed, to generate more interviews with informants of similar experience and quality; “snowballing” being a legitimate technique described by Flowerdew and Martin (2005) as the use of one contact to help recruit another, and another after that.

Snowballing enabled connections to be established with interviewees outside the DRM field, such as software development and biopharmaceutical product development.

- Interview guide:

Prior to beginning the interview, a research brief was sent to the interviewees, requesting information on their heterogeneous team experience and providing a context for the research project, (see Appendix F). In addition, all interviewees' CVs and LinkedIn profiles were requested to double check criteria for interviewee experience and to assist in data analysis, post interview (see Appendix E). Finally, all interviewees were asked explicitly for their permission to record audio from the interview.

On contact with interviewees, permission to record the audio was re-confirmed, prior to commencing questioning (with option being offered to record but remain anonymous). All interviews were recorded with audio either via Skype or using smartphone microphone app. Video was not recorded because of frequent issues with bandwidth and Skype performance, and a decision to limit data analysis to verbal responses only. The application for recording Skype audio was 'Mp3 Skype Recorder' and mobile telephone recorder was Samsung Galaxy S5's built in 'Voice Recorder' application.

Interviews were opened with a description of the research brief, the interviewer's personal background, and genesis of the research concept, after which introductory questions commenced on interviewees' past team experiences. Following the introductions, two broad questions commenced relating to "what worked" and "what did not work" for interviewees' heterogeneous team experiences. Prompting questions were occasionally used to guide the interviewee back to the specific question, or to encourage further detail on an interesting or unexpected response; and a final open prompting question was asked to canvas any additional information not covered in the interview. Details on the interview and questions structure are provided in Appendix F.

2.3 Data analysis methodology

Data analysis was divided into two parts, reflecting the combined methods for data collection: Part 1) analysis of the secondary data generated from the concept review in both DRM and innovation literature; and Part 2) analysis of qualitative primary data, generated from interviews with practitioners in both fields.

2.3.1 Secondary Data

Secondary data was analysed by seeking to identify core concepts in the desk-based study: from the literature gathered first in the background literature, and later in the targeted concept review. The background literature, which guided the search terms and shaped the analytical framework, is introduced in section 3 (conceptual framework). Specific search terms were identified using a method similar to a DRM scoping analysis conducted by Beerens and Tehler (2016).

The literature sought key themes and descriptions of key concepts by primarily focusing on the abstract, key words, introduction and literature review sections of publications. Where required, the discussion and conclusion sections of each publication were read and analysed. Methodology, results and analysis were not typically reviewed for reasons of falling outside scope and relevance. Key concepts and emergent themes were noted in the results section, with diverging or counter-arguments being noted for further analysis.

To correct against potential biases in the concept search process supplementary discussions were held with and literature obtained from researchers at Lund University; in DRM (Tove Frykmyer) and innovation (Prof. Cristina Chaminade) who provided additional supplementary readings.

2.3.2 Primary Data

Primary data was analysed using open coding and MS Excel. Interviews were first transcribed manually using a combination of 'O-Transribe' (a free online transcription site) and MS Word. All transcriptions were then coded manually, using open coding to identify 'emergent codes' (UCDavis, 2017) and extract themes identified in the general literature review. Responses were categorised manually using a system of colour categorisation, according to emergent codes and patterns or repetitions. Codes were then entered into MS Excel, allowing for further sub-categorisation and numbering, according to key concepts or statements. This allowed for further analysis and searching within MS Excel to gauge the repetition and frequency of concepts across transcripts.

Importantly, a qualitative assessment was frequently required by the researcher to assess the links between emergent themes in the secondary and primary data. This is owing to differences in terminology and concepts between the scientific research literature and practical experiences of two separate fields. For example, the theme of *diversity* in DRM has links to *related variety* in

innovation; similarly, *situational awareness* in DRM has links to *knowledge transfer* and *knowledge integration* in innovation.

2.4 Research Quality

2.4.1 Assumptions

The research is founded on an assumption that establishing and then comparing core concepts from secondary data was possible between two multi-disciplinary fields. The breadth of these concepts, and the breadth of these two fields, has involved differences in literature, terminology and conceptual understanding.

It was assumed that core concepts could be established from a systematic search of literature, using 'highest cited' to rank literature results and reveal principles and concepts that are widely agreed on by researchers and practitioners. This assumption was bolstered by scoping studies of DRM literature, which suggested some convergence among researchers towards core concepts and principles, emerging in the literature (Beerens & Tehler, 2016; Goldschmidt & Kumar, 2016). However, the comparability of DRM concepts with innovation still rests on an assumption that this is a possible and valid approach.

Similarly, an assumption was made that the professional experiences gathered as primary data could be compared and analysed between two different fields. Furthermore, the assumption was made that reflecting the primary data back against the secondary data was possible, such that potential insights or lessons would be a valid and reliable method.

A final assumption was made that the field of innovation, and specifically technology-based innovation, holds novel insights and different perspectives that are new to the field of DRM. This assumption was based on literature covered in the background research, which suggested new approaches of collaboration and emergent trends among technology-based organisations (Berggren, 2011). This assumption was discussed with Prof. Cristina Chaminade who concurred and provided both supporting literature and relevant terminology.

2.4.2 Reliability and Validity

In social science research, no single method of data collection is ideal – all contain inherent strengths and weaknesses. However using a combined methods approach allows some balancing

of these strengths and weaknesses, through the triangulation of data (Abowitz & Toole, 2010). Nonetheless, reliability and validity issues remain – the effects of which require consideration.

i) Reliability

Reliability is the uniformity of results over time, or the ability to replicate results when other relevant factors remain unchanged (Abowitz & Toole, 2010). Ensuring the replicability of qualitative data is a challenge, and therefore a systematic and transparent approach was developed for both the concept review of literature and for the interviews.

For the conceptual review, specific attention was given to creating a system using Boolean search queries, with explicit inclusion and exclusion factors (see Appendix A). The aim of which was to improve replicability of search results. Similarly, for the interviews, an explicit set of inclusion and exclusion criteria was created for interviewees, and a consistent and transparent set of questions were used to enhance replicability (see Appendices E & F).

However, in both the concept search and interviews, a final qualitative judgement was required in the selection of articles and interviewees, and thus a different researcher could have potentially obtained different data. While the transparent and systematic methodology for both interviews and concept review gives some confidence in reliability of the data, the presence of biases did have a noticeable effect; for example, in the findings of *management and leadership* as an emergent theme (section 4.2.2) which was not originally included in Boolean search terms. In this example, the combined method approach noticeably improved reliability of the findings.

ii) Validity

Validity describes the accuracy of the data relative to its intended research purpose; or in other words, to what extent does the data obtained measure what it is intended to measure (Abowitz & Toole, 2010). The use of a combined methods approach here is specifically directed towards maintaining validity, given that neither primary or secondary data are analysed in isolation – both data sets were gathered with the intention to complement each other, and facilitate comparisons with each other. Sub-questions were also generated to further assess the validity of the data, by prompting interviewees to consider the different questions from different perspectives.

A potential issue with data is the method of recruiting interviewees. Snowballing was used to identify additional interviewees and can possibly have led to homogeneity in the data. There is potential for homogeneity in interviewees from the DRM field, where informants were

snowballed from Lund University, either from within or connected with the Department of Risk Management and Societal Safety. This was attempted to be mitigated by sourcing interviewees from different faculties or with different professional experiences.

2.4.3 Boundary of Analysis

A boundary was required for DRM concepts, given the breadth of this multi-disciplinary and multi-phase field. The boundary needed to include concepts or principles relating to disaster risk management, specific to direction and coordination in disaster reduction, and societal resilience. To enable a discussion on DRM and not be confined to any one specific phase, the temporal boundary remained broad over all four phases of DRM (*mitigation*, *preparedness*, *response* and *recovery*). This created a problem for defining teams, which is addressed specifically in the framework section 3.2.1 (A team or a group?).

It was required to exclude concepts relating to 'crises' or 'disaster management' in fields such as emergency medical response, public relations crisis management (relating to business), and technical research specific to psychology and cognitive science; because these issues were considered far beyond the scope of the research. These fields are disciplines in themselves, and so the choice was made to exclude search terms not focused on DRM and TBI.

A boundary for innovation was also required given the multi-disciplinary nature of this field. This was initially limited to concepts relating to TBI, specifically focused on CSCW and H-MI. However, following discussions with Prof. Chaminade the boundary was expanded to include additional notions of team collaboration from across innovation, not necessarily discussed in TBI literature. This decision was made owing to an insight from Prof. Chaminade that any innovation – regardless of its field – rests on the underlying processes of *knowledge transfer* and *team collaboration*. These concepts were felt to be highly relevant to the comparative analysis, and accordingly the boundary was adjusted.

2.4.4 Limitations

A significant limitation for the research was the conflation of terminology across two multi-disciplinary fields. Within DRM, research is persistently hampered by "fragmented terminology" (Ekman & Uhr, 2015, p. 1). Comparing terminology under such conditions was a challenge and required the development of a conceptual framework (Section 3.0), in which key terminology was defined and a boundary of analysis identified.

Similar to conflation of terminology was the breadth of the two fields being analysed. Despite developing boundaries and a conceptual framework, it remained a challenge to identify how to include or exclude literature, if/when to transpose terms, and whether the results from such decisions were valid and reliable.

An additional limitation was the low number of interviewees, with potential homogeneity among some respondents. All interviewees were sourced in Sweden, with strong commonality around Lund University. Three DRM interviewees were connected to Lund University's Division of Risk Management and Societal Safety, and one was from Sweden's Civil Contingencies Agency (MSB) creating a potential homogeneity of experience or view. Similarly, all technology-based interviewees were snowballed from connections within Lund University, potentially over-representing Swedish work culture and values.

A limitation for comparing interview responses also exists regarding the difference between private practice (from TBI) and public service. This is somewhat mitigated by taking one innovation interviewee from Lund University's department of Digital Archaeology, providing a perspective of heterogeneous team collaboration from innovation occurring in the public service.

During the interviews, some inconsistencies were experienced with probing questions and background briefings to the interviewees, which could influence the data. Probing questions were modified in response to the interview, and in some cases, interviewees chose to answer questions in a different sequence to the interview structure. Also, the pre-interview briefing was modified slightly in response to some confusion among some interviewees over the boundary of the questions. Specifically, some clarification was added to address confusion over teams and multi-team systems, and regarding the perspectives of team leader or subordinate.

3. Conceptual Framework

This chapter outlines the terminology and concepts which framed the research questions and analysis. Specifically, the importance of using complexity theory and emergent properties to frame DRM is introduced, to meet the boundary conditions and to analyse the findings.

3.1 Disaster Risk Management (DRM)

The field of DRM is hampered by fragmented terminology (Ekman & Uhr, 2015), what Uhr (2017) refers to as a "semantic fog". The management of a crisis or disaster can mean different things, in different contexts. For this research, the term DRM will refer to the actions taken by individuals and societies to decrease their exposure to the consequences of disasters, develop measures to address their initial impact, and implement post-disaster response and recovery (Coppola, 2011, p. 1). In addition, the term *disaster* is framed by what Quarantelli (1988, p. 373) referred to as "collective stress situations" that deal "exclusively with consensus related community crises", born out of "natural or technological effects". The specific term of *disaster* will take the UN ISDR definition:

Disaster: "A serious disruption of the functioning of community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources" (ISDR, 2009, p. 9)

3.1.1 DRM as a comprehensive framework

It is important to note the temporal nature of DRM activities – 'before, during and after' a disaster has occurred; and the influence this has on framing a *team*. In a recent scoping study, Goldschmidt and Kumar (2016, p. 1) found that "the humanitarian community remains a culture of response, resulting in an unbalanced mix of response and development activity". Meanwhile, Ginige et al. (2014, p. 548) argue that "the emergency preparedness and response phases include actions taken prior as well as during and after a disaster event in order to reduce human and property losses".

Focusing on response and recovery alone is inadequate and therefore the international community is now widening its focus to also include disaster prevention (Coppola, 2011). Consequently, the research sought to acknowledge this widened focus in the research, by maintaining a comprehensive framework for DRM to include all temporal phases: *mitigation*, *preparedness*, *response* and *recovery* (Coppola, 2011; Goldschmidt & Kumar, 2016). This required a framework for teams that could handle broad timeframes and diverse objectives.

3.1.2 Complexity theory as a framework for DRM

Taking a comprehensive framework for DRM presented problems, because different collaborative team-types are required across many DRM phases and contexts. This created a difficulty in comparing and analysing teams – how to compare 'like' with 'like'?

To solve this difficulty, complexity theory was adopted as an analytical framework. Complexity theory recognises that emergent properties occur in complex-dynamic systems (Bergström et al., 2016). Rather than seek to define DRM teams through pre-determined team taxonomies, the analytical framework used complexity theory to view teams as part of a larger DRM system. In such an approach, the system possesses emergent properties, and teams become defined by what Mathieu, Maynard, Rapp, and Gilson (2008) refer to as *underlying substantive themes;* which are the core concepts, underlying beliefs and the purpose for which the team exists. This is explained further in section 3.2.2 (Emergent Themes).

Using complexity theory fits extremely well with DRM. In a study on DRM teams operating in complex-dynamic systems, Bergström et al. noted that "it is fundamentally impossible for any actor to grasp the complete working of the system as a whole"; and "the behaviour of the system as a whole cannot be reduced to the functioning of the constituent components, but only sought in their non-linear interactions and relations" (2016, p. 6). Therefore, seeking to analyse teams through a specific taxonomy is inappropriate for DRM , given seemingly infinite variety of potential conditions and team-types.

Additionally, complexity theory provides an ideal framing device because of our understanding of societal resilience in DRM. It resonates with the fourth state of societal resilience, as an emergent property of the system. Here, resilience emerges from " … the ability of human-environment systems to anticipate, recognize, adapt and learn from variations, changes, disturbances, disruptions and disasters …" (Becker, 2014, p. 146). Our understanding of heterogeneous team collaboration in DRM would suffer from a rigid team definition. Instead, framing teams through their core concepts and emergent themes gives a flexible framework that can adapt to the complex-dynamic systems in DRM.

3.2 Framework for heterogeneous team collaboration

My starting point for discussing teams and collaboration will begin with a wide framework, to allow for emergent themes. It will use teams' substantive themes as opposed to specific team-

types. This section will provide the rationale why; and then team and collaborative concepts will be deepened in the analysis/results section.

3.2.1 A team or a group?

Prior to any discussion on teams, it is necessary to first discuss the terms *team* and *group*; as these are often conflated or used interchangeably. A *group* can be defined as "a general collection of people or things, located, gathered or classed together", while a *team* is characterised with intention or purpose, being broadly defined as: "two or more people, working together" (Dictionary.com, 2017). Salas, Sims, and Burke (2005, p. 562) provide a more focused definition of a team as: "two or more individuals with specified roles, interacting adaptively, inter-dependently, and dynamically toward a common and valued goal".

It is the notions of inter-dependency, adaptive interaction and dynamism that will form a crucial role in framing *heterogeneous teams* operating in DRM, because of their relation to 'emergent properties'.

3.2.2 Emergent themes

Adhering to prescribed team-types across DRM's four phases is difficult, to the point of being un-workable due to the myriad of contexts and objectives. Teams come in many different configurations, tasked with different types of functions that can acquire different forms (Mathieu et al., 2008; Salas et al., 2005). Numerous definitions of groups, teams and other forms of collectives have been proposed, and "often there is as much heterogeneity within team-types as there is across team-types" (Mathieu et al., 2008, p. 411).

It is therefore arguably more useful to analyse teams on the basis of their underlying substantive themes rather than any prescribed team types (Mathieu et al., 2008, p. 412). *Underlying substantive themes* are the core concepts, the underlying beliefs of team members, and the purpose for which the team has formed (Mathieu et al., 2008). Themes can change over time as the team interacts with a system, similar to emergent properties in complexity theory. Therefore, *emergent themes* can be considered underlying substantive themes, with a temporal consideration. In other words, *emergent themes* are the core concepts, underlying beliefs and team purpose, which emerges as the team interacts with systems.

Framing teams through *emergent themes* allows commonality across the myriad of different team-types in DRM. For example *emergent themes* in different teams or contexts could include

interdependence (Mathieu et al., 2008) *common ground* (Klein et al., 2005) and *situational awareness* (Endsley, 1995) among others. These are discussed further in sections 3.3 Core concepts; and 4. Results and discussion.

Framing teams according to *emergent themes* allows the consideration of a wider variety of literature and interviews across diverse team types, which are all relevant to DRM. This is because the definition of team is kept open to allow for different team types and contexts. For example, team literature can be considered from contexts such as: 'individuals in organisations'; 'multi-team systems'; humanitarian actors and organisations; and the international cluster system. Using e*mergent themes* allows these different contexts to be compared and analysed. Conversely, taking a narrower prescriptive definition would have restricted the research and analysis.

It should be noted that there is a difference between emergent properties and emergent themes. *Emergent properties* relate to complexity science and are a micro-macro effect from complex systems. Meanwhile *emergent themes* are referred to here as the underlying substantive themes of teams in DRM, that emerge over time. *Emergent properties* in complex systems is the rationale to justify seeking *emergent themes* across various team types in DRM.

With the team framework of emergent themes established, it becomes possible to frame the concept of collaboration.

3.3 Framing technology-based innovation

Having defined concepts for heterogeneous team collaboration, it then became necessary to outline concepts and frameworks for using technology-based innovation (TBI) in this research.

3.3.1 Innovation as a broad field

Similar to DRM, *innovation* is a field broadly characterised by ongoing disruption, and the need for collaboration across complex-dynamic, multi-system interactions in a global context (Berggren, 2011; Grillitsch & Chaminade, 2016). Berggren (2011, p. 4) describes innovation as "rapid technical change", while Grillitsch and Chaminade (2016, p. 2) cite a variety of sources to describe innovation as "… the result of interactive learning with external sources of knowledge", in which firms innovate in open models with strategic links to other firms, users and a variety of actors. Berggren (2011, p. 3) points to particular trends in the global economy which resonate with DRM, in which firms face increasing disintegration and dispersal of activities, while at the

same time requiring a "strong need for interactive and integrated development". More-so, "Firms need capabilities to allow them to rapidly integrate different types of knowledge and enable cross disciplinary and cross-organization interaction" (Berggren, 2011, p. 3).

Innovation therefore holds strong congruence with DRM, and so the lessons from collaborative interactions among firms in the complex, disruptive situations of innovation, might hold potential insights for DRM.

3.3.2 What is technology-based innovation?

Being such a broad field, it was initially felt that *innovation* needed a narrower framework, and so *TBI* was identified. This was identified during the initial concept search, because of two main factors: 1) the increasing use of technology as a tool for team collaboration and remote operations in DRM, and therefore the potential for technology to improve DRM (Ergun et al., 2014; Ginige et al., 2014); and 2) the highly disruptive nature of technology development/innovation, which is forcing novel collaborations out of necessity (Berggren, 2011).

Technology-based innovation (TBI) is defined here as the process of innovating new products, methodologies, techniques or tools. Berggren (2011, p. 4) describes it as "developing high-technology and complex products [that] requires coordination and cooperation among experts within a multitude of fields. This is especially the case if this is *at the edge of the physically possible*" (my italics). This notion – collaboration for new developments, *at the edge of the physically possible* – was highly interesting and illustrates TBI's congruence with DRM contexts.

Specific fields in TBI were identified for the detailed concept review during the initial background research; these being Human-Machine Interaction (H-MI) and Computer-Supported-Cooperative-Work (CSCW). These fields are specific research areas in innovation, with associated journals and literature, making them ideal for conceptual analysis and comparison with DRM. They were identified because of their strong focus on concepts shared with DRM, such as shared awareness, team interaction, joint activity and common ground; in a context of accelerating technical complexity.

3.4 Summary of framework

To summarise, the framework for this research rests on complexity theory and emergent properties. This framework itself emerged from the complex-dynamic situations that characterise DRM and societal resilience – including the variety of teams and objectives required

in various DRM phases; and the problem of examining DRM in restricted team types, temporal boundaries or specific team objectives.

Innovation was identified as a field to compare against, because of its reliance on collaborative interactions in complex-dynamic situations. Specific to innovation, H-MI and CSCW were identified as a framing device to guide further concept and interview research; chosen because of field characteristics such as: disruption, the requirement for heterogeneous team collaboration, and new developments into collaborative concepts in these fields – all of which resonate strongly with DRM.

With the research framework identified, it was then necessary to create a methodology for generating primary and secondary data, and how to analyse the data in order to meet the research aim.

4. Results and findings

This chapter is structured over three sections, presenting findings from core concepts in the literature search (section 4.1); emergent concepts from both the secondary and primary data collection phase (section 4.2); and a summary of the findings and how they relate to the understandings of team collaboration (section 4.3). This is used to then motivate a following discussion of the results and their implications (section 5.0).

The structure is intended to reflect and answer the sub-research questions SQ1-3. Specifically, each section is structured by firstly presenting (i) the results from the targeted concept search, (hence answering SQ1 and SQ2); and then by (ii) comparing secondary data with primary data from interviews with practitioners (hence answering SQ3). Lastly, the summary will draw overall understandings (RQ1) to thereby satisfy the aim of the research; to deepen our understanding of heterogeneous team collaboration in DRM, by a comparative analysis with innovation.

Table 1. Summary of secondary data (expanded further in Appendix D):

Field of inquiry	Database	Summary of themes for Boolean Search	Boolean Search returns	Number of texts selected
Heterogeneous teams in DRM				
Disaster Risk Management	Scopus	Collaboration in DRM/DRR; Common ground; Collective decision; Joint Activity; Shared Intentions; Knowledge Transfer	2245	39
TBI				
Computer supported cooperative work	LUBsearch	Computer supported cooperative work; heterogeneous team or group	48	2[1]
Machine Learning	LUBsearch	Machine learning; heterogeneous team or group	709	0[2]
Human-Machine Interactions	LUBSearch	Human-Machine Interactions; heterogeneous team or group	595[3]	0[4]

Table 1 summarises the results of the secondary data search, (variations on Boolean search queries). It illustrates a high number of search returns obtained from 12 Boolean search queries

[1] Indicates the unique number of texts selected. The low number is because many texts were previously selected in the DRM Boolean search results.
[2] Not considered a reliable result. This motivated a search for supplementary literature with Prof. Chaminade, to maintain validity of results and analysis.
[3] Initial search result was 0. Search re-run after analysis was completed, with new result, suggesting a problem with this search. Additional motivation for supplementary literature.
[4] Not considered a reliable result. Supplementary literature was sought.

for the DRM field. A lower number of returns came from 3 Boolean Search queries conducted in TBI, due to repeated literature and un-useful returns. Therefore, further discussions with Prof. Chaminade and supplementary literature was sought.

Table 2. Summary of primary data (expanded further in Appendix E):

Interviewee Sex/Gender	Area of expertise	Years of experience	Interview time (mins)
Disaster Risk Management			
M	Swedish Fire Service; MSB; UNHCR; WFP	20	21
F	MSB; UNDP; Swedish Red Cross; Lund University	19	30
M	WFP Logistic Coordinator; Lund University	6	32
M	Swedish Military; Swedish Rescue Agency; MSB; Lund University	9	29
TBI			
M	Software development team leader	10	42
M	Wireless communications specialist; International team technical lead	10	20
M	Archaeologist; Assoc. Prof. of Digital Archaeology, Lund University	10	38
F	Biopharmaceutics research specialist; Inter-disciplinary team coordinator	16	21

Table 2 illustrates a concentration of expertise among DRM respondents, focused on MSB and Lund University, suggesting potential homogeneity. TBI interviewees were well represented across a breadth of fields, illustrating heterogeneity of expertise. Generally, the sex/gender representation in both fields showed under-representation of females, with only two out of eight interviews conducted with women. All interviewees had ten or more years of experience, lending reliability and credibility to the data they provided.

4.1 Core concepts for DRM team collaboration – SQ1

The earlier presented core concepts of team collaboration were strongly supported in targeted search results and supplementary literature.

4.1.1 Shared Intention, common ground and joint activity

i) Shared intention, *common ground* and *joint activity* were well-represented in literature findings. Results confirmed a need to continually establish and maintain *common ground*, as DRM teams regularly work in scattered locations and complex-dynamic situations (Convertino et al., 2011b; Noran, 2014; Wu, Convertino, Ganoe, Carroll, & Zhang, 2013). For *Joint activity* the findings continually referred to DRM activities involving a diverse array of actors, working together in multi-organisational systems and using interdisciplinary interactions (Convertino et al., 2011b; Kapucu & Garayev, 2011; Nadi & Edrisi, 2017; Noran, 2014; Uhr, 2017; Wu et al., 2013).

ii) All interview respondents, from both DRM and innovation, expressed strong recognition of the need for *common understanding* and a *shared intention* among their teams, when conducting *joint activity* between multiple actors.

When commenting on collaboration requirements, DRM respondents were particularly supportive of establishing common ground. A highly experienced DRM practitioner with the Swedish civil contingencies agency (MSB) and the UN World Food Program (WFP) stressed the importance of "*the same perspective that we are doing this together*"; and how "*it's much easier to be flexible if you have a common platform to work from"*. Similarly, a DRM practitioner with experience at MSB, the UN Development Programme (UNDP) and Swedish Red Cross, stated that "*together we provide comprehensive perspectives*"; however, "*If they don't buy into the common vision, that creates a problem*"; and "*one critical thing is shaping that common vision*". Furthermore, she stated that effective team collaboration in DRM requires "*knowing the people (...) have the kind of people who have worked together previously (...) that really helps you to get things done*".

A former WFP logistics coordinator noted that in multi-team systems "*you have to build strong relationships within and across organisations*"; that "*teams need to pull in the same direction*" for successful joint activities; and "*I think that's why it's really important on this global level to have these cluster settings, so (the team says) let's do this together"*. These responses indicate a strong acceptance of *common ground* and *shared intentions* when undertaking *joint activity*.

Interviews with TBI practitioners from different disciplines also supported these core concepts. For example, a research specialist and team leader in biopharmaceutics stated:

> *"There must be a willingness and a desire to succeed from every member in that team; and I think that's totally crucial to actually have a successful outcome. So, that is the priority"*; and this can only occur *"when you understand what your task is and you move towards a common goal".*

The biopharmaceutics specialist further noted the importance of *shared intention*, stating:

> *"If you come from different angles you have different realities in your backpack, so to speak (…) however, you need to understand where you fit in the holistic view of things and what is your mission. So, it needs to be clarifying the issue, and actually have a mutual understanding that that is the issue".*

This speaks very strongly to the notion of *shared intention*, which was similarly expressed by a professor of digital archaeology, who noted: *"It's a question of establishing something new, which demands a specific level of listening and a collaborative attitude from all the field".* Finally, a team leader for software development stated: *"your team is basically willing to bridge the differences between each other"* and *"all the teams (…) regardless of background, have a sense of direction".*

What these findings show is that the basic concepts of team collaboration, where *shared intention* and *common ground* are needed in *joint activity*, compare well with the experiences of practitioners who were interviewed. These concepts were represented in both secondary and primary data across various fields. While the specific terms used by practitioners varied, we can see from these results that general concepts of collaboration outlined in section 1.6 (How does a team collaborate?) compare well with the practical experiences, in both DRM and TBI.

4.1.2 Situation awareness and knowledge transfer

i) Situation awareness was well-represented in the findings of both secondary and primary data. Secondary data regularly called for the maintenance or improvement of *situation awareness* in DRM team efforts (Ginige et al., 2014; Sapateiro & Antunes, 2009; Van de Walle et al., 2016; Wu et al., 2013). The literature also discussed the difficulties of DRM teams who attempt to maintain their *situation awareness* in complex-dynamic DRM situations (Artman & Garbis, 1998; Grabowski & Roberts, 2016; Mathieu et al., 2008).

Knowledge transfer was well supported and strongly connected with *situation awareness,* given the specific challenges for DRM contexts (Eriksson, 2009; Ginige et al., 2014; Marsden, Treglia, & McKnight, 2012; Militello, Patterson, Bowman, & Wears, 2007; Wu et al., 2013). Maintaining *Situation awareness* requires *knowledge transfer* through communication and information flows, with technology used to improve effectiveness in DRM contexts (Fleştea, Fodor, Curşeu, & Miclea, 2017; Ginige et al., 2014; Marsden et al., 2012). Supplementary literature provided by Prof. Chaminade also recognised the importance of *knowledge networks* in complex systems. Specifically, *knowledge networks* are crucial in combining and diffusing knowledge (Chaminade & Vang, 2008), and are critical features of any industry in a field of rapid technological progress and change (Powell & Grodal, 2005, p. 58).

ii) Situation awareness and *knowledge transfer* was well-supported in the interview findings, with responses covering issues of communication, adaptability and transferring knowledge across diverse teams. For example, DRM interviewees discussed the importance of daily briefings, with almost all DRM interviewees calling for "*regular coordination meetings"* or "*regular coordination mechanisms*" to maintain situation awareness. The DRM practitioner experienced at MSB, UNDP and Swedish Red Cross stated:

> *"We cannot work in silos in this sector, these are interconnected"; "as the team leader you have to have a consultative process, you know, that engages everyone, to make use of the diversity (…) the diversity should sit with everyone, not just the leader".*

The DRM practitioner with Swedish military and MSB experience stated:

> *"we have a round-table (…) everybody gets to give some input of what they are doing and how to solve potential challenges (…) you save a lot of time if you have those deliberations".*

Finally, the former WFP logistics coordinator spoke at some length on communication for collaboration, stating that:

> *"people need to be able to communicate with each other. If there are misunderstandings, they can escalate quickly, and you want to come together to sort it out (because) things happen and that's when you just need to adapt".*

The strong support for these concepts was similarly recognised among TBI data. The biopharmaceutics specialist emphasised "*continuous team orientations*", while the professor of digital archaeology similarly stated: *"It's good to explore different directions, but always discuss this together".*

A software development team leader also discussed why *knowledge transfer* is so important, stating:

> *"if you have good communication then you will have a highly effective team"*, and *"it is quite important to have the knowledge spread. Not concentrated to one or two individuals that are seen as experts, but really try to spread it out. So that everybody can pick up whichever"*.

These findings indicate the strength of these core concepts in both secondary and primary data. They indicate the importance of regular communication and discussions, specifically to *share knowledge* across the team and to maintain *awareness* of each other's situation. They also suggest the importance of guiding this process using team structures, management and leadership, which became emergent themes discussed further in section 4.2.

4.2 Emergent themes – SQ1 and SQ2

In keeping with the methodology, the data analysis allowed for emergent themes to arise. The themes emerged from findings in the secondary research, insights from interview responses, and from supplementary readings. They have been grouped here as: 1*) new team perspectives*; 2) *management and leadership*; and 3) *related variety*.

4.2.1 New team perspectives

i) Findings from secondary data suggest that traditional understandings of hierarchies and team structures are proving ineffective for modern DRM requirements, instead requiring new team perspectives. The "increasing scope and frequency of disasters is now beyond the capability of any individual organisation to manage", and "the failure to collaborate effectively is having increasingly dire consequences" (Noran, 2014, p. 1032).

The findings suggested a need to view teams as interdisciplinary, multi-actor collaborations, across the various phases of DRM (Eriksson, 2009; Klima & Jerolleman, 2017; Nadi & Edrisi, 2017). Specifically, collaboration in DRM requires new perspectives of teams as: operating in nested

multi-team systems; using collaborative decision making; sharing common resources across various entities; and working towards commonly held goals (Fleştea et al., 2017; Kapucu & Garayev, 2011; Nadi & Edrisi, 2017; Noran, 2014; Wu et al., 2013).

Team processes play an essential role in building structures that can reflect these new team perspectives. Modern DRM teams require fast and efficient team-structures, capable of handling inherent task complexity yet flexible enough to handle the unpredictability of a fast-changing context (Fleştea et al., 2017, p. 44). Indeed, "effectiveness is influenced by within as well as between team processes (i.e. communication, coordination) and emergent phenomena (i.e. situational awareness)" (Fleştea et al., 2017, p. 44).

ii) The need for new perspectives was strongly reflected in the primary data. All interview respondents discussed in some way the need for adaptability, centred around interdisciplinary collaboration and communication. Two experienced DRM practitioners directly mentioned flexibility to adapt to changing conditions, with one stating: "*things won't get done as planned, so you need to be flexible*". The former WFP logistics coordinator stated: "*when I saw people failing was someone who could not accept that things all the time changed, because everyday things changed"*. He elaborated on how team structures should reflect this constant change:

> *"you have a formal setting in the evening (…) but during the day everything is kind of informal, and during that informal phase things happen, and you need to adapt"*; and *"then you have to just accept that nothing works and you have to have really good people skills to get the people together (…) to try to come up with these structures, are people willing to communicate and collaborate?".*

The need to constantly adapt to changing contexts was also reflected in responses from TBI practitioners. The professor of digital archaeology specifically mentioned how inter-disciplinary collaboration is a way forward in his profession, calling for: "*not only one perspective, but multiple perspectives*". He elaborated on this, stating:

> *"collaboration should happen even earlier. Start discussing (…) how are we going to serve multiple specialists in a proper way?"* and, *"sometimes it's really a matter of putting together people with different skills in the very same room, posing them a problem giving them an instrument and saying, 'well this is your workshop (…) fix it'"*.

This was similarly reflected by the biotechnology specialist, who identified the challenge of harmonising a cross-functional team of experts:

> *"The different interfaces, from the different disciplines (…) either you have a front player from each organization, and that works well with the logic cross-functional teams we usually call them. And those are experts from different professions (…) those need to be quite humble and have to understand the issue and respect each other, to have a successful outcome".*

These findings illustrate how new perspectives are needed for cross-functional teams operating complex systems characterised by ongoing disruptions. However, they also illustrate how management and leadership has a critical role in guiding and implementing these new team perspectives, which forms the next emergent theme.

4.2.2 Management and leadership

i) Management and leadership, as specific terms, were not included in the Boolean search query for secondary data. This is a possible limitation of the research design because *management and leadership* are their own disciplines and were considered outside the scope of the literature review. Therefore, this theme emerged almost exclusively from primary data, illustrating the value of **SQ3** and the combined methods approach.

ii) Almost all interviewees mentioned the function of *management and leadership*, as a requirement for successful heterogeneous team outcomes. All 4 DRM interviewees mentioned the need for regular meetings, guided by a team leader, with clear decision making. There was much discussion of seeking team consensus, with the leader making a final judgement. For example, an MSB practitioner stated:

> *"Everyone has to put the things on the table and in some way, we have to find a solution for that. And when the decision is made, that's final and everyone has to accept the decision and work according to that"*; and "*always try to have a majority decision (…) but the group expects the manager to take a decision"*.

Another DRM practitioner experienced with Swedish military and MSB stated that successful teams required: *"clear instructions; delegation, to make everybody feel sense of ownership for this specific task, which (...) generates motivation and good results"*. The former WFP logistics

coordinator stressed the effect of a good leader on adaptation and collaboration, stating for dynamic and chaotic situations:

> *"How do you react to it? Then you have to have really good leadership. But if the leadership is there and the team is kind of reacting together and pulling together, then it can be really magic happening".*

The emphasis on consensus and leadership could be a product of all interviewees being trained in the Swedish emergency response system. However, the responses were based on experiences in international collaboration, which might mitigate against this potential Swedish bias. Furthermore, the emphasis on leadership was strongly reflected in the TBI interview data.

All TBI interviews regularly referred to *management and leadership* as important for successful team outcomes. A software developer, commenting on implementing a change or decisions, stated: "*somebody needs to pick it up from a higher level, so it could be pushed through all the teams*", while a second developer also noted "*leadership (...) I would say that you need some kind of strong coordination or management"*. The biopharmaceutics specialist also discussed leadership in guiding a heterogeneous team, stating:

> *"The leader of the cross-functional team has a really important role to play there, to lay out what is really the issue and to put it to every member of the cross functional team (...) you need to prioritise what is actually the real issue and where does it lay".*

The importance of *management and leadership* in guiding a heterogeneous team led to the emergency of the final theme, *related variety*.

4.2.3 Related variety

i) *Related variety* is the notion that diversity needs to be complementary, for optimal team outcomes. While heterogeneous teams generally tend to out-perform homogeneous teams with improved innovation outcomes (Østergaard, Timmermans, & Kristinsson, 2011), the effect is limited and dependent on the *types* of heterogeneity (Horwitz, 2005, p. 230). Indeed, heterogeneity can conversely increase team conflict, complicate internal communication and hamper coordination within teams (Horwitz, 2005, p. 230). This is perhaps because increasing team diversity simultaneously increases the need for interactions and communication, to avoid conflict and distrust (Østergaard et al., 2011, p. 3).

Related variety is the spill-over of knowledge across shared and complementary sectors (Asheim, Boschma, & Cooke, 2011). It is a term taken from innovation-specific literature provided by Prof. Chaminade. It recognises the importance of bringing together different, but complementary, knowledge bases (Asheim et al., 2011). What *related variety* indicates is that team diversity and heterogeneity need to be somehow selectively managed, to ensure the diversity is complementary.

ii) *Related variety* as a theme was strongly reflected in interview data, with almost all respondents discussing culture and diversity. DRM respondents working internationally spoke strongly on managing cultural diversity. An MSB team leader noted:

> *"One big issue is always the cultural awareness, especially on an international mission because you go to another country and it's a different culture and you have to adapt and make sure that the whole team work according to standard for the cultural awareness"*.

Similarly, a DRM practitioner with MSB, UNDP and Swedish Red Cross experience stated:

> *"even as the team leader, you have to have a consultative process that engages, to make use of the diversity"* and, *"diversity is not just within the international community, it has to expand out to the affected population"*.

Finally, a DRM practitioner with MSB and Swedish military experience referred specifically to the value of gender diversity, stating:

> *"also, very important is to mix gender in the teams. Both because I believe females and males can reach out to different groups, but also because within the team (...) the atmosphere is always better when it's about half-half"*

Related variety was also represented in data from TBI interviews, with all respondents discussing inter-disciplinary teams and cultural diversity. A software developer, discussing Swedish and Chinese international collaboration, stated *"You have to respect that the culture brings maybe different qualities to each other, so there are some good things (that) happen".* Another software development team leader also discussed the issue of creative divergence, what he termed "*releasing the steam".* This was an acknowledgement that arguments among team members were often constructive, even necessary, in the collaborative process: *"even if a team is a little bit dysfunctional, if they have an opportunity to release the steam, it actually works".*

What we see here is the theme of *related variety* being managed by leaders. Creative tensions, within and across teams that are well-managed by the team leader can lead to breakthroughs, insights and innovations. As Denise (1999, p. 3) stated, “collaboration is not about agreement. It is about creation”.

4.3 Summary of results

We can see strong evidence, in both secondary and primary data, for core concepts sought in **SQ1**. Namely, that the performance of heterogeneous team collaboration in DRM relies on inter-linked functions of *common ground, shared intention* and *joint activity*. These are an essential foundation for effective collaboration to occur. In addition, teams need to maintain their *situation awareness* through ongoing *knowledge transfer*; to remain aware of one-another’s actions and to adapt effectively to inevitable disruptions, in complex-dynamic situations.

The comparative analysis between the fields of DRM and TBI was useful for testing and uncovering just how important core concepts are to both fields. This provides a broader answer to **SQ2 –** that our understanding heterogeneous team collaboration *can* be improved through a comparative analysis between DRM and TBI. The emergent concepts of *new team perspectives*, *management and leadership*, and *related variety* provided useful insights into DRM team collaboration. *Related variety* could be argued as a new insight into DRM team collaboration, as this concept did not appear in the background research or core concepts for **SQ1**. Similarly, the need for *management and leadership* in guiding collaboration and diversity confirms the importance of leaders, or leading organisations in collaborative clusters. It could also motivate further research on how to achieve this.

The emergent themes and the interplay between secondary and primary data, also provides an answer for **SQ3.** The testing and comparing of core concepts was deepened by the practical experiences of practitioners from both fields. The background concepts presented in section 1.6 were strongly represented in primary and secondary findings, bolstering them as *core concepts* of heterogeneous team collaboration. In addition the emergent themes and new insights provide additional perspectives and knowledge, for a deepened understanding of how to improve heterogeneous team performance in DRM.

5.0 Discussion of results – RQ1

In this section, the findings are combined to seek an answer to the overall research question, **RQ1:** *What -if any- insights concerning how to improve team performance can be drawn from the concepts and experiences of heterogeneous team collaboration, by comparing TBI to DRM?*

The findings showed strong complementarity between the fields of DRM and technology-based innovation, evident in both secondary and primary data. Secondary data was sourced from reliable databases, and similarly primary data was generated from highly experienced professionals in a variety of fields. DRM Interviewees were strongly represented from Swedish emergency response sectors (MSB and Lund University) which could introduce homogeneity. However, all DRM respondents were exposed to international collaboration experiences, which arguably mitigates against homogeneity. Although gender diversity was sought, female representation was low which could affect primary data.

The findings revealed nuances, emergent themes and indicated limits to beneficial diversity and team heterogeneity. Core concepts were found to be strongly represented in both fields of DRM and innovation. This was expected, as the background research had identified high complementarity between the two fields. The use of innovative technology in DRM contexts has long been integral to DRM operations, and ongoing research into technology is rapidly advancing in areas of human-machine collaboration and communication. It was thus expected these two fields would hold similar conceptual understandings, which was confirmed.

Where the findings yielded insights (**RQ1**) was in the data analysis for emergent themes. The findings uncovered the importance of divergence and disagreement, in fostering creative collaboration. This appears perhaps more relevant to TBI, however practitioners in DRM regularly stressed the importance of airing grievances and discussing issues daily, so the team could maintain common ground and coalesce on agreed strategies (joint activity). The importance of divergence and disagreement was unexpected and could potentially constitute a new insight.

Similarly, the importance of managing diversity through *related variety*, or a sense of complementarity among collaborators, was an unexpected finding from innovation. Unrelated diversity, where team members are too diverse such that they have insufficient *common ground*, low *shared intentions* or conflicting goals (low *joint activity*), is not necessarily beneficial, despite ideals of diversity and inclusion. This conforms with notions of *common ground* and *shared*

intentions; whereby collaborators might appear on the outset to have high heterogeneity, however their *variety* is still *related* to each other and therefore beneficial because of their common purpose, shared mission, or simply a mutual willingness to collaborate.

Related variety was perhaps the most interesting finding. The use of a comprehensive analytical framework in the methodology offers the opportunity to apply this finding to various scales of collaboration. It can be argued that the principle of *related variety* applies from smaller teams, to nested team systems and even to macro levels of national and supra-national collaboration. Of particular interest was that heterogeneity may impose costs as well as benefits, to the point where un-managed heterogeneity can risk dysfunctional collaboration. Careful management of *related variety* and commitment to it by participants at all levels of collaboration are therefore required to achieve the desired beneficial effects and avoid the dysfunction that can arise from *unrelated variety*. This finding may have implications to heterogeneous collaboration, beyond the field of DRM.

Finally, the importance of *management and leadership* emerged as necessary to guide heterogeneous teams. This is against a move towards consensus culture and egalitarianism in modern team collaboration. While consensus and equality among teams was mentioned, as a function of mutual respect, there was also strong data on the expectation of leaders to take decisions and steer teams. DRM respondents also mentioned training and education in advance of collaborative missions, to establish common ground in teams. Technology-based innovation respondents similarly mentioned trust, built up from previous collaborations, as essential in handling disagreements. This offers some insight into how to *management and leadership* can prepare teams to handle *related variety* and creative divergence, in advance of collaborative ventures.

What the findings did not show was how technological innovations should be developed or adopted by DRM teams, such as CSCW and Human-Machine Interactive systems. The research did not yield insights into the many rapid advances in this field or how they can assist DRM collaboration. For example, *Artificial Intelligence* (AI) offers a vast potential for improving the efficiency of decision making and prediction-models in complex situations. AI has enormous relevance for DRM collaboration requirements, particularly during disruptions or uncertainty, potentially assisting in complex-dynamic situations. The way in which human teams can collaborate in partnership with AI/machine systems is a vast and accelerating field of

development, that went surprisingly un-mentioned in the data. Increased research on human-machine collaborative systems could potentially yield breakthroughs to persistent problems faced in DRM collaboration.

6.0 Conclusion

"He who knows only his own side of the case, knows little of that"

- John Stuart Mill, *On Liberty* (1869)

This research began as an investigation into the benefits of heterogeneity and inter-disciplinary collaboration, by comparing two related but different fields. As Mill (1869) famously alluded to in his defence of free speech, we must know opposing viewpoints and perspectives if we are to understand our own more completely. We benefit from seeking heterodoxy over orthodoxy. However, in complex-dynamic situations heterogeneity also imposes costs. It was found that while heterogeneity can hold significant operational benefits, if managed properly and when *related variety* exists among participants; conversely, mis-managed heterogeneity and a strong level of *unrelated variety* can be dysfunctional or detrimental to collaborative performance, at various system levels.

To obtain the findings, a research method was designed to compare core concepts and seek emergent insights from secondary and primary data. A combined methods approach was adopted specifically to allow for unexpected insights, and the analysis similarly relied on emergent themes in the data. This was in keeping with the conceptual framework to define teams according to their emergent properties, thereby allowing for teams to be assessed across all DRM phases and temporal conditions (*mitigation*, *preparedness*, *response* and *recovery*). The comparison of secondary and primary data across two fields successfully led to several insights for heterogeneous team collaboration in DRM.

A first finding was that it is possible, indeed necessary, to consider teams from a complexity perspective rather than prescribed team taxonomies; by allowing for emergent properties. This is because the sheer variety of contexts and objectives for DRM teams makes the use of prescribed team-types and taxonomies difficult, to the point of being unworkable. However, the use of complexity theory facilitates the analysis of various team types, via their core concepts and emergent themes.

A second finding was that DRM and innovation are highly complementary fields, operating in similar contexts of complexity, disruption and inter-disciplinary collaboration under pressure. This was suggested in the initial background research and confirmed through the research process, across both fields. The findings consistently illustrated similar contexts; of high uncertainty, rapid changes, and a high reliance on heterogeneous team collaboration, in both DRM and TBI. Accordingly, the benefit of comparing these two fields and sharing insights or lessons between them can be considered a strong finding.

A third finding was that understanding heterogeneous team collaboration should include the emergent themes of: *new team perspectives*, *management and leadership*, and *related variety*. *New team perspectives* suggest the recognition of the complex-uncertain contexts in DRM and the need for new ways to understand team collaboration. *Management and leadership* suggests the importance of techniques and training for managers, to guide teams. *Related variety* suggests that heterogeneous collaboration can both benefit and fail from heterogeneity depending on the level of *related variety* among participants; challenging (perhaps controversially) the notion that diversity is a monolithic virtue, without any costs or risks of dysfunction.

A fourth finding was an insight that DRM team management should somehow foster divergence and the sparks of dissent, if collaboration is to be truly innovative and beneficial. This shows that while the research confirmed it is worthwhile to seek insights for DRM from TBI, there remains uncovered territory in this area with far more scope to improve our understanding of heterogeneous team collaboration. This is perhaps expected, given the rapid pace of technological innovation. It suggests exciting scope for further research into emerging technologies and their use in DRM, which is covered further in section 7.0 Recommendations.

7.0 Recommendations

This section presents a series of recommendations, covering potential future research areas and lessons for DRM to improve performances of heterogeneous team collaboration.

Of all the findings, the concept of *related variety* is perhaps the most novel for DRM collaboration. How to create team structures and processes that allow for – and even foster – creative tensions and disagreements among collaborators? More-so, how to do this in complex-dynamic situations characterised by stress, disruption and various layers of cultural differences and heterogeneity,

while still maintaining a workable level of harmony? The findings suggest a strong role for *management and leadership* in this process, to actively guide team diversity and variety. More research to improve *related variety* could yield significant benefits in meeting DRM objectives. Recommendation 1 - to investigate how team processes or leadership training might be designed to facilitate divergence in teams, while still enabling harmonious collaborations and improved effectiveness.

DRM respondents mentioned team processes and leadership techniques that were effective in managing *related variety*. The use of background reviews of team members' profiles was an effective way to know and understand their competencies. Introductory meetings were also used as a way for unfamiliar team collaborators to describe themselves and to receive a briefing of the competencies needed for task completion. This process enabled team personalities and competencies to be balanced and matched the task requirements. Recommendation 2 - to develop and standardise the practice of team selection and task distributions, across more sectors and phases in DRM.

The importance of *management and leadership* in handling related variety also extends from the individual team leader to the role of lead-organisations in cluster systems. Furthermore, any move towards consensus collaboration should be resisted and instead the primacy of leaders and lead-organisations should be maintained. In addition, structures and training should continue to recognise the importance of *management and leadership*. This is not to remove the role of consensus, but rather to maintain a structure that gives a central figure or cluster-lead the final authority in needs to guide a team decisively. Recommendation 3 - to maintain the primacy of leaders and lead-organisations so that final authority is recognised and to resist any move towards consensus collaboration.

The use of technology to improve knowledge transfer and situation awareness in DRM contexts was often repeated in the data. Based on this finding, a recommendation is to continue and improve training among DRM practitioners in their ability to collaborate using emerging technology, such human-machine interfaces and *Artificial Intelligence* systems. This holds exciting potential for managing complexity and would resonate with the emergent theme of *new team perspectives*, which calls for adaptable team processes in highly dynamic situations. A further recommendation is to develop a process of identifying and adopting ongoing innovations in communication and technology. Such innovations hold huge relevance to DRM collaboration.

Developing a process of identifying, testing and adopting innovations would recognise and incorporate this constantly shifting space, for the betterment of DRM outcomes. Recommendation 4 - to improve the ability of DRM practitioners to collaborate using emerging technologies. Recommendation 5 - to develop systems and practices to better identify and adopt ongoing innovations in communication and technology.

7.1 Future Research

Further research might include how to assist and train team leaders, to better manage or improve the *related variety* of their DRM teams; to guide team heterogeneity as an ongoing benefit. Similarly, future research could also include training for DRM team leaders and organisations in how to manage *related variety* at different levels of teams, through creative disagreements; to ensure a positive use of disagreements to improve collaboration and innovation. Significant scope also exists for future research into identifying and adopting technological innovations into collaborative DRM processes. Advances in CSCW, Human-Machine Interactions, Artificial Intelligence and Blockchain are accelerating rapidly. A *process* might be researched into how to identify, test and adopt these advances into the DRM field, as they will inevitably occur with accelerating pace. The field of innovation could provide exciting insights into such a process.

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9.0 Appendices

Appendices A-D cover the secondary data for concept review, including: identifying databases, searching terms, selecting publications and analysing results.

Appendices E-G cover primary data including: interviews, questions, interviewee selection data coding and analysis.

Appendix A: System for identifying relevant publications and studies

Beerens and Tehler (2016) conducted a scoping study for Disaster Risk Reduction, which was adapted to create the system for the core concept review. This system involves: 1) *identifying relevant databases* (i.e. where to search); 2) *search query identification* (i.e. how to search); 3) *selection of results* (i.e. which publications to include/exclude); 4) *overall analysis* (i.e. what was found in the literature); and 5) *results and review* (i.e. what are the relevant concepts). Their system was adapted to this research as outlined below.

Identifying relevant databases

A broad initial search was first conducted using Lund University's LUBSearch database, to provide background understanding, and to identify the underlying assumption of a comparative potential between innovation and DRM. This pre-search was used to cast a wide net to build an early understanding of the topic (Flowerdew & Martin, 2005) and prepare for the targeted literature search. Scopus (Elsevier) was then used for the targeted literature search, due to its wide indexing of peer-reviewed material.

Search query identification

Creating the search query required some consideration on terminology, owing to a 'semantic fog' from nearly 50 years of discussion on collaboration in DRM (Uhr, 2017). For example, "concepts such as management, command & control, and coordination have many meanings and are used inconsistently" (Uhr, 2017, p. 12). Ergun et al. (2014) also noted that collaboration is frequently conflated with coordination and cooperation in DRM literature. As a result, synonyms and search variations were required to adequately cover terminology overlap, discussed further in Appendix B.

Specific search terms were based on concepts identified in the background readings. The results of these readings provided strong emergent concepts, including: *shared intentions* (Bratman, 1992; Gilbert, 2009; Searle, 1990; Tomasello & Carpenter, 2007; Tuomela & Miller, 1988); *common ground* and *joint activity* (Clark, 1996; Convertino et al., 2011b; Klein et al., 2005; Wollocko, Farry, Voshell, Jenkins, & Pellicano, 2015); *situational awareness* (Artman & Garbis, 1998; John M Carroll et al., 2003; Endsley, 1995; Sapateiro & Antunes, 2009); and *knowledge transfer* (John M Carroll et al., 2003; Convertino et al., 2011b).

Search query system

The search query adopted a Boolean approach, using concepts from the research aim (See Appendix C for specific concept synonyms and variations). Distinctive concepts from the research aim are: (a) collaboration; (b) heterogeneous teams; (c) disaster risk management; and (d) innovation. While a number of variations were used (see Appendix B), the queries were focused either on DRM [concepts (a) AND (b) AND (c)] or technology-based innovation [concepts (a) AND (b) AND (d)]. For example:

DRM concept search =(a) AND (b) AND (c)
=(*collaboration* OR *cooperation* OR *coordination*)
AND (*heterogeneous* AND *team* OR *group*)
AND (*emergency*)

Terms used for search query

Concepts and key phrases used were the following:

(a) collaboration, cooperation or coordination; common ground, awareness, collective decision, joint activity, shared intentionality;

(b) heterogeneous team or group; team diversity; team or group diversity;

(c) emergency, crisis, disaster, disaster risk management or reduction, complex;

(d) innovation, computer supported collaborative work, CSCW, machine learning and artificial intelligence.

The motivation for these specific search terms is outlined further in Appendix B

Filters applied in search query

Search results were filtered, ranked and then selected using a system of inclusion/exclusion and author judgement. Results were first filtered using 'peer reviewed only' and 'accessible to Lund University'. An additional search exclusion was applied to search results over 1,000 hits, which was the search term 'AND NOT TITLE-ABS-KEY (*medical*)'. This term was applied because searches related to *emergency*, *crisis* or *disaster* frequently returned a high number of publications specific to medical emergencies and medical research, which was outside the research scope.

Ranking

Search results were first ranked by order of most highly cited, and then by order of newest publications first. The rationale for using two rankings was to first identify core concepts from the most highly cited publications (seeking to address RQ1); and then to identify recent innovations via newly published material (seeking to address RQ2). For each ranking, the first 100 hits per page were displayed on a page, from which the most relevant articles were flagged to view their abstracts. The number 100 was chosen because of the amount of 'noise' from overlapping concepts, terminology and emergency disciplines (particularly health and medical research); this provided a coverage of the literature, while also allowing for the 'noise' of publications from the many 'emergency' disciplines.

Final selection of publications

The 'most relevant' publications were determined by combining a selection system of inclusion/exclusion parameters, and final author judgement. The selection system involved comparing title, keywords and database against a set of specific inclusion/exclusion parameters outlined in Appendix B. Final author judgement was then applied, by viewing the abstract, and comparing the publication emphasis and keywords against the stated research aim. A final set of articles were chosen according to this system, with search results and selected publication numbers from each search query variation being included in Appendix C.

Appendix B: Specific search term variations

A backwards review was first conducted for references used in the articles "Common ground and coordination in joint activity" (Klein et al., 2005) and "Knowledge integration and innovation: Critical challenges facing international technology-based firms" (Berggren, 2011). These two articles were provided by research supervisor Christian Uhr, owing to their relevance to DRM and collaborative team innovation. In addition, an initial concept search was first conducted as background research, to determine which team collaboration concepts would guide the specific Boolean search variations.

Identifying these search terms was guided by publications from: 1) John M Carroll et al. (2003) on 'Notification and awareness: synchronizing task-oriented collaborative activity'; and 2) from Klein et al. (2005) on 'Common ground and coordination in joint activity'. These publications were identified from consultations with supervisor Christian Uhr, and held relevance for both DRM. From initial publications, further terms were gathered from regularly occurring synonyms, conflations, or terms being used interchangeably, such as '*collaboration'*.

Concept (a) 'collaboration'.

The synonyms used for collaboration were coordination and cooperation, searched together as (*collaboration* OR *coordination* OR *cooperation)*. These three specific words are frequently conflated in literature (Ergun et al., 2014) which is why they were searched together using the Boolean 'OR' operator.

Additional search terms were gathered from initial background search of related literature. The literature indicated a variety of collaboration concepts and terminology common to both fields (Convertino et al., 2011a; Ergun et al., 2014; Klein et al., 2005; Uhr, 2017), along with new developments occurring in TBI (John M. Carroll et al., 2006; Klein et al., 2005; Koschmann, 2016; Tenenberg et al., 2016) .

The resulting terms were: *situation awareness*, *common ground*, *collective decision making*, *joint activity*, *shared intention* and *diversity*.

The terms *command* and *management* were not included in concepts because of the specific aim to direct research towards horizontal team collaboration and away from hierarchical team top-down command. This was based on the international cluster system, and the use of collaborative

team management. In addition, management and leadership is a broad topic in itself, and this considered outside the scope of this project.

Concept (b) 'heterogeneous teams'.

The terms used were: *heterogeneous, team, group* and *diversity*. These terms were selected to reflect the research aim for heterogeneous teams.

Search term (c) 'disaster risk management'.

Terms searched were e*mergency*, c*risis* and *disaster risk*. These terms were gathered from pre-search readings and in consultation with Christian Uhr. These terms were selected to direct the literature captured from concepts (a) and (b) towards DRM, to therefore address RQ1.

Search term (d) 'innovation'.

Terms used were *innovation*, *computer supported collaborative work*, *CSCW*, *machine learning*, and *human machine*. The terms used in addition to *innovation* were garnered from pre-readings, where significant work was noted in the fields of CSCW and H-MI collaborations (John M. Carroll et al., 2006; Ergun et al., 2014; Ginige et al., 2014). Additionally, these terms were used to focus literature towards technology-based innovation, to therefore address SQ2.

Inclusion/exclusion criteria was developed under guidance from supervisor Christian Uhr, and adopting a framework taken from a recent scoping study conducted by Beerens and Tehler (2016). This study and framework was chosen because of its specific focus on DRM literature, providing a useful framework to adapt to this project; and because of the systematic reasoning provided for including/excluding material, which was a valuable influence.

Appendix C: Inclusion and exclusion criteria and rationale

Appendix table 1. Inclusion/exclusion criteria and rationale:

		Rationale/Comments
Inclusion criteria		
I1	Full text available in English	To be understood and analysed, the publication must be in English.
I2	Journal is peer reviewed	Use only peer-reviewed publications for specific concept search (not background search)
I3	The paper will contain 3 of the 4 research concepts; I.e. (a)AND(b)AND(c); or (a)AND(b)AND(d)	Using search concepts directed the concept review to either DRM or technology-based innovation studies.
I4	Papers accessible to Lund University	For practical reasons, the search will only include studies accessible at Lund University
I5	Full text is accessible	Concept review will rely on full availability of knowledge contained within the article.
Exclusion criteria		
E1	Answer is “no” to I1 to I5	Inclusion criteria is prioritised.
E2	Studies related to risk management outside the defined boundary analysis and limitation	Only studies relevant to DRM will be included; not other forms of risk management in other industries (eg finance).
E3	Exclude any title, keywords or abstract without explicit DRM or innovation-specific focus	The high quantity of un-related literature containing concepts of ‘emergency’ or ‘risk’ management created significant number of hits. This exclusion was applied to ensure selected literature is relevant to research aim.
E4	Exclude experimental studies	The study seeks to identify differences in ‘established principles’ or practical experiences; experimental findings are therefore considered outside the scope.

Appendix D: Variations on Boolean search queries

The Scopus database was used as a preliminary filter for reliable information, ensuring selection of robust results from academic and peer-reviewed papers. If the search in Scopus yielded poor results, then a search in LUBSearch was conducted. The results of this process are presented below:

Appendix table 2. Presentation of Boolean search query results

Concept search	Database	Boolean search query	Total Hits	Sort by	Selected
Heterogeneous teams in DRM					
1. **Collaboration in DRM/DRR**	Scopus	<collaborat* OR coordinat* OR cooperat*> AND <heterogeneous AND team> AND <emergency>	37	Highest cited	8
2.	Scopus	<collaborat* OR coordinat* OR cooperat*> AND <team OR group> AND <emergency> AND NOT <medical OR health>[5]	1902	Highest cited	6
3.	Scopus	<collaborat* OR coordinat* OR cooperat*> AND <team OR group> AND <disaster risk OR reduc*> AND NOT <medical OR health>	109	Highest cited	3
4.	Scopus	<collaborat* OR coordinat* OR cooperat*> AND <team OR group> AND <disaster risk OR reduc*>	7	NA	0
5. **Situation Awareness**	Scopus	<situation AND awareness> AND <team OR group> AND <disaster risk OR reduc*>	45	Highest cited	3
6. **Common ground**	Scopus	<common AND ground> AND <team OR group> AND <disaster AND risk OR reduc*>	13	Highest cited	2
7. **Collective decision**	Scopus	<collective AND decision> AND <team OR group> AND <disaster AND risk OR reduc*>	22	Highest cited	2
8. **Joint Activity**	Scopus	<Joint AND activity> AND <team OR group> AND <disaster AND risk OR reduc*>	21	Highest cited	16

[5] Large search result from medical-emergency fields required additional filter

[6] Repetition of articles from previous search results leading to low selection number.

9. **Shared Intentions**	Scopus	<Shared AND intent*> AND <disaster AND risk OR reduc*>	10	NA	0
10. **Diversity**	Scopus	<diversity> AND <team OR group> AND <disaster AND risk OR reduc*>	59	Highest cited	1
12. **Knowledge Transfer**	Scopus	<knowledge AND transfer> AND <team OR group> AND <disaster AND risk OR reduc*>	20	Highest cited	2
Technology-based Innovation					
12 **Computer supported cooperative work**	LUBsearch	<Computer AND supported AND cooperative AND work> AND <heterogeneous> AND <team OR group>	48	Relevance	2
13 **Machine Learning**	LUBsearch	<Machine AND learning> AND <heterogeneous> AND <team OR group>	709	Relevance	0
14 **Human-Machine Interactions**	LUBSearch	<Human AND Machine> AND <heterogeneous> AND <team OR group>	0 results	NA	NA

Technology-Based Innovation literature

Boolean search terms for technology-based innovation were intended to seek divergent views, as a way to test the previous DRM concepts. Owing to low or irrelevant article returns, an additional discussion was held with Professor Cristina Chaminade (Innovation Studies; Faculty of Economics and Management; Lund University). Prof Chaminade introduced innovation specific literature that led to the emergent concept of *related variety* – how and why teams ought to manage their heterogeneity in order to improve their effectiveness.

Appendix E: Interviews

Analysis of Interviewees

i) DRM practitioners

4 DRM practitioners were interviewed. All remain active in the field and therefore anonymity is maintained by presenting only the initials of the interviewees. Background and experience was requested however age was not considered.

1. JT: Firefighter and incident commander. 20 years of response experience including: MSB, WFP and UNHCR. Male. 21-minute interview.
2. JIO: International collaboration and development researcher. 19 years of experience in trans-disciplinary humanitarian, capacity development and resilience building projects including: MSB, UNDP and Swedish Red Cross. Female. 30-minute interview.
3. JK: Lecturer in Humanitarian Logistics. 6 years of experience as Logistics Coordinator for WFP. Male. 32-minute interview.
4. PM: Researcher in risk analysis and crisis management. 3 years of experience coordinating international DRR-projects and humanitarian operations at MSB (Swedish Civil Contingencies Agency); 6 years of experience as process leader for Swedish Rescue Services Agency; unspecified years in Swedish Military. Male. 29-minute interview.

ii) Technology-based Innovation Practitioners

4 Innovation practitioners were interviewed. All remain active in the field and similar to DRM, anonymity is maintained by presenting only initials of interviewees. Background and experience was requested however age was not considered.

1. MP: Team leader in software development. 10 years of experience as a senior software developer including on-site support in international collaborations. Male. 42-minute interview.
2. MhL: Wireless communications specialist, technical lead and product team leader. 10 years of experience in telecommunications industry including collaboration between Sweden and China for product development. Male. 20-minute interview.

3. NDU: Assoc. Professor of digital archaeology. 10 years of experience in international archaeology projects and research into design science, humanistic lab and digital archaeology. Male. 38-minute interview.
4. UT: Research scientist and team leader in Biopharmaceutics. 15 years of experience in international and inter-disciplinary research. Female. 21-minute interview.

Appendix F: Interview questions and guide

The text below is an email sent to all interviewees prior to the interview. The text showed the research title, introduction to the research and context, interview structure, and specific questions.

Research title: "Improving collaboration among heterogenous teams in disaster risk management: lessons from innovation".

Introductory Description and Context:

Disaster Risk Management (DRM) is a field that is heavily reliant on heterogeneous team collaboration; involving diversity and complexity, in both team compositions and operating environments. Ongoing issues in DRM team collaboration suggest that room for improvement exists, in our understanding and application of heterogeneous team collaboration. Developments in the field of machine learning and computer supported cooperative work (CSCW) are re-examining and refining previous definitions of team collaboration. The field of innovation is highly comparative with DRM, being characterised by disruptive and dynamic environments and the need for novel collaboration. This research aims to improve our understanding of team collaboration in DRM, by comparing core theories and practical experiences with those emerging from fields of 'high-tech innovation'. In doing so, this research will seek to identify what -if anything- can be added to our understanding of DRM team collaboration, by drawing lessons from teams collaborating in 'high-tech innovation'

Interview Structure:

Interviews will be semi-structured, with a length of 20 minutes.

The interview will open with the above paragraph, followed by an explanation of the ongoing challenges of heterogeneous team understanding and the intention of these interviews to provide a foundation for comparison and analysis of team theories and practical experience.

Two broad themes will be used for the subject to answer directly, namely 'what works', and 'what does not work' in heterogeneous team collaboration. Additional questions will be used to establish subjects' operating context and experience, for analytical requirements.

A reminder will be provided to all interviewees that for the purpose of analysis, the interview will be recorded, with notes taken during interview. The subject will be requested for permission to quote where needed and will be given permission to remain anonymous if desired.

Interview Questions:

Opening questions:

i) Please state your current role and organisation, and the field in which you operate.

ii) Please state previous roles (if any) you have held, in which collaborative team functions were needed.

iii) Please state your academic background, and professional training/experience.

Central Questions:

1.1 "What worked?" - in your experience of heterogeneous team collaboration, what factors existed to create successful team outcomes?

1.2 Similarly, what factors were absent that could have strengthened successful team outcomes, if they had been present?

2.1 *"What didn't work?"* – in your experience of heterogeneous team collaboration, what factors existed that hindered successful team outcomes.

2.2 Similarly, what factors existed that, through their absence, might have hindered successful team outcomes?

3.0 other information:

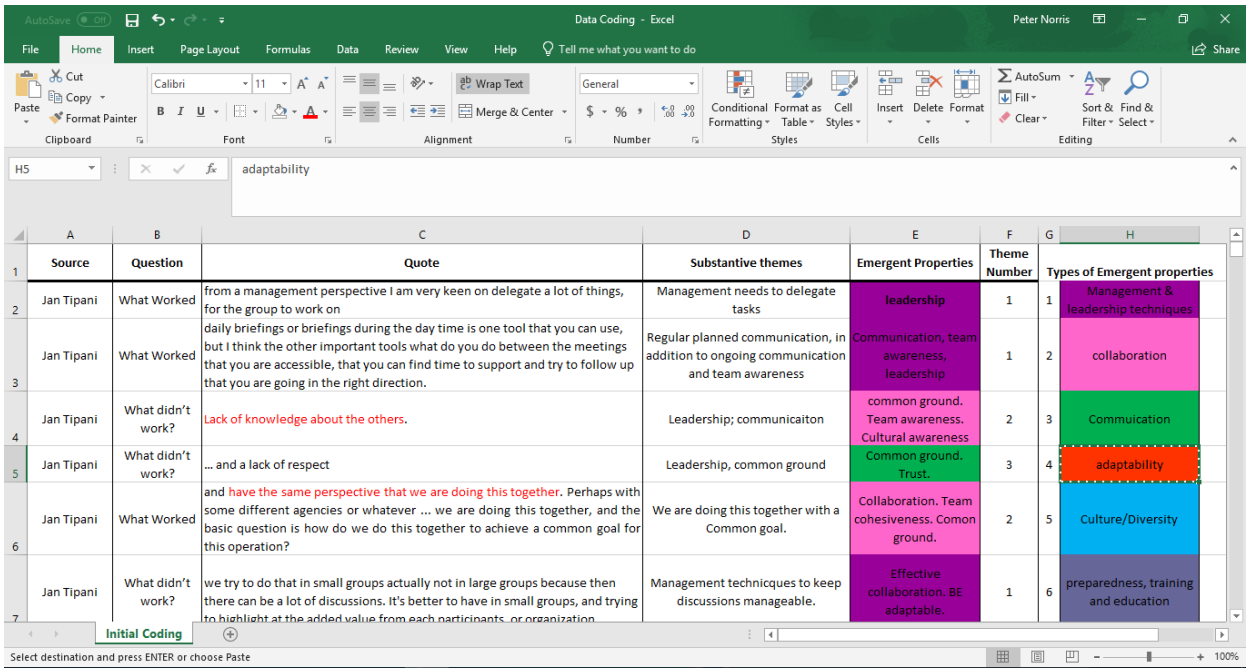
That concludes the formal questions. However, are there any other statements, information or ideas you might like to add from your experience in team collaborations? Is there anything additional that you think could be better understood to improve heterogeneous team collaboration?

Appendix G: Primary Data Coding

Attached here is a screen grab of the Excel file and method used for data coding. The process was open, manual coding. Interviews were first transcribed from audio to MS Word, after which important quotes were entered into the Excel spreadsheet.

A first round of coding was run to identify substantive themes. Substantive themes were then grouped again, into emergent properties, which eventually became six emergent themes. These include: 1) Management and Leadership; 2) Collaboration; 3) Communication; 4) Adaptability; 5) Culture/Diversity; and 6) Training and Education (numbered and coloured in the screen grab). The final emergent themes were colour coded to assist in comparisons and analysis.

The use of these emergent themes in the comparative analysis against secondary data is described in section 3.3 Data analysis methodology; and section 4.0 Results and findings.



	Source	Question	Quote	Substantive themes	Emergent Properties	Theme Number	Types of Emergent properties
2	Jan Tipani	What Worked	from a management perspective I am very keen on delegate a lot of things, for the group to work on	Management needs to delegate tasks	leadership	1	1 Management & leadership techniques
3	Jan Tipani	What Worked	daily briefings or briefings during the day time is one tool that you can use, but I think the other important tools what do you do between the meetings that you are accessible, that you can find time to support and try to follow up that you are going in the right direction.	Regular planned communication, in addition to ongoing communication and team awareness	Communication, team awareness, leadership	1	2 collaboration
4	Jan Tipani	What didn't work?	Lack of knowledge about the others.	Leadership; communicaiton	common ground. Team awareness. Cultural awareness	2	3 Commuication
5	Jan Tipani	What didn't work?	... and a lack of respect	Leadership, common ground	Common ground. Trust.	3	4 adaptability
6	Jan Tipani	What Worked	and have the same perspective that we are doing this together. Perhaps with some different agencies or whatever ... we are doing this together, and the basic question is how do we do this together to achieve a common goal for this operation?	We are doing this together with a Common goal.	Collaboration. Team cohesiveness. Comon ground.	2	5 Culture/Diversity
7	Jan Tipani	What didn't work?	we try to do that in small groups actually not in large groups because then there can be a lot of discussions. It's better to have in small groups, and trying to highlight at the added value from each participants, or organization	Management technicques to keep discussions manageable.	Effective collaboration. BE adaptable.	1	6 preparedness, training and education

Appendix figure 1. Coding of qualitative Data