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Improving Emergency Response Operations in Maritime Accidents using Social Media with Big Data Analytics:

the MV Wakashio Disaster Case Study

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Purpose: This paper explores how Big Data Analytics (BDA) emerging technologies crossed with the Social Media (SM) Twitter can be used to improve decision-making before and during maritime accidents. We propose a conceptual early warning system (ComACom) to prevent future accidents.

Design/methodology/approach: Based on secondary data, we developed a narrative case study of the MV Wakashio maritime disaster. We adopted a post-constructionist approach through the use of Media Richness & Synchronicity Theory, highlighting wider community voices drawn from social media (SM), in particular Twitter. We applied BDA techniques to a dataset of real-time tweets to evaluate the unfolding operational response to the maritime emergency.

Findings: We reconstituted a narrative of four escalating sub-events and illustrated how critical decisions taken in an organisational and institutional vacuum led to catastrophic consequences. We highlighted the specific roles of three main stakeholders (the ship's organisation, official institutions and the wider community). Our study shows that SM enhanced with BDA, embedded within our ComACom model, can better achieve collective sense-making of emergency accidents.

Research limitations/implications

Our study is limited to Twitter data and one case. Our conceptual model needs to be operationalised.

Practical implications

ComACom will improve decision-making to minimise human errors in maritime accidents.

Social implications

Emergency response will be improved by including the voices of the wider community.

Originality/value

ComACom conceptualises an early warning system using emerging BDA/AI technologies to improve safety in maritime transportation.

Key words: Social Media, Big Data Analytics, Media Synchronicity Theory, Media Richness Theory, maritime accidents, human error

1. Introduction

Although historically, the number of tanker accidents has fallen, one single incident can have catastrophic and long-term consequences for marine ecosystems, the environment and local socio-economies. Maritime transport accidents are complex and operational responses involve communication, co-operation and co-ordination between a collaborative network of stakeholders. These include institutional (e.g. public authorities, ship owners, ship captains) and non-institutional actors from the wider community (e.g. local and global communities, NGOs, experts). In some cases, where there is a lack of complete and transparent information, decisions taken in response to maritime accidents can potentially cause more harm, with unnecessary loss of life and catastrophic socio-ecological damage.

As Social Media (SM) near ubiquity, the volume of big data continues to grow exponentially. Recent studies have advocated the use of SM as a valuable source of vital information for more effective communications and decision-making in responding to emergencies and disasters (Ngamassi *et al.*, 2019). However, to date, our understanding of the effective use of SM in disaster management is still limited, with many gaps (Liu and Xu, 2018), especially in the context of maritime transport.

In order to improve the quality and outcomes of decision-making in a maritime context, our paper concentrates on three main research questions: (i) how effective is Twitter as a media for enhancing media synchronicity? (ii) how can Twitter improve emergency operations? (iii) how can we implement emerging Big Data Analytics (BDA) techniques to improve SM capabilities useful in risk mitigation and crisis communication?

To answer these questions, we base our study on an in-depth case of the Motor Vessel Wakashio (MVW) that ran aground on the Mauritius coral reef in July 2020, leaking tonnes of pollutants into a protected area, resulting in a national environmental emergency. We show how current communications are largely bilateral within the ship's organisation, consisting of the insurers, the ship owners and the ship's captain. As such, many of the critical decisions related to the accident were taken in a vacuum, lacked transparency and were driven by tensions and trade-offs including competing economic interests (Matos *et al.*, 2020). Our analysis shows that these delays and decisions led to irreversible economic, social and ecological consequences, which could have been avoided.

Through the lens of Media Synchronicity Theory (MST) (Dennis *et al.*, 2008), we explore how SM can improve communications performance for emergency operations in response to maritime accidents. We focus specifically on MST's concepts of conveyance and convergence and its role in decision-making optimisation. Specifically, our study highlights the potential value of including the wider community's 'voice' (citizens, witnesses, NGOs, etc.) in the development of a shared and holistic framework for understanding the causes and consequences of the disaster. By applying a suite of Big Data Analytics (BDA) techniques, Narrative Inquiry and Scenario Building, we illustrate how the final outcomes of the MVW accident could have been improved by preserving human life and marine ecosystems.

2. Theoretical background

2.1 Maritime Transport: an Overview

The merchant ship industry represents over 90% of the world's total freight transport. Over 115,000 vessels distribute 11 billion tonnes of cargo annually (UNCTAD, 2020), and nearly 60% of the world's crude oil is transported via maritime tankers (Burgherr, 2007). Maritime transportation systems are becoming ever more complex, dynamic and highly distributed with many heterogeneous stakeholders. We term these formal institutions, which include (i) the ship's organisation, which is made up of the captain, the crew, the owners and insurance and legal representatives; and (ii) official institutions concerned with public and environmental safety, such as the Coast Guard and Port Authorities who provide shore-based Vessel Traffic Monitoring Services (VTS).

Despite decades of improvement, maritime oil tanker accidents still happen with immeasurable environmental costs and long-term damage (Martins and Maturana, 2010). In this highly competitive global sector, the size of vessels and the volume of maritime traffic are increasing, and with them risk of accidents. Human error has been identified as one of the primary factors in over 75% of maritime accidents (Authors, 2021). To prevent human-based risks, the industry is investing in new technologies, including GPS, that rely entirely on digital communications between ship-to-ship and ship-to-shore stakeholders (Rødseth and Lee, 2015). Their collective aim is to enhance ship-to-shore coordination and communication to improve safety.

2.2 Emergency Operational Response to Maritime Accidents

Disaster management seeks to improve measures related to prevention, mitigation, preparedness, emergency response and recovery through systematic observation and analysis of disasters (Carter, 2008). An effective operational response to unexpected emergency events requires collaboration between multiple public and private agencies distributed geographically (Janssen *et al.*, 2010). In the event of maritime accidents, good communication processes and situational awareness from all parties are critical (Nordström *et al.*, 2016). Situational awareness is the process of obtaining reliable and accurate information to build a coherent and common picture of an emergency situation. It also incorporates sense-making (Weick, 1995), which is the capacity to make sense of a complex situation with high levels of ambiguity and uncertainty. However, with digital media, sense-making capacity can be affected by potentially flawed data and the limited processing capacity of the people who manage those flawed data (Weick, 2009). To address these limitations, we defend the idea that sense-making should include not only maritime professionals, but also the wider community. We maintain that this strengthens and extends situation awareness beyond the formal institutions, by including the interests of the wider community in the decision-making process.

In the case of a maritime accident involving oil spills, immediate action by Search and Rescue (SAR) first responders occurs in four phases (Chemsar, 2019). The first "Awareness Phase," focuses on identifying and gathering relevant information, developing an understanding of the safety status and building scenarios. Second, the "Action Phase" includes risk assessment, rescue plans, understanding and assessing the live situation. Third, the "Operations Phase" involves rescue and evacuation. The final "Concluding Phase", deals with the completion and stabilisation of the situation. This final phase also reports the outcomes and generates learning points feeding forward to marine stakeholders.

A fundamental part of the first two phases is concerned with communicating the safety and threat situation of the accident site, which are critically reliant on rich information that can change understanding within a time interval (Daft and Lengel, 1986). Difficulties can arise due to a lack of a

common understanding and thus sense-making between stakeholders. Using an information-sharing platform can connect different stakeholders to enable them to achieve a co-created operational picture in real time (Treurniet and Wolbers, 2020).

2.3 The role of social media (SM) in disaster response

Social media (SM) is 'made up of various user-driven platforms that facilitate diffusion of compelling content, dialogue creation, and communication to a broader audience' (Kapoor *et al.*, 2018: 536). Over 49% of the world's population now use SM (Statistica, 2020). This is transforming how individuals, communities, and organisations create, share and consume information from and between each other (Aral *et al.*, 2013). Many studies have examined how SM affects organisational outcomes (Demircioglu and Chen, 2019), especially in business, education, and healthcare.

SM has also been used for disseminating information about disasters (Abedin and Babar, 2018), and is considered to be a key contributor to emergency response and disaster management. SM is emerging as a global hub of up-to-date information sources before, during and after a disaster and is proving to be a valuable tool for emergency response. SM can also contribute to disaster resilience, by enhancing 'community preparedness and the ability to respond to and recover from a disaster' (O'Rourke, 2007:25). Apart from serving as an outlet for eye-witnesses in the affected community, it also 'facilitates two-way communication between humanitarian responders and affected populations' (Madianou *et al.*, 2015: 3021), especially in the case of Twitter. All this highlights the importance of the community in supporting public safety measures (White, 2011).

Research in SM applied to the domain of disaster management and emergency response is growing (Kavota *et al.*, 2020). Studies have focused on SM for (i) sharing information during critical events and co-ordinating help, (ii) distributing real-time and timely warnings from formal/official and informal (individuals) sources (Taylor *et al.*, 2012), (iii) establishing situational awareness (Ogie *et al.*, 2018). In these studies, the microblogging site Twitter is ranked among the most popular source of emergency information (Kim and Hastak, 2018).

Over the past decade, Twitter has emerged from being a simple social networking platform to become a global strategic communication tool. Twitter's geo-referencing functionality can provide exact location coordinates of disasters or emergencies, which is critical for accessing and dispersing resources directly to the affected areas (Wang and Zhuang, 2017). User-generated tweets can also be used to coordinate help for victims and empower citizens to become more situationally aware at the time of disaster (Kumar *et al.*, 2020; Akter and Fosso Wamba, 2019). It is being used in increasingly innovative ways by the public during a crisis event (Comrie *et al.*, 2019). Indeed, the majority of studies in this domain have used Twitter as the source of their SM datasets for analysis (Simon *et al.*, 2014; Kavota *et al.*, 2020). In line with other studies, we have selected Twitter as the most appropriate SM platform for our MVW case study.

2.4 Media Richness and Media Synchronicity Theory Enhanced with BDA

Media Richness Theory (MRT) (Daft and Lengel, 1986) has been used for decades to explain the diffusion and use of communications technologies in different contexts. This theory highlights two fundamental outcomes of 'rich media', which are to reduce equivocality and uncertainty. Uncertainty

results from a lack of information, which can be reduced by accumulating more information (volume). Whereas equivocality, means ambiguity resulting from ‘multiple and conflicting interpretations about an organisational situation’ (Daft and Lengel, 1986: 556). This can be addressed by improving the quality of information. Rich media, such as face-to-face, are preferred in the context of decision-making and problem solving, as these facilitate a shared vision and understanding of a situation among several stakeholders.

Arguably, MRT is not sufficiently developed to fully evaluate the novel functionalities and complexities of SM in our context. To better understand the viability of SM including Twitter as an effective and reliable communications medium for emergency response, we apply Media Synchronicity Theory (MST).

2.4.1 Media Synchronicity Theory (MST): *Effectiveness of SM in Emergency Response*

MST extends MRT to incorporate the ability of a medium to support synchronicity, a shared pattern of coordinated behaviour for team-working (Dennis *et al.*, 2008). The effectiveness of the communications process for achieving a shared understanding and good task performance is based on data quality, quantity and time. These characteristics of MST are especially relevant in the context of emergencies.

In a seminal paper, Denis *et al.* (2008) evaluated a number of media, based on five capabilities that might influence transmission and processing: symbol sets (physical/visual/verbal), parallelism (number of messages transmitted at the same time), transmission velocity, rehearsability (ability to fine-tune a message before sending), and reprocessability (enabling a message to be re-examined after sending). Their concept of media synchronicity embeds two slightly different aspects. On the one hand, it deals with the co-ordination capacity of people to work together or at the same time. On the other hand, it refers to the capacity or ‘demand’ of the media for synchronous modes of communication. ‘High levels of synchronicity can generate expectations of rapid interaction, which can interfere with deliberation processes’ (ibid: 583). According to MST, conveyance of information and convergence of understanding ultimately impact communication performance (Denis *et al.*, 2008). While conveyance focuses on the transmission of large amounts of new, diverse and raw information sets and requires lower media synchronicity, convergence concentrates on processing smaller volumes of information into higher-level abstractions involving verification and distillation processes, in order to develop a shared understanding requiring higher levels of media synchronicity. However, the only link they make between synchronicity and conveyance and convergence processes, is that ‘convergence processes benefit from synchronicity ... while conveyance processes do not’ (Dennis *et al.*, 2008:581).

In the case of decision-making in novel situations, such as emergencies, high synchronicity of media is required, but when these situations become more familiar, less synchronicity is required for communication effectiveness (Fuller and Dennis, 2009). However, electronically-mediated (digital) media with high synchronicity can hinder information processing (Weick, 2009). Thus, there is a need to step back from the digital medium in order to allow sufficient space and time for thinking and deliberation. So, contrary to Dennis *et al.* (2008), we argue that information processing in convergence is as important as in conveyance.

Furthermore, in the case of emergency response, the information processing needs are not limited to the two binary steps of conveyance and then convergence for decision-making. As Son *et al.* (2019) show, each phase of a disaster (preparedness, response, and recovery) implies two distinct communication processes: risk communication that involves producing general information about the disaster; and crisis communication that provides specific and ‘ideally’ accurate information about highly dangerous, life-threatening events (p. 58).

While Twitter’s ‘representational features’ such as number of words, URLs and hashtags can influence synchronicity and speed of disseminating emergency information to the public (Son *et al.*, 2019), one of its weaknesses is its convergence capabilities. For Twitter to be an effective means of communication, we argue that there is a need to ensure that information can be processed in real time to provide reliability and generate a shared sense-making of the emergency. Here, we argue that Twitter associated with BDA can facilitate the co-ordination of people (through an improved shared sense-making of a complex situation) and provide richer information (through URLs that lead to pictures and videos) (Yu *et al.*, 2018) useful to enhance deliberation. We defend the idea that “off-line” debates are not inhibited by Twitter. On the contrary, people are more likely to engage in the social exchange process that could be on-line (through retweets) and off-line (in face-to-face debates). Advances in Big Data Analytics (BDA) have the potential to provide this additional functionality for real-time processing of large volumes of aggregated and pre-prepared Twitter data. We posit that SM supported by a platform embedding BDA and AI techniques can facilitate information processing, which we develop further in our conceptual model (ComACom).

2.4.2 Big Data Analytics (BDA): An Overview

The full potential of ‘big’ data can be unlocked through analytics techniques for deeper understanding to enrich decision-making. Big Data Analytics (BDA) has become a widely adopted practice in organisations to reveal new knowledge and improve operational efficiency (Sivarajah *et al.*, 2017). BDA techniques can extract sense from data through *descriptive analytics*, which defines the current situation ‘what happened’; *inquisitive analytics*, which focuses on why something happened; *predictive analytics* to forecast and anticipate what is likely to happen in the future; *prescriptive analytics* to help optimise decision-making; and *pre-emptive analytics*, which helps to take precautionary actions ahead of time (Sivarajah *et al.*, 2017). The types of BDA tools and techniques being used for these purposes include data and text mining, machine learning, deep learning, and simulations, and follow a process of acquiring, storing, mining, cleansing, aggregating, integrating, analysing, modelling and interpreting ‘big’ data (*ibid*). Our application of BDA focuses on descriptive, inquisitive and prescriptive analytics, with potential for predictive and pre-emptive analytics in future research.

BDA has transformed operations and improved performance in a number of manufacturing organisations (Popovic *et al.*, 2018), but there is ongoing research into how BDA can be utilised and embedded in other organisations and contexts. Applying emerging technologies such as Artificial Intelligence (AI), Blockchain and Big Data Analytics (BDA) to SM in the context of disasters is of vital importance, but is as yet under-researched (Akter and Fosso Wamba, 2019; Yu *et al.*, 2019). BDA is considered a powerful tool that can integrate, aggregate, visualise and make sense of large volumes of data to improve the quality of emergency response decision-making and potentially transform emergency services (Akter and Fosso Wamba, 2019). Early applications of BDA techniques are already providing new useful functionalities to improve awareness, response and recovery. In a review of the

literature on intelligent disaster response with SM analysis, Nazer *et al.* (2017) presented a set of functionalities corresponding to each disaster phase: warning (warning systems and event prediction), impact (language change, event detection), response (situational awareness, disaster tracking), and relief (crowdsourcing and tools). In the case of human error-based accidents, we argue that early warning is the most important functionality that helps not only to avoid the initial accident, but also to mitigate the risk of serious domino-effect escalations. This idea underpins the conceptual foundations of our proposed ComACom model.

Extant studies have applied a number of BDA techniques to analyse tweets related to disaster management such as text mining, sentiment analysis and structure-based analytics, to better understand the roles of individuals and groups within a network (Gandomi and Haider, 2015). However, these studies tend to only apply one or two BDA techniques to SM data. Here, we apply a suite of BDA techniques to gain a full understanding of the causes and consequences of the MVW accident.

2.4.3 Applying MST to Twitter Enhanced with BDA for Improving Emergency Response

To improve decision-making, organisational data can be supplemented with big data derived from other sources, including SM/Twitter (Popovic *et al.*, 2019). In their raw format, these data are mainly unstructured and in a variety of forms including audio, image, video, and unstructured text (Karami *et al.* 2020) with potentially questionable value. Nevertheless, the application of the 6Vs of big data (Rehman *et al.*, 2016) to Twitter data reveals that its strengths are volume (+++), variety (++), velocity (+++) variability and complexity (++), but low veracity (-). The overall value of Twitter data is low, but this increases considerably with BDA (++). Applying MST to this 6V analysis of Twitter (see Table 1) illustrates how the information transmission capabilities of Twitter are high for the communication process, but indicates that information processing is low. Ostensibly, this is because of risks associated with poor quality data and the costly process of checking their reliability and validity. Nevertheless, in this study we demonstrate how the full value of Twitter data can be leveraged through BDA to acquire meaning and reliable intelligence for improved decision-making in disaster management.

INSERT Table I

In the remainder of this paper, we evaluate how Twitter big data might have impacted decision-making at each operational phase of the emergency response to the MVW disaster. We apply BDA to this data and propose a model for institutionalising SM through BDA to improve emergency awareness and response through a holistic, inclusive and transparent decision-making process.

3. Methodology

Here, we adopted a post-constructionist case study approach based on secondary data, to better understand the operational response to the MVW disaster from multiple stakeholder perspectives. For this study we applied a two-part methodology (summarised in Figure 1). The first part focused on collecting and analysing data from Twitter related to the MVW disaster, applying a suite of Big Data Analytics (BDA) techniques (e.g. text mining, machine learning, natural language processing and deep learning) to fully understand the causes and consequences of the accident. We corroborated this information with other sources (websites, images and videos) in order to evaluate the veracity, authenticity and accuracy of the real-time Twitter information.

INSERT Figure 1

The second part of the methodology applied narrative inquiry and scenario building using secondary web-based sources in addition to Twitter data. We systematically gathered, analysed and represented people's stories published in their own words and through their own perspectives in order to provide a holistic real-time perspective of the emergency situation. By generating a narrative of the MVW disaster, we reconstituted the different sub-events (SEs) that appeared to subsequently escalate into four main accidents after the initial grounding illustrated in Figure 4. Based on this data, we developed scenarios to demonstrate how alternative responses and decisions might have been taken (Table III).

3.1 Data Collection

We gathered two datasets drawn from secondary sources that focused on the MVW case, using the same search keywords (e.g. Wakashio, Mauritius oil spill, etc.). The first dataset was drawn from Twitter and the second was collated through a narrative review of the literature from established media and other reliable published sources.

3.1.1 Tweets

We collected a dataset of 6,027 tweets related to the MVW accident between 25/7/2020 and 19/12/2020, which covers the period of the emergency event and its aftermath. The relevant tweets were collected in real-time using relevant hashtags (e.g. Wakashio, Mauritius oil spill) and downloaded on a daily basis using a Twitter API (Tweepy). The dataset comprised the full texts, keywords hashtags and user names and was stored in a database for subsequent analyses. This dataset was based on keyword Twitter messages in both English and French. After removing irrelevant and incomplete tweets, a total of 5,476 tweets were selected as our final corpus. In order to combat potential fake news/misinformation, we only included Tweets that had been corroborated and validated with reliable sources (e.g. established media, international organisations, NGOs). This 'fact' checking process was done manually by the researchers as there is currently no publicly available algorithm or AI-based tool that can do this. The dataset was pre-processed by removing stop words and special characters after which it was tokenized and lemmatized to prepare the corpus for text analysis, which is fundamental to any BDA, Machine Learning, Deep learning and Natural Language Processing (NLP).

3.1.2 Web-based Sources: Institutional & Non-institutional

In order to triangulate and corroborate the Twitter information related to the MVW case, we drew on secondary web-based data. For consistency, we used the same search keywords as those used for the Twitter dataset to search for web-based content, including videos, reports, articles, blogs, images and audio. Each of the sources was analysed and evaluated manually and any items that were inaccurate, unreliable or incomplete were rejected. This search process resulted in content drawn from 56 websites (a full list of sources is available via the link at the end of references). In order to provide additional insights and depth to our narrative inquiry, following Abedin and Babar (2018), these data were manually categorised according to whether the sources were formal official/governmental institutions or non-institutional. Here, institutional/formal sources included official statements from the Mauritian Government, Port authorities and other national and international governmental entities, international organisations such as the International Maritime Organization (IMO),

public/private sector partnership of experts in maritime oil spills. Non-institutional/informal sources included established media/news outlets that provide updated news or information around the world (e.g. Forbes, CNN, BBC), expert blogs and any other 'informal' websites (such as Greenpeace).

3.2 Data Analysis

The first objective of our data analysis was to apply BDA techniques to our Twitter dataset. We used a deep learning technique to check the tweets in our dataset were consistent with the topic of disaster at the highest level.

We then applied a suite of additional BDA techniques to understand the causes and consequences of the emergency incident in more depth. First, we used Named Entity Recognition (NER) processing (Grishman and Sundheim, 1996) to focus on those who were speaking (tweeting/retweeting). We then used manual codification and topic modelling using Machine Learning (ML) to focus on the content and what was being said. Third, we applied a ML Hate Speech algorithm to identify the extent of the emotion of our online Twitter community in response to the disaster. Finally, we used NLP for sentiment analysis to visualise the evolution of Twitterati sentiment over time and in line with the initial accident and subsequent events (Figure 3).

The second objective of our data analysis was to reconstruct the narrative of the MVW incident, from two perspectives (institutional and non-institutional). The aim was to identify the actions (subevents) resulting from the institutional decision-making subsequent to the accident. By comparing each of these narratives chronologically, we showed how the catastrophic sub-events could have been avoided if the rich information from the tweets was available and accessible to the institutional decision-makers. Instead, decision-makers relied solely on the official voice of the ship's organisation and stakeholder authorities, which were limited and only began to be fully disseminated 15 days after the disaster first occurred. The information collated for the narrative was triangulated with information from the tweets, including videos and web links, to manually check the accuracy of Twitter information and eliminate any 'fake news' or misinformation. In Figure 4 below, we reconstituted the timeline of the MVW disaster corresponding to the SAR phases.

INSERT Figure 4

4. Results

In line with our methodology, there are two parts to our results from the BDA and narrative analysis.

4.1 Findings from the BDA

The tweets analysed using a suite of BDA techniques yielded the following results.

(i) Firstly, we identified the profiles of the 'Twitterati', who were most active in sending and sharing tweets. The top 100 Twitterati profiles were manually checked to determine whether they were an organisation or individual, had been validated (with a blue tick) and their affiliations. This data was used to train the model. We then applied Named Entity Recognition (NER) processing to the whole dataset to categorise our Twitterati into stakeholder groups (Grishman and Sundheim, 1996). A total of 54% of Twitterati in our dataset were individuals with no affiliation to any formal institutions or

organisations, while 46% were formal organisations. Most posts and retweets were generated by non-institutional actors highlighting their importance and potential influence in disseminating information about the emergency event.

(ii) Then, we applied deep learning in order to determine whether our dataset of tweets was on-topic (relevant) or off-topic (not relevant) to the disaster. We used the Long Short-Term Memory (LSTM) model for on-topic and off-topic labelling derived from a dataset of 60k tweets related to crisis communication (Olteanu *et al.*, 2014) with 98% accuracy and 88.2% validation. We first set up rules to explain our labelling, for example, off-topic tweets were those that might mention Wakashio but had no relevance to the incident, or were related to a different topic (e.g. COVID). This was very useful to exclude false positive tweets from the dataset and improve its validity and reliability.

(iii) The tweets were then analysed manually by the researchers and classified to identify the causes and consequences of the MVW accident. As part of the manual coding process, we defined the potential causes of the accident based on the first event resulting in the grounding of the vessel (SE1). We then classified the consequences of the grounding (resulting in SE2-4). These categories were informed by the literature review (Dominguez-Péry *et al.*, 2021) and discussions with very experienced maritime experts (including seafaring captains). This process was iterative to ensure consistency of meaning and understanding of the events and their categorisations. We extracted 297 tweets from the whole dataset as being the most relevant for highlighting the accident causes and consequences. These were organised into 16 categories (see Table II), 10 of which were associated with causes (5 organisational errors; 5 individual errors) while 6 were associated with consequences (4 related to institutional actions and decisions and 2 related to the wider community). Following Takahashi *et al.* (2015), we conducted a double researcher codification process to assess the inter-coder reliability.

INSERT Table II

In order to validate these categories, reinforce the internal validity of our manual codification and extend our understanding of the whole dataset, we then used topic modelling Machine Learning to all 5,476 tweets (Son *et al.*, 2019). From this process, we obtained 9 thematic clusters identified as context of the accident, opinions from official institutions, oil spill and its impact on the wider community, consequences of the accident and related emotions, causes of the disaster and actions to cope with it, legal responsibilities related to the ship, national debate at the Mauritius Parliament, impact on ecology and local environment, actions of the local and international community.

(iv) Fourth, we analysed the frequency of the top hundred retweeted tweets in order to assess the trending themes over the time period of the accident. We mapped the spikes in the frequency of tweets onto the SEs of the accident to illustrate its effectiveness as a potential alert system. Figure 2 illustrates how the frequency spikes corresponded to relevant SEs during the different phases of the emergency operation.

INSERT Figure 2

(v) Fifth, we applied machine learning techniques using the “hate speech” dataset. While there is no universally accepted definition of hate speech, which presents challenges in defining precisely what hate speech is and how it can be accurately detected with algorithms (MacAvaney *et al.*, 2019), we still found this technique useful to understand the overall sense of the real-time emotions of the Twitter community in response to the accident. We used the Random Forest Classifier for detecting

hate speech on our dataset, which showed that 75% of the tweets in our dataset were labelled 'hatespeech' (4,327 labelled as HateSpeech, 1,096 labelled fine and 53 labelled as offensive language). To address the main limitations of this technique, which also includes an inability to visualise the specific tweets labelled HateSpeech over time, we conducted a more refined sentiment analysis. We using Python's textblob to evaluate the sentiment of tweets on a polarity scale of -1 (very negative sentiment); 0 (neutral sentiment) and +1 (very positive sentiment) (Pourebrahim, 2019). This provided a more fine-grained understanding of the peaks and troughs of Twitterati sentiment in response to the accident and sub-events as they occurred over time, which is illustrated in Figure 3.

INSERT Figure 3

4.2 Findings of the Narrative Inquiry

From our analysis of the various sources, in this section, we reconstituted the MVW case narrative as a series of sequential escalations of four main sub-events (SE) or accidents leading to the catastrophic loss of human life, socio-economic damage to local communities and irreparable ecological destruction. Each of these SEs, illustrated in Table III, is described based on the consequences that occurred within a timeframe.

INSERT Table III

In the following section, we present the narrative details of our case study organised in 4 separate sections based on each of the MVW accident sub-events that occurred in chronological order. For each sub-event, the narrative inquiry from two different perspectives (institutional and non-institutional) is placed side-by-side¹ for ease of comparison.

4.2.1 SE N°1: Grounding (14th–24th July 2020)

Prior to this event, there were several warnings about the ship's safety records. The publicly available Electronic Quality Shipping Information System (EQUASIS) database [38] showed 96 safety flaws including faulty navigation and communication systems, serious on-board equipment and fire safety flaws, and serious omissions in on-board operational processes and procedures. Some of these safety failures were flagged again earlier in the year, in Australia (record-keeping) and 10 days before the accident after refuelling in Singapore; no internet connection was reported but the port authorities allowed MVW to continue on its journey to Brazil from China. No action was taken to remedy these issues.

Institutional Narrative	Non-Institutional Narrative
On 21st July , the ship deviated from its planned route and steamed towards the Mauritius coast at a speed of 12 knots. Reports from Mitsui O.S.K. Lines (MOL) confirmed that on 23 rd July, the vessel veered off its planned course 22 nautical miles off the island of Mauritius. The on-shore SOSC operating within the ship's organization to	Just before the ship's grounding, citizens posted tweets that the MVW was illuminated near the shore in the lagoon. Several maritime experts from the wider community posted videos explaining that the grounding could have been avoided at this stage [31] [32] [33].

¹ The references cited in these tables are listed in the Googledocs link in the references.

<p>monitor its vessels did not correct the ship's course. (They provided no reason for this lack of action, which led to speculation, including a potential cyberattack [15]). The MVW steamed within 5 nautical miles of the Mauritian coast to enter an area within the communication range of mobile phones [29], until it hit the protected coral reef at Pointe d'Esny at 7.25 pm on 25th July [1,2].</p>	<p>Immediately after the grounding, several tweets highlighting the incident were posted; extracts include: @saurabh_bali: "... it's really very astounding discovery horrendous unprofessional act with absolutely zero safety behavior birthday party and quest for Wi-Fi revealed in lead up to Wakashio grounding off Mauritius".</p> <p>Our BDA revealed a spike in frequency and negative sentiments of tweets.</p>
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4.2.2 SE N° 2: Oil spill in the lagoon (26th July – 15th August 2020)

Institutional Narrative	Non-institutional Narrative
<p>MOL was informed of the MVW grounding 4.5 hours after the event [44]. On 29th July, the ship owner awarded the Dutch SMIT Salvage company the contract [59] to re-float the tanker and then deal with the stern which currently rested on the coral reef [5;5b].</p> <p>For the first twelve days, there was no evidence of decisive action or decision-making in response to an environmental emergency by the Mauritius Authorities.</p> <p>Information from the formal institutions within the Mauritius Government was contradictory. On 28th July, the Environment Minister informed Parliament that the National Coast Guard's 'inquiry' into the traces of hydrocarbons in algae 300 meters around the coast, may have originated from the engine room and that no additional leakage had been observed [3,4]. The Mauritius Authorities denounced reports of oil leaks as 'fake' news.</p> <p>On 31st July, a team of experts from SMIT Salvage boarded the vessel to inspect it, assess the situation, organise operations to pump the oil out of the vessel's tanks and refloat the ship.</p> <p>On 5th August, cracks in the hull of the vessel and oil spilling into the sea were reported, but no announcements were made [1].</p> <p>On the morning of 6th August, oil leaked out of a fuel tank. On the same day, a command post was set up by the French Prefect for the South Indian Ocean Defence and Security Zone, gathering various stakeholders including AEM (French State action at</p>	<p>Between 26th July & 10th August: the shortcomings of both the Mauritius Government and the ship organization were being highlighted in real time by the local community. For instance, one local activist maintained that the vessel ignored warnings from the coast guards and that the Coast Guards later failed to adequately secure its coastal borders [22].</p> <p>5th August: Videos and warnings by local divers with maritime experience showing cracks in the hull of the MVW were tweeted [26]. Tweets by the wider community with diverse profiles such as scientists [33], maritime captains and local navigation</p>

sea), FAZSOI (French Armed Forces in the South Indian Ocean), DM SOI (French maritime affairs directorate for the Indian Ocean), the South Indian Ocean MRCC and the French Naval staff for the defence zone. Cedre was placed on alert. Under the auspices of the sub-regional oil spill contingency plan for the Western Indian Ocean Islands, France is providing support to the Mauritian Authorities.

It was not until **7th August** that the Mauritian Prime Minister (PM) officially declared an environmental emergency [1], and made official statements about the incident including operational response [45, 57]. This triggered the implementation of national oil spill contingency plans, coupled with requests for international assistance. Countries such as France and Japan, NGOs, the IMO and the ITOPI responded [1, 5]. Specialist emergency teams and equipment were sent and the IMO joined efforts towards providing technical advice and coordinating the response [1a].

France then offers to help Mauritius.



On the **9th August**, the PM explained that the country 'doesn't have the skills and expertise to re-float stranded ships' [54].

On the **12th August**, the PM announced 'all the fuel has been pumped from the reservoirs' [1b]

experts warned of risks of a major oil spill in the protected area if nothing was done in the following days.

On 7th August, a video posted on YouTube by a local aerial photographer maintained that when the MVW ran aground, nothing was done to pump the fuel. He confirmed that "the citizens were told that the images that they are seeing on various media platforms were doctored" [23].

As a result of the emergency, thousands of volunteers (i.e., students, environmental tourists, residents, NGOs and international organizations) gathered to help in the clean-up of the oil spill. Several tweets encouraged volunteers to provide their hair to build booms [24] placed near the entrance to the Blue Bay Marine Park [55]. Tweets from the local community included:

@CWojcieszczuk: "A community called to action! Working against the clock to clean up oil spill off Mauritian's coast"

@MariDeal: "Donate your hair in one of our agencies & receive Rs.100 MariDeal Gift Card. All hair collected will be used to create buoys to absorb oil spills in the lagoon".

A maritime expert from Mauritius criticized the positioning of the buoys by the Authorities, maintaining they should be positioned all around the MVW and not so far away [32].

On **15th August**, SMIT Salvage announced their oil pumping operations had been complete [5]. Approximately 3,000 tonnes of oil had been removed from the MVW after 1,000 tonnes of oil had spilt into the sea, thus damaging the fragile ecosystem.



"The cracks have reached the top of the boat. It is therefore very likely that the boat will break at any moment, exposing large quantities of fuel oil in the Pointe d'Esny lagoon and in the Mahébourg lagoon," warns an environmental engineer and oceanographer [56].

On **11th August**, experts said the decision to elevate the front section of the MVW might weaken the hull structure and break up the ship [39].

On **15th August**, the situation worsened as the MVW split into two parts, as predicted by expert sources. Several videos with aerial images of the MVW showed the large expanse of oil in the sea [33,34]. Experts suggested that decisions taken during rescue operations probably exacerbated the disaster outcomes [32]. With little information from the authorities regarding the causes of the accident and the decisions taken to mitigate the spread of the oil spill, the highest number of tweets was recorded between the **11th and 18th August**.

4.2.3 SE N°3: Deliberate Sinking (16th August - 24th August 2020)

<i>Institutional Narrative</i>	<i>Non-Institutional Narrative</i>
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The seven official Government press releases between the **18th and 24th August** provided no information on the sinking decision and location.

On **18th August**, the bow section of the vessel was towed 15 miles to sea by two tugboats. After consultation with formal institutional stakeholders (the shipowner, the salvage company, the Japanese Government, the authorities of La Reunion, the IMO), the Mauritius Government allowed the vessel to be scuttled [7,5]. When the decision was taken to sink the bow section of the MVW and after six days of towing the vessel, all institutional stakeholders were on site [43].

On the day after the wreckage had been removed, the Government of Mauritius maintained that 'consultations were underway' on how to deal with the stern section [19b].

On **24th August**, the bow section was sunk at an 'undisclosed location' in the afternoon [5,7]. On **26th August**, more than 50 dead dolphins were washed on shore [19]. The fisheries minister declared these deaths to be unconnected to the oil spill and rather due to 'shark bites', and that autopsies would be conducted [19c].



On **17th August**, the rear of the MVW remained on the reef with 7,000 gallons of diesel on board [42].

On **18th August**, experts raised concerns that the two salvage vessels might have caused further damage to the ecosystem while dragging the bow part [40]. Five days before the vessel was sunk, Greenpeace recommended towing the MVW to another harbour:

"Out of all available options, the Mauritian government is choosing the worst one," [42] – Greenpeace Africa Senior Campaign Manager. Similar criticisms came from other independent organizations such as the Mauritius Wildlife Foundation.

On **19th August**, video evidence of the tugboats towing the vessel out to sea was posted [20]. This video and the absence of any official detail triggered a spike of tweets questioning the government's decision-making and obfuscation.

On **24th August**, the wider community raised concerns about institutional cover-ups. For instance,

@niti_bhan: *"The evidence in a major international crime appears to be disappearing the oil spill and deliberate sinking of the Japanese owned Wakashio in Mauritius is a crime actually several national and international laws appear to have been broken";*

@GregAtkinson_jp: *"Why is a large section of the ship scuttled before the accident investigation is completed Wakashio bow*

	<p><i>section [sic] scuttled off Mauritius shipping maritime”.</i></p> <p>The decision to sink the boat, against the voice of the wider community, questions both the operations and governance of the several stakeholders involved in a decision with such dramatic consequences.</p>
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4.2.4 SE N° 4: Salvage operation, collision and four dead (25th August – 1st September 2020)

Institutional Narrative	Non-Institutional Narrative
<p>On 25th August, oil removal operations continued in the stern section of the vessel [5]. The Mauritius Port Authorities sent “Sir Gaetan Duval” (SGD) tugboat to support the salvage operation and tow an oil barge from the place of the oil spill to the harbour. They made several round trips from the sea to the harbour.</p> <p>On 31st August, in dark and bad weather conditions the barge collided with the SGD tugboat pulling it and sank into the coral lagoon [14]. On 1st September, four members of the tugboat crew were rescued, but three members were confirmed dead and one person missing [14,42] later confirmed dead.</p>	<p>The Salvage operations for the MVW were coordinated by the Mauritius Government, especially the Port authorities in coordination with MRCC; the Salvage company awarded the contract had to work in coordination with a larger network of stakeholders.</p> <p>On 31st August, overnight reports initially indicated the oil barge had sunk. A video taken by a local fisherman early on 1st September revealed the oil barge drifting unattached along the coast of Mauritius [41].</p> <p>The sinking of the tugboat led to four crew members losing their lives. The BDA shows an increase in Twitter activity and negative sentiment as part of this event.</p>

This narrative inquiry highlighted the gaps in publicly available information and communications just before, during and after the accident of the MVW. By placing the institutional and non-institutional stream of communications side-by-side and organised chronologically, there are clearly times where there was institutional silence on the one side, but at the same time there was a wealth of rich information available from the relevant tweets and other ‘non-institutional’ sources. This narrative inquiry also highlighted the failings of the current system, regulations and decision-making both at the national and international levels. It showed how the decision-making process could have been improved and how the catastrophic consequences (including deaths and damage to marine ecosystems) might have been avoided. We contend this non-institutional information would have made a difference to the overall outcomes of the accident and possibly avoided one or all of the catastrophic sub-events that followed.

4.3 Findings of the Scenario-Based Approach

Building on the narrative inquiry, we then compared the details from the two perspectives and used a scenario-based approach to map whether and how the domino-effect of the SEs might have been avoided. In Table III, we contrasted the escalation of events as they occurred in real time (traced

through the red lines) from SE1 to SE4 with potential scenarios that could have been possible (traced through the blue lines) if both the ship organisation and the officials had considered the information from the wider community when taking their decisions.

INSERT Table III

For SE1 the main causes can be attributed to deficient equipment onboard MVW and human error, but also lack of coordination between the Ports of Singapore, Mauritius and the SOSC of the ship owner each of which, individually or collectively, could have stopped or altered the course of the MVW before it was grounded on the reef.

The main cause of SE2 is the 12-day delay that was observed before any action was taken to pump the oil and/or tug the MVW outside the lagoon. This delay was due to the lengthy discussions between the ship owner, insurance brokers and lawyers to determine the most 'cost-effective' way of proceeding while considering the competing organisational economic interests. There was also a lack of coordination and synchronicity between the ship organisation and the official institutions in deciding to send the right tugboats to the accident site. Against the advice of non-institutional experts (Greenpeace) and the interests of the local and wider community, SE3 resulted from the controversial decision to scuttle the ship rather than recycle the bow part of the MVW, which led to increased damage caused to the protected lagoon and longer-term environmental damage. The tragic deaths and the sinking of the tugboat in SE4 can be attributed to the earlier decision to sink the ship, in addition to poor operational decision-making.

5. Discussion

Our case study has established how the original accident itself could have been directly or indirectly avoided by the ship's organisation, notably by co-ordinating with or responding to the relevant authorities (port Authorities & Coast Guard). Our case study showed that, consistent with the literature, much of the formal institutional stakeholder decision-making focused on economic interests, which led to (un)anticipated consequences related to negative social and environmental factors (Matos *et al.*, 2020). It also shows the catastrophic domino effect deriving from poor decision-making subsequent to the initial accident (SE2-4), all of which might have been avoided had there been a shared understanding of the situation, based on multimedia information collated from the different institutional and non-institutional stakeholders.

Through the lens of MST, consistent with recent studies (Son *et al.*, 2019), we found Twitter to be an effective medium for communicating risk and crisis information. To our knowledge, our study is one of the first to apply MST in the context of maritime disasters resulting from human error. It is also one of the first, apart from Beedasy *et al.* (2020), to apply BDA to tweets in accidents due to human error. However, our approach is more comprehensive in that it applies a full suite of BDA techniques harnessing the power of algorithms to predict and prevent future accidents using more data.

5.1 Theoretical Contributions

According to MST, communication performance, which ultimately influences decision-making and negotiation, is dependent on two fundamental communication processes of conveyance (information transmission) and convergence (information processing) and is largely affected by the fit between the capabilities of the selected medium and the communication needs of the situation.

By applying MST to a novel context, our study clearly showed that, consistent with MST, without adequate conveyance of information, incorrect conclusions can be reached; and without adequate convergence on meaning, there will be a lack of shared understanding. In the MVW case, the ship's organisation and formal institutions ignored the information from the informal institutions and the wider community, and reached inaccurate conclusions about the causes of the MWV accident. Equally, in our case, there was also a clear lack of shared understanding between formal and informal institutions (wider community), thus leading to inadequate decision-making that ultimately escalated the disaster with catastrophic repercussions.

5.2 Theoretical Implications

Our study found that Twitter has highly effective information transmission capabilities with large quantities of diverse and relevant information that needed to be disseminated rapidly in order to provide more detail of the situation and causes – just before and after the accident. Here, we have also demonstrated that BDA-facilitated Twitter also provides convergence, where the interpretation of a situation is iterative, with the objective of reaching a common understanding of the situation among stakeholders. With a suite of BDA techniques, we were able to achieve conveyance and convergence through (i) machine learning for topic modelling and entity recognition, in order to fully grasp not only the content of tweets in real time, but also the dynamic events as they are occurring to inform the relevant SAR Phases 1-3 and provide post-accident learning for SAR Phase 4; (ii) deep learning to validate the content as being relevant to the disaster (on-topic) or not (off-topic); (iii) NLP (hate speech/sentiment analysis) so as to clearly understand the sense of feelings and emotions about the causes and consequences of the disaster and the institutional response, amplified throughout the wider community; and (iv) text mining to explore the frequency of tweets over the event timeline.

5.3 Practical Implications: Operationalising the Media Synchronicity of Twitter

Having demonstrated the value of Twitter in the decision-making process in the context of maritime accidents, we now propose an AI-based public community alert and communications interface (ComACom AI System) solution that effectively harnesses this value. This solution draws on the core functionality and media capabilities of Twitter, and its media synchronicity for conveyance and convergence. The ComACom AI system can link the expertise and information from the informal/non-institutional wider community to the formal/institutional actors (the ship's organisation and official stakeholders), to improve its synchronicity. This system (see Figure 5) provides the transparent, fact-based, reliable, fast and verified information that is required to take effective, proactive and real-time decisions in fast-paced emergency response operations.

INSERT Figure 5

Information can be input into the AI system to be processed in real time using existing BDA to analyse the content, frequency and sentiment being expressed within the large volumes of information. We further propose two additional layers of pre-processing before the information is disseminated to the final reporting mechanism for decision-making. The first is a 'relevance and accuracy' process to corroborate the veracity and reliability of input information based on pre-set criteria. The second is a 'trust and transparency' process to validate the account holders and establish their reputation within the community. Future research could develop algorithms for these processes, which we have

manually demonstrated here. These different processes will be linked together to generate a usable and easy to understand early-warning alert dashboard highlighting issues from the wider community amplified through social media (conveyance). This tool will ultimately empower and include the expertise and capabilities of the wider community in the SAR decision-making process, but also help achieve a common understanding of the disaster through a process of co-construction of the on-going situation, with formal institutional maritime organisations and the non-institutional wider community, to assess the causes and consequences and avoid potential risks of sub-events.

For future work, the AI engine of the system should be developed and improved through a continuous process of learning, feedback and integration with other sources of big data, including sensors integrated into the Internet of Things (IoT) and GPS trackers.

5.4 Limitations

The main limitation of this research is that the social media data we use is drawn from only one platform, namely Twitter. Future research could include data drawn from other social media platforms (such as Facebook) to compare the capabilities and contributions to conveyance and convergence of each respective SM platforms. Another limitation is the relative recency of the accident and the short period for reflection and learning. This study will benefit from a retrospective review of the case after the publication of the official report on the accident. The main objective of this study was to propose the conceptual foundations of ComACom, a tool which at this stage is a prototype with BDA functionalities. While this research is based on one case study, to further develop and operationalise this early warning system, future research should collate more cases of maritime accidents to improve the BDA and AI elements of the system.

6. Conclusion

The MVW case shows how the maritime industry can still improve their emergency operations. This case highlights how the lack of information, capabilities, coordination and synchronisation among the main stakeholders led to an escalation of sub-events that culminated in a major disaster. To improve the disaster outcomes, we first recommend a continued automatic monitoring of ships from the shore not only by the ship owner, but also by the official onshore authorities as part of their effort to protect their jurisdiction. A second recommendation lies into the integration of the information from the wider community through a Community Alert and Communications system (ComACom). This platform should include the latest BDA and AI techniques in order to increase the veracity and reliability of integrated information and thus improve resilience.

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