TRUST AND BIG DATA IN COORDINATING DISASTER RESPONSE

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INTRODUCTION

During the Uttarakhand disaster of 2013, a herculean multi-agency effort was mounted to rescue tens of thousands of survivors who were physically and mentally maimed, and relocate more than 100,000 pilgrims stuck in far-flung mountainous high-altitude areas. While the urgency of saving lives and limbs ensured coordination and collaboration among all the agencies, there were many things that could have been done better. More importantly, the case needs to be dissected in detail with data-based analysis to come out with the correct lessons-learnt. This is important because it has been accepted as one of the most difficult missions ever carried out, with a record number of helicopters, agencies and volunteers involved.

There was considerable innovation that took place on the ground in terms of adopting newer technology and incorporating big data. For example, the use of mobile-based Whatsapp (new and less used at that point in time) by helicopter pilots for self-regulation, traffic control and collision avoidance in narrow and remote valleys. Similarly, a missing persons bureau was hastily set up to take up the challenge of registering pilgrims coming back, file

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missing reports and other inputs to laboriously track them meaningfully on computer-based programmes. This resulted in accurate analyses besides uniting many separated family members. While Indian disasters await genuine research of many such instances, this article tries to track two unique issues of handling *big data* and establishing *swift trust* among responders worldwide. It is based on articles and research carried out across the world.

Resilience to disaster includes capacities of cognition, communication, collective sense-making, improvisation, innovation and problem-solving of the community as a whole. A disaster response scene is dynamic and complex, with an acute need for timely and adaptive action. This calls for a balance between established structures and flexible thinking. The response can be thought of as a complex adaptive system that continuously meets these ever-changing and demanding situations[1]. Identification and detection of risks, assessments for the short and long terms, and communication of these to key nodes is a first step that requires a healthy mix of cognition and technology. The next step of self-organising by a complex adaptive system needs healthy dosages of swift trust that permeates across the physical and virtual domains. With multiple sensors, monitoring instruments and virtual connectivity rising exponentially, the challenge is to intelligently integrate and distribute analyses to the right people, at the right time, avoiding information overload.

COGNITION, IMPROVISATION AND COORDINATION

In disaster response, improvisation can be seen as a mental activity leading to action by the use of creativity under severe time and resource constraints. Roles are a mix of expectations from a position or professional status,

1. C. Coetzee, V.D. Niekerk and E. Raju, "Disaster Resilience and Complex Adaptive Systems Theory: Finding Common Grounds for Risk Reduction," *Disaster Prevention and Management*, vol 25, no. 2, pp 196-211. Accessed at www.emeraldinsight.com on December 31, 2016.

relationships because of being part of a network, and behaviours needed for an effective disaster response. Role behaviour can encompass improvisations in procedures, status or change in roles, tools or equipment for a task, and geographical positioning or dispersal of men and material. Identification of response goals, observing field conditions and hypothesising about actions and consequences are some of the cognitive functions that are undertaken before decisions are made. Decision-making is under time-pressures, high stakes and consequences, and extreme complexity in a major disaster response. Leaders resort to both recognition-primed decisions in familiar situations and more reflective but time-consuming decisions in completely unfamiliar situations.

Cognition and Learning: Cognitive abilities, in terms of processes and representation, encompass intelligence, learning and knowledge management. Away from computational approaches, an interpretive methodology can examine how meanings are created in a social context. This needs to be based on subjects such as sociology of knowledge, social psychology of organisation, social cognition, organisational learning and knowledge management. Studies in the USA on the World Trade Centre (WTC) 9/11 attacks and 1995 Oklahoma bombing clearly bring out the prominence of conventional behaviour coupled with the cognitive process and linked to the observation among responders. Improvisation was normally limited to procedures and status, rather than material aspects. However, when improvising, actors do undertake observation and hypothesising[2].Lack of sufficient information or cognitive abilities to process and analyse leads to uncertainty in an organisation. Propositions of bounded rationality and attendant complexities apply during task completion and are dependent on levels of uncertainty.

Individual cognitive processes contribute to the larger domain of explicit and implicit organisational knowledge. This allows group and institutional sense-making and knowledge creation as in a helical spiral. High levels of organisational process maturity, capability and performance are directly

2. D. Mendonca, G. Webb, C. Butts, andJ. Brooks, "Cognitive Correlates of Improvised Behaviour in Disaster Response: The Cases of the Murrah Building and the World Trade Centre", *Journal of Contingencies and Crisis Management, 2014,* DOI: 10.1111/1468-5973.12057. John Wiley & Sons Ltd.

High levels of organisational process maturity, capability and performance are directly associated with higher degrees of organisational cognition and knowledge base. Individuals, in turn, gain from the organisation's vastly larger cognitive base.

associated with higher degrees of organisational cognition and knowledge base. Individuals, in turn, gain from the organisation's vastly larger cognitive base. Yet, the organisational domain is a created or artificial system that can be changed, redesigned and improved. This is greatly influenced by goals, participants, technology, social structure and inter-organisational relationships[3].

Emotion is important where humans exist in a social structure, more so in a disaster scene. It is important in motivating, directing and regulating individual actions towards an objective goal. It complements all the cognitive processes of intelligence, attention, learning, decision-making and problem solving if it is positive. In the same manner, good cognitive abilities enable stability and emotional well-being. Organisational learning is the process of change in structure, functions and behaviour for the betterment of the organisation. This is a result of experience, cognition, emotion and environmental influences that the organisation undergoes while functioning or interacting with the outside. A state of meta-learning is reached when an organisation is acutely aware of its learning processes and in control of them; those with a higher degree of cognition have better capacities for the same.

Managing Dependencies: Alvin Toffler used the term 'ad hocracies' for a decentralised network of teams involved in a project which undergo rapid changes. Malone et al (1994) define coordination as managing dependencies between activities. It can exist between a spectrum of competition, co-operation and collaboration[4]. The key is to clearly identify dependencies and processes to manage them constructively. This is possible only by identifying the needs and capacities of all the agencies in a disaster response. One type of dependency is sharing

3. F.S. Nobre, M.A. Tobias and D.S. Walker, "A New Contingency View of the Organisation: Managing Complexity and Uncertainly Through Cognition," *Brazilian Administration Review*, vol 7, no. 4, Article 4, pp. 379-396. Accessed at www.axpad.org.br/baron on December 25, 2016.
4. W.T. Malone and K. Crowston, "The Inter-Disciplinary Study of Coordination," *ACM Computing Surveys*, vol. 26, no. 1, March 1994.

limited resources. A range of economic theories explain coordination across competition and collaboration such as Classical Microeconomics, Transaction Cost Theory, Agency Theory, and Mechanism Design. Research using sociology and psychology in Organisation Theory points to the optimisation value of division of activities and management of dependencies between actors. Inter-dependencies can be pooled (only sharing resources), sequential (activity dependent), and reciprocal (input dependent). These are done by a range of mechanisms like standardisation, supervision and mutual adjustment. To manage inter-dependencies between groups first requires clubbing those with strongest inter-dependencies into distinct groups such as the UN cluster system for humanitarian action.

The first act of group coordination is to identify a common or shared goal. This is then decomposed into activities based on functional aspects, type of product, consumption requirements or by geographical dispersion. This process can be top-down or bottom-up which allows more buy-ins and commitment in a multi-agency set-up.

One concern is prerequisites based on activities that follow other actions. This is done by notifying the schedules, sequencing and tracking progress. It allows interventions and reminders where progress lags. The next is transfer where physical transportation and communication allow the next activity to begin on receiving a product. This may include concepts of buffers, surge capacities, just-in-time and parallel processes. Another concern is usability wherein standardisation and participatory design of processes and products allow unimpeded flow of interrelated activities. The first act of group coordination is to identify a common or shared goal. This is then decomposed into activities based on functional aspects, type of product, consumption requirements or by geographical dispersion. This process can be top-down or bottom-up which allows more buy-ins and commitment in a multi-agency set-up. A top-down approach based on a hierarchical set-up, however, has less transaction costs and is more responsive, but is more prone to processor failure. However, all this is underlined by trust and trustworthiness.

TRUST IN DISASTER RESPONSE

The two main concerns of disaster response are time-sensitivity and effectiveness, and this is also underlined by the overall costs of the operations. A mix of centralised and decentralised mechanisms could address these concerns. Computers and Information Technology (IT) networking allows real-time collaborative decision-making without being collocated, e.g. video conferencing, digital signatures, etc. Yet, changes in this consensus-based structure are inevitable in circumstances where high reliability and rapid response are critical. Coordination is a major theme in disaster response simply because no agency has the capacity to go it alone and satisfy critical needs. In normal life, coordination aspects are generally only noticed when there is a lack of them, causing problems and wastages. A simple definition of coordination is working together harmoniously, which has the important element of managing dependencies. Goal relevant relationships, critical to effectiveness and efficiency, are termed inter-dependencies. For disaster response, the definition of "composing purposeful wholes" seems to be most apt for coordination[5]. Disaster coordination is primarily based on protocols and accepted artefacts for information flow. Coordination mechanisms can vary, e.g. avoidance, reservation schemes, commitments, polling approaches, shifting task dependencies (learning), third-party means and multi-stage negotiation strategies. However, a prerequisite for effective coordination, cooperation and collaboration is different degrees of trust among the actors responding.

Conceptual Framework of Trust: The concept of trust permeates across all disciplines of human and social endeavour; however, each has a different lens to define it. Sociology sees it as a social construct, e.g. institutional-based arrangements of certification, membership or rules such as in the medical profession. Psychology, on the other hand, sees it as an individual trait-based construct where childhood developments influence dispositions to trustworthiness. The truth is both these aspects contribute to trust formation among individuals, groups or networks. One classification

5. A.W. Holt, "Diplans: A New Language for the Study and Implementation of Coordination," ACM Transactions on Office Information Systems, 6(2), 1988. pp. 109-125.

mooted by Zucker (1986) trifurcates it into the process, characteristic and institution-based phenomenon. Process is about past experiences and interaction, which are often based on personal relationships and earned trust. This leads to a reputation that could be transmitted through third parties. Characteristic-based trust is based on the personal attributes of others and a belief-system that is innate. This is what leads to stereotyping. Institution-based trust is a systems approach where objects are technical or social.

Power equations in relationships between individuals or groups exist due to asymmetry of information. Many actions are not visible or cannot be tracked, therefore, one trusts the reliable pattern of behaviour. Managing these power dynamics is the key to managing trust, and a big part is played by sharing of power.

Across the literature on trust, the most prevailing themes are of competence, integrity, predictability and benevolence. Competence is task-, profession- or skill-based that focusses on individual capabilities. Integrity is commitment to one's part of the obligation, sticking to your word and reciprocity. The belief that another has mutual interests at his core is benevolence. Predictability is about consistency and reliable behaviour that allows reasonable forecasting. Repeated social and professional interactions strengthen trust as it graduates from conditional to unconditional, and thereafter, to blind trust[6].

Power equations in relationships between individuals or groups exist due to asymmetry of information. Many actions are not visible or cannot be tracked, therefore, one trusts the reliable pattern of behaviour. Managing these power dynamics is the key to managing trust, and a big part is played by sharing of power. Mayer et al (1995) have put up a model of trust at work which incorporates the properties of the trustor, the attributes of the trustee and the risks in the situation[7]. The essence of trust is a willingness to be vulnerable to

6. K.L. Belton, "Research in Role of Trust in an Evolving Network for Knowledge Translation," PhD Thesis, Epidemiology, Dept of PHS, University of Alberta. Accessed at www.cra.library.ualberta.ca on December 30, 2016.
7. R.C. Mayer, J.H. Davis and F.D. Schoorman, "An Integrative Model of Organisational Trust," *Academy of Management Review*, (20), pp. 709-734.

Trust developed quickly, implicitly or explicitly, allows a range of coordination, deliberation, cooperation or collaboration. Therefore, trust can be defined as a belief in one that the other can be relied upon to behave according to expected and accepted norms, fulfil mutually agreed obligations and, in general, act in the best interests of each other. This definition has a key element of inter-personal trust.

the actions of others even if one is not able to track or monitor them. A traditional model of trust encompasses elements of familiarity, threats, deterrent to opportunism, shared experiences, demonstrated trustworthiness, etc. However, in an internet and computer linked world, the concept has moved to "swift trust" with presumptive trust networks based on roles categories and functions.

TRUST IN HASTILY FORMED RELIEF NETWORKS

The area of supply chain management and collaboration documents trust as a core theme underlying its efficiency and optimisation. Inter-organisational relationships based on trust are mostly focussed on long-term mutually beneficial areas. However, disasters invite Hastily Formed Relief Networks (HFRN) that work in extremely complex, emergent and adaptive environments. The challenge here is to develop swift trust[8]. This is a critical facet in relief supply chains where flexibility in operations is most evident. A mix of government and non-government organisations competing for resources and credibility heightens the need for swift trust.

An HFRN has been defined as a network of people established rapidly, from different communities, working together in a shared conversation space, in which they plan, commit to, and execute, actions to fulfil a large, urgent mission. Emergent response groups are crisis-driven, task or goal-oriented, self-evolving, time-sensitive and temporal, composite and complexly networked. Also, the membership is dynamic and ever-evolving, depending on the phase of response, with need-based relationships. There may be neither a shared

8. D. Meyerson, W. DeWitt and R.M. Keebler, "Swift Trust and Temporary Groups," in R.M. Kramer and T.R. Tyler, eds., *Trust in Organisation: Frontiers of Research and Theory* (Thousand Oaks, CA: Sage Publications Inc,1996), pp. 166-195.

history nor a future in terms of working together. Trust developed quickly, implicitly or explicitly, allows a range of coordination, deliberation, cooperation or collaboration[9]. Therefore, trust can be defined as a belief in one that the other can be relied upon to behave according to expected and accepted norms, fulfil mutually agreed obligations and, in general, act in the best interests of each other. This definition has a key element of inter-personal trust[10].

Trust in Virtual Groups: Hung et al (2004) suggest that trust in such virtual set-ups starts strong through the peripheral route as no other choice is available. This is moderated by perceived risks and takes long to graduate to the central route of knowledge-based trust. It is also easily repairable by its very nature. The central route is subject to available interactions and is a cognitive assessment of the other party's integrity, ability and benevolence. Better outcomes over time and repeated interactions lead to strengthening trust and its robustness. Of course, the ultimate stage is the habitual route where emotional and personal identification is made. But the central and habitual stages require face-to-face contacts or additional guarantees since computer mediated communication lacks personal knowledge accumulation and increases perceived risks.

As a leader, one needs to strengthen peripheral cues such as clearly defined roles, rules of engagement, standard categorisation and reputational aspects. The emphasis must shift to ability, integrity and benevolence aspects as trust matures. This can only happen if a leader is knowledgeable on these constructs and intervenes proactively. Team building exercises are among other means to remove stereotyping, negative biases and preferences. A perception of control helps in removing misgivings and encourages a personal disposition to trust.

Models of Swift Trust: The model suggested by Hung et al (2004) appears to be apt for disaster response scenarios where multiple agencies converge[11].

9. HFN Research Group (2006) www.hfncenter.org/. Accessed on December 22, 2016.
10. P. Tatham and G. Kovacs, "Developing and Maintaining Trust in Hastily Formed Relief Networks". G. Kovacs and K.M. Spens, eds., *Relief Supply Chain Management for Disasters: Humanitarian Aid and Emergency Logistics.* [Business School Reference (IGI Global). ISBN 978-1-60960-825-85 (e-book)].
11. Y-T. C. Hung, A.R. Dennis and L. Robert , "Trust in Virtual Teams: Towards an Integrative Model of Trust Formation". In Proceedings of the 3rd Hawaii International Conference on Systems Sciences, Track 1, Vol. 1, 2004. Accessed on December 22, 2016 from www.deepblue.lib.umich.edu.

Development of common approaches, rules and structures allows newcomers to join in with confidence and dissuades maverick behaviour. However, in a dynamic environment where flexibility is the key, overstructuring can impede effectiveness; therefore, a balance needs to be found.

This is premised on three routes to build trust: peripheral, central and habitual. This network and model is mediated not only by an active feedback mechanism, but perceived risks and the attendant communication environment to actively moderate outcomes. Also, as time passes, interactions increase and relationships mature and trust moves from the peripheral to the habitual. A lot depends on collocation and face-to-face meetings, as also the cultural context of the situation. Quick turnover of people and leaders at this dynamic stage also brings in additional complexities. At the same time, despite competition between agencies and turf-battles, a common humanitarian goal unifies people at inter-personal levels with considerable inter-dependence at all levels. The levels of trust also vary from issue to issue as well as across time. In forming networks, some level of trust is implicit, a baseline from where it either grows or declines.

The first element in the peripheral route is third party information. This is essentially organisational or an individual professional reputation that includes expertise and demonstrated historical performances against laid down criteria. This is relayed through third parties or common databases. The second element is dispositional or an individual propensity to trust. Nothing much can be done about this except being aware of the pitfalls and individuals with these traits. The groupings too can be made aware of this problem. The third element of the peripheral route is rules, the presence of which regulates behaviour towards predictability. Development of common approaches, rules and structures allows newcomers to join in with confidence and dissuades maverick behaviour. However, in a dynamic environment where flexibility is the key, overstructuring can impede effectiveness; therefore, a balance needs to be found. The fourth element is categorisation, including perceived ideological and ethical differences,

and stereotyping. These judgemental issues need to be tackled by leaders of agencies by organising more official and social interactions. The final element in the peripheral route is roles. Roles can be accepted implicitly depending on competence certified through standardisation and recognised frameworks. For example, doctors and engineers can be accepted at face value, as also certified logisticians.

In a disaster, the dangers of physical harm to respondents and the chances of failure affect trusting behaviour. Where perceived risk is high, trust becomes more difficult to assume or enact. An ambiguity in roles, responsibilities and accountability increases this aspect, and needs to be mitigated by transparency and more face-to-face contacts. Skewed task load and fatigue are also factors that challenge trust in perceived risky situations. Computer networks and related communications do not clarify or add to trust building even through video conferencing as much as face-to-face briefings and debriefings. There are implications for agency leaders and strategic leadership if a swift trust model is to be adopted. The following are some obvious ones flowing from the discussions so far.

- The central and habitual routes of trust are important where the stakes and perceived risks are high. But these are based on long-term issues such as earlier experiences of working together, agency reputation and size, etc.—aspects that need to be planned and enacted over time.
- Third party information and transparent databases of track records and certified competencies allow establishing of quick credibility. This can be furthered by enabling face-to-face interactions.
- Dispositional aspects are highly individual and difficult to address in a general manner. However, common approaches, Standard Operating Procedures (SOPs), standardised forms and assessment templates do mitigate this to some degree. Transparent processes and standard rules for communication could be the key in allowing trust despite dispositional differences.
- In both dispositional and categorisation elements, awareness at leadership levels will allow remedial actions where required. Leaders need to be ready to educate their teams or individuals on these aspects.

In a study of the Israeli Defence Forces and US Army, the dominating themes in building of swift trust were: differences in perception of goals; action-based tasks enhanced possibilities; success in smaller tasks led to better and larger trust, standardisation of processes, SOPs and communications; prospects of working together in the future; and evolved leadership.

- Standardisation of competencies and certification that is aligned to worldwide standards will allow knowledge of this to serve as the proxy for actual competence. This must come along with transparent and objective evaluation of the work that is in progress or has been completed.

Inter-Organisational Trust: This could be an extension of inter-personal trust by means of transfer through and between individuals. Temporary teams may be characterised by limited or no history of working together, diversity of skills and capacities, little prospects of working together in the future, action-based tasks with complexity, uniqueness and high inter-dependence, and a requirement for continuous inter-relating and coordinating. In such complexity and uncertainty, swift trust needs team identity, role clarity, cultural moderation or adaptation, and free flow of communication.

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trust which was critical to what developed later[12]. Secondly, action-based tasks shifted the focus from social themes, helping swift trust to grow. Thirdly, positivity and transparency in communications enhanced collaborative efforts. Lastly, leadership of the team was critical in steering these efforts.

A virtual community of tech-savvy volunteers helped make the response quicker and more effective. Big data is large, unstructured and dynamic data-sets that cannot be handled by traditional information technology or computer hardware and methods.

TRUST, BIG DATA AND SOCIAL MEDIA IN DISASTER RESPONSE

Crisis informatics was a term introduced a decade ago, but shot into prominence only a few years ago after 2010 because of technological leaps in mobile phone processor and network capacities. Social Media (SM) especially plays a crucial part in this area. There are three main sub-groups under which this subject has advanced. The first is information collection which includes aspects such as SM data mining, SM-based crisis recognition, and SM-based geo-location applications. The second is communication, with facets such as detecting misinformation, Twitter analysis for improved Situational Awareness (SA), crisis-communication with the public, and use of SM by agencies to communicate. Finally, there are apps and systems to enable collective sense-making and collaboration among organisations and volunteers: for example, map mashups and crowd sourcing of geo-tagged information[13].

Big Data Analytics as Decision Support: After the earthquake in Haiti (2010), an era of digital humanitarians has dawned with the emergence of big data gathering and analysis during disaster response. A platform named 'Ushahidi' was copiously used to develop crowd-maps and actively involve the affected and the concerned through mobiles and web-based activity. A

12. S.L Jarvenpaa, R.T. Shaw and D.S. Staples, "Toward Contextualized Theories of Trust: The Role of Trust in Global Virtual Teams", I*nformation Systems Research*, vol. 15, no. 3, September 2004, pp. 250–267. issn1047-7047. eissn1526-5536 04 1503 0250.
13. S.N. Lee, S. Hirschmeier, S. Muller and L.J. Luz, "Enablers in Crisis Information Management: A Lit Review," Proceedings of the 50th International Conference on System Sciences, 2017, pp. 274-283. ISBN 978-0-9981331-0-2.

Knowledge management from diversified and dispersed individuals entails accurate aggregation and transforming tacit knowledge quickly to the research table for timely use. Nowhere is this more pertinent than the field of disaster management.

virtual community of tech-savvy volunteers helped make the response quicker and more effective. Big data comprises large, unstructured and dynamic data-sets that cannot be handled by traditional information technology or computer hardware and methods. There are many sources of big data: mobile Call Detail Records (CDR); online activity such as SMS and Twitter; sensors such as Unmanned Aerial Vehicles (UAVs), satellite feed and mobiles suitably networked in real-time; personal data and location through mobiles; publicly available web-based government websites; and, crowd sourcing, which is an active method based on volunteers and participation. The current focus by national governments on e-governance can enable all these sources to contribute meaningfully in disaster response.

Some applications of big data analytics are public health (epidemiology); population tracking during migrations; sociological behaviour of the affected, etc. Recent technological revolutions in communication have made this simple and mass-based. Mobiles (smart phones) can act as accelerometers (to detect movement), provide audio/visual content, provide co-location through Bluetooth and Global Positioning System (GPS), and allow crowd sourcing SMS. Tracking all these can provide an analysis of community movement and behaviour. Neo-geography platforms such as OpenStreetMap allow participative mapping techniques with audio-visual inputs also. This allows quick crisis mapping to provide situational awareness and support to decision-making for effective response.

Swarm Intelligence: Collective or swarm intelligence deals with behaviour of decentralised and self-organised systems, e.g. ants and bees in nature. It applies to human beings when minds meet to collectively solve problems in real life. Many studies have brought out the relevance of swarm

optimisation, ant colony systems and bee algorithms for human crowd sourcing to solve problems. Knowledge management from diversified and dispersed individuals entails accurate aggregation and transforming tacit knowledge quickly to the research table for timely use. Nowhere is this more pertinent than the field of disaster management. Any system that is modelled on complex adaptive theories has scope to benefit from swarm intelligence approaches. Quick data collection, spot analysis and real-time research allow problem solving in dynamic and fast-changing scenarios. The reasons for such application are many, among which some are as follows. First, data only starts becoming available as the problem emerges and develops. Second, quick dissemination of issues allows ideas to be exchanged from diverse stakeholders in real-time. Third, in an inter-connected and networked environment, it is increasingly possible to use technology to break "silo mentalities" to allow boundary spanning inter-disciplinary approaches. Crowd sourcing, social media, probabilistic mechanisms and metaheuristics allow tapping the potential of crowds. Lastly, in a world that is increasingly transparent and accountable to the public, stakeholder engagement in real-time has been made possible by technology[14].

Use of Social Media: The use of social media and crowd sourcing to populate maps with synthesised information in creating accelerated memory is based on the theory of metaheuristics. Ant colony algorithms point to modelling optimum paths that allow success to attract more and better ideas. All these nature-based applications are providing breakthroughs that cannot be ignored. Gone are poll-based methods, replaced by real-time connected swarm methods that allow interactive and reflective methods in tapping crowd wisdom. Some issues in this are workflow, hierarchy and task allocation, synchronising and sequencing, quality control and reputation, motivation and incentive, and active or passive intelligence guidance. Members of these virtual communities may not have rigid structures or hierarchy but can be flattish and unconventional, and transition from workers to leaders and vice-

14. C.W. Callaghan, "Knowledge Management and Problem Solving in Real Time: The Role of Swarm Intelligence," *Interdisciplinary Journal of Information, Knowledge and Management,* vol. 11, 2016, pp. 177-199. Retrieved from www. informingscience.org on November 22, 2016.

versa. Guidance to such a fluid arrangement can be by unique signals or information at the interfaces of a problem. This allows larger contributions and the attendant advantages of scales. There is implicit or explicit division of labour and invisible guidance which leads to synergy just like *stigmergy* in insects. The structures and changes are driven by real needs from bottom-up that leads to evolution towards optimisation.

Crowd wisdom can be tapped through crowd sourcing or crowd computing. In disasters, the former has been effectively used in searching, micro tasking, translation, data verification and data classification, using open-source principles. Crowd computing is used for solving complex problems by breaking it down into solvable parts. The other innovative thrust is to mix the data-handling ability of computers and better pattern-finding ability of humans to arrive at complementary hybrid models. One example is the Artificial Intelligence for Disaster Response (AIDR) platform which can automatically classify tweets after being 'taught' by crowds. Experience shows that early tweets are mostly about cautions and warnings, while later ones reflect damage, casualties, requirements, donations, etc. AIDR collects relevant tweets of a disaster and asks a crowd to label a subset of this data, which, in turn, trains an automatic classifier to handle huge amounts of data. Therefore, this method becomes very specific to a disaster and leads to user-friendly relevant processes. AIDR combines human intelligence and machine capabilities to handle large amounts of data to obtain labels from a subset of the data. The classification process is based on an active learning approach by the machine using crowd sourced wisdom[15].

Extracting meaningful information from micro blogging messages has been done many times in large disasters. For example, Hurricane Sandy in 2012 with two million tweets, the Japan tsunami in 2011 where 5,500 tweets were posted every second, and 2 million tweets after the earthquake in Haiti in 2010. Real time analysis of twitter data to extract casualty reports, critical requirements, geo-location of crisis sets, etc. has been done very effectively to

15. M. Imran, C. Castillo, J. Lercas, P. Meier and S. Vieweg, *AIDR: Artificial Intelligence for Disaster Response,* 2014, WWW'14 Companion, Seoul, Korea. www.dx.doi.org/10.1145/. Accessed on December 6, 2016.

enhance the situational awareness of disaster managers. Systems are generally based on machine learning techniques that rely on crowd sourcing. Experimental dashboards such as Disaster Response.9, in partnership with the United Nation's Office for the Coordination of Human Affaiars (OCHA) are refining this further for speed and accuracy[16]. Many platforms on the internet use Twitter to gather meaningful information on disasters for analysis by responders and helpers. All of them are based on ingesting or collecting data from Twitter using machine learning classification techniques, along with help from crowd sourcing methods. Extracting from 140 character limited tweets is much more difficult than from longer texts such as blogs and texts. Also, classifiers do not work on different disasters or templates; therefore, a fresh effort has to be made in every new disaster.

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The 2004 Indian Ocean tsunami witnessed the first-ever volunteer generated internet-based website that was modulated for about two weeks. Today, social media and different approaches of handling mass data and crowd sourcing allow the public at large to play a crucial contributory role in disaster management, especially in improving SA and coordination of activities. It allows the emergence of networks that are complex and adaptive, and creatively solves problems through crowd wisdom. This role is not limited to the response phase only but covers the entire cycle. An example of improving SA is the Australian Emergency Situational Awareness (ESA) platform which detects tweet outbursts and presents information in terms of timelines and spatial maps by event detection, classification, clustering and geo-tagging. On the other hand, platforms such as CrisisMapping use

16. M. Imran, S. Eebassouni, C. Castillo, F. Diaz and P. Meier, "Extracting Information Nuggets from Disaster Related Messages in Social Media," proceedings of the 10th ISCRAM Conference, Baden-Baden, Germany.

A highly tight-knit and bureaucratic set-up with standard procedures and formalities, is still not very comfortable with crowd sourcing data and analysis from emergent and independent groups. It is difficult to integrate these in a formal or highly accountable manner since the concept of command and control is not acceptable to them.

digital volunteers to do this job on a sample, and machines to learn and do this on a mass scale. A crucial factor is the nature of applied programming interface of major social network platforms that are unique, and determine the access of outsiders. Geo-tagging allows retrieval of spatial data but it needs GPS enabled programmes on the devices. Geo-coding is based on references to geographical features that allow coordinates to be fixed. This can be also done by automatic searches for geographical clues. Some platforms alternate between archived and live data processing which allows regular feeds for better latency as well as better contextual analysis by working deeply and retrospectively[17].

UN and the Virtual Community: The UN Office for the Coordination of Humanitarian Affairs (OCHA) primarily collaborates with governmental and non-governmental agencies to facilitate a coordinated response in humanitarian disasters and logistics supplies in such crises. A highly tight-knit and bureaucratic set-up, with standard procedures and formalities, is still not very comfortable with crowd sourcing data and analysis from emergent and independent groups. It is difficult to integrate these in a formal or highly accountable manner since the concept of command and control is not acceptable to them. The Digital Humanitarian Network (DHN) is a volunteer-based virtual group that is loosely structured to become active during disaster management. OCHA and DHN are increasingly collaborating for mutual benefits; the latter being able to take advantage of OCHA's formal network with most humanitarian agencies. The contrast between the two in terms of bureaucratic structure, hierarchy, formal SOPs, etc is stark. OCHA's Field Information Service (FIS) is responsible for

17 M. Imran, C. Castillo, F. Diaz and S. Vieweg, "Processing Social Media Messages in Mass Emergency: A Survey," *ACM Computing Surveys,* vol 47, no. 4, Article 67.

information coordination between clusters (UN). Its network with the virtual community has allowed it a role as a boundary spanner.

The UN's OCHA is mobilised in the case of major disaster events where the national capacities are overwhelmed. The normal UN method is to divide the task among 11 clusters with the initial assessment of requirements by OCHA, after which it takes on the mantle of coordination of the Humanitarian Programme Cycle. The start is a Multi-Cluster Initial Rapid Assessment (MIRA) by OCHA within two weeks. This requires systematic collation and analysis of data, including community level inputs and analysis. During Typhoon Haiyan over the Philippines in November 2013, OCHA approached the digital volunteer organisation MicroMappers to use Twitter to map out the crisis. While this first attempt did not prove decisive, it gave an impetus for future research into this area. The MIRA framework is focussed on eight themes: crisis drivers; scope and profile; population status; response capacities and effectiveness; international efforts; humanitarian access; gaps; and, priorities[18]. OCHA now formally accepts Twitter as a source to triangulate or confirm information through other conventional sources. It also accepts that social media is a valuable source for early or real-time information during critical phases.

DHN includes virtual organisations such as Humanitarian OpenStreetMap Team, Standby Taskforce, GEOCAN and CrisisMappers. These are focussed on disaster responses or humanitarian crises and based on peer-to-peer networking. Their strength lies in harnessing diversity and dispersed talents towards common objectives. However, capacities, core strengths and specialisations vary and are unpredictable. Sustainability over a long time is also a problem. Integrating this diversity into a formal structure is problematic, and requires a flatter and more flexible approach. Shared Situational Awareness (SSA) for humanitarians and disaster responders is a critical issue in a melee of complexity. It requires a synthesis and synergy of modern information technology and time-tested institutional practices to build up real-time SSA. Incorporating new and stranger communities such as DHN may be the key to the survival of bodies such as OCHA in

18. S. Vieweg, C. Castillo and M. Imran, "Social Informatics," *Lecture Notes on Computer Science*, vol 8851, Springer International Publishing. Accessed at www.springer.com on December 10, 2016.

Usability by the end-user is critical in the designing stage. A further development would be to graduate from enhancing situational awareness to decision support such as forecasting. A core requirement and challenge would continue to be validating the credibility and truthfulness of the social media context.

an increasingly connected world. The roles of boundary spanners and creative leaders seem to be game-changers.

CHALLENGES IN USING BIG DATA WITH TRUST

Experiences in Nepal in 2015 indicate many problems in handling of big data by volunteers. Firstly, volunteers are essentially untrained in the specifics such as the nature and extent of damage to infrastructure. Secondly, local language barriers and cultural contexts are not understood by most, resulting in poorly structured and unsynthesised data. Thirdly, standard formats to fill data are not available or not readily accepted. Fourthly, the virtual community may not be able to elicit responses from formal organisations due to a lack of credibility or face-to-face contact. Fifthly, quick rotation of volunteers inserts a large component of unpredictability. Lastly, virtual volunteers may not adhere to the core humanitarian principles.

There are many challenges to big data being credible and reliable. Some of these are variety (structure), velocity and volume (speed and quantity), veracity, vagueness (language) and validity (removing biases). There are other issues of volunteers and misuse potential that require caution when relying on big data. It must also be remembered that this is only an enabler or facilitator; decisions leading to action are still taken and implemented by humans. Response is extremely time-sensitive, and, therefore, real-time credibility, security and tolerance to disruption of infrastructure must be ensured. The final issue is putting all the analyses and information in a user-friendly package.

There are pitfalls to look for when handling such large data. First, the velocity of flow can be overwhelming in unpredictable bursts. Secondly, the size may run into millions of items, occupying many gigabytes of space. Finally, much of the information may comprise duplication such as retweets.

In terms of context, the ungrammatical and short-form nature of micro-blogging is difficult to sort out and analyse by simple machine learning templates. There are other attributes such as clarity, timeliness, objectivity and context that are difficult for a non-human to handle with accuracy. All media, including print media, videos, photographs, etc need to be integrated into a coherent holistic analysis. Filtering and classification may take into account subjective or objective context, type of information, source, credibility, time or location[19]. What is finally most important is usefulness and efficacy to the whole process of disaster management. Usability by the end-user is critical in the designing stage. A further development would be to graduate from enhancing situational awareness to decision support such as forecasting. A core requirement and challenge would continue to be validating the credibility and truthfulness of the social media context. Also, it must graduate from a passive approach to active questioning, or posting, of requirements. A desired end-state would be to use these platforms for active coordination of a chaotic disaster scenario.

The main concern in using social media for information on disasters is authenticity and reliability. Many media houses such as BBC and CNN use contrasting or multiple sources and phone interviews to check this out. YouTube videos can be confirmed by correlating the time of day with shadow, weather and accents of people, as also geographical features by using Google Earth. The internet explosion and social networking has allowed a revolution in social mobilisation. The Red Balloon Challenge by the US Defence Advanced Research Projects Agency (DARPA) clearly demonstrated the means of making sense of contradictory and dynamic data from a large geographical area. This was done by a team from the Massachusetts Institute of Technology (MIT) on laptops using social media, crowd sourcing and a recursive incentive mechanism. Claims and counter-claims can be verified based on mass participation and multiple evidences volunteered for an incentive. Evaluation is done through crowd sourced voting[20]. Platforms such as Verily have been developed for

19. Ibid.
20. A. Popoola, V. Naroditskiy, C. Castillo and I. Rahwan, "Information Verification during Natural Disasters," WWW 2013 Companion, Rio de Janiero, Brazil.

A network established purposely or incidentally, aims for knowledge sharing, problem solving, innovating or capacity building. It allows cross-fertilisation of ideas and inter-disciplinary approaches. There is evidence that some of the factors that attribute to successful networks are clarity of purpose and goals, leadership, core values, resources and flexibility.

disaster scenarios, which use these concepts to collect and verify inputs such as photos or status reports. It is based on rewards and incentives to those whose contributions lead to verified information that allow effective action by responders. These are not in monetary form but as recognition and trust-based allowances for more access to functions on the dashboard. It is felt that the spirit of disaster volunteerism responds better to recognition and reputation rather than monetary benefits. However, some platforms in the developing countries reward with airtime on mobiles.

Network Challenges: A network established purposely or incidentally, aims for knowledge sharing, problem solving, innovating or capacity building. It allows cross-fertilisation of ideas and inter-disciplinary approaches. There is evidence that some of the factors that attribute to successful networks are clarity of purpose and goals, leadership, core values, resources and flexibility. But a network of organisations that are independent and differ on many counts has multiple challenges. Firstly, a combination of competition and inter-dependence creates vulnerabilities that can be taken advantage of by opportunistic parties or behaviour. Secondly, this collaborative social identity can get tied to a group-think that can put blinkers on the effort to look for fresh ideas. Group or network loyalties may inhibit the required change or evolution. Thirdly, people or personality factors and cultural contexts among organisations require time and effort to be sustained. Lastly, the usefulness or success criteria of networks need objective and honest evaluation.

Among large crisis responders, a new specialisation has emerged, i.e. the social media analyst, who, while monitoring and engaging with the SM

community, helps to detect problems, identify trends and senses real needs[21]. He/she also detects and addresses rumours and misinformation among the community. He/she contributes to SA enhancement by providing information such as videos after validation through means such as corroboration, authenticity check by reverse imaging, tracking reliable sources, etc. He/she has to constantly update himself/herself on relevant handles, hashtags and websites. Assessing sentiments and emotions is another vital role along with a proactive programme to mitigate them if required.

No decision will satisfy all the stakeholders, and, therefore, there is no right or wrong—only good enough solutions. A number of variables, including terrain, resources, capacities, awareness, weather, etc. ensure that each context is unique and requires deeper understanding by responders. The solution is also context-unique, and, therefore, a one-shot operation. Finally, since there is no given alternate solution, group consensus and creativity will define emergent solutions.

WAY AHEAD

Table-Top Exercises: Large disasters are 'wicked problems' that are complex, virtually unsolvable and vexing. They are characterised by: a problem not understood till the formulation of a solution; a no-stopping rule; no right or wrong solutions; novelty and uniqueness; each problem a one-shot operation; and, no alternative solutions. Many approaches have been suggested to manage these problems. One is 'muddling through' which is based on using small and incremental actions from past-learning and adaption, depending on current progress. A second approach by Stubbart (2008) advocates pre-disaster planning as a social learning process so that all agencies are on board a common ground of shared understanding[22]. The underlined theme is that problem solving and learning go together when addressing 'wicked problems'.

21. R. Power and J. Kibell, "The Social Media Intelligence Analyst for Emergency Management," proceedings of the 50th International Conference on System Sciences, 2017, pp. 313-322. ISBN 978-0-9981331-0-2.
22. C. Stubbart, "Uncertainty, Complexity, Conflicts of Interests, Emotional Involvement and the Quality of Crisis Thinking," Faculty Working Paper 1289, 1986, College of Commerce and Business Administration, University of Illinois at Urbane-Champaign.

Complete understanding is a problem because of the complexity and dynamic nature of the environment. Multiple stakeholders with different perceptions and agendas only compound the issue. Conflict of interests among stakeholders and the affected community has a great impact on decisions. Since problem definition is not static or firmed up, there can be no fixed criteria for success. And, therefore, the no-stopping rule. No decision will satisfy all the stakeholders, and therefore, there is no right or wrong—only good enough solutions. A number of variables, including terrain, resources, capacities, awareness, weather, etc. ensure that each context is unique and requires deeper understanding by responders. The solution is also context-unique, and, therefore, a one-shot operation. Finally, since there is no given alternate solution, group consensus and creativity will define emergent solutions.

In a wicked problem, it may be futile in terms of time constraints to fully grasp a situation and act in the most optimum manner. Expertise and experience can weigh limited factors and use heuristics to act fast. At the same time, feedback channels are open to make sense, as events unfold and 'surprises' creep up, to adapt and modify strategies. However, group-think must take into account well documented biases such as collocation blindness which refers to the tendency of collocated members in a distributed command or 'virtual' control team to resist reaching out to distributed members even when they may have better expertise. Another well-documented bias is in-group bias, where members favour own group over people from other groups. In the effort to break up complex or wicked problems into manageable parts by different teams, a `deference to expertise', wherever it lies, must never be lost sight of. This must be monitored by senior leaders who may be preoccupied in undertaking strategic oversight and garnering resources. The decision support must have mechanisms of feedback to senior levels and the ability to allow informed dissent by experts on the decisions being taken.

A table-top exercise simulating disaster response is planned around interaction, coordination mechanisms and integration of organisational differences and ethos. It focusses on communication between agencies for

a collaborative system to emerge. These are very structured and normally unsuitable to creatively attack 'wicked problems'. However, this can be addressed by: allowing players to tame the issue in the table-top rather than the planning stage; focus on unsolved and vexing issues rather than routine ones; and, use plans and lessons-learnt to collaborate in the present. Focussing on unplanned and unpredictable issues will allow more dynamism in table-tops.

Overload of information needs to be avoided. Design of information flow must cater to individual group or agency requirements. DSA is based on just-enough and tailored information and not all that is available. This also aids quick decision-making at dispersed locations. The overall aim being the right information, in the right format and at the right time.

Lessons Learnt: Table-Tops: In many multi-agency tasks in disaster response, a common refrain is lack of understanding of each other, leading to sub-optimal collaboration in a critical life and death scenario. Limited sharing of information is due to poor incompatible structures, poor information management, lack of interoperability of equipment or plain agency agendas of keeping information to themselves. Misinformation or misunderstanding is due to the lack of a common operating picture that is relevant and contextual to an agency. It could also be due to the lack of clarity on the roles, responsibilities and capabilities of each other. Confusion over leadership (shared, distributed or specialisation-based) also distorts mutual accommodation. A similar effect is caused by a poor structure of command and control, which varies from phase to phase. Cultural differences in processes such as decision-making create friction if not countered with more experience of working and exercising together[23]. The following measures are suggested to ensure better collaboration and coordination in disaster response tasks between agencies:

23. S. Edzen, "Table-Top Exercises for Emergency Management: Tame Solutions for Wicked Problems," Draft Paper, Lulek University of Technology, Sweden. Accessed from www.itu.diva-portal.org on December 3, 2016.

- Meta situation awareness is about knowing and understanding other agencies' capacities, actions and status at a point of time. Along with clear roles and responsibilities, and areas of overlap and mutual support, this will lead to automatic coordination to avoid conflict and duplication.
- Shared or compatible mental models are critical to Distributed Situational Awareness (DSA) and coordination among dispersed actors. This is possible by joint training, exercises and scenario-building. This is then supported by procedures, protocols and systems that allow each agency to augment its cognitive processes and personal schema to grasp real-time SA. Therefore, the end-user is important in terms of the form of communicated information.
- Overload of information needs to be avoided. Design of information flow must cater to individual group or agency requirements. DSA is based on just-enough and tailored information and not all that is available. This also aids quick decision-making at dispersed locations. The overall aim being the right information, in the right format and at the right time.
- A 'system' of leadership that caters to distributed roles and tasks, changing priorities during different phases and specialisation focus at critical points, and, allows trust for collaboration that has to be put in place. This can happen only through exercising jointly or gaining experience through actual work. The core task of such leadership also includes monitoring and evaluation of performance of teams.
- There may also be a need to incentivise collaboration through active or passive measures. Awareness and understanding of the benefits of the collaborative and synergised model can create all-round positivity, clarity and trust.