Coordination quality index: a metric for measuring the quality of coordination efforts in humanitarian supply chain

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Abstract: The effectiveness of the coordination practice has a direct consequence on the performance of humanitarian supply chain operations and it becomes imperative for the managers to quantify the effectiveness of the coordination activities. This study aims to provide humanitarian agencies with a tool to measure effectiveness of its coordination strategies. Coordination quality index (CQI) is introduced as an aggregate measure of the degree of implementation of various coordination practices carried out. Furthermore, the application of the proposed methodology is demonstrated in the setting of Chennai flood relief activities. The results indicate that the overall quality score obtained for coordination during the Chennai floods was moderate to low. The major reason for the poor coordination was due to poor information sharing, large diversity of actors and lack of streamlined organisational mandates. It also found that, though there were efforts to improve coordination, the expected benefits of these activities were not achieved.

Keywords: coordination quality index; CQI; coordination; humanitarian supply chain; HSC; case study; Chennai floods.


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1 Introduction

In the case of commercial supply chain (CSC), intense global competitions have led the business organisations to rally away from a firm level competition to a CSC level competition. Hence, the role of coordination between the participating organisations in a CSC becomes paramount. Naturally, the quality of coordination between the actors in CSC is vital for the effectiveness of CSC operations. This understanding has led to studies on improving the coordination quality between the actors in CSC. Kanda and Deshmukh (2008) draw our attention towards the importance of quantifying the coordination efforts and proposed a model for measuring the strength of coordination in CSC which uses coordination mechanism such as contracts, use of information technology, information sharing (IS), joint decision making etc. Despite its significance, similar studies in humanitarian supply chain (HSC) have not been widely developed and systematically implemented.
HSC focuses on reducing the impact of disasters on the lives of the vulnerable and affected people in the wake of a disaster. It comprises a large number of stakeholders such as international and national humanitarian relief organisations (HROs), governments, military, donors, private sector organisations etc. Unlike CSC, HSC does not have a profit motive and they do not generate any income. It primarily depends upon the support received in the form of donations and aid materials received from multiple donors across the globe. With an increase in the number of disasters every year, the international community is pledging billions of dollars for aid work every year. According to Global Assistance Report (2015), total humanitarian funding has increased at a rate of 8.9% annually from 16 billion USD in 2009 to 24.5 Billion USD in 2014. The donors are no longer tolerant to the fire-fighting operational mechanisms that characterised humanitarian operations in the past (van Wassenhove, 2006) and have started demanding result oriented operations. Moreover, with increased frequency and scale of disasters, scarce resources, and the need for accountability, competition between the humanitarian agencies has increased (Lindenberg and Bryant, 2001). This competition leads to inefficiencies in HSC operations, wastage of resources, increased cost of operations and lower impact on the lives of affected (Van Wassenhove, 2006). For an efficient, effective and transparent relief operations, coordination between the agencies is imperative (Jahre et al., 2009). According to Xu and Beamon (2006, p.4) the coordination mechanism in HSC is defined as the “set of methods used to manage the interdependence between the organisations”.

However, coordination is often considered as a cost centre (Balcik et al., 2010). At the tactical levels, the cost includes salaries for the staff, travel cost for the coordination meeting, etc., while at the operational level; the cost includes expending resources in terms of personnel, material and infrastructure for the coordination, which might often become difficult for the smaller HROs. Therefore, the HROs need to understand the impact of coordination activities on the performance of HSC in terms of metrics such as cost of operations, number of people served, number of disaster incidents that were catered to, amount of aid material distributed, etc. (Beamon, 2004). These activities are aimed to assist humanitarian practitioners in their decisions which help in improving the effectiveness and efficiency of relief operations and improve the performance of the HSC (Beamon and Balcik, 2008). However, to gauge the quality of the coordination efforts effective measurement systems are required.

Previous studies on performance measurement in HSC are based individual organisation. No studies have attempted to evaluate the quality of the coordination activities and to understand its impact on the effectiveness of the humanitarian operation. This is important since, individually each organisation will focus on improving its own performance. This leads to a localised strategy creation for each organisation which might not be beneficial for the entire relief operation. Though the individual organisation might perform well, the disaster management operation at large might be affected. This study focuses on measuring the effectiveness of coordination in the humanitarian operations based on the inputs from various stakeholders of the HSC. In this paper, an attempt has been made to address this gap by proposing an index to measure the quality of the coordination activities undertaken in HSC. The main objectives of this study are:

- to create a single point measure for the quality of coordination activities in HSC
- propose a model for measuring the quality of the coordination activities in HSC
• to illustrate the application of the measure by applying to Chennai floods as a case study.

2 Literature review

The nature of interactions for coordination can be broadly classified into inter-relationships between the traditional relief organisations and interactions between the traditional HROs and private sector (Balcik et al., 2010). Hence, the literature is accordingly classified to understand the characteristics of coordination under these categories. In addition, the factors and issues that affect coordination are also identified.

2.1 Coordination mechanisms between traditional HROs

The international humanitarian community differs in their mandates, sizes, expertise and operating philosophies and have operated individually in past. However, off late, due to growing international pressure from the donors, HROs are required to jointly operate with each other. The coordination efforts between HROs can be understood in terms of coordination between international organisations and coordination between international and local organisations.

Many international HROs tend to get into horizontal coordination with other HROs, i.e., coordination between the agencies at the same level of operations. These organisations involve in joint procurement, joint warehousing, sharing of aid material among themselves, etc. Most common coordination mechanism here involves formation of an umbrella organisation under the gambit of which the horizontal coordination takes place. Since pre-positioning is an expensive affair, international HROs tend to significantly gain from the horizontal coordination (Schulz and Blacken, 2010). In case of the horizontal coordination, the autonomy of the HROs is preserved and the relationships are usually not bound. UN joint logistics centre (UNJLC), is one such organisation which formally came into existence in 2002 to handle the operational logistics and to make best use of the scarce resources (Kaatrud et al., 2003; UNJLC, 2008).

Another approach for the coordination between international HROs is the cluster approach. Cluster concept is defined functionally in terms of areas of activity such as water and sanitation, health, shelter and nutrition, etc. (IASC, 2006). Cluster approach was adopted for improved coordination between HROs to meet current and future humanitarian needs, create a predictable leadership at global and local level, strengthen partnership between UN bodies and create accountabilities among HROs (Adinolfi et al., 2005). The cluster concept is operationalised through designated global lead for each cluster, creating and building capacity at both local and global levels.

The coordination between the international HROs and local HROs is also imperative. International HROs interact with various local institutions such as local governments, local HROs, NGOs, military etc. Multiple factors such as local politics, institutional frameworks, cultural backgrounds etc. affect the coordination activities within the local setting (Balcik et al., 2010). The international HROs are often required to closely operate with the local institutions adhering to their mission, code, culture and operating procedure (Kehler, 2004). To reduce friction, the international agencies often operate through the national partner organisations in each country. These partner organisations interact with
the local governments and local agencies to help the international HROs operate in the aid-receiving country (Linderberg and Dobel, 1999).

2.2 Coordination mechanisms involving private companies

The HROs have two major kinds of relationships with the private sector – namely, the philanthropic relationship and commercial relationship. The coordination efforts and procedures for both these relationships vary.

The private sector and international HROs engage both vertically and horizontally. Donation based relationships are often extended for limited time duration typically during the span of the disaster relief operation. On the other hand, the strategic partnerships with the private sector for effective coordination would include sharing expertise in handling large-scale logistics, improving organisational commitment, forming joint-partnerships, etc. (Thomas and Fritz, 2006). One such strategic partnership is the association of world food program (WFP) and TNT (a logistics company) (Tomasini and van Wassenhove, 2004). Other examples of similar partnerships can be found in association of FedEx and American Red Cross, DHL and Mercy Corps, and DHL and International Federation of Red Cross (IFRC).

From a commercial standpoint, humanitarian relief is a multibillion-dollar industry (Binder and Witte, 2007). HROs often require large quantities of aid material for the relief activities. This often require vertical coordination between the supplier and HROs. The need to be responsive requires HROs to procure aid material for the local market which does not help in forging long-term relationships with the suppliers. Except for large HROs constantly engaged in the relief activities across the globe, smaller HROs do not have a steady set of suppliers with whom the HROs have a long-term agreement. Under these conditions, UN global market place acts as a liaison between the HROs and suppliers helping the HROs in joint pre-planning, procurement and warehousing (UNGM, 2008). Another initiative is the global fleet forum, jointly launched by IFRC, WFP, and World Vision to help plan for the transportation requirements of the HROs across the globe.

However, various initiatives undertaken by the HROs to improve the coordination between the humanitarian agencies fail owing to poor understanding of the activities of partner HRO (Balcik et al., 2010), lack of trust between the coordinating agencies (Stephenson, 2005), failure to incentivise the agencies to coordinate across the various stages of HSC (Oloruntoba, 2005) etc. The subsequent section provides a brief discussion on the failure of the various coordination initiatives.

2.3 Challenges with coordination

Though umbrella organisations for coordination have been a successful model in the past, the mere presence of the umbrella organisation does not guarantee effective coordination. For instance, during the relief activities after the Indian Ocean tsunami, the efforts of United Nations (UN) failed to coordinate between the various HROs (Volz, 2005). UN organised a large number of meetings (up to 72) per week. Many such meetings did not have a clear agenda and since these meeting were held in English, instead of the local language, resulted in poor understanding and lack of clarity to the members of the local NGOs (Balcik et al., 2010). Furthermore, with large number of HROs responding to the
relief needs after the Indian Ocean tsunami, the varied specialisations of these agencies also added to poor coordination (Adinolfi et al., 2005). The major reason for the failure of the umbrella system during the Indian Ocean tsunami relief was the lack of any association with these agencies in the preparedness phase, while handling issues such as contingency planning, appeals management, transportation management etc. (Jahre and Jensen, 2010).

The failure of the cluster system was evident during the Pakistan floods (2005) relief efforts. The clusters formed during Pakistan floods was accused of not being inclusive and local NGOs were not involved in the implementation or decision making phase (Stoddard et al., 2007). The cluster system in Pakistan created dual power structures. The international cluster head was not able to command the local members in the cluster to operate, as they were not associated with the international clusters. This rendered the local cluster head to be inefficient in getting the cluster activities completed. Often, the local cluster head in Pakistan had to complete the cluster based operation by itself rendering the entire operation to be partially operationalised and being a failure (Stoddard et al., 2007; Jahre and Jensen, 2010; Adinolfi et al., 2005). Furthermore, the clusters in Pakistan often competed for the resources which also led to poor inter-cluster coordination. This again can be traced back to the lack of clear mandate for the clusters and creation of alternate power structure (Cosgrave et al., 2007).

Sometimes the local agencies in association with international agencies operate as an umbrella organisation to facilitate the coordination. However, this mechanism does not always yield results. During Mozambique floods (2000), National Institute for Disaster Management (INGC) was appointed by the Government of Mozambique as the nodal agency to facilitate the coordination between the relief agencies. INGC was responsible for coordinating, deliberating and monitoring the activities of the NGOs arriving for the relief activities. However, the INGC lacked the skill or capability to manage such an event and hence it was unsuccessful in their coordination efforts (Moore, 2003). Also most of the NGOs did not recognise INGC as the central coordinating authority and did not register or inform their activities to INGC. The lack of coordination even led to the situation where the aid recipients were injured or killed in the struggle to procure the aid material distributed by the unregistered aid agencies (Matsimba, 2003).

The above examples and discussions show that the not all coordination activities undertaken by the HROs result in the effective coordination. Though large number of studies (Balcik et al., 2010; Jahre and Jensen, 2010; Stoddard, 2005; Stephenson, 2005; Zetter, 1995) have explored the various reasons for the success and failures of coordination activities and have proposed frameworks for the coordination, they have not focused on quantification of the quality of coordination activities. The quantification of the quality of coordination activities has been well discussed in the context of CSC. Kanda and Deshmukh (2008) finds that in the CSC, multiple strategies such as CFPR, SCOR, etc., are used to initiate coordination in the CSC. But, initiatives undertaken as the coordination activities cannot be easily measured through the traditional supply chain performance metrics since it is difficult to identify the impact of individual initiatives on the performance metrics. Hence, it is imperative to create additional or proxy measures to quantify the quality of coordination activities undertaken in supply chain. Perakis and Roels (2007) quantified the impact of the price only contracts in achieving supply chain coordination. Ramanathan (2014) used simulation to quantify the performance of supply chain collaboration and identified the optimum conditions to be achieved to make coordination in CSC effective. Narasimhan and Nair (2005) explored the role of vendor
managed inventory in achieving CSC coordination and listed out the antecedents related to IS and coordination quality. Forker et al. (1997) examined the impact of the quality of upstream coordination activities on the downstream performance of the SC. Zhou and Benton (2007) analysed the role of IS on the quality of the coordination achieved across the CSC. These studies highlighted the importance of measuring the quality of the coordination in a commercial SC. In the case of HSC no studies have been found which focuses on quantifying the quality of the HSC coordination operations. Moreover, most of the studies on CSC considered various individual practices to understand its impact on the coordination. None of the studies attempted to understand the impact or quality of coordination when multiple practices or efforts of coordination are considered together. Hence, a mechanism has been proposed to quantify the quality of the HSC coordination efforts and illustrate the use of the proposed mechanism in the context of Chennai floods (2015).

3 Perceived benefits of coordination in HSC

The coordination between the stakeholders in a CSC results in, elimination of excess inventory, reduction of lead times, increased sales, improved customer service, efficient product developments efforts, low manufacturing costs, increased flexibility to cope with high demand uncertainty, increased customer retention, and revenue enhancements. Coordination is perceived as a prerequisite to integrate operations of stakeholders in CSC to achieve common goals. Since, HSC operates in a different environmental setting with a varied operating philosophy, does share some of the benefits of coordination that are typically observed in the CSC setting. For HSC, the benefits due to coordination include improved usage of aid material inventory (van Wassenhove, 2005), better utilisation of available resources (Oloruntoba, 2005), increased flexibility in operations (Stephenson, 2005), improved visibility across the supply chain (Schulz and Blacken, 2010) etc. Some of the other benefits that can be achieved due to improved coordination which are specific to the HSC are improved interaction and association between the local and international NGO’s (Balcik et al., 2010), streamlining the organisational as well as operational mandates of the stakeholders in HSC (Jahre and Jensen, 2010), addressing the donor expectations without compromising on the quality of the relief provided to the affected community (Régnier et al., 2008), improving the trust between various humanitarian agencies (Stephenson, 2005), formation of coordination clusters thereby reducing the number of individual actors in relief operations (Jahre and Jensen, 2010), reduction of the aid addiction by the affected community (Kovács and Spen, 2009), etc. Thus, the quality of coordination can be measured, if these benefits are achieved or at least as perceived by the stakeholders in HSC on account of implementing various efforts or practices that establishes or improves coordination among these stakeholders. Hence, the perceived benefits of coordination are combined into five major categories. These are:

- improvement in resource utilisation (RU)
- improved IS
- increase in the perceived value of coordination (PV)
- streamlining the organisational mandates (OM)
- reducing the impact of diversity of actors (DA).
Therefore, the effectiveness of the coordination efforts can be quantified based on how these efforts are effective in achieving these benefits due to coordination.

### 3.1 Improvement in RU during HSC operations (RU)

The HSC faces a unique challenge of having scarcity and oversupply of products simultaneously. The critical resources such as medicines, potable water, food items etc. are always scarce in the initial phase of disaster relief. However, as the situations stabilise, a large influx of aid from various donors would arrive. Often such donations are unsolicited and consume storage space and clog the supply chains (Balcik et al., 2010; Reitjens et al., 2007). Secondly, the scarcity of the essential materials often leads to competition between the agencies involved in HSC. The competition stems from poor understanding of the overall requirement and lack of coordination (Altay and Labonte, 2014; Oloruntoba, 2005). The wastage of aid material also combined with poor stock keeping of the inbound aid material leaves little stock visibility in the HSC (Bealt et al., 2016). During the response phase, the duplication of efforts is rampant which often leads to repeatedly serving the same affected community while neglecting the others (Heaslip et al., 2012; Jahre and Jensen, 2010). Owing to poor stock keeping and lack of coordination between the agencies, the humanitarian agencies tend to either overstock or under stock the resources required. Though effective RU is often a major challenge in HSC, coordination between actors is aimed to achieve better utilisation of the available resources.

The coordination activities undertaken by the HRO’s include joint assessment of the needs, partnering with local NGOs to understand local needs, joint warehousing and logistics facility utilisation, exchanging workforce, etc. (Stephenson, 2005; Gonzalez, 2010). The primary reason for the poor RU is lack of knowledge about the needs of the beneficiaries. The coordination initiative primarily aims to reduce the information asymmetry in the HSC (Tatham et al., 2017). Joint assessment of the HROs in the post-disaster scenario avoids duplication and multiple counts of the requirements from the same area. Also by including the local NGOs, the exact needs of the beneficiaries are gathered which includes socio-cultural needs as well which might not be known to international agencies leading to wastage of the aid materials. Also joint warehousing gives a better visibility of the stock available and therefore helps in efficient routing of the material to the affected areas. These coordination initiatives help in achieve better RU during the HSC operations.

### 3.2 Improved IS between the humanitarian agencies (IS)

The nature of IS between the agencies during the HSC operations is imperative for the efficient coordination and improved effectiveness of humanitarian operations (Day et al., 2012). Though the importance of IS is well understood in the context of HSC, it never becomes the top priority for the agencies specifically within HSC (Ergun et al., 2014). Moreover, each agency collects and processes data based on their requirement leading to multiple data formats. The lack of consistent data formats also makes inter-agency IS and processing inefficient and ineffective (Seybolt, 2009). Lack of uniform need assessment techniques also leads to varied estimates of the requirements. The agencies seldom arrive at a consensus regarding the need assessment (Altay and Labonte, 2014). Poor IS between the agencies distorts the actual need of the beneficiaries in many cases and
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Affects the relief operations (Sheppard et al., 2013). In a post-disaster scenario, even while coordination efforts are undertaken through the exchange of IS between agencies, due to the lack of pre-disaster phase associations between the agencies, these efforts are often rendered ineffective (Moshtari, 2016).

Since IS is indispensable for the coordination in HSC, HROs need to craft effective IS mechanism for better coordination. Firstly, the agencies need to collaborate during the preparedness phase of the disaster management with a focus on formulating strategies for post-disaster information sharing (Cosgrave et al., 2003). The associations between the HROs during the preparedness phase helps in building trust between the agencies (Zetter, 1995). The information sharing mechanism include, joint data collection and standardised data recording formats (Ergun et al., 2014), developing platforms for easy data sharing (Seybolt, 2009), joint information sharing regarding stock positioning and availability (UNJLC, 2008), information sharing regarding serviced areas, etc. These mechanisms of information sharing designed during the preparedness phase primarily focuses on reducing the variability during information collection and processing and building the trust between the agencies to ensure smooth and effective information sharing. This planning for coordination prior to relief operations enhances the post-disaster IS (Van Wassenhove, 2006).

3.3 Reducing the impact of diversity of actors in HSC (DA)

In a post disaster scenario, large numbers of volunteers arrive at disaster site for rescue and relief operations. Often these volunteers lack prior experience in handing a disaster situation and overlook the importance of coordination leading to a chaotic environment (Zetter, 1995). Though the local government is expected to act as the central authority in managing the relief activities, often scale of the disaster leave the authorities overwhelmed with little and no on-field coordination (Van Wassenhove, 2006). Moreover, the diverse natures of the agencies, majority of which are not specialised in disaster management, fail to understand the complexity of HSC operations and coordination with these agencies becomes a difficult task (Tomasini and Van Wassenhove, 2009). On the other hand, coordination between specialised agencies are primarily due to personal contacts between the humanitarian logisticians and rarely due to organisational policies. This informal coordination is short lived and lacks a strategic focus for long-term coordination (Heaslip et al., 2012).

The DA in HSC stems from two major sources. First, the volunteers arriving at the disaster site lack any prior training or experience of disaster response. These volunteers are often the first responders to the disasters. They also act as the source of primary data which is helpful in planning the relief activities. Therefore, it becomes imperative to improve coordination between them (Falasca and Zobel, 2012). To facilitate inter-organisation coordination, the organisations tend to develop a large pool of stand-by volunteers by training the public and in particular – the adolescent students through schools, colleges, etc. This helps to create volunteers who are familiar with relief operations and those who understand the importance of coordination (Callow, 2004). Secondly, the coordination between the HROs has to be addressed. This can be achieved through the pre-disaster agreements to jointly operate in the affected area, formation of standing committees to integrate multiple agencies and to assign responsibilities. Since most of the HROs have specific modus operandi for relief operations, unless pre-defined,
it becomes difficult for the HROs to arrive at commonly acceptable operating mechanisms while coordinating. Thus, prior agreements on coordination can help streamline the coordination efforts (Chandes and Paché, 2010).

3.4 Perception of value due to coordination (PV)

Though coordination between the agencies is expected to improve the effectiveness of HSC activities, it is often considered to be a cost centre owing to the need to expend resources such as manpower, infrastructure, money, etc. (Ergun et al., 2014). The gap between the cost of coordinating with other agencies and the perceived benefit due to coordination acts an impediment (Morales and Sandlin, 2015). The lack of mechanism for performance accountability is the key reason why agencies stay away from forming any long-term coordination partnerships with other agencies (Stephenson, 2005). A short-term association between the agencies warrants only a lower levels to inter-agency commitment and therefore, the HROs tend to invest lesser amount of resources for coordination (Balcík et al., 2010). Furthermore, when the coordination activities are neglected, the perceived benefits due to coordination is not achieved and further adversely affecting the perception of value in terms of improved HSC operational effectiveness achieved through coordination (Charles and Lauras, 2011).

To improve the perception of the value attained due to coordination, constant review meetings are organised to assess the situations. These meetings are aimed at taking the stock of the situation (Bisri, 2016). The meeting also encourages the members to bring forth the challenges faced by them and provided opportunity for cross learning. It also facilitates formation of sub committees to tackle specific problems (Hossain and Uddin, 2012; Healip et al., 2012). Also the standing committees often decide the commonly acceptable performance parameters which are constantly reviewed to asses and track the HSC activities (Apte et al., 2016). Furthermore, the coordination standing committees also helps in the creating and maintaining common pool resources which is not efficient for an individual organisation to maintain. This helps in creating value for the agencies to be a part to the standing committee rather than operating alone (Sheppard et al., 2013; Seybolt, 2009).

3.5 Streamlining conflicting OM

The coordination between the agencies is also affected due to the need to satisfy the ‘customers’ (aid recipients and donors) at the both end of HSC and the lack of trust among the agencies. Since HSC considers both aid recipients and the donors as customers (Van Wassenhove, 2006), catering to the donor requirements often conflicts with beneficiary requirements and hampers the coordination between the agencies (Ertem et al., 2012). The agencies that participate in the HSC activities have varied specialisation with each agency specialising in a limited range of activities in disaster management (Day et al., 2012). For instance, the Red Cross primarily focuses on the health and hygiene related activities in the HSC operations while, the armed forces such as army, navy and air force are trained for search and rescue missions (Opdyke et al., 2016). However, irrespective of their specialisation, these agencies tend to participate in all stages of disaster management and affect the coordination between the agencies (Schulz and Blecken, 2010). Furthermore, the agencies have a divergent set of interests
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(Stephenson, 2005; Oloruntoba, 2005) which stems from the varying donor expectation. The lack of trust between the international agencies, international and national agencies and between national agencies and the competition between these agencies for donor recognition affects the trust formation between the agencies and coordination (Stephenson, 2005).

To address the above-mentioned issues, the coordination committees chart out the entire operation plan for the disaster relief and rehabilitation. The operations are often categorised based on the phases of HSC. In the preparedness phase, the primary aim to build and create capability, while in the response phase, it is search and rescue whereas the rehabilitation phase focuses on long-term rehabilitation (Lee and Zhinden, 2003). Further, depending upon the capabilities of the organisation, specific parts of operations are assigned. This helps each organisation to focus on the activities they are best capable to handle (Altay and Labonte, 2014). Secondly, this assignment processes often leads to close association with agencies with complementary skills and helps in trust formation between the organisations. For instance, water, sanitation and hygiene (WASH) includes all humanitarian organisation primarily trained and equipped in the managing similar operations. This helps them to formulate combined strategies for better effectiveness (Stoddard et al., 2007).

The above discussion helped in understanding the various challenges for coordination within the HSC context and also suggests potential solutions/efforts to mitigate the same. If these are the perceived benefits to be achieved by the stakeholders due to the efforts related to coordination, then it is possible to establish the quality of coordination efforts by developing a coordination effectiveness index (CEI). Since, this index is a function of multiple factors, a multi-criteria decision making model is used to obtain the CEI.

Table 1  Fuzzy quality grades for perceived benefits

<table>
<thead>
<tr>
<th>Quality fuzzy vector</th>
<th>Quality level</th>
<th>Fuzzy Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Extremely high</td>
<td>T(8, 10, 10)</td>
</tr>
<tr>
<td>B</td>
<td>High</td>
<td>T(6, 8, 10)</td>
</tr>
<tr>
<td>Ĉ</td>
<td>Moderate</td>
<td>T(4, 6, 8)</td>
</tr>
<tr>
<td>Ď</td>
<td>Low</td>
<td>T(2, 4, 6)</td>
</tr>
<tr>
<td>Ė</td>
<td>Very low</td>
<td>T(0, 2, 4)</td>
</tr>
<tr>
<td>Ė̄</td>
<td>Extremely low</td>
<td>T(0, 0, 2)</td>
</tr>
</tbody>
</table>

Source: Chang and Qi (2003)

4 Methodology

Chang and Qi (2003) proposed a fuzzy performance grade for measuring the performance of multiple sub-systems in the CSC. The performance of the supply chain operations was quantified by converting the performance measures to a fuzzy performance metric called the performance grades as summarised in Table 1. The performance grades were calculated for the CSC performance metrics like inventory levels, inventory turnover, cycle time, etc. A similar methodology was adopted in the context of HSC to measure the
quality of the coordination activities, since this methodology helps to quantify the benefits in terms of HSC.

Each disaster is unique in terms of challenges and offers unique set of operating conditions. Therefore, it becomes a challenge to identify and benchmark the performance of HSC to other disasters. On the other hand, it also becomes difficult to quantify the improvement of HSC operations based on past performance since the disaster relief activities are usually disaster dependent and is not a continuous activity unlike CSC. Moreover, HSC operations have large number of stakeholders and each stakeholder might have a different perspective of the HSC operations. This method helps in integrating the opinions of various stakeholders, which in turn helps in reducing the bias in identifying the perceived benefits through coordination in HSC. However, the methodology proposed by Chang and Qi (2003) is based on the objective facts from CSC, while in the case of HSC, such objective metrics are not available. Therefore, the weights used for evaluating the perceived benefits achieved are based on the scale used in analytic hierarchy process (AHP). The weights obtained by the AHP for the perceived benefits act as an input to the methodology suggested by Chang and Qi (2003). Combining AHP and Chang and Qi (2003) methodology a hybrid method is proposed for measuring the effectiveness of the coordination activities in HSC based on the fuzzy theory. Fuzzy methodology has been used in this context since it can effectively capture the subjectivity in decision maker’s perception of the situation. Since the perceived benefit of coordination in HSC is quantified as the quality of the coordination, this subjectivity needs to be factored in. Fuzzy logic is applied in the situation where understanding is quite judgmental and the processes where human reasoning and human decision making is involved like the complexities in HSC (Deb, 2001).

The proposed methodology has the following main steps:

- selection of the perceived benefits
- calculation of relative weights of perceived benefits
- conversion to measurement scale and creating fuzzy quality grades for various coordination practices under each benefits
- aggregating measurement results
- calculating global coordination quality index (CQI) and benchmarking.

4.1 Fuzzy quality grades

The degree of the benefit achieved due to the coordination in HSC is calculated based on the perception of the extent to which the benefits were achieved. For instance, if the evaluator feels that a high degree of RU was achieved due to coordination, then the quality of the RU as a perceived benefit of the coordination among the actors is ranked high. Based on perceived degree the quality of the benefit achieved is categorised in to grades. Here a fuzzy measurement scale is introduced to convert the perceived benefit achieved to quality grades. Since each evaluator might have his/her own judgement regarding the perception of the quality for each of the perceived benefit of coordination, the quality of the perceived benefit is categorised into quality grades.

The perception of each evaluator regarding the degree to which each of the benefit of the coordination is achieved is based on the two factors: their experience in the
humanitarian sector and the expected benefit, which they feel, should have been achieved. Based on these, each evaluator has a bottom value, which is the least degree of benefit that can be achieved. Further, they compare the present degree of benefit achieved due to coordination with the least degree of benefit. The lowest degree of the benefit achieved denotes the minimum acceptable benefit that should have been achieved. Similarly, the top point, perfect value denotes the totally satisfactory degree of benefit achieved as perceived by the evaluator. Bottom value and perfect value of the measurement scale are not necessarily based on the absolute goal and history of HSC operations, but are based on the evaluator’s judgement. For instance, consider a joint need assessment initiative comprising of a group of HROs carried out with the intention of reducing the duplication, streamlining the aid distribution, accurate estimation of the needs of the beneficiary etc. The least benefit expected from the joint need assessment would include the participating members to diligently collect and collate data collected from the various areas. If the coordination activities fail to achieve least expected benefit, then it does not incentivise the members to coordinate with each other. The evaluators are required to compare the actual benefit achieved due to coordination with the least expected benefit due to coordination.

Since there can be multiple evaluators and by the nature of human reasoning, the quality grades are calibrated through dividing the interval proportionally. The judgments on the quality of coordination activities contain much fuzziness and imprecision. At this point, the actual degree of perceived benefit due to coordination in HSC is compared with the lowest and highest degree of quality grades of perceived benefit achieved. Further, these grades are converted to a single measure within a scale ranging from 0 to 10. The number 0 denotes the lowest degree of the perceived benefit that is achieved due to coordination, and the number 10 denotes the highest degree. For instance, lowest degree would refer to extremely poor RU, poor IS, etc. even though there were significant coordination efforts to achieve these perceived benefits. This would indicate the poor quality of the implementation of the coordination efforts. The scale is further divided into six equal fuzzy intervals with a corresponding grade. A fuzzy quality grade set will be defined as the fuzzy measurement result, which is denoted by a fuzzy vector \( G = \{A, B, C, D, E, F\} \). These six grades \( A, B, C, D, E, F \) denote the measurement results ranging from the perfect to the worst (Table 1). The grade \( A \) refers to the extremely high degree of the perceived benefit achieved through coordination, whereas grade \( F \) refers to the extremely poor degree of the perceived benefit achieved though coordination. The fuzzy quality vectors and its significance are summarised in Table 1.

This quality grade set \( P \) in the finite universe of discourse \( G = \{A, B, C, D, E, F\} \) is defined by a set of ordered pairs as follows (Chang and Qi, 2003).

\[
P_\mu = \{(p_\mu(\mu), X = A, B, ..., F)\}
\]

where \( p_\mu(\mu): G \rightarrow [0, 1] \) is a mapping called the membership function of the fuzzy set \( G \), and \( p_\mu(\mu) \) indicates the degree of belongingness or membership value of \( \mu \) in \( G \). the membership function refers to the probability with which given value of \( X \) belongs to the fuzzy grade.

Since, multiple evaluators were available for estimating the degree to the each of the perceived benefit has been achieved, each evaluator has a corresponding quality grade for each of the perceived benefit. The combined quality grade of each of the perceived
benefit combining the grades obtained for each evaluator is given by $P_{i}(\mu)$, which can be written in the form of a ‘sum’ as follows:

$$P_{i}(\mu) = \frac{P_{A}(\mu)}{A} + \frac{P_{B}(\mu)}{B} + \frac{P_{C}(\mu)}{C} + \frac{P_{D}(\mu)}{D} + \frac{P_{E}(\mu)}{E} + \frac{P_{F}(\mu)}{F}$$

(2)

Or

$$P_{i}(\mu) = \frac{\sum_{X \in \Omega} P_{X}(\mu)}{X}$$

(3)

Physically, this gradation represents the quantification of the degree to which a particular performance satisfies the performance criteria set by the evaluators (Chang and Qi, 2003).

4.2 Calculation of relative weights for perceived benefits

As explained in the previous section, the first part of the proposed hybrid methodology is calculation of the weights of the perceived benefits achieved through the coordination efforts in HSC. The extent analysis method used by Chang (1996) is applied to calculate the relative weights of each perceived benefit achieved due to coordination in HSC. The method proposed by Chang (1996) is most extensively used in the domain of fuzzy AHP.

The relative importance or strength of the impacts on a given element is determined, similar to AHP, by using pair-wise comparisons with a scale of 1–9 (Saaty, 1994). The pair-wise comparison is converted to fuzzy numbers based on triangular fuzzy membership function. The fuzzy numbers are given in Table 2 (Chen and Chen, 2010). The triangular fuzzy membership function is a special case of trapezoidal fuzzy numbers with a single point mode, compared to the flat line in trapezoidal fuzzy numbers. The single point mode in triangular fuzzy number (TFN) gives a lower error variance while converting to crisp values, compared to the trapezoidal fuzzy number (Giachetti and Young, 1997). Hence, the triangular fuzzy number is used in this study.

Table 2

<table>
<thead>
<tr>
<th>Fuzzy number</th>
<th>Linguistic variable</th>
<th>Triangular fuzzy number (TFN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Extremely important/preferred</td>
<td>(7, 9, 9)</td>
</tr>
<tr>
<td>7</td>
<td>Very strongly important/preferred</td>
<td>(5, 7, 9)</td>
</tr>
<tr>
<td>5</td>
<td>Strongly important/preferred</td>
<td>(3, 5, 7)</td>
</tr>
<tr>
<td>3</td>
<td>Moderately important/preferred</td>
<td>(1, 3, 5)</td>
</tr>
<tr>
<td>1</td>
<td>Equally important/preferred</td>
<td>(1, 1, 3)</td>
</tr>
</tbody>
</table>

Source: Chen and Chen (2010)

For Chang’s extant analysis, let $X = \{x_1, x_2, \ldots, x_n\}$ be an object set and $U = \{u_1, u_2, \ldots, u_n\}$ be a goal set. Each object is taken and extent analysis for each goal, $g_i$, is performed, respectively. Therefore, $m$ extent analysis values for each object can be obtained by $M_{g_i}^{1}, M_{g_i}^{2}, M_{g_i}^{m}, i = 1, 2, \ldots, n$ and all the $M_{g_i}^{j}, (j = 1, 2, \ldots, m)$ are TFN’s.
Coordination quality index

The value of fuzzy synthetic extent with respect to the \(i\)th object (perceived benefit in our case) is defined as

\[
S_i = \left( \sum_{j=1}^{n} M_{ji} \right) \ominus \left[ \sum_{j=1}^{n} \sum_{i=1}^{m} M_{ji} \right]^{-1}
\]  

To obtain \(\sum_{j=1}^{m} M_{ji}\) perform the fuzzy addition operation of \(m\) extent analysis values for a particular matrix such that

\[
\sum_{j=1}^{m} M_{ji} = \left( \sum_{j=1}^{n} l_j, \sum_{j=1}^{n} m_j, \sum_{j=1}^{n} u_j \right)
\]  

And to obtain \(\left[ \sum_{j=1}^{n} \sum_{i=1}^{m} M_{ji} \right]^{-1}\) perform the fuzzy addition operation of, \(M_{ji}^j (j = 1, 2, ..., m)\) values such that

\[
\left[ \sum_{i=1}^{n} \sum_{j=1}^{m} M_{ji} \right]^{-1} = \left( \sum_{i=1}^{n} l_{ij}, \sum_{i=1}^{n} m_{ij}, \sum_{i=1}^{n} u_{ij} \right)
\]  

The degree of possibility of \(M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)\) is defined as

\[
V(M_2 \geq M_1) = \text{sup}_{x \in \mathbb{R}} \left[ \min \left( \mu_{M_1}(x), \min \left( \mu_{M_2}(x), \mu_{M_2}(y) \right) \right) \right]
\]  

Can be equivalently expressed as follows:

\[
V(M_2 \geq M_1) = \text{hgt}(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 
1, & \text{if } m_2 \geq m_1 \\
0, & \text{if } l_2 \geq u_2 \\
\frac{l_2 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{else}
\end{cases}
\]

where \(d\) is the ordinate of the highest intersection point \(D\) between \(\mu_{M_1}\) and \(\mu_{M_2}\).

Figure 1  Intersection between \(M_1\) and \(M_2\)
To compare \( M_1 \) and \( M_2 \), we need both the values of, \( V(M_1 \geq M_2) \) and \( V(M_2 \geq M_1) \). This is given in Figure 1.

The degree of possibility for a convex fuzzy number to be greater than \( k \) convex fuzzy numbers \( M_i (i = 1, 2, ..., k) \) can be defined by

\[
V(M \geq M_1, M_2, ..., M_k) = V(M \geq M_1) v e(M \geq M_2)
\]

\[
and \ ... \ and (M \geq M_k) = \min V
\]

For \( i = 1, 2, ..., k \). Assume that \( k = 1, 2, ..., n \), for both \( k \) and \( i \).

\[
d^i(A_i) = \min V(S_i \geq S_k)
\]

Then the weight of the vector is given by

\[
W^t = (d^1(A_1), d^2(A_2), ..., d^n(A_n))^T
\]

where, \( A_i(i = 1, 2, ..., n) \) are \( n \) elements.

Via normalisation, the normalised weight vectors are

\[
W = (d(A_1), d(A_2), ..., d(A_n))^T
\]

where \( W \) is a non-fuzzy number.

### 4.3 Aggregating fuzzy quality grades to degree of perceived benefits

The previous steps give the weights (measure for degree of quality achieved) for each perceived benefits as given by each evaluator. Also the same was applied to the consolidated evaluation given by each evaluator by taking the average of the pair wise rankings given for each of the comparisons. The consolidated weights matrix from the fuzzy AHP is given by

\[
D_{NM} = \begin{bmatrix}
d_{11} & d_{12} & \cdots & d_{1M} \\
d_{21} & d_{22} & \cdots & d_{2M} \\
& & \ddots & \vdots \\
& & & d_{N1} & d_{N2} & \cdots & d_{NM}
\end{bmatrix}
\]

Let, the number of perceived benefits, \( i = 1, 2, ..., N \) and number of evaluators be, \( j = 1,2, ..., M \). Equation (13) represents the weights given by the individual experts for the perceived benefits column wise.

Since, the perception of the effectiveness of the coordination activities on the performance of the HSC are subjective in nature, no best (upper) and worst (lower) levels of performance are available that could be considered. Therefore, as proxy for the actual degree of the quality of the perceived benefits achieved though coordination in HSC, the weights obtained from the evaluators are considered. The weights given by each evaluator for the factors are converted into the quality grades as given in Table 1. For each perceived benefit, the lowest weight by all the evaluators is taken as the bottom value and highest weight is taken as the upper value. This is used to scale the degree of
quality achieved for all perceived benefits of coordination to a comparable interval. For each \( d_{ij} \) to be converted into the fuzzy quality grade, the following steps are used.

First, the range of the weights for each perceived benefit is being calculated. The maximum and minimum weight for each factor is given by

\[
d_{ij}^{\text{max}} = \max \left[ d_{ij} \right] \forall i = 1, 2, ..., N
\]
\[
d_{ij}^{\text{min}} = \min \left[ d_{ij} \right] \forall i = 1, 2, ..., N
\]

The fuzzy quality grade weights matrix \( T_{NM} \) is given by

\[
T_{NM} = \begin{bmatrix}
t_{11} & t_{12} & \cdots & t_{1M} \\
t_{21} & t_{22} & \cdots & t_{2M} \\
\vdots & \vdots & \ddots & \vdots \\
t_{N1} & t_{N2} & \cdots & t_{NM}
\end{bmatrix}
\]

where

\[
t_{ij} = \left\{ \frac{d_{ij} - d_{ij}^{\text{min}}}{d_{ij}^{\text{max}} - d_{ij}^{\text{min}}} \left( 10 - 0 \right) \right\} \forall i = 1, 2, ..., N, \; \forall j = 1, 2, ..., M
\]

The fuzzy quality grades are then converted to the membership functions of the TFNs sets, \( f_{\tilde{a}}(t_{ij}) \). The membership function for each of each grade is calculated according to (Chang and Qi, 2003):

\[
f_{\tilde{a}}(t_{ij}) = \begin{cases} 
0, & t_{ij} < 1 \\
\frac{t_{ij} - l}{m - l}, & l \leq t_{ij} < m \\
0, & t_{ij} > u
\end{cases}
\]

The degree to which each of the perceived benefit is achieved is based on the perception of the experts based on their experience in the field of humanitarian
operations. Therefore, based on the experience of the experts, a weight is given to each of the experts. The weights can be calculated as

\[ w_j = \frac{e_j}{\sum_{j=1}^{M} e'_j} \text{ and } \sum_{j=1}^{M} w_j = 1 \]

(20)

where \( e_j \) represents the number of years of experience of each evaluator in number of years.

The fuzzy indicator matrix \( U_{GxM} \) for all indicators is multiplied with the weights matrix \( W_{Mx1} \) to obtain the perceived quality indicator matrix for each perceived benefit. This step normalises the impact of the judgmental considerations of each individual evaluator for each perceived indicator. The perceived quality indicator matrix for each indicator is given by

\[ V_{Gx1} = U_{GxM} \times W_{Mx1} \]

(21)

\[ V_{Gx1} = \begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1M} \\ u_{21} & u_{22} & \cdots & u_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ u_{G1} & u_{G2} & \cdots & u_{GM} \end{bmatrix} \times \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_M \end{bmatrix} \]

(22)

\[ V_{Gx1} = \begin{bmatrix} v_{11} \\ v_{21} \\ \vdots \\ v_{G1} \end{bmatrix} \forall i = 1, 2, \ldots, N \]

(23)

Perceived quality indicator matrix for each perceived benefit can be used to find the quality of coordination of HSC on that perceived benefit. The de-fuzzified result is obtained by

\[ PI = \frac{10xp_A + 8xp_B + 6xp_C + 4xp_D + 2xp_E + 0xp_F}{p_A + p_B + p_C + p_D + p_E + p_F} \forall i = 1, 2, \ldots, N \]

(24)

The quality of each of the perceived benefit can be calculated as given above and the quality measure of indicator matrix can be written as (Chang and Qi, 2003)

\[ PMI_{i,N} = \begin{bmatrix} PMI_{1i} & PMI_{2i} & \cdots & PMI_{Ni} \end{bmatrix} \]

(25)

To aggregate the quality of coordination into a single crisp value representative of the quality measured on all perceived benefits, the aggregated measure of the indicators need to be calculated. The consolidated weight given by each evaluator is given by \( D_{NxM} \). The group aggregated measure of the indicators weights is normalised based on the weights given to the evaluators.

\[ Q_{Ni1} = D_{NxM} \times W_{Mx1} \]

(26)
Calculation of crisp value for the quality measurement of effectiveness of coordination activities in through the perceived benefits of coordination in HSC can be obtained by taking the product of performance measure of factor matrix, $PMI_{1\times N}$ and aggregate measure of indicator matrix, $QN_{x1}$ as given in equation (28)

$$PI = \left[ PMI_1 \ PMI_2 \ \cdots \ PMI_N \right] x \left[ \begin{array}{c} q_{11} \\ q_{21} \\ \vdots \\ q_{N1} \end{array} \right]$$  \hspace{1cm} (29)$$

5 Case study

The coromandal coast of the Indian peninsular region was hit by the annual northeast monsoon during the months of November and December 2015. The unprecedented rainfalls affected the southern states of Tamil Nadu, Andhra Pradesh and the union territory of Puducherry. The initial reports suggest that more than 450 lives were lost and more than 200,000 people were displaced. The combined losses due to the floods were estimated to be more than 10 billion USD (The Hindu Business Line, 2016). Chennai, the capital city of the state of Tamil Nadu was the worst hit with a death toll of more than 400 (Janardhanan and Arun, 2015a). Chennai received a rainfall of more than 483 mm in a span of two days (December 1st and 2nd, 2015) which led to flooding of the low lying areas in the city. The situation was worsened due to the illegal encroachments of the city’s natural water bodies, unplanned construction and poor flood control measures (Janardhanan and Arun, 2015b). The authorities feared a heavy flooding and opened the Chembarambakkam reservoir without adequate warning and time for evacuation for the people. A total of 50,000 cusec of water was released in to the Cooum River, Adyar River and Buckingham Canal (Rajendran and Ramanathan, 2015). It was expected that the excess water would drain off to the Bay of Bengal. However, since the periodic desilting of these rivers was not carried out as part of flood preparedness program, the natural flow of water was restricted leading to the flooding of the banks of the river.

On 2nd December 2015, the state of Tamil Nadu declared the situation as a ‘national disaster’ (Zee News, 2015). By this time nearly 40% of the city was under water and all modes of connectivity including telecommunication lines were disrupted. Southern railways cancelled all trains through, to and from Chennai until further notice (Janardhanan and Arun, 2015b). The Chennai floods had affected more than a million
people in Chennai and adjacent areas like Kanchipuram, Cuddalore, Puducherry in Tamil Nadu. Though the relief works were carried out, poor coordination between the between various volunteer groups, NGO’s and governmental agencies undermined the effectiveness of the relief activities (Lakshmana, 2015). Many parts of the city, especially those inhabited by the poor and socio-economically backward communities were marginalised and relief did not reach them due to the poorly coordinated relief activities. Numerous complaints were filed against the government of Tamil Nadu alleging their inability to coordinate the relief activities which had led to the loss of lives of many. Public interest litigation (PIL) was filed against the Government of Tamil Nadu in Madras High Court seeking explanation from the government on poor coordination during the relief activities. The PIL was subsequently converted to a suo moto proceeding (Kumar, 2015).

Therefore, it was decided to study the factors that affect coordination in disaster relief based on Chennai floods. Several key personnel involved with the Chennai flood relief activities were contacted and interviewed. A semi-structured interview pattern with open ended questions was used for data collection. Further probing was done to understand their experiences in coordinating the relief activities during the Chennai floods. Five experts who were directly involved with the relief activities during Chennai floods were interviewed. The interviewed personnel included senior government official in government of Tamil Nadu, NGO members, academicians who were actively involved in relief and rescue activities, local volunteers and members of political parties. These interviews were conducted during the fourth week of December 2015 and second week of January 2016. The experts were also asked to fill a questionnaire as the primary data for the proposed methodology.

### 6 Results

The data collected from the experts was tabulated and converted to the fuzzy numbers as suggested in Table 2. The fuzzy AHP methodology described in equations (3) through (11) is applied for the responses given by each of the evaluators and weights for the performance indicators as indicated by each evaluator is obtained. Table 3 summarises the data collected, which was converted to fuzzy numbers based on Table 2 for respondent 1. To obtain the fuzzy synthetic extent number $S_o$ was calculated $\sum_{i=1}^{m} M_{i g}$, $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{i g}^{-1}\right]^{-1}$ using equation (5) and (6). The results are given in Tables 4 and 5. Each element in Table 5 is based on equation (6).

**Table 3** Data converted to fuzzy numbers

<table>
<thead>
<tr>
<th>RU</th>
<th>IS</th>
<th>CB</th>
<th>OM</th>
<th>DA</th>
</tr>
</thead>
<tbody>
<tr>
<td>RU</td>
<td>1, 1, 1</td>
<td>3, 5, 7</td>
<td>1, 0.143, 0.111</td>
<td>1, 1, 3</td>
</tr>
<tr>
<td>IS</td>
<td>0.333, 0.2, 0.143</td>
<td>1, 1, 1</td>
<td>5, 7, 9</td>
<td>1, 0.333, 0.2</td>
</tr>
<tr>
<td>CB</td>
<td>5, 7, 9</td>
<td>0.2, 0.143, 0.111</td>
<td>1, 1, 1</td>
<td>0.333, 0.2, 0.143</td>
</tr>
<tr>
<td>OM</td>
<td>1, 1, 0.333</td>
<td>1, 3,5</td>
<td>3, 5, 7</td>
<td>1, 1, 1</td>
</tr>
<tr>
<td>DA</td>
<td>1, 3, 5</td>
<td>0.333, 0.2, 0.143</td>
<td>0.333, 0.2, 0.143</td>
<td>0.333, 0.2, 0.143</td>
</tr>
</tbody>
</table>
Table 4:Extent analysis for each object perceived benefit

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>RU</td>
<td>7</td>
<td>7.476</td>
<td>11.311</td>
</tr>
<tr>
<td>IS</td>
<td>10.333</td>
<td>13.533</td>
<td>17.343</td>
</tr>
<tr>
<td>CB</td>
<td>9.533</td>
<td>13.343</td>
<td>17.254</td>
</tr>
<tr>
<td>OM</td>
<td>9</td>
<td>15</td>
<td>20.333</td>
</tr>
<tr>
<td>DA</td>
<td>3</td>
<td>4.6</td>
<td>6.428</td>
</tr>
</tbody>
</table>

\[ \sum_{i=1}^{n} M_{ij} = 38.867 \quad 53.955 \quad 72.669 \]

Table 5:Synthetic extent analysis for each perceived benefit

<table>
<thead>
<tr>
<th></th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>0.096</td>
<td>0.139</td>
<td>0.291</td>
</tr>
<tr>
<td>S2</td>
<td>0.142</td>
<td>0.251</td>
<td>0.446</td>
</tr>
<tr>
<td>S3</td>
<td>0.131</td>
<td>0.247</td>
<td>0.444</td>
</tr>
<tr>
<td>S4</td>
<td>0.124</td>
<td>0.278</td>
<td>0.523</td>
</tr>
<tr>
<td>S5</td>
<td>0.041</td>
<td>0.085</td>
<td>0.165</td>
</tr>
</tbody>
</table>

Each synthetic extent value \( S_i \) is compared with all other synthetic values. Table 6 is obtained based on equations (7) and (8). The second last column in Table 6 represents the row minimum as given by equation (10) and last column represents the normalised weights for each of the perceived benefit as given by equation (12).

Table 6:Weights for perceived benefits obtained for respondent 1

<table>
<thead>
<tr>
<th></th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>( d'(A_i) )</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>1</td>
<td>0.57</td>
<td>0.595</td>
<td>0.545</td>
<td>1</td>
<td>0.545</td>
<td>0.156</td>
</tr>
<tr>
<td>S2</td>
<td>1</td>
<td>1</td>
<td>0.922</td>
<td>0.922</td>
<td>1</td>
<td>0.922</td>
<td>0.263</td>
</tr>
<tr>
<td>S3</td>
<td>1</td>
<td>0.988</td>
<td>0.912</td>
<td>0.912</td>
<td>1</td>
<td>0.912</td>
<td>0.26</td>
</tr>
<tr>
<td>S4</td>
<td>1</td>
<td>1.077</td>
<td>1.085</td>
<td>1</td>
<td>1</td>
<td>0.285</td>
<td></td>
</tr>
<tr>
<td>S5</td>
<td>0.564</td>
<td>0.123</td>
<td>0.174</td>
<td>0.177</td>
<td>1</td>
<td>0.123</td>
<td>0.035</td>
</tr>
</tbody>
</table>

Table 7:Weights for the perceived benefits

<table>
<thead>
<tr>
<th>Perceived benefits</th>
<th>Resp. 1</th>
<th>Resp. 2</th>
<th>Resp. 3</th>
<th>Resp. 4</th>
<th>Resp. 5</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource utilisation (RU)</td>
<td>0.1556</td>
<td>0.182</td>
<td>0.164</td>
<td>0.183</td>
<td>0.204</td>
<td>0.2036</td>
<td>0.156</td>
</tr>
<tr>
<td>Information sharing (IS)</td>
<td>0.2633</td>
<td>0.285</td>
<td>0.254</td>
<td>0.273</td>
<td>0.204</td>
<td>0.2849</td>
<td>0.204</td>
</tr>
<tr>
<td>Perception of value (PV)</td>
<td>0.2605</td>
<td>0.213</td>
<td>0.201</td>
<td>0.216</td>
<td>0.248</td>
<td>0.2605</td>
<td>0.201</td>
</tr>
<tr>
<td>Organisational mandates (OM)</td>
<td>0.2855</td>
<td>0.274</td>
<td>0.266</td>
<td>0.286</td>
<td>0.262</td>
<td>0.2857</td>
<td>0.262</td>
</tr>
<tr>
<td>Diversity of actors (DA)</td>
<td>0.0351</td>
<td>0.045</td>
<td>0.115</td>
<td>0.043</td>
<td>0.082</td>
<td>0.115</td>
<td>0.035</td>
</tr>
</tbody>
</table>

Similar procedure is repeated for all respondents and the weights for the perceived benefits are obtained. Table 7 shows the weights obtained for the perceived benefits for each evaluator and the maximum and minimum weights for each perceived benefit.
Consolidated weights matrix for the weights $D_{NM}$ is represented by the weights given in Table 3. The minimum and maximum values for the weights for the perceived benefits are calculated according to the equations (14) and (15).

Based on the maximum and minimum values, the elements in matrix $D_{NM}$ are converted to the values ranging between 10 and zero. The conversion is carried out according to equation (17) and $T_{NM}$ is shown in Table 8. For respondent 1 under IS.

\[
t_{ij} \left[ \begin{array}{l}
0.2849 - 0.2633 \\
0.2849 - 0.204
\end{array} \right] (10 - 0) = 2.655
\]

Other values in Table 8 are calculated in a similar manner.

**Table 8**  Fuzzy quality weights matrix $T_{NM}$

<table>
<thead>
<tr>
<th>Perceived benefits</th>
<th>Resp. 1</th>
<th>Resp. 2</th>
<th>Resp. 3</th>
<th>Resp. 4</th>
<th>Resp. 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource utilisation (RU)</td>
<td>10</td>
<td>4.4355</td>
<td>8.3042</td>
<td>4.3261</td>
<td>0</td>
</tr>
<tr>
<td>Information sharing (IS)</td>
<td>2.6555</td>
<td>0</td>
<td>3.7872</td>
<td>1.5188</td>
<td>10</td>
</tr>
<tr>
<td>Perception of value (PV)</td>
<td>0</td>
<td>7.9978</td>
<td>10</td>
<td>7.4889</td>
<td>2.0551</td>
</tr>
<tr>
<td>Organisational mandates (OM)</td>
<td>0.0861</td>
<td>4.8186</td>
<td>8.4837</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Diversity of actors (DA)</td>
<td>10</td>
<td>8.7327</td>
<td>0</td>
<td>9.0429</td>
<td>4.0981</td>
</tr>
</tbody>
</table>

Consolidated weights matrix is converted to the fuzzy grades using equation (18). This step converts the fuzzy grades into the membership function for each of the fuzzy grades for each respondent for all indicators. Appendix summarises the matrices $U_{GAM}$ $\forall i = 1, 2, \ldots, N$. According to respondent 1, the fuzzy quality weight for RU is given as 10 in Table 8. From Table 1, it can be seen that the weight 10 can be a part of quality grade A and quality grade B. Therefore, by using equation (18) the membership function for the quality weight for RU was calculated. The results for the membership function are summarised in a table titled ‘RU’ in Appendix for respondent 1. From this table (i.e., RU table in Appendix), it can be seen that the quality weight 10 lies with a probability of 1 in the quality grade A and with probability of zero in all other grades. Similarly, for respondent 2, the weight of 4.4355 lies with probability of 0.218 and 0.782 in grade C and D respectively. Similarly, for all perceived benefits the quality grades for all the respondents are calculated and summarised in Appendix.

Table 9 summarises the number of years of experience of each of the evaluator and the corresponding weight associated with the evaluator. The weights are calculated according to the equation (19). Since the perceived benefits of the coordination are measured, weights of the evaluator are used to normalise the perception bias. An evaluator with a greater experience is given more weight compared to others.

**Table 9**  Experience and weights associated with each evaluator

<table>
<thead>
<tr>
<th>Respondent</th>
<th>Experience (no. of years)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resp. 1</td>
<td>11</td>
<td>0.15</td>
</tr>
<tr>
<td>Resp. 2</td>
<td>12</td>
<td>0.17</td>
</tr>
<tr>
<td>Resp. 3</td>
<td>25</td>
<td>0.35</td>
</tr>
<tr>
<td>Resp. 4</td>
<td>17</td>
<td>0.24</td>
</tr>
<tr>
<td>Resp. 5</td>
<td>7</td>
<td>0.10</td>
</tr>
</tbody>
</table>
The product of the fuzzy indicator membership function matrix and the weights matrix gives the normalised performance indicator for each of the indicator. The matrices are given in Figure 1. The RU column is obtained by multiplication of RU membership function matrix in Figure 1 with the weights matrix in Table 9. This gives the normalised quality score for the RU. Similarly, normalised RU is calculated for each of the perceived benefit. The normalised quality score is given for each of the perceived benefit is obtained as a column vector. The column vectors are aggregated to get the combined normalised quality matrix as given in Table 10.

<table>
<thead>
<tr>
<th>Perf. grade</th>
<th>Resource utilisation (RU)</th>
<th>Information sharing (IS)</th>
<th>Perception of value (PV)</th>
<th>Organisational mandates (OM)</th>
<th>Diversity of actors (DA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.206</td>
<td>0.097</td>
<td>0.347</td>
<td>0.181</td>
<td>0.337</td>
</tr>
<tr>
<td>B</td>
<td>0.294</td>
<td>0</td>
<td>0.342</td>
<td>0.263</td>
<td>0.218</td>
</tr>
<tr>
<td>C</td>
<td>0.075</td>
<td>0</td>
<td>0.061</td>
<td>0.068</td>
<td>0.005</td>
</tr>
<tr>
<td>D</td>
<td>0.328</td>
<td>0.360</td>
<td>0.003</td>
<td>0.099</td>
<td>0.093</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
<td>0.319</td>
<td>0.095</td>
<td>0.007</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>0.097</td>
<td>0.223</td>
<td>0.153</td>
<td>0.382</td>
<td>0.347</td>
</tr>
</tbody>
</table>

The quality of the coordination in HSC on each of the perceived benefit can be found using equation (23). The crisp value of each perceived benefit on is summarised in the Table 11. In other words, Table 11 gives the quality score of each perceived benefit of coordination in HSC. For RU, the quality score can be calculated as

\[
P_I = \frac{10 \times 0.206 + 8 \times 0.294 + 6 \times 0.075 + 4 \times 0.328 + 2 \times 0 + 0 \times 0.097}{0.206 + 0.294 + 0.075 + 0.328 + 0 + 0.097} = 6.171
\]

<table>
<thead>
<tr>
<th>Perceived benefits</th>
<th>Crisp value of quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource utilisation (RU)</td>
<td>6.171</td>
</tr>
<tr>
<td>Information sharing (IS)</td>
<td>3.051</td>
</tr>
<tr>
<td>Perception of value (PV)</td>
<td>6.773</td>
</tr>
<tr>
<td>Organisational mandates (OM)</td>
<td>4.734</td>
</tr>
<tr>
<td>Diversity of actors (DA)</td>
<td>5.516</td>
</tr>
</tbody>
</table>

The previous step gives the crisp values of quality under each of the perceived benefit separately. This steps helps in identifying which of the individual benefits were achieved and to what extent each of them were achieved. However, to obtain a consolidated quality score for the perceived benefits achieved through various coordination activities, these individual quality scores have to be aggregated into a single value. Therefore, to get a crisp score of the quality measure of the coordination in HSC, the consolidated weights matrix \( D_{\text{Nat}} \) obtained using equation (13) is multiplied with the evaluator weights matrix. This step normalises the impact of the evaluator judgement on the weights obtained as given by equation (27). Table 12 shows the normalised weights of performance indicators \( Q_{\text{Nat}} \) obtained by the results of equation (25) through (27).
Furthermore, to convert the aggregated normalised weights of each indicator to a crisp performance value, equation (28) is used. The crisp value of the quality of coordination in HSCM can be obtained according to equation (29), as given in equation (30). This can be written as

\[
\begin{bmatrix}
0.174 \\
0.260 \\
0.220 \\
0.274 \\
0.071
\end{bmatrix}
\begin{bmatrix}
6.172 \\
3.0515 \\
6.773 \\
4.734 \\
5.5168
\end{bmatrix}
\begin{bmatrix}
0.220 \\
0.275 \\
0.071
\end{bmatrix}
\] (30)

\[
PI = 5.052
\]

The above value of PI is termed as ‘CQI’.

7 Discussions

The CQI obtained in equation (30) in the last section provides a score for the quality of the coordination efforts measured through the perceived benefits of the coordination. The quality of the coordination in HSC was measured based on the effectiveness of activities undertaken for better coordination. Experts evaluated the effectiveness of coordination based on their experiences in Chennai floods. Table 11 summarises the score of the effectiveness of the coordination activities on the objectives of the coordination. The quality score obtained shows moderate to low quality of coordination. Though the perception of value for coordination and effectiveness of RU ranged from moderate to high in this case, the major reason for the poor coordination was due to the poor IS, large DA and lack of streamlined OM. Though, there were efforts to improve coordination between the stakeholders in HSC during the relief operation of Chennai floods, these perceived benefits of the coordination were not achieved. It seems counter intuitive that though there was a general consensus on the importance of coordination, the perceived benefits of coordination were not all achieved. The primary reason for this can be traced to manner on which the HSC operations were planned. The coordination mechanisms as described in the previous sections draw primarily from the preparedness stage. In the case of relief activities during Chennai floods, the coordination efforts were drawn after the occurrence of the event mostly as a reactive mechanism based on prior experience of Indian Ocean tsunami (2004). However, there was no proactive measure during the preparedness phase for improving coordination. Thus even with a high perception of
value for coordination, the benefits achieved through coordination activities were marginal.

It can be seen from Table 11 that perception of value for coordination has obtained the highest score for the quality. This is derived from the fact that in 2004, Chennai was one of the most affected areas in India during the Indian Ocean tsunami. The experts recounted that one of the major takeaways from the tsunami relief efforts was need for coordination among the various actors. During the tsunami relief activities, poor coordination led to the loss of lives, poor aid distribution, gender insensitive relief programs etc. (Telford and Cosgrave, 2007). These challenges and learnings from the previous disaster had led to the realisation that the stakeholders in HSC need to coordinate for the effectiveness of the relief operations. Therefore, during Chennai floods various stakeholders who were previously associated with the relief activities focussed on the coordination between the stakeholders. However, the major challenge arose due to the large number of untrained volunteers. Since there were not many preparedness activities focussing on capability building at grassroots levels and training volunteers for disaster response, the volunteers were largely uncoordinated. This affected the coordination initiatives taken by the experienced agencies and thereby undermining the impact of the coordination activities undertaken.

Second perceived benefit achieved through coordination was effective RU. Though there was large number of actors during the relief and rescue activities after Chennai floods, these organisations formed clusters for coordination and mobilising resources. A centralised Chennai relief centre (CRC) was set up with the help of government, NGOs and overseas technology support teams. This was facilitated since Chennai is a prominent business centre in India with a strong software presence on the global map. Chennai flood relief coordination unit acted as a central unit to help various agencies and stakeholders to coordinate among themselves. CRC acted as an umbrella agency to help collect and streamline the information flow. Though CRC tried to avoid duplication, not all agencies that were operating as the part of Chennai relief work were a part of CRC. Although CRC had adequate governmental support, it was not an agency operating under legal mandate. Therefore, many organisations did not feel the need to be bound by CRC. This lack of authority of CRC acted as a major impediment in complete coordination across the relief agencies. The coordination practices as discussed in previous section were undertaken, yet the failure to achieve full potential can be attributed to lack of capacity and capability of the umbrella agency to include the stakeholders. This incapability led to duplication of effort and wastage of resources.

The formation of coordination clusters also improved the effective utilisation of the resources. The coordination clusters helped to achieve effective joint collaboration between public and private organisations. Another example of coordination was effective operation of large public kitchens which provided freshly cooked meal to the stranded people. An effective supply chain was set where the needs were informed to these public kitchens. The kitchen also relied on own forecast on the amount of food that might be required. Subsequently, the food was prepared, packed in smaller packets with water packets and were transported to various location depending on the needs that were informed to the centralised coordination centre. However, there were cases of duplication of efforts as well; some regions received aid multiple times but the other areas were completely ignored. Those areas that did not receive attention were especially socio-economically backward communities.
Though social media and other IS mechanism was thoroughly used in the Chennai floods relief, the effectiveness of the same for facilitating coordination was not well achieved. The primary reason for this is the large amount of duplication and recirculation of information leading to poor information quality for need assessment. Since the social media was a major mode of IS, the information was never out of circulation. This led to large inflation in the actual need assessment and also resulted in duplicating the information. Many anti-social elements focused on exploiting the situation for siphoning and hoarding aid material. Furthermore, unscrupulous organisation also tried to spread false information to create panic among the affected people. Though there was a conscious effort to share information at all stages of operations during the relief activities during relief in Chennai floods, the effectiveness of the IS was not achieved.

Large number of volunteers with little or no prior experience across the states arrived for the relief activities at Chennai. This affected the coordination during the initial stages of the relief. However, once the Indian defence forces and National Disaster Relief Force (NDRF) arrived at disaster site, they took over the search and rescue activities. These specialised forces helped to coordinate the relief and rescue activities with the help of the local volunteers. Another instance of coordination challenge arose due to multiple organisations with conflicting mandates. Especially the organisations having conflicting political affiliations were often at loggerheads. The experts recounted that certain religious and social groups with specific affiliations were not too keen on sharing their resource with people outside their ethnic or religious groups. They were more focused on targeting of religious sects and socio-economic groups by aid agencies, which led to delimitation of the relief efforts. These kinds of actions undermined the coordination efforts in the Chennai floods. This is shown by the average rating on the effective of coordination on OM and DA.

From a practical standpoint, the results help us to draw some interesting conclusions. Though the importance of need for improved coordination between various actors in HSC is accepted throughout in literature, our results indicate that the practitioners too share the same viewpoint about the need for coordination. However, one needs to explore why then the coordination between various actors is not easily achieved. Firstly, the impact of the coordination activity is dependent on the nature of IS. Simatupang and Sridharan (2001) have given a detailed exposition on the impact of IS between various agencies in a commercial setting. Though similar arguments can be drawn in the case of HSC as well, here, the complexity is increased primarily due to nature of information generation, collection, collation and sense making. Since, there are no standardised formats for information collection and sharing, the act of IS does little to improve coordination between the actors. Thus, for an improved coordination between the agencies, there needs to be a standardised mechanism of information collection, collation and sense making. Secondly, though the organisation mandates of each agency is different, the agencies need to identify the possibility of long-term associations. These associations need to be built during the preparedness phases where the organisation mandates need to be evaluated and possibility of long-term associations need to be worked out. One of the easier ways to build trust between the agencies and to ease out the association, the agencies can work-out the inter-agency resource exchange, primarily the human resource. This kind of resource exchange offers opportunities for cross learning and improves trust building.
8 Conclusions

The coordination under the ambit of inter-organisation coordination is undertaken with the objective of achieving benefits such as improved RU, better IS between the organisations, streamlining organisation mandates, improving the perception regarding the coordination in SC. The effectiveness in achieving these objectives of coordination is taken as the precursor for achieving better HSC operations and increasing the impact of humanitarian operations on the lives of the affected people. The results indicated that during Chennai flood relief, the perception of the value of coordination was well accepted. Therefore, one would expect that the coordination activities would have been undertaken effectively and quality of the effort would have been good. However, a counter-intuitive result is obtained when coordination during the Chennai floods was moderate to poor in terms of the quality grade. This can be attributed to the poor quality grade of the perceived benefits such as IS, reducing the DA and streamlining OM. This draws attention towards the importance of preparedness activities drawn towards formulating strategies and relationships with the stakeholders for effective coordination. Therefore, it is concluded that the coordination efforts in HSC needs to be more proactive rather than being reactive.

One of the limitation of this study is that the data collected for testing the model is based on only one incident, i.e., Chennai floods. To gain further generalisability, model needs to be tested in multiple contexts. But this would be a major challenge because occurrence of such disasters cannot be predicted. Secondly, even a similar disaster cannot be compared on one to one basis as each disaster is of different situation and magnitude. Each disaster may also differ based on technology used, geography, impact, etc., and hence they might be different. Despite this limitation, performance of the model can also be validated using secondary sources.

The main contribution of this paper is two-fold. The proposed index-CQI can be used a measure to quantity the quality and effectiveness of coordination activities, which can be measured in terms of perceived benefits of coordination. Secondly, the paper demonstrates the use of CQI with the case of Chennai floods by validating the effectiveness of coordination activities with the data from field and secondary sources.

References


Appendix

Table A1  Fuzzy membership function for each indicator

<table>
<thead>
<tr>
<th>Resource utilisation</th>
<th>Perf. grade</th>
<th>Resp1</th>
<th>Resp2</th>
<th>Resp3</th>
<th>Resp4</th>
<th>Resp5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>0</td>
<td>0.151</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0</td>
<td>0.848</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>0.217</td>
<td>0</td>
<td>0.163</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
<td>0.782</td>
<td>0</td>
<td>0.837</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Information sharing</th>
<th>Perf. grade</th>
<th>Resp1</th>
<th>Resp2</th>
<th>Resp3</th>
<th>Resp4</th>
<th>Resp5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>D</td>
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<tr>
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<td>0.241</td>
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</table>

<table>
<thead>
<tr>
<th>Perception of value</th>
<th>Perf. grade</th>
<th>Resp1</th>
<th>Resp2</th>
<th>Resp3</th>
<th>Resp4</th>
<th>Resp5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>0.999</td>
<td>0</td>
<td>0.744</td>
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<td>0</td>
</tr>
<tr>
<td>C</td>
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</tr>
<tr>
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<td>0</td>
<td>0</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Organisational mandate</th>
<th>Perf. grade</th>
<th>Resp1</th>
<th>Resp2</th>
<th>Resp3</th>
<th>Resp4</th>
<th>Resp5</th>
</tr>
</thead>
<tbody>
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<td>A</td>
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<td>0</td>
<td>0.242</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
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</tr>
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<td>C</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
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<td>0</td>
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<td>0</td>
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</tr>
<tr>
<td>F</td>
<td>0.043</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>G</td>
<td>0.957</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diversity of actors</th>
<th>Perf. grade</th>
<th>Resp1</th>
<th>Resp2</th>
<th>Resp3</th>
<th>Resp4</th>
<th>Resp5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<td>0.366</td>
<td>0</td>
<td>0.521</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
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<td>0</td>
<td>0.479</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
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<td>0</td>
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<td>0.049</td>
<td>0</td>
</tr>
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<td>E</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
</tr>
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<td>F</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>G</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>