Abstract

The increasing use of cordons after major seismic events necessitates an improved understanding of how post-earthquake cordons work in practice. The use of cordons in 3 case study countries (New Zealand, Italy and Nepal) were examined following damaging earthquakes to understand decision-making by emergency management authorities related to cordon implementation and management during the response and recovery. A qualitative research approach included 44 interviews with expert knowledge holders. This paper provides a synthesis of the results of these case studies and proposes a new working definition for cordons that addresses their dynamic temporal and spatial nature. The paper presents a model that captures the practical implications and recommendations of this research, Cordon Operations and management and Decision-making following Earthquakes (CODE), to support emergency managers and relevant authorities to be better prepared, make informed decisions and aid in operational activities in future seismic events.

Cordon operations and decision-making following earthquakes: a model for understanding cordons in practice

Peer reviewed

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Introduction

In recent decades, major seismic events around the world have resulted in the use of cordons as a response approach immediately post-earthquake. Following the 2011 Christchurch earthquake in New Zealand and the 2009 L'Aquila earthquake in Italy, cordons remained in the respective central city areas for years (Underwood et al. 2020). These cordoned-off areas were colloquially known as 'red zones' (in Christchurch) and 'zona rossa' (in L'Aquila). Post-earthquake cordons can have significant effects on response and recovery of a city (Hulsey et al. 2022; Chang et al. 2014). However, there has been limited research to understand post-earthquake cordons in practice to support emergency managers and relevant authorities to make informed decisions on the implementation and management of operational cordon activities over time.

To this end, 3 research papers (Shrestha et al. 2021; Shrestha et al. 2022; Shrestha and Orchiston 2023) are summarised to investigate the use of post-earthquake cordons in 4 different cities and an updated working definition for cordons is proposed. In the papers, case studies were conducted of Christchurch (2011 Christchurch earthquake), Wellington (2016 Kaikōura earthquake), L'Aquila (2009 L'Aquila earthquake) and Kathmandu Valley (2015 Gorkha earthquake). The research used qualitative research methodology involving 44 expert interview participants who had varying backgrounds, roles and responsibilities during the earthquakes. This paper uses the empirical data from these interviews, presented in detail in the 3 papers, to propose a practical model to guide the use of post-earthquake cordons to support preparedness for future seismic events.

Understanding how people perceive, experience and respond to emergencies reveals why they do or do not take action to minimise risks. Within government agencies, they constitute social groups with established customs and practices over time, shaping their approach to managing risks and disasters (Tierney 2007).

The 3 research papers synthesised in this article were approved by the University of Otago Human Ethics Committee under category 'A' or 'B'.

Post-earthquake cordons

According to Underwood et al. (2020, p.2) a cordon is '…a barrier established by an authority to temporarily exclude the public from a defined area'. The main purpose of a cordon is to protect the life safety of people from potential risks during critical situations, which can include fire hazards, active shooter situations, riots, etc. After damaging earthquakes, the criticality of the situation and safety concerns arise from the potential collapse of buildings and/or falling debris. Unlike for other uses of cordons, this criticality persists for an extended period of time because large earthquakes are usually followed by a sequence of aftershocks. Aftershocks make it difficult to assess the structural damage caused by the mainshock. As time goes by, it becomes increasingly uncertain whether the structural capacity of the built structures has been further compromised by aftershock activity. In many cases, damage may not be visibly apparent, requiring detailed engineering assessments to ascertain the structural integrity of buildings. These assessments may be necessary for numerous buildings depending on the scale of damage. Thus, it is important to restrict access to the public until authorities have completed these tasks and deemed the area safe.

While the primary purpose of establishing cordons is life safety, post-earthquake cordons also serve additional purposes. By creating a restricted zone, cordons form a secure area within which it may be necessary to protect against theft, looting and vandalism. Experts from Christchurch and L'Aquila pointed towards acts of theft and looting that reinforced the justification for maintaining cordons. In Kathmandu Valley, it was suggested that one of the reasons for cordon placement around temples was to protect them against theft of heritage artefacts. It should be noted that crimes may increase (Leitner and Helbich 2011; Prelog 2016) or decrease/remain stagnant (Barsky et al. 2006; Hombrados 2019) after disasters, so it is difficult to justify establishing cordons based on security considerations alone. Imperiale and Vanclay (2019) documented that the extent of cases of lootings in L'Aquila may have been overstated.

It is interesting to note that concerns regarding looting were not noted in the Wellington case study. This difference is explained by the relative level of damage and devastation caused by the earthquakes. In Christchurch, L'Aquila and Kathmandu Valley, the damage and destruction to properties and lives lost was much more significant compared to the Wellington case. Additionally, the effects of the earthquake were also more spatially and logistically localised in Wellington such that it was sufficient for authorities to manage the risk by placing smaller cordons around individual buildings or streets for a shorter time. This meant that the resources required were significantly lower in Wellington. In large and complex city environments, establishing and maintaining cordons are significantly more resource intensive and logistically challenging.

As the response phase moves into recovery, a number of challenges emerge. People who have been evacuated from buildings need to retrieve their belongings and other items needed for day to day lives, wellbeing and work. To support this, large-scale cordon access programs were established in Christchurch and L'Aquila by local authorities. A smaller scale operation was also observed in Wellington. These cordon access programs followed similar procedures to enable members of the public to enter the cordon, accompanied by emergency services personnel (often firefighters) to access their premises to retrieve essential items. The duration of stay within the cordons ranged from 5 minutes up to several hours depending on life safety risk assessments by the authorities.

Technical tasks were also required by engineers, contractors, labourers and insurers who required access to assess building damage, inspect services and undertake repair and demolition work. As such, when cordons are placed for lengthy periods of time, there are usually conditionally authorised people (journalists, service people etc.) who can enter the cordons. The results of this research showed that cordons are typically porous because absolute exclusion of the public is not tenable. The case studies showed that cordons are unpopular with the public when maintained for long periods of time, which in part, led to public protests in Christchurch and L'Aquila.

This study revealed legal and ethical challenges surrounding the use of cordons. According to Underwood et al. (2020), the statutory powers within a country determine the permissible authoritative actions after an earthquake, including the establishment of post-earthquake cordons. In New Zealand, the *Civil Defence Emergency Management Act 2002* allows Civil Defence to enforce exclusion of the public from a given area when a state of emergency is declared. As observed in Wellington, cordons can also be established through the Chief Executive of the Local Territorial Authority. In this approach, senior council executives must justify the cordon placement and seek approval from the Chief Executive. In L'Aquila, cordons were placed in the city centre for more

than a decade through the use of ordinances. The lengthy duration of cordon placement highlights the myriads of ethical challenges involved in cordon management. Post-earthquake cordons halt and/or limit many of the rights of citizens such as freedom of movement, access to resident and business premises, they affect livelihoods and, broadly, the rights to the city.

There was a desire to provide access to the so-called 'red zone' cordon in both Christchurch and L'Aquila. In Christchurch, the authorities prioritised the demolition of houses and reduction of cordons around access routes to facilitate the opening of the temporary Re:START mall. Additionally, there were red zone bus tours into Christchurch city centre for the public. These initiatives highlight some of the ethical considerations that authorities employed to enable the public to regain some degree of control. Similarly, in L'Aquila to encourage some degree of social life in the city, a few businesses and bars were given temporary permits to open within the cordons. Furthermore, residential reconstructions were prioritised over public buildings to enable people back into the historic city centre. This is in part due to the pressure from the public, but also a response to people's desire to return to their homes, their streets, their neighbourhood and to contribute to the economic recovery of the city.

Post earthquake cordons can also be used as a tool to support recovery. Cordons reduce bureaucratic 'red tape', for example, expediting demolition/reconstruction, traffic management and storage of materials and equipment. In Christchurch, because the access points into the cordons were controlled and records kept with regular monitoring, it became easier to keep track of demolition and construction works. This was useful to avoid health and safety issues and other potential hazards, such as asbestos poisoning. Cordons presented an opportunity for businesses and residents to undertake repair, retrofit or redesign work on their buildings even if there was limited or no damage due to the reduced cost of operating within the cordon (i.e. cost of permits and approvals from the council). Similarly, in L'Aquila, reconstruction projects were supported financially through fee waivers of large sums of money for occupying public land necessary to set up a construction site.

Over time, the space within a cordon becomes a transitional space for recovery. In Christchurch, the demolition process was fast-tracked because the space within the cordon, in essence, became a giant construction site where contractors could work faster without worrying about risk to bystanders. The low vehicular traffic allowed for ease of movement and storing demolition debris, construction materials and large vehicles. Similar experiences were observed in L'Aquila and, to a lesser extent, in Wellington.

Updated definition of cordons

The proposed definition of cordons provides a complete account of the characteristics of cordons and their use and updates the previous definition provided by Underwood et al. (2020). There are 2 main points of departure from the earlier definition. First, it highlights that the criticality of the situation is a prerequisite for establishing a cordon. Due to their restrictive nature, cordons should not be established if the situation is not risk sensitive. Authorities should have the discretion to decide whether the level of risk warrants establishing a cordon, similar to the discretion authorities have in declaring states of emergency (bearing in mind there is often a high degree of uncertainty). However, if risk is not apparent, then the risks must be communicated effectively to the public. This will reduce the potential for dissatisfaction from the public while encouraging compliance with cordon rules. Figure 1 shows that even though cordon boundaries are monitored by authorities, it is highly likely people will trespass the cordon boundaries, particularly when cordons are established for a long time over a wide area.

Second, the proposed definition also alludes to the dynamic scope of cordons such that their use goes beyond life safety of the public. As demonstrated by the case studies, when cordons are established for a long time, they evolve from an initial life safety response tool into a transitional function that enables and facilitates operational activities that support recovery.

Practical model for post-earthquake cordons

We present a conceptual model to support and guide practical consideration for post-earthquake cordons. It is anticipated that this Cordon Operations and Decision-making following Earthquakes (CODE) model (shown in Figure 2) will support emergency managers and relevant authorities to understand the complex and dynamic factors that emerge during the implementation and management of post-earthquake cordons. The 3 fundamental notions of risk, law and ethics are nested within the decision-making dimension of the model for understanding post-earthquake cordons. The notion of risk is the first thing that is discussed in the context of understanding disasters. However, the idea of 'risk' is complex, multifaceted, nuanced and requires a broader understanding of additional elements such as risk tolerance, risk acceptance and risk perception. Additionally, there are a myriad of legal and ethical challenges that need to be considered when post-earthquake cordons are used. This is because cordons are complex and multi-dimensional with a potential for significant consequences for the response and recovery of the city and its citizens after a major seismic event. When cordons are maintained for a long time, the

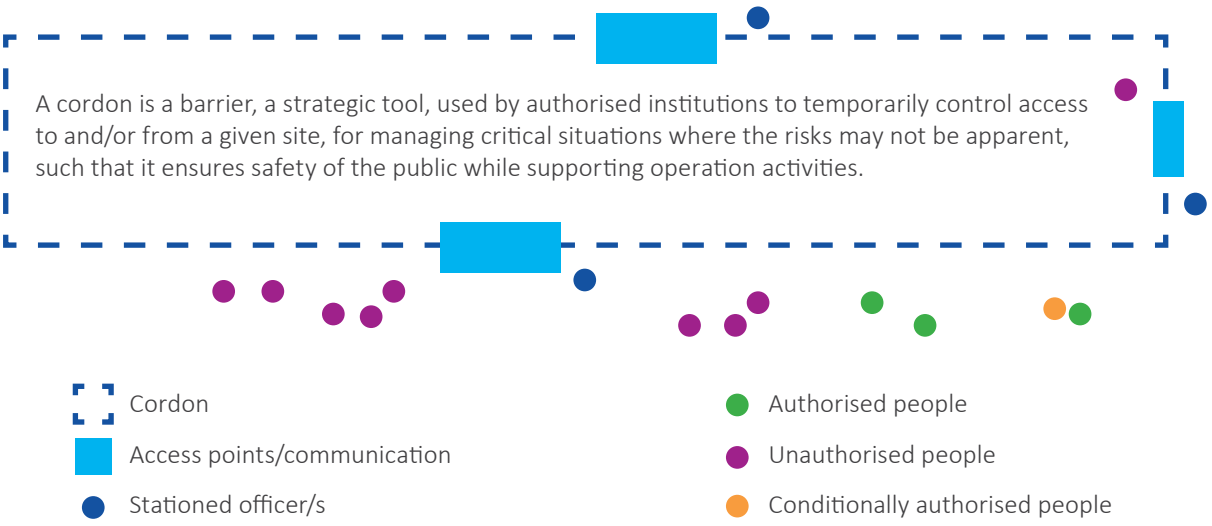

Figure 1: Proposed cordon definition and illustration of its function.

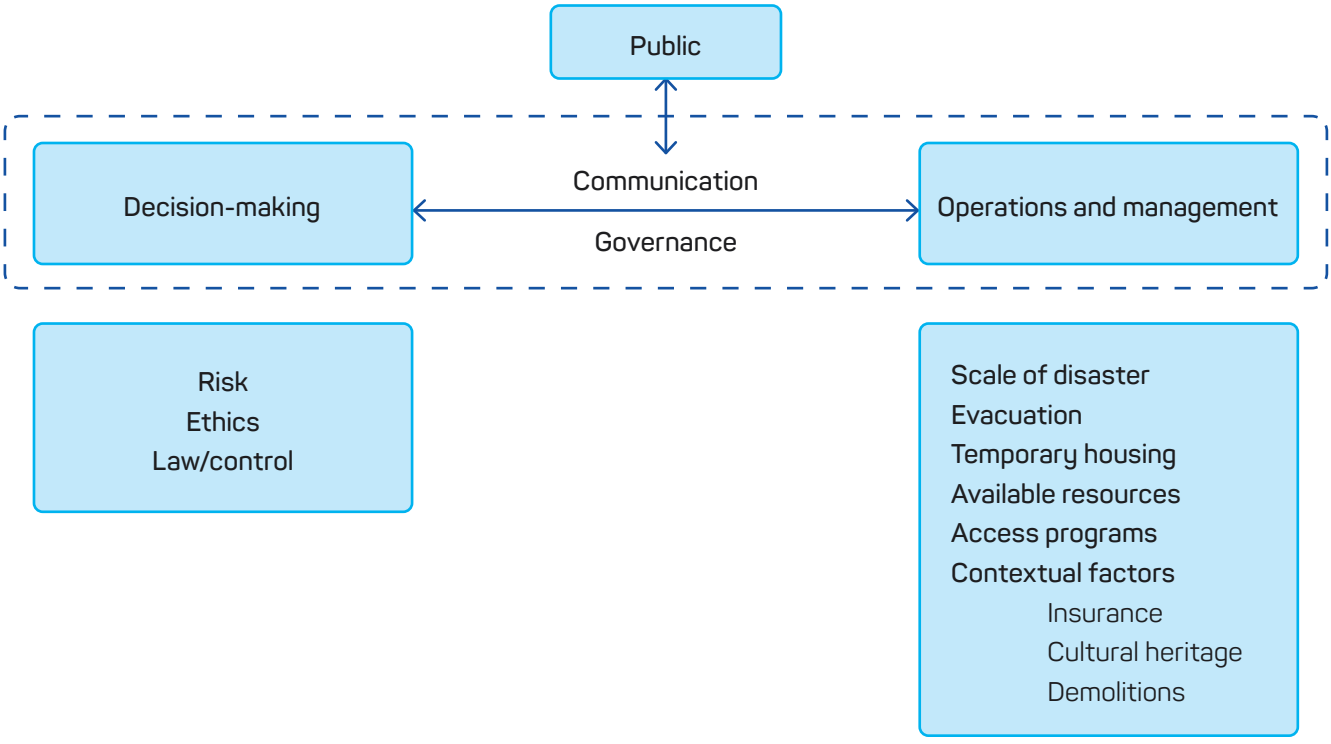

Figure 2: Model to guide practical considerations of Cordon Operations and management and Decision-making following Earthquakes (CODE).

inherent restrictive and top-down management of cordons can lead to other challenges particularly on the democratic principles of freedom of movement and people's autonomy to choose their risks.

The practical considerations for establishing and maintaining post-earthquake cordons can be synthesised through 2 key dimensions: decision-making and operations and management. These dimensions continuously interact as part of a complex system. This model is primarily based on case studies of Christchurch and L'Aquila due to the extended spatial and temporal scale of cordon use in each case. However, references to Wellington and Kathmandu Valley are made where appropriate.

Authorities need to consider whether establishing a cordon is necessary. As shown in the case studies, the initial establishment of post-earthquake cordons is mainly determined by the scale of the disaster, specifically the degree of damage to buildings and potential risks to

life safety. Although this is the main criteria, as noted in Kathmandu Valley, there may be nuanced reasons why the establishment of post-earthquake cordons is avoided (e.g. due to legal uncertainty, cultural nuances and lack of available resources). In Nepal, government official participants in this study noted that establishment of cordons is not specifically provisioned in the law. However, they indicated that post-earthquake cordons were legally tenable because they protect life safety, which is the major objective of Nepal's emergency legislation. Additional concerns relate to the availability of resources to actualise post-earthquake cordons, such as physical barriers and personnel to patrol the boundary. When cordons cover a large area, it leads to inaccessibility of many businesses (restaurant, shops and services), which greatly reduces commercial activity and directly effects social and economic recovery.

Once the decision has been made to establish a cordon, the next decision relates to defining their spatial extent. The spatial positioning and extent of post-earthquake cordons is directly related to building damage. In a study conducted by Hulsey et al. (2022), who modelled the effects of post-earthquake cordons on recovery of downtown San Francisco area following a Mw 7.2 earthquake, they found that cordons accounted for loss of around one-third (219 days) of expected functional use of office spaces.

If the scale of damage is too great, post-earthquake cordons need to encompass wider areas to account for practical considerations of operational ease and available resources (human, economic, physical). This was observed in L'Aquila as well as in Christchurch where the initial cordon extents exceeded the boundaries of damaged areas. For Christchurch, 4 avenues around the central business area offered a simple and practical demarcation of the damage zone in the early stages, whereas in L'Aquila the existing historic walls provided an existing barrier to control access to the city centre.

When post-earthquake cordons are established, immediate evacuation of the public within the cordon boundary is required (Underwood et al. 2020). Subsequently, shelter and temporary housing needs to be provided and managed for evacuees. The case studies showed that this can create significant challenges depending on the number of people affected. Evacuation and temporary housing challenges were significant in L'Aquila, highlighted by the substantial number of residents still in temporary housing after a decade (Imperiale and Vanclay 2019). This points to the potential emergence of unintended risks to the public and demands ethical consideration to mitigate such challenges. For example, removing residents from within a cordon will displace them from their livelihoods and social networks, which may lead to negative outcomes for their wellbeing.

Once the immediate emergency response phase passes (~1–2 weeks) and recovery becomes established, the reduction of cordon extent is heavily dependent on the approach chosen by authorities. In Christchurch, elimination of risk through demolition of damaged structures was the driver to reduce cordon extent (MCDEM 2015). In contrast, L'Aquila prioritised conserving cultural heritage. This led to a focus on shoring of buildings and emphasis on structural strengthening. Similarly, in Kathmandu Valley, the limited cordons used after the earthquake were intended to protect temples and heritage monuments. The differences observed in institutional approaches and ethical values in all 3 countries emphasise the highly context-specific nature of post-earthquake cordon use.

In Christchurch and L'Aquila, the massive cordon access programs required significant communication and collaboration between the various government authorities such as police, fire, emergency management, service providers, local and central government and consultants, among others. This was a challenging task due to the scale of the disasters, which consequently led to involvement of large numbers of stakeholders, agencies and organisations. In Christchurch, the formation of Christchurch Earthquake Recovery Authority (CERA) was established through a rapidly developed Act of Parliament that set a precedent for disaster recovery in New Zealand. According to a report by the Auditor General, the authority achieved a lot during its initial phase, but faltered due to tensions between Christchurch City Council and CERA during the recovery phase (Controller and Auditor-General 2017). Additionally, the high uptake of insurance in New Zealand led to increased governance and communication challenges as insurers had issues getting access into the cordon and carrying out damage assessments. This meant that demolitions of buildings could not occur or materialise quickly enough and slowed the reduction in cordon extent over time.

The value of cultural heritage is an important determinant of post-earthquake recovery decision-making and can influence operationalisation of cordons. In the case of L'Aquila, significant resources were invested to conserve heritage buildings and to preserve the cultural integrity of the old part of the city. In Kathmandu Valley, the importance of cultural and religious practices such as celebrations and daily worship meant that cordons placed around temples were frequently breached by priests and members of the local community. In stark contrast, to expedite the recovery of the Christchurch CBD, 1,240 demolitions had been carried out within the 4 avenues by 2015, 20% of which were heritage buildings (Gates 2015).

Similarly, in L'Aquila agencies such as Civil Protection, universities and the Ministry of Cultural and Architectural Heritage collaborated with firefighters to design, develop

and implement an alternative urban shoring system. However, there were difficulties in coordinating these agencies (Grimaz 2011). Alexander (2010) provided a detailed account of the governance challenges across various institutions observed after the L'Aquila earthquake. Negative issues with governance and inter-institutional communications and collaboration are not surprising when they are established against the backdrop of a major disaster, as evident from Christchurch and L'Aquila. It can be reasonably assumed that there will be political manoeuvring when a new governance structure is developed with significant executive power and influence. This suggests that there are significant challenges that authorities face in their attempt to control the response and recovery following a major disaster.

The challenges of communication and governance are not limited to institutional systems, but also for public risk communication. Regular communication about post-earthquake cordons was necessary in Christchurch, Wellington and L'Aquila, especially in relation to the respective access programs. Honest, regular and 2-way communication is necessary to reduce distrust from the public, avoid protests, increase compliance of rules and foster the values of reciprocity.

In the absence of appropriate ethical and transparent decision-making, political pressure in relation to post-earthquake cordons is increasingly likely to be exerted by the public. This was evident in Christchurch and L'Aquila, where individuals or groups exerted political pressure explicitly through public protests (Dines 2015; McLean et al. 2012) as well as privately through various channels. Wellington suffered from political pressure although to a lesser degree, but enough to influence decisions regarding post-earthquake cordons following the Kaikōura earthquake. The heightened politics around post-earthquake cordons is evidenced by the fact that the then Mayor of Wellington had to defend his decision not to establish more extensive cordons (RNZ News 2016).

The interaction between the public and the authorities was somewhat different in Kathmandu Valley. For example, cordons around an apartment complex were removed by the public, but the authorities remained silent as they were not able to provide alternative solutions, such as temporary housing or alternative transport routes. The range of communication and governance challenges that emerged in each case study highlight the contextual nature of post-earthquake cordon decision-making and operations.

Conclusion

There is a growing need to understand the practical aspects of using post-earthquake cordons due to their increasing use after seismic events. To this end, this paper summarised 3 research papers that investigated post-earthquake cordon used in 4 different post-earthquake case studies that applied cordons as a response tool at varying spatial and temporal scales. It is clear that the purpose of post-earthquake cordons evolves from the initial need for a safe and secure area into a transitional space focused on reconstruction to support recovery of the city. An updated definition has captured the broader characteristics of cordons and the dynamic decision-making and management required for their effective use, from initial response to long-term recovery. The CODE model for post-earthquake cordons can guide emergency managers and relevant authorities to understand the range of practical considerations involved with cordons. The CODE model could be used by the authorities to make informed decisions for effective response and recovery following future seismic events.

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