Post-earthquake sheltering needs; how loss of structures and services affects decision making for evacuation

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ABSTRACT: Considerable research has been undertaken in New Zealand and overseas on peoples' decisions to evacuate during hazard events. However, the majority of this research is focussed on events for which warnings are possible. For a major Wellington earthquake event decisions about evacuation will occur after event impact. A household's decision on whether to evacuate or shelter in place is based on a range of factors, including those directly related to earthquake damage such as structural damage and lifeline utility function, and factors that relate to household or neighbourhood liveability such as access to resources, social networks, mobility or dependency. Because transport out of Wellington is expected to be severely hampered by a major event in the region, many of those that choose or are forced to evacuate their homes will require public shelter within the damaged area. A model framework for calculating evacuation numbers and sheltering requirements is proposed based on a variety of damage and non-damage related factors that contribute to evacuation decision making.

1 INTRODUCTION

Wellington City is situated on, and in proximity to, many active faults. In the long-term for the people of Wellington it is not a question of if, but when a severely damaging earthquake will occur. Widespread building and infrastructure damage (particularly on soft soils) can be expected (Cousins, Power et al., 2009). For a large event in Wellington it is expected that all major transport routes (air, sea, rail and road) out of the region and many within the region will be affected (Wellington Region Emergency Management Group, 2005). A critical social and economic consequence of building and infrastructure damage from a large earthquake will be the decisions the residents of Wellington make about evacuating their homes or sheltering-in-place. There is expected to be substantial pressure on Wellington's Civil Defence Emergency Management welfare services to provide shelter and support to those displaced because in the short- to medium-term evacuees will not be able to seek shelter outside of the region with friends or family.

1.1 Evacuation Options

Earthquakes are one of the few natural hazards that have little or no available warning time, whereas other significant natural hazards such as distant tsunami, flooding, hurricane, snowstorms, and volcanic eruption are largely able to be forecast and when time allows official warning notifications may be provided by authorities. Warnings typically provide instructions on human safety actions; simply put: either evacuate (from and to a specified place, following particular routes), or shelter-in-place. Evacuation is advised when the damage or consequences are deemed to pose a life safety risk to those in the expected impact zone (e.g. low lying coastal areas and tsunami hazard) and evacuation is expected to reduce this risk (i.e. there is a lesser additional risk posed by the evacuation process). Sheltering-in-place is advised when "riding out the event" is determined to be the safest option, rather

than travelling (e.g. reinforcing doors and windows and staying home during a wind storm). Evacuation can be mandatory (ordered by authorities and backed by statutory powers), or voluntary (advised but not regulatory or via self-evacuation where the evacuee decides without an advisory to leave). The process of evacuation may be organised and coordinated by authorities or largely the outcome of self-evacuation; in either case, there will always be some evacuees who will require assistance to evacuate (e.g. transport, mobility aid, resources). In the case of earthquakes, decisions to evacuate will be made after onset of the event, and mostly after the initial shaking has stopped, although the threat of aftershocks will provide some pre-warning of possible further events (Mileti & O'Brian 1993). Therefore, decisions related to earthquake-triggered evacuation are complex and include not only immediate and future human safety concerns but also social, economic, and cultural factors. This paper introduces the concept of a sheltering needs decision tree based on a severe Wellington City earthquake scenario.

1.2 Earthquake Evacuation Literature

Research into evacuation decision making has largely been focussed on those hazards for which warnings are provided, examining how people receive and interpret warnings, and whether they choose to evacuate or not. In particular, a large body of research into hurricane and tsunami evacuation behaviour exists in the international literature, but there have been limited studies into the post-event evacuation processes that follow earthquake events. Studies and research into post-earthquake evacuation come mostly from the United States (Bourque et al., 1973; Bourque & Russell, 1994; Chang et al., 2009). Studies of actual and modelled events in the United States suggest that post-earthquake evacuation decision making is complex, and not solely explained by building structural safety or loss of lifeline utility factors. New Zealand events that provide some comparison in terms of decision making after an event and a loss of lifeline utility services (lifelines) are the Auckland electricity blackout of 1998 (Newlove et al., 2003) and the Canterbury snowstorm of 2006 (Wilson et al. 2009) In these instances other community functions (e.g. schools, shopping, and employment) were also interrupted along with utility loss, and therefore some parallels around whether households chose to evacuate can be drawn.

2 FACTORS CONTRIBUTING TO EVACUATION DECISION MAKING

Factors identified as contributing to evacuation decision making can be characterised into two main groups – those that are related directly to levels of damage caused by earthquake rupture and shaking and those that are less tangible, but perhaps equally important to the decision making process.

2.1 **Building structural safety – is the building structurally uninhabitable?**

New Zealand adopted and adapted the US building safety evaluation process: red (unsafe), yellow (restricted use), green (safe to use) in the 1990's (Brunsdon, 2009). Following the relatively small impact December 2007 Gisborne Earthquake, the system was used for the first time in NZ for rapid assessment of commercial and residential buildings. The rapid assessment is not equivalent to a full inspection. Due to limited specialists being available and a desire to get unaffected businesses open as soon as possible, only the CBD was assessed in this manner. Assessment takes on average half an hour per building. In a severe Wellington earthquake, the damage is likely to be widespread to the degree that building damage classification systems will initially and in the medium-term be overwhelmed. For the most severe damage it will be obvious whether a residence is inhabitable or not due to structural integrity failure such as roof collapse, movement on foundations, or walls failing. Where professionals are unavailable to classify building damage, residents will be left to decide themselves whether it is safe to remain in their home based on their own knowledge of building design and construction. How residents will determine what is structural (dangerous) and what is cosmetic (relatively safe) damage is unknown, although some research has been conducted into evacuation rates and types of building damage as assessed by residents following the 1989 Loma Prieta earthquake

(Bourque & Russell, 1994).

2.2 Building fit for purpose – is the building functionally uninhabitable?

While households may be able to remain in buildings that are structurally safe, the loss of lifelines may provide the impetus for evacuation (Bourque & Russell, 1994). Functioning lifelines are essential for maintaining health and safety of households and communities. Many New Zealanders have experienced short-term electricity outages, and some communities have experienced outages of several weeks (e.g. the Canterbury snow storm of 2006, the Auckland CBD "Blackout" of 1998). Impacts from electricity loss will vary between households; factors that will mitigate impacts include: homes having alternative heating and/or cooking facilities such as a woodstove, barbeque or open fire; households being specifically prepared for emergencies with battery operated lighting and radios; supportive neighbours and strong social networks; and other lifelines continuing to operate. Factors that will exacerbate impacts from electricity loss are: dependency on electricity for health equipment, cooking or heating; isolation; apartment dwelling (Bourque & Russell, 1994), limited or no battery operated emergency equipment in the home, and the loss of function of other lifelines such as water or sewage systems. Communities in parts of New Zealand are dependant on limited (rain or bore) water supplies and during dry years experience shortages including having to purchase water for households' consumption and hygiene. However, the widespread loss of water supply is not a common occurrence in Wellington and could pose severe problems for many households as recent research (MCDEM, 2009; WCC, 2008) suggests over half of Wellington City households do not have sufficient supplies of water stockpiled for emergencies (the recommended amount is 3 litres per person per day for at least three days). Recent research into Wellington's water supply network, which crosses the Wellington Fault multiple times and is brittle and aged in many places, suggests that full restoration of supply could take several months (Cousins, Hancox et al., 2009). The loss of sewage systems could result in a secondary crisis through public health issues. It is not feasible for apartment dwellers to live with no sewage system but households can potentially remain in their homes with the loss of this lifeline by burying waste, as long as adequate water supplies remain to ensure hygiene levels.

2.3 Household liveability – individual decision factors, neighbourhood uninhabitable?

Factors that are not structural- or lifeline-related, that are recognised as part of the decision making process for individuals or households, often involve the functional needs of the household members (e.g. mobility, income, dependencies) (Vogt & Sorenson, 1992). Factors that make it more likely for a household to evacuate are: access to a vehicle; access to resources for travel (money, fuel); a household that includes dependant children (except sole parent/caregiver households); a household where members have somewhere accessible to evacuate to (Bourque et al., 1973; Bourque & Russell, 1994; Chang et al., 2009). Factors likely to make sheltering at home more likely include: whether the household is a sole-parent or sole-caregiver home; whether members of the household have mobility or health issues (medication, support equipment requirements); whether the house is rented; whether the house is close to the earthquake epicentre; and whether the household is experiencing (or members have a fear of) aftershocks. Because these factors vary from household to household, identification of households more or less likely to evacuate is problematic. Much of the data that could be used to identify households that will be more or less likely to evacuate would best be cross-tabulated on an individual household basis. Although such data is collected in the New Zealand census, for privacy reasons this data is aggregated and the smallest census unit is a meshblock. Some assumptions could be made about higher needs meshblocks in the event that evacuation was desirable or mandatory (e.g. low rates of vehicle ownership, low average incomes, higher than average rates of sole-caregiver households) which may be useful when considering potential evacuation support and sheltering requirements.

2.4 Neighbourhood liveability – community decision factors, neighbourhood uninhabitable?

Evacuation decision-making not related to structural damage is based upon neighbourhood liveability,

as well as household liveability. Neighbourhood liveability is determined by the support systems and services required for household wellbeing and function. The longer recovery takes, the more difficult it becomes for households to remain in their homes when these systems and services are removed.

(1) Public transport is required by many to meet their everyday needs for social and commercial contact (seeing friends/family, purchasing household supplies, visiting health care services etc).

(2) Schools, a focal point for many communities providing education for children but also community networks for parents/caregivers, and allowing caregivers to undertake employment during school hours - schools are often used as civil defence centres. Whether a school is unable to function because of loss of utility services, damage to buildings, or use as a civil defence sector post, pressure will be placed upon families with children. The loss of normal routines can place psychological stress on caregivers and children, and as experienced after Hurricane Katrina, when school services were restored, stress levels among caregivers lowered considerably (Williams, 2006). Another neighbourhood-related post event factor that contributed to delayed evacuation following Hurricane Katrina was the loss of access to livelihoods. For some, it was that their businesses had closed down through damage, evacuation of owners and staff, lack of customers and for others it was environmental degradation (Campanella, 2006). Although following major events some employment sectors typically experience increased activity (e.g. construction), many sources of employment and income will be disrupted following a major Wellington earthquake. However, seeking employment out of the region wouldn't be possible, so how strong a factor loss of livelihood will be as an evacuation decision contributor will be difficult to calculate. In many communities, social networks such as ethnic or refugee based groups, church groups, age care groups, and recreational clubs provide essential services to residents. Where these groups and clubs are disbanded due to hazard events, individuals and households can feel isolated or unsupported. The loss of social support networks can increase the stress of the event, and can contribute to the desire to relocate. Where social support networks continue to function, sheltering in place is likely to be viewed more favourably. These networks and groups can often take on new response and recovery roles during and after emergencies, when this process occurs they are termed "emergent groups" (Murphy, 2007) and ideally their skills and resources incorporated into civil defence emergency management (CDEM) planning. Another factor that will affect whether residents of a particular neighbourhood will evacuate is whether a mandatory evacuation order is given, and how it is delivered and by whom. As has been researched extensively for many types of disasters, even under a mandatory evacuation not all residents will leave. When this occurs the decision can be based on individual factors (don't believe the threat is real, lack of trust in authorities, unable to evacuate due to mobility etc) or neighbourhood factors (e.g. local friends and family are choosing not to go).

3 EVACUATION RATES AND SHELTERING NEEDS

From the decision-making process there are three common outcomes: households choose to shelter–in place, assessing that the factors encouraging evacuation do not outweigh the benefits to remaining in their homes or risks associated with evacuation are too high; households choose to self evacuate using their own resources; households evacuate but require assistance (either voluntarily or ordered to through mandatory evacuation orders). All those that evacuate will require alternative accommodation and this will either be to a public shelter or accommodation of their choosing. For short term events where transport is not significantly hampered there is greater choice for those with resources, to stay with friends or family outside the at risk zone, or to pay for temporary accommodation. In the case of a Wellington earthquake, where transport out of the region will be severely hampered, and large parts of the region damaged and not suitable for providing alternative accommodation, a greater demand on public shelters can be expected. In particular, the options of sheltering in multi-storey hotels/apartments will not be viable should electricity be disrupted. Typically for disaster events, those requiring public shelter are the minority, however, with the large proportion of apartment dwellers in Wellington's central business district more are likely to need shelters. Those requiring assistance to evacuate may or may not require the use of public shelters (i.e. immobility does not mean there are no friends or relatives in the area), however, for ease of assisted transport it is likely that some staging at

a welfare centre will take place before these people can move to an preferred destination. The numbers requiring public shelter following a major Wellington earthquake event are yet to be determined; it is expected the decision tree model in this paper (Figure 1) will provide greater understanding of the likely sheltering requirements.

Those that remain in their homes, perhaps with limited services, will also require support. It may be that a loss of one utility such as water supply or electricity can be managed, if self-powered equipment or tank water is supplied. This approach will reduce demand on welfare agencies assisting those in public shelters.

4 THE EVACUATION DECISION TREE

Figure 1 shows the proposed decision tree framework based on Chang et al 2009's model for Californian earthquake events. Steps of the decision making process are yet to be assigned weighting.

The framework incorporates the damage and non-damage related decision factors identified previously. When weighting values are assigned and affected population numbers are input into the model, numbers of people requiring shelter at home support, and public shelter can be estimated. These values can then be used for civil defence emergency management response and recovery planning, and also to identify high needs populations where public education and preparedness resources may be targeted (Vogt & Sorenson, 1992).

An issue for the decision tree process is that peoples' attitudes may change over time. Restoration of services (lifeline and community) following a major Wellington earthquake could potentially take weeks or months, the tolerance for sheltering in place may decrease the longer households are without essential services. Also the expectation is that access routes into the Wellington region will be a high priority for civil defence emergency management (CDEM), as transport links are restored the opportunity to evacuate out of the region will influence household decision making.

Ongoing research will explore weightings for decision factors and Wellington City data will be used to estimate evacuation rates and sheltering needs. This work will be paralleled with research into the capacity of Wellington (CDEM) to provide shelter and support for those displaced.

It is anticipated that the decision tree outputs will be useful for CDEM and lifeline utility planners when considering restoration and recovery prioritisation. For example, greatest benefit for resource allocation could be in restoring electricity to apartments and multi-storey hotels as they will reduce demand for public shelters, and in the case of hotels potentially provide temporary accommodation options for those displaced from their homes.

5 CONCLUSION

An evacuation and sheltering needs framework has been developed based on the Californian model of Chang et al (2009) and will initially be applied to a major Wellington earthquake scenario. Multiple factors that contribute to household evacuation decision-making have been included to recognise that post-earthquake evacuation decisions are based not only on damage states of buildings or loss of lifeline utility services, although they are contributors to the process. The outputs from this model will assist those tasked with planning for readiness, response and recovery for a major Wellington earthquake event.

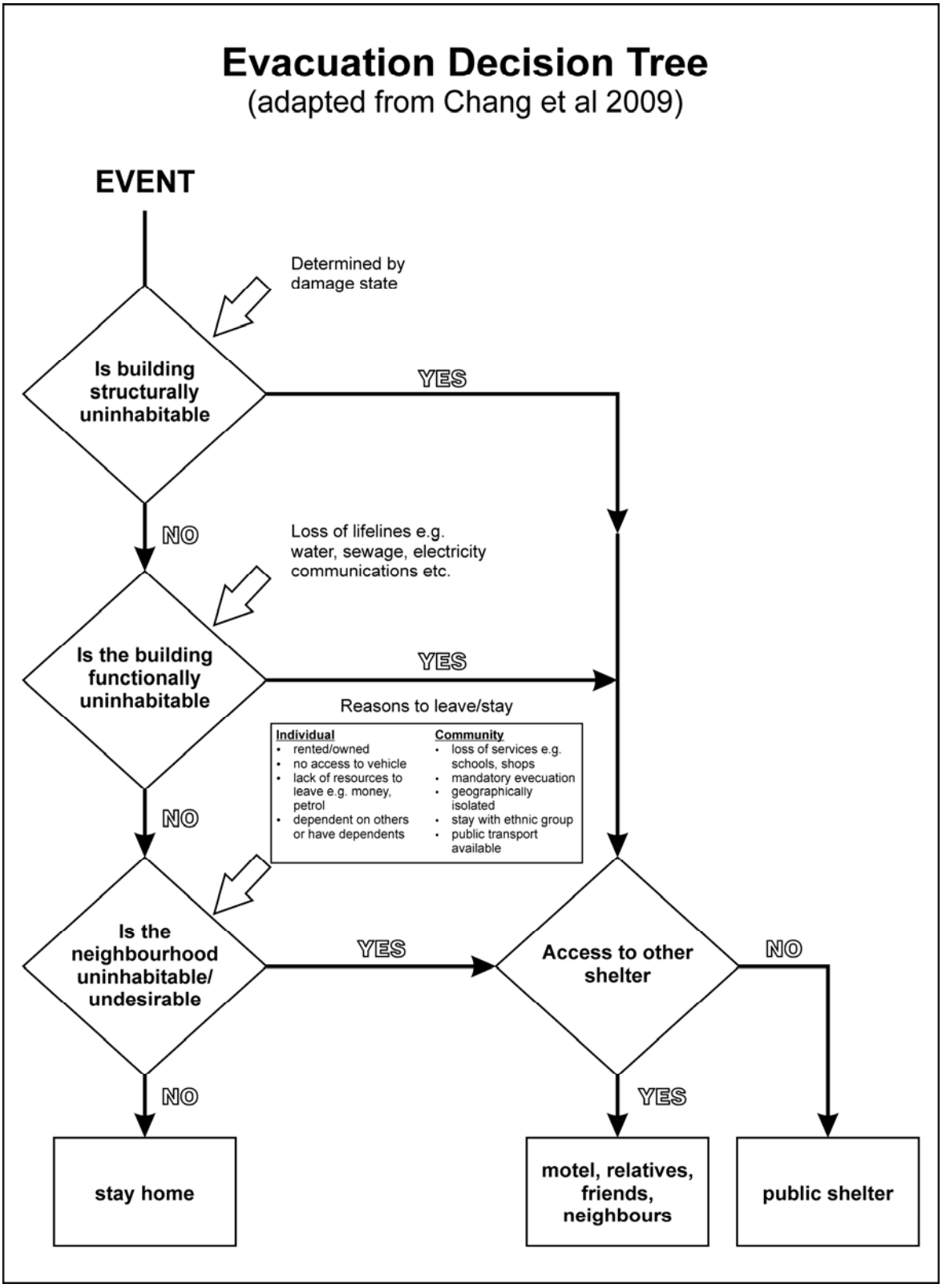

Figure 1 Framework of the evacuation and sheltering needs decision tree based on Chang et al 2009

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