ARTICLE

Establishing Principles for Bushfire Resilient Urban Planning

Abstract

The aim of this study is to elaborate on the built and natural environment disciplines' potential to develop applied understandings of resilience, using the example of land-use planning design guides in bushfire prone areas. The central argument of this study is that land-use planning can develop and apply spatial and physical resilience principles to disasters, contributing to developing meaningful ways of achieving resilience by bridging the space between overarching goals and the specificity of individual contexts. The study concludes that there are nine design principles that can improve settlements resilience in bushfire prone areas to reduce bushfire risk, organized under two major categories: acting on vulnerability and facilitating response.

Keywords: resilience; disaster; bushfire; wildfire; land-use planning

1. Introduction

As awareness of the scope and potential negative impacts of disasters upon settlements increases, the need to clarify and delineate the nature of resilience in useful ways gains momentum. Current international trends suggest that more disasters will occur per year, that their economic impact will be higher, and that more people will be affected over time (Coppola, 2015, pp. 18-20). An important consideration that can inform urban planning activities is recognition that natural hazards might not necessarily translate into disasters – *if* adequate measures are taken early to reduce vulnerability factors (Shah & Ranghieri, 2012, p.XXI). The concept of *resilience* is now being taken up with vigour, not just as 'bouncing back' but as improving conditions, to 'bounce forward'. In parallel is a need to establish conditions that avoid or minimize disasters and other emergent risks in the first place. Under the broad umbrella term of resilience, the ability to establish clear pathways to deal with the threat of disasters resulting from interactions with hazards such as floods and bushfires is now understood as a core part of urban management. However, the challenge of translating resilience from a descriptive and multifaceted ideal into useful on-going practices remains.

Using an examination of bushfires (otherwise known as wildfires) as a specific hazard type, this research argues that applied, critical and nuanced use of resilience concepts can provide ways forward. Urban planning can use this concept meaningfully, but only as it is applied to specific circumstances. Among diverse approaches to spatial management, land-use planning appears to have great potential for risk reduction, as it can be an effective design facilitator and guide. However, there are often limited connections between urban planning and emergency planning, breaking the disaster management continuum and limiting spatial planning's attention on disaster management measures and requirements.

This paper argues that middle-tier and applied understandings are essential to developing meaningful ways of achieving resilience, bridging the space between overarching goals and the specificity of individual locations and challenges. This paper reports research into the example of land-use planning design guides in bushfire prone areas. Based on documentary analysis of international land-use planning policies, coupled with interviews with experts, the research establishes nine fundamental principles that guide the design of settlements at the site and subdivision level. These provide an illustration of the range of issues and possibilities relating to land-use planning that, as a built form outcome facilitator, can contribute to the development of resilience in bushfire environments. The principles are organized under two categories: 'acting on vulnerability' and 'facilitating response'. From the documents analysed, it is argued that there is considerable convergence of themes across the international contexts where bushfire risks exist.

The paper begins by outlining the problem of risk and disasters and the case of bushfires. This is followed by setting out urban planning's potential for disaster risk reduction and developing resilience. Further, the research method used to assess the design principles is described. Next, the relationship between planning and settlements' vulnerability to bushfires is explored. The final section considers planning's potential as an integrative force for the facilitation of response in case of bushfire events.

2. The Problem of Disaster Resilience and the case of Bushfires

Natural hazards represent great risks for vulnerable communities and interest in developing resilience is increasing. Disasters are events where disruption occurs and the functioning of a community or a society and the subsequent losses and impacts are such that the affected community or society can no longer cope (International Strategy for Disaster Reduction (ISDR), 2009). However, while natural hazards can result in significant impacts upon communities, this does not have to necessarily be the case. In fact, disasters are not 'natural' (Lizarralde, Johnson, & Davidson, 2010, p.1); but rather result from the relation between exposure to natural hazards, vulnerable built environments and lack of capacity to cope with possible events (International Strategy for Disaster Reduction (ISDR), 2009). Thus, disasters are not unfortunate or unavoidable accidents, exogenous to humans and their settlements, or even unpredictable in most circumstances, but rather they are to some extent human–made. Consequently, there is an increasing interest in developing resilience to help vulnerable populations face unpredictable disruptions (Fainstein, 2013, p.4). The incorporation of the concept of resilience to the disaster discourse changed the approach to disaster management. This can be seen as 'the birth of a new culture of disaster response' (Manyena, 2006), contributing to improve the understanding of risk and vulnerability, and changing the focus from emergency management to development of resilience. It is increasingly addressed not only by academic discourses but also by government policy ones, reciprocally influencing each other (Welsh, 2014, p.15). However, as the increasingly powerful concept of resilience is taken up across business and government, its broad use is also bringing challenges to its clarity and specificity, disguising inconsistencies and illusions (Gleeson, 2013, pp.10-11). This calls attention to the need to develop understandings of middle-tier and applied ways of achieving resilience, bridging the space between overarching goals and the specificity of individual locations and challenges.

Disaster resilience is based upon balancing abilities to resist and avoid impacts with the capacity to adapt to them. Often, the emphasis when approaching disaster resilience is placed on one of both, yet balancing the strength and flexibility of systems, communities or societies provides a more comprehensive and realistic approach for disaster contexts. In fact, Davis and Alexander (2016) broadly define resilience as the combination of resistance and adaptability; arguing that since hazards and disasters cannot be eliminated; society must adapt to them but also should resist their impacts. This approach is also supported by Zhou, Wang, Wan, and Jia (2010) definition – the capacity to resist loss during a disaster and to reorganize after it. Resistance can be related to resilience in a structural sense, meaning buildings and other constructions are able withstand the action or effect of hazards (Davis & Alexander, 2016, p.258). Maintaining and improving systems' capacity to resist is directly related to disaster mitigation and disaster risk reduction. It can contribute to reduce greatly losses by reducing likelihood or the impact of hazards.

Resilience is often understood broadly as 'bouncing back' or after some form of adversity such as a cyclone, flood or bushfire, yet a 'bouncing forward' conceptualization appears to be valuable for disaster contexts. The bounce back approach is related to disrupted system coping capacity during the response and recovery phases to return to an approximation of its previous functions (Manyena, O'Brien, O'Keefe, & Rose, 2011). This implies a return to conditions that caused the disaster in the first place, which arguably is a short term focus on recovery and reconstruction – called 'passive resilience' – with limited value (Sudmeier Rieux, 2014). From this perspective, change is only associated with strengthening the existing structures to resist disasters, calling attention to a need for more transformative approaches to resilience. Transformation should be encouraged during mitigation and preparedness phases, to move innovatively to a more desirable trajectory (Davoudi, Brooks, & Mehmood, 2013). Transformability refers to the capacity of systems, communities or societies' to adjust to disasters in order to innovatively evolve into a different more desirable long term development (Holling, Gunderson, & Peterson, 2002), which is more appropriate to address the underlying risk factors and to engage in new development pathways for disaster risk reduction and prevention in the long term (Sudmeier Rieux, 2014, p. 75). Transformation can be facilitated by mechanisms established by societies to prevent and prepare to deal with uncertainty and change, through values, norms, practices and governance systems (Manyena et al., 2011, p.419). This is significant because it means societies may consciously and gradually evolve into more desirable, better prepared, new states.

3. Planning's Potential

It is well accepted, at least at a conceptual and policy level, that if disaster management processes and emergency planning are integrated with spatial planning, significant gains in risk reduction could be achieved. Advantageous settlement patterns themselves are a fundamental element in the avoidance or reduction of disaster impacts. This is primarily a physical or resistance view of resilience based on ensuring that structures are appropriately sited and designed; however, it cannot be separated from ecological, economic and social aspects. In particular, land-use planning mechanisms and processes, as facilitators providing guidance for the design of settlements, could contribute much more to reducing the likelihood and consequences of hazards.

In seeking to resolve multiple goals, urban planning establishes processes to achieve better spatial arrangements than those that would occur without intervention (Hall, 2002, pp.1-4). Since emergency planning has at its base geographical and spatial components, it is strongly linked with urban planning (Alexander, 2009, p.165; Sapountzaki et al., 2011, p.1470). Territorial (regional and strategic) planning can be considered the natural extension of risk management (International Strategy for Disaster Reduction (ISDR), 2004, p.314), functioning as a coordinating platform. However, until recently there have usually been limited connections between spatial planning and disaster risk reduction. This has meant that effectiveness in planning and preparation phases has been limited (Sapountzaki et al., 2011, pp.1445-1446), leading to spatial planning often focussing on response and recovery requirements.

Among the urban planning approaches available, land-use planning regulation and design guides appear to have significant ongoing potential for disaster risk reduction. Given that land-use planning's objective is to deliver improved spatial arrangements, coordinating competing interests to act in the light of collective good (Healey, 1997, p.310); it has great potential to address the conflicting considerations that are inevitably part for disaster risk reduction and life protection. Moreover, land-use planning allows agencies to think and act in different scales of space, time and governance (Hürlimann & March, 2012, pp.480-481) while performing locally to establish the most favourable spatial arrangement for each particular place (March & Henry, 2007, p.17). Land-use planning can be an effective facilitator of reduced risks, in terms of locational and design outcomes (Burby, 1998, pp.9-10). Locational risk refers to limiting development in locations exposed to unreasonable risks. This approach is effective in reducing losses, but implies economic sacrifice associated with non-development of land, even if risks are at low to medium levels. Design outcomes refers to ensuring adequate design and development standards for safe construction in hazard prone areas through land-use regulations (Burby, 1998, pp.9-10; Council of Australian Governments (COAG), 2011, pp.11-12).

Design, as an aspect of urban planning, is a process of solving problems through analysis, synthesis and evaluation of planned spatial outcomes. It involves identifying problems within a particular context that require action to improve them (Lawson, 1990, 2004). Design facilitated via land-use planning requirements can provide a logical and consistent basis to offer guidance to positively influence design outcomes (Blessing & Chakrabarti, 2009, p.87). By incorporating disaster management parameters, land-use planning has the ability to guide settlements' design to reduce disaster risks, while still allowing some growth in medium risk areas (Burby, 1998, pp.9-10).

Despite recognition in the literature and higher tier government policies, practical ways of integrating urban planning for developing resilience have not been explored in depth. While there are connections between urban planning and emergency planning, these can actually disrupt and limit spatial planning's attention on the whole spectrum of PPRR measures available (Sapountzaki et al., 2011, pp.1445-1446). Ideally, for the development of land-use plans, local governments gather and analyse data to determine the suitability of land for development (Burby, 1998, pp.1-2, 18). Risk assessments should be incorporated into the analysis, so that land is managed in a compatible way (Deyle, French, Olshansky, & Paterson, 1998, p.160). However, during the land-use planning development and process, only hazard identification and vulnerability assessments are commonly used instead of overarching risk analysis assessments that provide a more complete risk description and estimations (Deyle et al., 1998). Moreover, planning urban development is a continuous process that should be constantly monitored (Hopkins, 2001, p.16). By including disaster considerations while monitoring, land-use planning can increase the effectiveness of disaster management. Indeed, emergency plans should be revised and tested regularly for effectiveness, yet they tend to be regarded as static documents that are an end in their selves (Alexander, 2005, p.160, 165).

In fact, Davoudi (2012) argues that most uses of resilience in urban planning fail to adequately translate resilience concepts. Problems exist with understanding prior intentionality of human actions, as opposed to resilience occurring after an event; the actual goals sought by resilience in different settings and assumptions of 'naturalness' that this might entail; the boundedness of actions that raises questions of 'resilience of what to what?'; and, the power-blind assumptions of resilience, when a core question remains – 'resilience for whom' (Davoudi, 2012).

While it is beyond the scope of this paper to fully resolve all of the challenges posed by resilience, it is argued, using an examination of a specific hazard, that applied, critical and nuanced use of resilience does provide ways forward. Urban planning can use this concept meaningfully, but only as it is applied to specific circumstances.

4. Bushfires as hazards, and the risks in urban-rural interfaces

As a natural hazard, bushfire has particular characteristics stemming from the physical world of their fuel sources: grass, scrub or forest fires (Ramsay & Rudolph, 2003, p.10). They can burn large areas of land. Topography, weather conditions and vegetation type are the main factors that affect fires' behaviour (Country Fire Authority (CFA), 2012, p.5). The slope of the terrain influences bushfire speed and intensity; uphill, fire spreads faster than across a flat terrain or downhill, generally doubling the speed for every 10° of uphill slope (Country Fire Authority (CFA), 2012, p.5). Weather conditions such as humidity, wind, and atmospheric conditions affect bushfires' speed, direction, size and intensity, promoting ignition and spread (Country Fire Authority (CFA), 2012, pp.5-6). Fuel availability and characteristics have considerable influence on the spread of fire (Country Fire Authority (CFA), 2012, p.6). When interacting with settlements, a small fire has three mechanisms of attack: embers, heat radiation, and direct flame (Ramsay & Rudolph, 2003, p.15). Embers are the most common mechanism of building's ignition during a bushfire (Country Fire Authority (CFA), 2012, p.7; NSW Rural Fire Service, 2006, p.69). Radiation represents the greatest danger for humans (Country Fire Authority (CFA), 2012, p.7). Direct flames can ignite buildings if close to fuel sources (Ramsay & Rudolph, 2003, p.9). A fourth mechanism could be included in large fires: fire-driven wind (Country Fire Authority (CFA), 2012, p.9; Ramsay & Rudolph, 2003, p.21); referring to the impacts of wind damaging structures, allowing embers to enter and ignite them.

Bushfires can pose considerable risks at urban interfaces with vegetated areas. However, actual disasters resulting from bushfires can often be avoided if appropriate measures are set in place to guide settlements' development and to manage them over time. Certain landscapes are naturally fire prone, often relying on fire as a process of regeneration. In these contexts, settlement patterns in urban-wild interfaces can affect the frequency and intensity of catastrophic bushfires, increasing the risks for humans, properties and the environment (Butt, Buxton, Haynes, & Lechner, 2009, p.1). Further, climate change might be increasing that risk (Buxton, Haynes, Mercer, & Butt, 2010, p.4). Therefore, the interface between urban land and wild land is where humans' lives and material goods are more exposed to fire (Gill & Stephens, 2009, p.1). Vulnerable settlement patterns in these interfaces are no new thing. In the past, it was common that development occurred in areas of inherent risk, a legacy that presents great ongoing challenges for management agencies (Ellis, Kanowski, & Whelan, 2004, p.92). Nowadays, many cities continue to expand to areas at risk due to growth pressures to provide urban land – commonly cheaper in the peripheries of cities – for increasingly urban populations. These growth pressures are often complicated by political concessions in order to stimulate economies, to keep construction industry productivity and to maintain housing affordability. Additionally, some individuals have a strong desire for connection with nature, leading them to settle in bushfire environments, or to modify the vegetation that surrounds them increasing the fuel sources, or even to oppose managing vegetation to reduce bushfire risk.

5. Assessing Design Principles

The research aims to elaborate on the built and natural environment disciplines' potential to develop applied understandings of resilience, using the example of land-use planning design guides in bushfire prone areas. The primary question that guided the study was: 'Internationally, what fundamental design principles guide settlements in bushfire prone areas at the level of the site and subdivision to develop resilience to bushfire hazard?'

Selection of method, methods of data collection and analysis

A qualitative method was employed based upon two main sources of data. Firstly, international policy and documentary information from USA, French, Spanish and Australian policies and guidelines were examined (see Table 1). These sources were selected because they are appropriate to answering the exploratory nature of the research question (Yin, 1994, p.6). The criteria for selecting the cases include the policy and documents being well established and comprehensive, their availability, the researchers' language abilities, and high bushfire severity within the areas they apply (County of San Diego, 2011, p.5; Ministère de l'écologie du developpement durable et de l'énergie, 2012; Ministerio de Agricultura Alimentación y Medio Ambiente, 2013; National Fire Protection Association (NFPA), 2013b; Orange County, 2005, p.III-3). Secondly, semi-structured face-to-face interviews with five key Australian professionals and scientists in the field were conducted. This was undertaken with the intent of generating additional insight into the planning and bushfire controls and to corroborate understandings (Yin, 1994, pp.80-84). Participants were selected based on their expertize, representation of the range of disciplines involved in bushfire management (see Table 2), and availability to be interviewed in Australia. The interview questions were based on the findings of the initial documents analysis phase, and included open-ended questions.

The documents and interviews were analysed to theme the main design principles for bushfire risk reduction, by creating categories, sub-categories, and preliminary core categories. The interview data complemented the preliminary categories developed via the documentary analysis, to further develop definitive core categories (Strauss & Cobin, 1990, pp.116-117); the fundamental design principles for bushfire risk reduction at the site and subdivision level.

The value of design principles and generalization

The generalisation of design principles can contribute to the subsequent development of resilience across jurisdictions. These principles refer to the physical environment and the policies that can guide development, assuming that land-use and design at the site and subdivision scale contributes to settlements' reduction in exposure to hazards. A rational approach to design can establish a logical and consistent basis through principles (Blessing & Chakrabarti, 2009, p.3) that offer guidance (Burgstahler, 2004, p.2) to positively influence on final designs (Blessing & Chakrabarti, 2009, p.87). Moreover, from an international perspective, disasters are to some extent unique; nonetheless, they are generally comprised of elements that have a basis in previous events (Alexander, 2009, p.163). Bushfires are no exception. Although bushfires take place in diverse contexts and fire regimes (National Wildfire Coordinating Group (NWCG), 2006, p.75), they behave according to well established scientific principles (Ramsay & Rudolph, 2003, p.12). This allows categorising and generalising of fundamental performance concerns that should be considered in sites and subdivisions within areas at risk of bushfire. These design principles are likely to be applicable anywhere in the world that has bushfire risk, and to contribute to policy development and evaluation, for development of professional abilities, and for communication purposes.

Limitations

It is acknowledged that the research has certain limitations, including the fact that many factors other than design impact upon risks, and that many non-physical factors such as community awareness and behavioural change have significant impacts (Coppola, 2015, pp. 230-252). Furthermore, the need to understand contextual factors remains. (Food and Agriculture Organization of the United Nations (FAO), 2006, pp.2-6). The data used also have limitations - documents could be biased in terms of initial selection; and the documents themselves could have author bias (Yin, 1994, p.80) or inaccuracies (Creswell, 2003, p.187). Additionally, the interviews were not conducted internationally, limiting the interviewees' perspective mainly to the Australian context, within their own perspectives (Creswell, 2003, p.186); in addition to possible involuntary biases due to the construction of questions (Yin, 1994, p.80) and institutional roles played by subjects.

6. Acting on Vulnerability

Urban planning for bushfire risk reduction provides an example of some of the ways that resilience is inherently connected with sustainability. It provides a practical example of urban planning improving resilience, based mainly on seeking resistance to the core features of the threats posed. Based on the documentary analysis of nine international cases of policies and standards dealing with bushfire, and integrated with the data collected from the interviews, five planning principles can be identified in the guidance of the design of buildings and their context to act on vulnerability, in relation to physical mitigation measures. These measures improve the mechanisms of interaction between fire as a natural process based in vegetated areas, and the physical structures that sustain humans' social, economic and physical well-being.

From the analysis and categorisation of the most relevant themes, five principles were developed and grouped under the main aim: 'acting on vulnerability', as can be seen in Table 3. The design principles are:

1) Considering the context and landscape impact on vulnerability
2) Adequate separation from fire source
3) Management or modification of vegetation, landscaping or other fuels sources
4) Managing the density of structures
5) Protecting infrastructure and land-uses of greater vulnerability

The first principle is *considering the context and landscape impact on vulnerability* as a critical beginning to informing design *responses to the particular nature* of fire threats presented. It is mentioned by five of the analysed cases; two documents refer to the principle at the subdivision scale and three at the site scale instead. Similarly, the interviewees also recognized the principle, from a risk assessment perspective. It is argued here that while resilience principles might in some ways be transferable, bushfire resilience requires an urban planning and design outcome that is directly responsive to the nature of the threat presented in a given place. Spatial risk assessments can be integrated with land-use planning to establish design requirements according to different risk levels and types. Risk assessments consider the particular characteristics affecting likely fire behaviour in the area, including topography, aspect, fuel load and proximity to the forest, fire weather, wind and likely direction of the fire front, and any water bodies. For instance, the California Government Code (1943, as amended)identifies very high fire hazard severity zones:

> *Based on fuel loading, slope, fire weather, and other relevant factors including areas where [….] winds have been identified […] as a major cause of wildfire spread.*

Ideally, this would also be matched in a temporal way with annual re-assessment on a site by site basis, considering any changes to vegetation over time, the severity of the season and the fire history of the area, allowing forecasting of ongoing exposure for each summer (FBS1). Moreover, based on risk assessments, zones with different risk levels can be determined. For example, Commune de la Gaude (2011) establishes five different risk categories within vulnerable areas. Through a customized approach like this one, classification of properties could inform people of their level of exposure. In this context, the insurance industry could play an important role for creating risk awareness through their fire levee and costing (FBS1; EAR2).

The second principle is determination of ***adequate separation from the fire source*** as a critical mean of reducing bushfire exposure and therefore vulnerability. The principle is explicitly considered by seven of nine of the analysed cases. The analysed documents approach the principle at the site or subdivision scale, or at both. Furthermore, the principle of separation was widely acknowledged as central to bushfire risk reduction by the interviewees. Separation can be achieved by providing setbacks between buildings or settlements, and the hazard or fuel source itself. At the subdivision scale, new developments can be required to provide firebreaks, roads or other low fuel-level spaces that increase separation from the fire hazard, and may even involve separating settlements from rural and forested environments. For example, Comunidad Autonoma de Extremadura (2006, p. 37005) mandates a 200 to 400m strip of land around settlements where preventive measures are applied. It must be considered though that evacuation should not rely on roads that work as low fuel areas because they can be compromised in an emergency (R2). At the site scale, separation can be achieved through buffer zones around buildings, considering ancillary structures, vegetation, slope and other structures. For instance, Comunidad Autonoma de Galicia (2006 p.10.471) requires a 50m. buffer zone. These spaces can provide a place of relative safety, allowing people to exit buildings after the fire front passes (EAR2). At the subdivision level, planning and design offers real abilities to deliver separation outcomes; in contrast to the individual site scale where possibilities may be limited on small properties (R2). This situation highlights two main issues. Existing lots or settlements can be constrained in their ability to provide the separation necessary, therefore retrofitting measures might be used to change fuel levels or improve the resistance ratings of individual structures themselves. At a strategic level, planning's role is critical to the correct location and siting of new settlements. However, it may also be that risks are too great, and that no development should occur in certain locales. Nevertheless, the strategic direction of development may be affected by the pressures of political and economic interests (R1) other than resilience.

In parallel with hazard separation is the third principle, active ***management or modification of vegetation, landscaping or other fuel sources*** near to settlements and structures. This principle is considered in eight of the analysed cases; all the documents refer to it at the site scale and California also addresses it at the subdivision level. Moreover, the principle was recognized by all the interviewees as fundamental to reducing exposure via urban planning and design. Fuel management is one of the most common approaches for reducing bushfire exposure, but it raises significant issues relating to the appropriateness of human interventions into natural systems, particularly the removal of natural vegetation, or imposition of artificial fire regimes. Considerations include clearance of dead or flammable vegetation, especially under trees and around structures (County of San Diego, 2011, p.8; National Fire Protection Association (NFPA), 2013a, p.10); appropriate location of other fuel sources, such as wood piles, combustibles or barbecues (Commune d'Assas, 2005, p.8,15; Commune de la Gaude, 2011, pp.21-22); and the use of greenbelts (California Code of Regulations, 2006, section 1276). Additionally, species choice and landscape design can play a central role in fuel management (FBS1). Management of fuel can be undertaken on a sliding scale in relation to the proximity to buildings, but appropriate maintenance over time, often by owners or occupants is vital to success. There may also be social constraints to vegetation management, such as people's desire to live in proximity to bushland (R1). Although managing and landscaping vegetation and other fuels is usually addressed at the site scale, the strategic planning or subdivision level can often be more appropriate and could play a more powerful role in land-use planning policies. This stage is when there is the greatest ability to appropriately manage fuels to limit exposure (R2). Successful resolution of vegetation management would represent an integration of resilience with natural and human processes.

Fourthly, *managing the density and arrangement of structures* can minimize exposure and reduce the likelihood of bushfire attack. However, it was not common in the policies analysed, being considered only in five of the nine cases via local planning documents at the subdivision scale. In contrast, the management of density (eg the number of dwellings per hectare) to modify vulnerability was widely acknowledged by the interviewees as important. Density establishes the appropriate development intensity to minimize exposure, in parallel with other relevant features. As a design criterion, density regulations need to respond to the specific characteristics of each area to determine an appropriate development balance. On the one hand, it needs to restrict isolated buildings where exposure is excessive. This is the approach of the French cases, which set density minima and separations between buildings for peri-urban and rural settlements at risk, prohibiting isolated dwellings (Commune d'Assas, 2005, p.6; Commune de la Gaude, 2011, p.17). On the other hand, higher densities in exposed areas should be discouraged in some circumstances to limit population numbers at risk and to avoid building-to-building fire spread. In a bushfire environment, building-to-building fire spread is more serious than in an urban scenario; because brigades' capacities to extinguish a fire are very different in each context (R2). Following this approach, the USA cases, for example, require density to reflect site specific risks to minimize populations' exposure to bushfire (County of San Diego, 2011, p.4; Orange County, 2005, p.V-75). However, larger settlements with clearly defined and well managed edges have demonstrated considerable resistance to fire penetration.

Fifth, *protecting infrastructure and land-uses of greater vulnerability* is another key planning consideration within bushfire environments, considering that certain infrastructure is critical for a rapid recovery (ie bounce-back) and that certain people and groups of people are more susceptible to disastrous consequences. This principle was considered by five of the nine analysed cases. It is notable that all documents dealing with this did so at the principle at the subdivision scale, excepting the Victorian case that also approaches it at the site level. However, the principle was not extensively addressed by the interviewees. This principle, of 'matching' the vulnerability of places to spatial hazard exposure can be achieved by zoning for appropriate land-uses and by establishing stronger requirements at the strategic level. The most common method observed of managing social vulnerability was via zoning or similar mechanisms seeking that land-uses appropriately reflect sites' bushfire risks. These include the activity allowed and its likely resilience, the number of users and their particular evacuation requirements (Commune de la Gaude, 2011; County of San Diego, 2011, p.4). Furthermore, stronger requirements can be established for relevant infrastructure, such as the case of California Public Resource Code (1939, as amended) and the Victoria Planning Provisions (2013) that set or allow for different buffer zone measures for certain uses of greater vulnerability. Interestingly, the Commune de la Gaude (2011, p.28) also establishes stronger requirements for existing buildings that receive the wider public (eg an entertainment venue) , mandating their retrofitting.

7. Facilitating Response

Incorporating response-facilitating design elements that improve resistance via urban planning processes is an fundamental aspect of risk management (International Strategy for Disaster Reduction (ISDR), 2004, p.314). Forward planning processes can facilitate and coordinate improved emergency response actions during and or immediately after potential bushfires. Four planning principles can be identified in the cases studied. This represents resilience manifest as a combination of social and physical resistance, paying heed to the interactions between human response to an impending disaster, and the fact that they do so within physical constraints of previously established physical structures and the human systems of response. Improving response can contribute to preventing escalation of a hazardous situation to a disaster situation.

Building on the previous five principles, an additional four elements were apparent. These were grouped under the main aim: ‘facilitating response’, as can be seen in Table 4.

6) Availability, capacity, location and travel times of emergency services
7) Efficient access and egress of emergency services
8) Water availability for fire-fighting
9) Resilience and resistance as a function of the actions of civilians as they evacuate, find refuge or defend properties

As a sixth principle, land-use policies need to consider the *availability, capacity, location and travel times of emergency services* – also admitting the possibility that it may not be possible to rely on this as a viable strategy in some locations, and that this would consequently suggest particular design parameters. Despite its importance, this principle is only considered by four of the nine cases analysed, always at the subdivision scale. Response assessment needs to integrate a number of non-planning considerations: dispatching, resources, location, and expected travel times. Availability of operating or planned services should be accounted for when proposing new developments (County of San Diego, 2011, p.8), and NPFA (2012, p.14) recommends assessing the impact of ongoing land-use changes upon fire protection services. Traffic management needs to plan for route redundancy in the case of traffic systems being overwhelmed, considering speeds and other variables in bushfire environments, which might be affected by smoke (EAR1), roads blockages (R2) and other fire effects. Likely travel times should be calculated for the distance from the response agency to the development farthest dwelling; for instance, County of San Diego (2011, pp.10-11) sets minimum requirements for travel times, varying according to development intensity. In recent years an underlying assumption that no citizen can expect emergency services to attend every site during an emergency has emerged in some places, notably Australia, as a reflection of resource realities; and to seek that individuals and groups take responsibility as a starting point for increased resilience. Due to the extensive scale of bushfire disasters, the built form becomes a spatial demonstration of emergency services’ need to prioritize response actions (R1), suggesting an increasing need to maximize communities' active response and resilience.

Seventh, assuming agency response can occur, facilitating the ***efficient access and egress of emergency services*** for particular sites is vital. It is considered in eight of the cases studied. As one of the most common design principles in the analysed policies, measures to achieve efficient access and egress of emergency services may include technical requirements ensuring fire-fighting appliances can circulate in ways that allow the most advantageous active defence. Road networks should allow the access of emergency services and residents' evacuation concurrently (California Code of Regulations, 2006, Section 1273; County of San Diego, 2011, p.8), and unobstructed traffic during the event (California Code of Regulations, 2006, Section 1273). At subdivision level, designs must consider road dimensions, grades, signage for address clarity and construction standards for turnoffs and bridges, among others (National Fire Protection Association (NFPA), 2012, pp.9-11). Additionally, opportunities for fire services to access the edges of the hazard must be provided (EAR2), as required by the Commune d'Assas (2005, p.9). At the site scale access considerations are assessed (Commune d'Assas, 2005, p.7; National Fire Protection Association (NFPA), 2012, pp.9-12), including clearing of vegetation along roads and establishing roads' setbacks from vegetation, and the appropriate times for them to act, before or after the fire front passes (EAR2).

Eighth, ensuring ***water availability for fire-fighting*** is a key design concern for land-use regulation. All the analysed documents considered it, as did all interviewees, being critical to facilitating response capabilities of emergency services. Technical water availability requirements were stipulated according to risk levels. At subdivision scale, water supply for suppression activities considers accessibility, availability and quantity of water, which can be provided by mobile water tenders, by natural sources, or by constructed containment structures (California Code of Regulations, 2006, Section 1275). Water points are required to be accessible and appropriately signed (California Code of Regulations, 2006, Section 1275). At individual site scale, water sources, including swimming pools or reservoirs equipped with engines that function in an emergency context (Commune d'Assas, 2005, p.15) need to be suitable for bushfire suppression (County of San Diego, 2011, p.9), close to buildings (Commune de la Gaude, 2011), able to sustain functionality throughout extreme fire events (EAR2). In addition, response mechanisms include automatic fire protection systems, such as sprinklers, and manual fire protection mechanisms, such as standpipes, that must be appropriately maintained (National Fire Protection Association (NFPA), 2012, pp.12-14; Orange County, 2005, p.V-75). However, passive measures should be prioritized over active ones, because active measures may require power and strict maintenance for systems to operate (R1; R2). If there is reliance on active systems, active maintenance failures can represent a risk.

The ninth and final theme deals with the inter-related matters of ***resilience and resistance as a function of the actions of civilians as they evacuate, find refuge or defend properties***. This principle is mentioned in only three of the planning policies analysed. However, it was extensively addressed by the interviewees. Allowing for appropriate *evacuation* and ensuring *defensible space* around structures is multi-dimensional. Adequate road network design should allow civilian evacuation to occur simultaneously with other response activities (County of San Diego, 2011, p.8). Ongoing policy in Australia has been to 'leave early, or to stay and defend'. While contentious, the policy appears on balance to be appropriate, and significantly, implies that resilience in this sense requires significant preparation, social learning and information. Late evacuation from a dwelling is highly risky (R1) and is strongly discouraged in Australia. Moreover, the concept of a safe area with a role for active defence can be implied in the concepts of *defendable space* established by Victoria Planning Provisions (2013) and of *defensible space* set by the California Code of Regulations (2006, section 1271). It is true that in many fires active defence by appropriately prepared, fit and informed people will prevent small fires escalating to destroy houses. Importantly, at the level of the individual site, if persons have elected to stay and defend, or have been surprized by events, the prior design and maintenance of a structure will also significantly aid the use of a house as a place of refuge as a form of resistance while a fire passes. In addition, if separation from vegetation and fuel management are integrated into the design of a structure on its site, even if a house does catch fire and is destroyed, the separation space from vegetation (such as a house's backyard) will provide a place of refuge, because the main fire front has passed by when they need to leave the building. However, given that evacuation cannot be relied upon as a failsafe mechanism (FBS1) and that provision of space for active defence is not always feasible, providing alternative refuges is critical. These might include protection from immediate effects such as fire refuges, group shelter buildings; private shelters (or bunkers); and, neighbourhood safer places including recreational facilities, sports fields, or car parks (Fire Services Commissioner Victoria, 2012, p.16-17).

8. Conclusions

This paper argues that urban planning and design can develop and apply spatial and physical resilience principles to disasters, also improving social outcomes, using the example of bushfire or wildfire. It is shown the application of particular risk circumstances and contextualization of risks bridging the space between overarching goals and the specificity of individual locations and challenges to reduce disaster risks. An effective way of achieving resilience is via forward planning and design approaches – directly seeking improved future outcomes, based on establishing procedures in the present – to prevent and prepare settlements to deal with uncertainty and change by balancing both the ability to resist the impact of a hazard and the capacity to adapt to them.

Human settlements with interfaces to bushfires need a number of characteristics to be in place to be resilient. The study shows that there are nine design principles that can improve the resilience of settlements in bushfire prone areas to reduce bushfire risk. These principles were organized under two major categories: acting on vulnerability and facilitating response.

In terms of acting on vulnerability, five principles were found across the analysed cases. The first one is *considering the context and landscape impact on vulnerability*, the critical beginning to informing design responses to particular natures of fire threats presented. *Adequate separation from fire source* is the second; it is among the most common identified criterion for dealing with exposure, as a critical mechanism of reducing bushfire exposure and therefore vulnerability. The third principle is ***management or modification of vegetation, landscaping or other fuel sources*** near to settlements and structures, working in parallel with hazard separation it is the most widespread consideration for dealing with exposure among the analysed policies. *Managing the density of structures*, the fourth one, responds to the rationale of considering buildings as a hazard source in a bushfire environment and can minimize exposure and reduce the likelihood of bushfire attack. Fifthly, *protecting infrastructure and land-and uses of greater vulnerability* can be achieved by zoning land for appropriate land-uses.

In terms of facilitating response, four additional principles were found. Sixth is *availability, capacity, location and travel times of emergency services*, due to the need of integrating several non-planning considerations in the response assessments. Assuming that agency response can occur, facilitating the *efficient access and egress of emergency services* is the seventh principle. Eight is the universal concern of ensuring ***water availability for fire-fighting*** by individuals and agencies. The final and ninth theme is ***resilience and resistance as a function of the actions of civilians as they evacuate, find refuge or defend properties***, which can have many dimensions for facilitating evacuation and providing refuge and defence alternatives given that evacuation is not a failsafe mechanism.

These principles are interdependent; none of them can be considered fail-safe. It stands out the over reliance of the study cases on defendable space requirements to achieve a large number of the principles. A system of complementary methods that support the defendable space provision would avoid depending just on one mechanism that eventually could fail. Furthermore, the strategic planning system should direct new development to appropriate areas without exposing settlements to unnecessary risk in the first instance, and special considerations should also be in place for retrofitting requirements of settlements at risk.

Lastly, practices to prevent and prepare to deal with risk depend on the capacity to learn from the experience of previous disasters and transfer disaster management knowledge while responding to each particular context. Urban planning process has the potential to learn and transfer knowledge in a contextualized manner, and the analysis of the study cases illustrate how planning instruments can deliver this. This potential can have a crucial role for communities and settlements to adjust to disasters and innovatively evolve into different more desirable development pathways for the long term risk reduction and prevention.

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		Year of Publishing	Name of the Policy	Name given to bushfire in the document
USA	Federal	2017*	NFPA 1141, Standard for Fire Protection Infrastructure for Land Development in Wildland, Rural, and Suburban Areas.	wildfire
		2017*	NFPA 1142, Standard on Water Supplies for Suburban and Rural Fire Fighting.	wildfire
		2013	NFPA 1144, Standard for Reducing Structure Ignition Hazards from Wildland Fire.	wildfire
		2014	NFPA 1143, Standard for Wildland Fire Management.	wildfire
	California State	2016	California Code of Regulations. Title 14- Division 1.5- Chapter 7- Subchapters 2 and 3	wildfire
		1943	California Government Code. Title 5, Division 1, Chapter 6.8. Very High Fire Hazard Severity Zones, Section 51175-51189	wildfire
		1939	California Public Resource Code. Division 4. , Part 2, Chapter 3. Mountainous, Forest, Bush and Grass Covered Lands 4291- 4299	wildfire
	San Diego County	2011	General Plan - Public Facilities, Services & Safety Element	wildfire
	Orange County	2014	General Plan	wildfire
FRANCE	Commune d'Assas	2005	Plan de Prévention des Risques Naturels Prévisibles d'Incendies de Foret (PPRif)	incendies de foret
	Commune de la Gaude	2014	Plan de Prévention des Risques Naturels Prévisibles d'Incendies de Foret (PPRif)	incendies de foret
SPAIN	Comunidad Autónoma de Extremadura	2014	Plan de Prevención de Incendios Forestales de la Comunidad Autónoma de Extremadura (Plan PREIFEX)	incendios forestales
	Comunidad Autónoma de Galicia	2006	Decreto 105/2006, do 22 de xuño, polo que se regulan medidas relativas á prevención de incendios forestais, á protección dos asentamentos no medio rural e á regulación de aproveitamentos e repoboacións forestais.	incendios forestais
		2007	Lei 3/2007, do 9 de abril, de prevención e defensa contra os incendios forestais de Galicia.	incendios forestais
AUSTRALIA	Victoria State	2014	Victoria Planning Provisions, clause 52.47	bushfires

*Note 2017, referenced as reported, pre-released edition.

TABLE 1: International cases analysed

Expertise of the interviewee	Identification code allocated
Emergency Agency Representative	EAR1
Emergency Agency Representative	EAR2
Fire Behavior Scientist	FBS1
Regulator	R1
Regulator	R2

TABLE 2: Expertize and code allocated to the interviewees

		Design Principles for Acting on Vulnerability									
		Considering the context and landscape impact on vulnerability		Adequate separation from fire source		Management or modification of vegetation, landscaping or other fuels sources		Managing the density of structures		Protecting infrastructure and land-uses of greater vulnerability	
		Site	Subdivision	Site	Subdivision	Site	Subdivision	Site	Subdivision	Site	Subdivision
USA	Federal	X	-	X	-	X	-	X	-	-	X
	California	-	X	X	X	X	X	-	-	-	X
	San Diego County	X	-	-	-	X	-	-	X	-	X
	Orange County	-	-	-	-	X	-	-	X	-	-
FRANCE	Commune d'Assas	-	-	-	X	X	-	-	X	-	-
	Commune de la Gaude	-	X	-	X	X	-	-	X	-	X
SPAIN	Comunidad Autón. de Extremadura	-	-	-	X	-	-	-	-	-	-
	Comunidad Autón. de Galicia	-	-	X	X	X	-	-	-	-	-
AUSTRALIA	Victoria	X	X	X	X	X	-	-	-	X	-
N° Cases that Consider each Principle (irrespectively of the scale)		5		7		8		4		5	

TABLE 3: Five Design Principles for Acting on Vulnerability found in the nine analysed policies

		Design Principles for Facilitating Response							
		Availability, capacity, location and travel times of emergency services		Efficient access and egress of emergency services		Water availability for fire-fighting		Resilience and resistance as a function of the actions of civilians as they evacuate, find refuge or defend properties	
		Site	Subdivision	Site	Subdivision	Site	Subdivision	Site	Subdivision
USA	Federal	-	X	X	X	X	-	-	-
	California	-	-	X	X	-	X	X	X
	San Diego County	-	X	X	X	X	-	-	X
	Orange County	-	X	X	X	X	-	-	-
FRANCE	Commune d'Assas	-	-	X	X	X	-	-	-
	Commune de la Gaude	-	-	X	X	X	X	-	-
SPAIN	Comunidad Autón. de Extremadura	-	-	-	X	-	X	-	-
	Comunidad Autón. de Galicia	-	-	-	-	X	-	-	-
AUSTRALIA	Victoria	-	X	X	X	X	X	X	X
Number of Cases that Consider each Principle (irrespectively of the scale)		4		8		9		3	

TABLE 4: Four Design Principles for Facilitating Response found in the nine analysed policies