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Evaluating the Source of the Risks Associated with Natural Events

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Abstract Within philosophy there has been little discussion of the risks associated with natural events such as earthquakes. The first objective of this paper is to demonstrate why such risks should be the subject of more sustained philosophical interest. We argue that we cannot simply apply to risks associated with natural events those insights and frameworks for moral evaluation developed in the literature considering ordinary risks, technological risks and the risks posed by anthropogenic climate change. The second objective of this paper is to identify and develop a framework for the moral evaluation of the source of the risks associated with natural events, or the actions which sustain and impact such risks. Our discussion concentrates on the ways the construction and modification of built and natural environments can alter the probability of occurrence of natural events and the character and magnitude of the impact that such events have. We then argue for the need to develop a standard of reasonable care for decisions about the built and modified natural environment, which accounts for technical and resource constraints, as well as the place of natural hazard mitigation in public policy.

Keywords Risk · Natural disasters · Engineering · Standard of care

Introduction

Between 1991 and 2005 almost 1 million people were killed and 3.5 billion people were directly affected by natural disasters such as earthquakes, wind storms,

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droughts, and floods (UNISDR 2005).[1] The earthquake of magnitude 7.0 that struck Haiti on January 12, 2010 illustrates the catastrophic consequences that natural disasters can have upon communities. It is estimated that the earthquake affected up to 3 million individuals, causing 230,000 deaths, 300,000 injuries, leaving 1 million homeless, and producing $14 billion in damage to the poorest country in the Western Hemisphere. Haiti has no building codes. Structures are built where space is available, including slopes, with inadequate foundations (Watkins 2010). Up to two million Haitians dwell on land they do not own (Greene 2010). Unsurprisingly, 30,000 commercial buildings and 250,000 residences collapsed or were so damaged demolition was necessary. Hospitals as well as transportation and communications systems critical for disaster response were destroyed (Sheridan 2010; Allen 2010).

Natural disasters do not only affect developing countries. Hurricane Katrina hit southeast Louisiana in the United States on August 29, 2005, causing severe damage along the Gulf coast. The levee system in New Orleans failed, leading to flooding in 80% of the city. Estimates of the economic impact of Katrina stand at $150 billion; this number includes repair and reconstruction costs, revenue lost from unemployment, and the impact of export interruption and industries, such as the forestry industry, negatively affected (Burton and Hicks 2005; Fagot and Winbush 2006).

Given the devastating consequences natural disasters can have for communities, devising and implementing effective mitigation measures against future natural disasters is, in the words of the Hyogo Declaration of the report of the United Nations World Conference on Disaster Reduction in 2005, 'one of the most critical challenges facing the international community' (United Nations 2005).[2] However, curiously, and despite extensive interest in development ethics, global justice, and risk, there has been little discussion within philosophy about the risks associated with natural events.[3] Risk is often defined as a set of scenarios, their associated probability of occurrence and consequences (Kaplan and Gerrick 1981; Hansson 2007).[4] Risks associated with natural events are potentially damaging or destructive natural events that might occur in the future.[5] Risk analysis is the process of determining the probabilities and potential consequences, and evaluating the

[1] For a comprehensive overview of the impact of natural disasters in recent decades see Center for Research on the Epidemiology of Disasters (2006).

[2] United Nations, World Conference on Disaster Reduction (2005), at p. 3.

[3] Natural hazards have not been the subject of extensive philosophical discussion. Discussion of the societal impact of natural hazards can be found in Murphy and Gardoni (2006, 2007, 2008) and Gardoni and Murphy (2009). Rubenstein (2007) also references natural disasters in the course of developing the principles that should be regulating international aid and in particular emergency and development aid.

[4] The definition we provide is more specific than some definitions found in the philosophical literature and reflects the fourth meaning of risk covered by Hansson (2007), where he writes risk is defined as 'the statistical expectation value of an unwanted event which may or may not occur. The expectation value of a possible negative event is the product of its probability and some measure of its severity.' In the philosophical literature, risk is broadly understood as a possible scenario in which adverse events take place. See Hansson (2007); Campbell and Curie (2006).

[5] Referring to such risks as those associated with natural events is preferable to natural hazards because, as it will be argued in this paper, the consequences associated with natural events are typically the results of complex interactions between the natural events and the built environment and not merely from the natural hazards per se.

assessed risks (Rowe 1980; Vose 2000; Bedford and Cooke 2001). Risk analysis forms the foundation for natural hazard mitigation policies.

The first objective of this paper is to demonstrate why the risks associated with natural events should be the subject of more sustained philosophical interest. One immediately obvious reason for focusing on such risks stems from the recognition of the importance of successful mitigation efforts for the achievement of the goals of development and global justice. Assessing and evaluating the risks posed by natural events is necessary for effective natural hazard mitigation. However, we argue that there is an additional reason why such risks should be the focus of philosophical attention: we cannot simply apply to risks associated with natural events insights and frameworks for moral evaluation developed by considering ordinary risks, technological risks and the risks posed by anthropogenic climate change—and it is these risks which are the risks considered in the literature.

We illustrate the distinctive questions the risks associated with natural events raise by considering a recent critique of traditional risk analysis offered in the context of technological risks by Jonathan Wolff (2006). Wolff has argued that the *cause* or *source* of a risk, that is, how 'a hazard comes into being, or is sustained, or perhaps, permitted,' should also be considered as an independent variable in risk evaluation. While Wolff's insight seems importantly relevant when considering technological risks, ordinary risks, and even risks due to anthropogenic climate change, it is not immediately clear how his insight would apply to risks posed by natural events. Natural events are not created by our actions in the same way as technology, nor do we permit or allow natural hazards in the way we may permit other kinds of risks. Furthermore, insofar as we play some role in sustaining natural hazards, it is not obvious how we play this role and so what would be the subject of moral evaluation for the source of the risks in such cases. As we discuss later, actions that affect natural events are not co-extensive with actions that contribute to anthropogenic climate change.

The second objective of this paper is to identify the source of the risk in the context of hazards associated with natural events and to develop a framework for the moral evaluation of this source. To identify the source, we discuss the way the construction and modification of the built and natural environments can alter the probability of occurrence of natural events and the character and magnitude of the impact that such events have. We then argue for the need to develop a standard of reasonable care for decisions about the built and modified natural environment, which accounts for technical and resource constraints, as well as the place of natural hazard mitigation in public policy. One interesting outcome of our discussion is that it demonstrates that the scope of moral concern and evaluation when thinking about risk, development, and global justice needs to be significantly broadened. In particular, the engineered built environment and implications of engineering for the natural environment should be a central concern.

The next section of this paper identifies the source of the risks due to natural events. The second section distinguishes this source from the source of three other kinds of risk and argues that differences in the mechanism of each source lead to differences in the moral questions that are relevant to ask about the source in each case. The third section develops a framework for evaluating the source of the risks due to natural events.

The Source of a Risk

In the context of technological risks, Wolff (2006) has recently argued that any evaluation of risks must take into consideration the source of a risk, or how risks are created and maintained. Using Wolff's example, consider three different scenarios in which an individual dies in a house fire; the three scenarios are identical except for the cause of the fire. In the first case, an electrical fault that led to the fire is caused by a 'freak accident' or a random mishap. In the second, the fault is caused by negligent workmanship. In the third, it is caused by deliberate arson. In these three cases, the cause of the house fire is different. When considering mitigation action for house fires, Wolff notes, all three risks would be judged equally urgent to mitigate if we only consider the consequences and probability of occurrence. However, Wolff argues that the public typically differentiates among how these kinds of risks are caused. Those risks stemming from malice, for example, are more threatening and more urgent to address than risks caused by accident. To capture these differences, we must include the source of a risk in our moral evaluation of risks. In this section, we define the source of risks associated with natural events. We then highlight key differences between the mechanism of this source and the mechanisms of the sources of three risks typically discussed in the literature: ordinary risks, technological risks, risks due to anthropogenic climate change.

Our interest in this paper is the source of risks associated with natural events. Tornadoes, hurricanes, droughts, and earthquakes are examples of natural events that pose risks to society. Such natural events pose risks because they may occur, but there is uncertainty surrounding their time, location and magnitude of occurrence, the nature and severity of their impact on society, and a given society's resilience (or ability to recover from such events). Consider earthquakes. The time of occurrence, the location of the epicenter, and the magnitude of a future earthquake are uncertain. In addition, given the occurrence of an earthquake of a certain magnitude at a certain time and location, the impact of that earthquake on society is uncertain because the impact depends on several uncertain factors, including the reliability of the built environment. The structural capacity of a given civil structure, or how much stress a given structure can withstand, is uncertain, as it depends on typically uncertain material properties, geometry, boundary conditions, and deterioration processes. Similarly, the seismic demand on a civil structure, or the stress that a given event will place upon a structure, is uncertain, even for a given earthquake. The seismic demand depends on the same uncertain quantities influencing the structure's capacity, as well as uncertain characteristics of the ground motion itself (e.g., its frequency content and duration), of the natural environment (e.g., whether the soil is vulnerable to earthquake induced liquefaction or the environment is vulnerable to a tsunami triggered by the earthquake), and of the modified natural environment (e.g., whether a tsunami being triggered is in an area with levees or without levees). Finally, there is uncertainty surrounding the impact that damage to structures and the infrastructure will have on a community. What the consequences of the loss of or damage to structures and the infrastructure are and how quickly society will be able to rebuild depend on a number of factors, including the socio-economic conditions of the region directly and indirectly affected by the earthquake, whether the affected region is part of a larger country that can help in the recovery process, and the availability and amount of international aid.

Risks from natural events are not a product of our creation; we cannot bring about a tornado in the way that we can cause a house fire through deliberate arson. Natural events are produced by, for example, unusual changes in atmospheric conditions or movements in tectonic plates. Thus, we are not, strictly speaking, the direct source of such risks. However, our actions do influence the character and extent of such risks and it is important to appreciate the complex mechanism through which risks associated with natural events are realized. By spelling out the ways in which we influence such risks we can understand how we can constitute an indirect source of such risks.

Both dimensions of risk, the probability of occurrence of natural events and the character and magnitude of the impact that such events have, are affected by the built environment and modifications to the natural environment. The built environment refers to the man-made structures and infrastructure systems that, linked to the natural environment, provide the physical and technological setting of human life and activities. Examples of such infrastructure systems include the transportation infrastructure (e.g., roads, bridges, airports, subways, railways, seaports), energy infrastructure (e.g., electric grids, natural gas pipelines), water and waste management infrastructures (e.g., sewage collection and disposal, drinking water systems, dams, irrigation systems, landfills), and communication infrastructure (e.g., telephone and mobile phone networks, internet servers) (Oxford English Dictionary 2010).

The natural environment refers to organic living and non-living things. The natural environment includes natural resources, such as water, air, and climate; naturally existing energy; systems, such as vegetation, animals, soil.[6] Modifications to the natural environment include those activities that alter or use natural resources and systems. Examples of modifications we make to the natural environment include land development by deforestation or the reclamation of wasteland or flooded land so that it can be cultivated, for example by diverting river streams, building dams, levees, or canals. Dams can also serve other purposes, such as providing electricity.[7] Anthropogenic climate change can lead to indirect modifications to the natural environment (or be a product of such changes).

[6] This understanding of the natural environment resonates with the emphasis on the vitality of matter in Bennett (2010).

[7] The built environment is man-made, but is often created by using natural raw materials. For example, a reinforced concrete structure is made using materials including aggregates (fine and coarse gravel), water, and iron, all of which are found in nature. However, the end product does not exist in the natural environment. Alteration of the natural environment refers to things that change the form or state of the natural environment, by transforming it into a new state that is also present in nature. For example, by cutting trees or deforestation you can create plains. By drying wetlands you can create plains. The end-state is still nature, but its characteristics have been altered by man.

Though we do not create or produce natural events, we can influence the probability of occurrence of some natural events directly and indirectly, and to varying degrees, in virtue of how we construct and modify the built environment and in virtue of how we modify the natural environment.[8] Similarly, choices in the construction and modification of the built environment and modification of the natural environment influence the likely severity of the consequences of natural hazards. Next we discuss how the constructed and modified built environment and the modified the natural environment can affect both the probability of occurrence of natural hazards and the extent of their consequences.

Consider earthquakes, a potentially economically devastating hazard which 75 million Americans in 39 states face (United States Geological Survey 2010). Though it is virtually impossible to affect their probability of occurrence, given current technological knowledge and capability, we can reduce the impact of earthquakes by not building in seismically active areas or improving the seismic design of structures (e.g., buildings and bridges) and construction practice in such areas. Similarly, the seismic performance of older structures may be improved by retrofitting them, a process through which they are brought up to current design standards. For example, cross-bracing, where diagonal steel beams are added to a structure, might improve its lateral resistance and ability to dissipate energy and in turn its ability to withstand earthquakes. Finally, we can reduce the impact of a hazard by improving a society's resilience and ability to respond to a disaster in a timely and well informed way. We can improve the resilience of a society by increasing the redundancy of structures and infrastructures. For example, having alternate routes for transportation by building a second bridge in an area of high commerce reduces the consequences of one bridge failing from a seismic event.

Landslides are natural events whose probability of occurrence and severity are affected by our actions. One kind of modification of the natural environment, namely, aggressive deforestation, directly increases the likelihood of landslides. The probability of occurrence is also affected by factors beyond our actions, including severe storms, earthquakes, and volcanic activity, all of which can increase slope instability. When deforestation is done for the sake of creating livable areas, which are then constructed, landslides become more potentially devastating in their impact.

Our actions also influence the probability of occurrence and severity of wildfires and drought. Anthropogenic climate change may indirectly increase the likelihood of droughts and wildfires (Gardiner 2004). Wildfire protection strategies allow small

[8] Natural events are thus not 'natural' in the sense that they are occurrences that are unaffected by our actions. Rather, they are 'natural' in the sense that they are the result of complex interactions and processes in the natural environment. This is not to suggest that the probability of occurrence is always under our control. For some natural hazards, such as naturally occurring earthquakes, we have little control over their probability of occurrence.

fires in some areas to remove flammable materials from regions where wildfires might potentially develop, which will reduce the severity of the primary and secondary effects of forest fires that do occur. Secondary effects, which consist of 'erosion, landslides, introduction of invasive species, and changes in water quality, are often more disastrous than the fire itself.'

Additional categories of natural event are flooding and hurricanes. Flooding causes $6 billion in damage to property in the United States each year (United States Geological Survey 2010). We influence both the probability of occurrence and severity of flooding. As Hurricane Katrina vividly demonstrated, flooding can be caused by failures in levees and dams. Inadequate drainage in urban areas can also lead to flooding. Indeed, urbanization and coastal development have contributed to the rise in economic losses associated with flooding. Living in coastal regions also increases the vulnerability of communities to hurricanes, which can lead to flooding, tornadoes, storm surge, and damaging winds. Hurricane Katrina stands as a stark reminder of the damage that hurricanes can inflict. Currently over 50% of the US population lives in coastal regions; many such regions are at risk for hurricanes.

Considerations Influencing the Moral Evaluation of the Source of Risks

There are important differences among the source of risks associated with natural events and the source of the risks considered in the literature, ordinary risks, technological risks and the risks posed by anthropogenic climate change. Ordinary risks are those stemming from routine daily or recreational activities, for example, mountain climbing (Hansson 2004; Sunstein 2002, 2005; Oberdiek 2009). Technological risks are produced by the creation and use of artifacts and their associated services (Franssen et al. 2009). Examples of technological risks include the risks posed by nuclear power, toxic wastes, smoking, driving, and concerns with occupational safety (Shrader-Frechette 1985, 2002, 2005, 2008; Wolff 2006). A third category of risks are those associated with complex systems, like the climate (Hansson 2007). Risks due to climate change in part stem from anthropogenic increases in greenhouse gas levels, including carbon dioxide (CO_2) and methane (CH_4). Burning fossil fuels in part through, for example, industrial and transportation activities, accounts for the majority of anthropogenic CO_2 sources, though changes in land use patterns are another important cause (Gardiner 2004). Causes of CH_4 emissions include 'fossil fuels, cattle, rice agriculture and landfills.' Once we understand the mechanism by which different kinds of risks are created, sustained, influenced, and mitigated, we can begin to morally evaluate the actions that brought this mechanism about. In this section, we distinguish the questions to ask about the source of risks associated with natural events, from those to ask about technological risks, ordinary risks, and risks from climate change.

In the case of ordinary risks and some technological risks, we are in a position to choose whether or not to assume certain risks. We can choose to engage in certain activities, like mountain climbing, and assume ordinary risks. Human actions lead to the creation of technology, and to the risks that stem from the objects and artifacts of our creation; such risks would not exist without our actions.[9] For example, we design and construct nuclear reactors or, as in Wolff's example, houses. Second, users of artifacts can create or cause risks through their actions. In the case of houses, for example, a poor electrical connection creates the risk of house fires.

Given that such risks are a function of our choices, one general question to consider is which risks we should allow. In other words, we can identify what individuals should be able to do or create, given that they themselves, as well as possibly others, may be harmed through their actions. This is in part a question of which risks we will allow in the basic structure of a community. We can specify which artifacts we will allow people to create, as well as which actions or activities we will permit individuals to engage in. We can also specify constraints on the ways that people will be permitted to use certain artifacts. In fact, philosophical discussions of ordinary and technological risks attempt to make such distinctions. Theorists distinguish, for example, between those actions or technologies that are too dangerous to be permissible and those which, though potentially harmful, are permissible, sometimes in light of their associated real or potential benefits. Discussions furthermore specify criteria for attributions of responsibility for any harms realized in risky activities or by technological creation and use, and how responsibility tracks being a source of a risk (McKerlie 1986).[10]

By contrast, though we exert influence on the character of risks associated with natural events, we do not create or, in most cases, choose to assume such risks. As noted earlier, we cannot, for example, create hurricanes. Hurricanes are a kind of natural event that exists independent of our actions; unlike artifacts, they are not a function of our making. Furthermore, we are not one of the sole avenues through which a particular natural event is brought about, in the way that, through deliberate arson, we can cause a house fire. Finally, though we have some control over our exposure to natural events, in most cases it is not appropriate to talk about individuals choosing to assume risks associated with natural events. While it may be a theoretical possibility to move the communities that are vulnerable to natural hazards, that is not a practical possibility, both because there are few areas of the world not vulnerable to a natural hazard of some kind and because it is not a

[9] Technological risks have a certain similarity with the view Joseph Raz takes with respect to law. Law is an institution that makes certain kinds of abuses possible, and the rule of law is a negative virtue which prevents these abuses from being realized. Without the law, in Raz's view, individuals and communities do not confront a risk of the occurrence of certain kinds of harm.

[10] Issues of responsibility are more complicated in the context of technological hazards, in part because the link between technology and certain harms can be more difficult to establish and responsibility for harmful consequences can be more diffuse. For example, there may be evidence that the chemical a particular factory is emitting has harmful health consequences for the local population, but the evidence may not amount to or pass the standards for scientific proof. This has led to discussions about the standard that should be met for legal liability for harm to obtain, and in particular whether legal action should be permitted when there are science-based reasons to be concerned about the negative impact of a substance on human health without the harmful effect meeting the rigorous standards for scientific proof [or who should be responsible for cleaning up a mess that occurs]. See Haack (2009), Cranor and Nutting (1990), Cranor (1990), Hansson (2004), Lemons et al. (1997) and von Magnus (1984).

reasonable option for many people to move to a different region or even country to avoid certain risks.[11]

Because risks associated with natural events are not risks that we create, the question of which risks communities should permit does not arise in the same way. Instead, the choices communities face with regard to risks associated with natural events concerns questions about the design, construction, and modification of the built and the modification of the natural environment, including mitigation actions that should be taken to reduce the impact of future natural events. This is a question about the management, not strictly speaking about the acceptance, of risks. Given the threat posed by natural events, risk management involves communities asking what level of potential disruption they will allow, not whether they will allow their community to face risks associated with natural events.

Risks from anthropogenic climate change are similar to the risks from natural hazards in that risks from climate change are influenced by our actions. Thus, the source of risks in both cases is indirect, linked to our actions which in turn have implications for the climate system or for natural events. Like ordinary risks and technological risks, risks due to anthropogenic climate change raise questions of responsibility. However the central question in this context is who bears responsibility for mitigation action; in this respect risks associated by natural events and risks due to anthropogenic climate change are similar.

Despite these similarities, the character of the link between responsibility and mitigation is importantly different for risks due to anthropogenic climate change and risks associated with natural hazards. Philosophical discussions of responsibility for risk mitigation in the context of climate change concentrate on justifying and defining the demands of intergenerational justice, that is, the requirements of people now alive to prevent harm to future generations (Caney 2009; Moellendorf 2009). A second question considered is what constitutes fairness of the distribution of greenhouse gas emissions, and whether and how much our answer to this question should take into consideration historical contributions to greenhouse gas levels and who is most at risk by climate change (Harris 2003). This second question arises in part because of the gap between those who influence the character of risks posed by climate change and those who are most vulnerable to such risks.

For risks associated with natural events, the question of responsibility for mitigation is not primarily or fundamentally a question of intergenerational justice. Mitigation action, or the failure to take mitigation action, characteristically affects current as well as future generations. Mitigation action taken for risks associated with natural events has implications for future generations, and so questions of intergenerational justice have implications for our understanding of where responsibility for mitigation action lies. However, the question of responsibility for mitigation action is not settled by understanding the demands of intergenerational justice. Furthermore, the issue of distribution of responsibility for mitigation action has a different character in the context of risks associated with natural hazards. There

[11] For some technological risks, it may be similarly claimed that it is not feasible for individuals to choose to avoid exposure to certain risks, like those stemming from driving, given that driving is so deeply embedded in the structure of life of many communities. This may diminish the extent to which we speak of individuals choosing to assume certain risks in these cases.

is less distance between those who influence the character of risks posed by natural events and those who are vulnerable to such risks. Construction in the United States does not change or negatively impact the risks associated with natural events in Haiti (setting aside indirect implications of such construction for greenhouse gas emissions) the way that construction in Haiti does.

Finally, it is important to recognize that the scope of the actions which affect the risks due to anthropogenic climate change and the risks associated with natural events are different. The actions which influence the risks associated with natural events are broader than the actions that influence greenhouse gas emissions. For example, reinforcing existing structures can directly reduce the likely severity of the consequences of a future earthquake, but have little influence on greenhouse gas emissions. In addition, not all of the consequences of anthropogenic climate change will be of interest when considering risks associated with natural events. In the case of risks associated with natural events, our interest is not fundamentally with the impact of our actions on greenhouse gas emissions and subsequent climate change. Rather, our interest is in the impact of our actions on the probability and severity of natural events. Thus, changes in greenhouse gas emissions will be of interest insofar as their impact on climate change affects the probability of occurrence or severity of impact of natural events.[12] That is only insofar as greenhouse gas emissions contribute to climate change in ways that lead to increases in the probability of occurrence or severity of the impact of natural events will anthropogenic sources of greenhouse gas emissions will be relevant for evaluating the risks due to natural events.

The Moral Evaluation of the Source of Risks Associated with Natural Events

Our actions influence the character of the risks stemming from natural events. It is the interaction between (i) the natural and the built environments and (ii) a natural event which is the source of a risk in the context of natural hazards. In this section we develop a framework for the moral evaluation of the source of the risks associated with events. Our evaluation concentrates on the decisions made with respect to how to construct and modify the built environment, as well as how to modify the natural environment, insofar as these decisions influence the risks associated with natural events. Our discussion takes as its starting point concepts and standards from tort law. We argue that tort law has theoretical resources that can inform the evaluation of the decisions in which we are interested.

The central issue in tort law is determining who should bear the costs of misfortune or disaster, the direct victim(s), the community, or those responsible for the misfortune or disaster itself (Coleman 2003). A necessary condition for an individual to be held liable for misfortune or disaster, and so be responsible for the costs, is that he or she commits a wrong. Wrongdoing in this context is understood to mean breaching a standard of conduct to which he or she should and could

[12] For a discussion of potential impacts, see van Aalst (2006) at p. 9.

instead adhere.[13] As Arthur Ripstein writes, the core idea of tort law is that '[p]rovided people treat others as they should, any losses that result are simply the problem of those they befall […] [b]ut if one person wrongs another, the latter's loss becomes the former's to deal with' (Ripstein 2002).

Wrongdoing is defined as the failure to fulfill the standard of conduct we can legitimately expect from others, including the kinds of risks individuals have a right to impose on others or have the obligation to mitigate. This standard in tort law is called a standard of reasonable care. This standard articulates how a reasonable person would act, when appropriately constraining his/her actions in light of the legitimate interests of others. As Coleman (2003) writes, 'What I can demand of you is that you take my interests into account and moderate your behavior accordingly. You need to take reasonable precautions not to harm me; you need to avoid being reckless with respect to my interests. And I am obligated to treat you similarly.'

The content of the standard of reasonable care categorizes actions in different ways. Some actions are absolutely prohibited and others are permissible so long as done with reasonable precaution. Absolutely prohibited actions are sufficiently harmful that individuals have a duty not to engage in them (Coleman 2003). An individual is liable for harm caused by him or her engaging in a prohibited activity. For permissible actions, an individual can be liable for harm insofar as she acted recklessly or negligently, failing to exercise due precaution or care. Precaution is defined in part by forseeability; that is, to claim that someone must refrain from certain actions depends on what consequences we can anticipate following from our action.

Tort law provides useful theoretical resources for thinking about how to morally evaluate decisions regarding the built and modified natural environments that have implications for the risks associated with natural events. The standard of care focuses our attention on what it is reasonable to expect from those involved in constructing and modifying the built and natural environments, including engineers, architects, policy makers, and construction companies. The standard of care for each group will be different because the kinds of decisions they make with respect to the built and natural environments are different. For example, policy makers define the boundaries of the built environment and boundaries of permissible modifications to the natural environment. They specify whether construction can occur in a particular region as well as what kinds of buildings and facilities can be located in that region. Engineering professional organizations specify minimum guidelines for design and construction through their professional codes.[14] Engineers and architects make choices about the specific design of structures and infrastructure. Construction companies make choices about materials for construction within the boundaries set by law and the code. In what follows, we outline the general kinds of considerations that should inform an evaluation of each kind of decision.

The first thing to recognize is that the standard of reasonable care for decisions about the built and modified natural environment will be constrained by current

[13] Within tort law, for a plaintiff to recover damages, the standard of conduct that has been breached must be a standard of conduct toward the plaintiff.

[14] For an overview of standards for engineering see Strand and Golden (1997).

knowledge about possibilities for the design, construction, and modification of the built and natural environments. This knowledge sets boundaries for the range of possibilities in our action. In the case of the built environment, reasonable options regarding construction may include building or not building in a particular area, or constructing a building using specific materials (e.g., steel, concrete, or wood). In the case of the modification of the built environment, choices may be whether to retrofit an existing building or not, and if so how. Choices with the natural environment involve, for example, land development by deforestation or the reclamation of wasteland or flooded land so that it can be cultivated, for example by diverting river streams, building dams, levees, or canals.

Whether a given choice should be viewed as satisfying the standard of care will depend on three factors. First, the influence of such decisions on the probability of occurrence and the associated consequences of natural hazards must be considered. For some natural hazards, choices may not impact the probability of occurrence. Based on our current state of knowledge and level of technologies, for example, it is not possible to reduce the frequency or magnitude of earthquakes. For other hazards, choices may influence the probability of occurrence. For example, in the case of landslides, public policy that controls deforestation and includes appropriate zoning ordinances may be able to reduce the probability that landslides will occur. More frequently, choices will influence the likely consequences of a natural hazard. For example, revising building codes, retrofitting existing structures, changing zoning laws, or restricting land use may diminish the likely consequences of an earthquake. There will always be some degree of uncertainty surrounding such analyses, because we may be uncertain about what the precise connection between the construction of the built environment and potential harms that could result from a natural event. Specification of any standard for reasonable care requires determining how foreseeable is the increase in the probability of occurrence or severity of the impact of natural hazards in any given case. Technical knowledge can inform the criteria of forseeability. Importantly, given that the state of engineering knowledge is expanding with new research findings, the boundaries of possibility may increase and uncertainty may be reduced over time as knowledge increases.

The second factor that should inform the reasonable standard of care is available resources; economic constraints delimit practical boundaries for possibilities. Engineers design and construct buildings and systems under resource constraints. Resource constraints set some boundaries around which technical options are financially feasible in any particular context. Thus, choices that have a greater increase in the probability of occurrence or consequences than alternatives may satisfy a standard of care if such choices are the only financially feasible alternative.

Furthermore, the standard of care must take into account competing priorities of individuals and communities. Not all financially feasible alternatives that most reduce vulnerability to hazards should automatically be pursued. Reduced vulnerability to hazards is not the only thing that matters to either individuals or communities. Individuals often have a number of valuable goals they want to pursue, all of which may depend on financial resources to be feasible. Individuals want to be adequately nourished, educated, able to enjoy leisure activities, all of which typically require financial resources. It can be reasonable for individuals to trade off certain gains in safety, by for example buying more affordable homes in order to increase the resources available to pursue other goals and objectives that matter. At the policy level, hazard mitigation is not the only priority that matters. Hazard mitigation is one of a number of important objectives of governments and communities to pursue. Other important objectives include, for example, education and health.[15]

Given these competing alternatives, the standard of care may be sufficiently broad to accommodate and indeed reflect reasonable disagreement about how to weigh and compare competing values. Some individuals may be more risk-averse than others. Likewise, some communities may place a higher priority on natural hazard mitigation than on, for example, national defense. The specification of what should reasonably be expected should be general enough to allow for some choice in the means used to achieve a particular goal. The standard for reasonableness can be updated in light of increases or decreases in general resources, which would suggest fewer or additional resources to be put towards natural hazard mitigation.

However, there will be constraints on the kind of variation that is reasonable. For example, implicit in any formulation and justification of standards will be the assumption of background conditions of distributive justice. Any analysis of the standard of reasonable care for the construction of the built environment and modification of the natural environment must account for the more serious resource constraints that many developing countries, for instance, face. At the same time, extreme and unreasonable resource scarcity among groups within a community or among poorer communities nationally, if not taken into account, may result in standards for reasonable care reflecting the constraints of poverty, rather than reasoned judgments about the relative value of natural hazard mitigation as opposed to other competing goods. Thus, it is necessary to identify a threshold kind and level of resources that are needed within communities and at the global level for any justifiable standard of reasonable care.

When the construction of the built and modified natural environment cannot be justified on the basis of the standard of reasonable care, we can examine where the source(s) of the fault lies. In some contexts, fault may lie with the global community, insofar as the global distribution of resources is such that it is impossible for a community to fulfill any minimal reasonable standard of care. In other cases, it may be government officials and policy makers who are responsible for the failure to meet a reasonable standard of care, insofar as governments fail to allocate the minimally justifiable resources to natural hazard mitigation or fail to support and supplement the efforts of professional organizations to come up with professional standards. Alternatively, individual contractors may be responsible for the failure to fulfill reasonable standards of construction that were both possible to fulfill and required by

[15] There is a complicated interrelationship between the impact of our actions on the risks associated with natural events and our other goals. Increased exposure to risks from natural events might contribute to our ability to achieve other important goals; one alternative although riskier might be deemed preferable in light of its associated benefits. For example, reclamation of wasteland or flooded land by diverting river streams, building dams, levees, or canals might lead to an increase risk of landslides but also enable us to cultivate the land.

law. Multiple levels of failure may be present in certain cases.[16] As these examples illustrate, the evaluation of the character of the built and modified natural environments will be complex. Diverse actors, including policy makers and members of the business community, as well as the general public, influence the character of the built and natural environments. The multiple actors involved in creating the built and modifying the natural environments compound the challenge of both assigning responsibility for its construction and ascribing intentions to actors judged responsible. However, the complexity of the evaluative process offers no principled reason to refrain from attempting to come up with appropriate categories and engaging in particular moral assessments.

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[16] We have argued that central concepts in tort law provide important resources for developing a framework for evaluating the built and modified natural environments. However, there are two important ways in which our use of such concepts departs from the use in tort law. First, our focus is on the ways in which the built and modified natural environments affect the risks posed by natural hazards, where no natural disaster or actual harm has yet occurred. In the tort law, someone must be harmed for tortuous liability to be obtained. Second, our use of the standard of care in relation to the built and modified natural environments has implications for who is responsible for mitigation action when needed. By contrast, in tort law the standard of care is used to determine whether an individual should be held liable and has a duty of repair and is responsible for the full costs of the harms that resulted from his or her wrong (Ripstein 2002).

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