Communication of urban heat island risks

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Foreword

This writing assignment is my last assignment before finishing my master Toxicology and Environmental Health at the Utrecht University, moreover it is also the end of my study period. During this period I have learned a lot. I want to thank Gerard Hoek, Denise Motagne and Kees Meliefste (supervisors/colleagues of my first internship), Ronald Groen and Ingrid Rijk (supervisors of my second internship), Fred Woudenberg (supervisor of this writing assignment) and especially Bert Brunekreef (supervisor of my first and second internship and of this writing assignment).

During my search for a topic for this writing assignment, I noticed that I wanted to study something useful for my future career. Soon, I mentioned that risk perception in general and especially risk communication of urban heat islands (UHIs) is a very interesting and difficult subject. Due to the complexity of risk communication and the few definitive empirical results, the field is often characterized as an 'art' instead of science (Bier, 2001).

During this assignment I became aware of the fact that we all have different thoughts and feelings about risks. What I think as worrisome, someone else perhaps does not bother. The fact that I wrote this thesis about risk communication of UHIs partly indicates my perception of this risk. My personal thoughts and feelings definitely had a certain affect on the way I wrote this assignment. However, I tried to make an objective review of the literature of risk perception/communication of UHIs.

Looking back, I can say that this assignment was a very interesting and fun learning process and definitely useful for my future career.

Content

Laymen's summary

Urban areas are usually warmer than their surrounding areas; this phenomenon is called the urban heat island (UHI) effect. This effect causes a higher exposure to heat and increases the risk of heat-related adverse health effects. To show the urgency for adaptive measures to reduce the UHI, risk communication can help. However, communication of health risks is a difficult task.

Scientists mostly determine risks based on expected annual mortality (probability of occurrence and effect). However, the perception of risk is not solely based on statistical analysis; other factors are also important. Sandman called these other factors, collectively, 'outrage'; the expected annual mortality was called 'hazard'. He introduced in 1987 a new definition of a risk:

Risk = hazard + outrage

There are several outrage factors (benefit, voluntariness, dread, control, origin, etc.) that contribute to our perception of a risk. These factors are no misperceptions of risk; they are intrinsic elements of our meaning of risk and explain why we worry more about a risks than another risk.

The UHI risk is a risk for a population. Managing risks for populations differs from managing risks for individuals. Risk managers judge risky activities not only based on health risks but to a large concept of health, social, financial and economical risks and benefits. These elements determine to a certain degree the tolerability of risk. The willingness-to-pay to reduce a risk is dependent on the tolerability of that risk.

To communicate UHI risks, it is necessary to (1) give an objective overview of the risk. Additional, one should try to (2) define how society perceives the risk. To influence this perception, one can make the outrage factors of UHI more outrageous. This will affect the tolerability of a risk which can in turn enhance the willingness-to-pay to reduce the risk. Eventually, (3) the risk communicator should analyse him/herself to understand how he/she is perceived by the audience.

1. Introduction

Several studies showed the impact of heat on mortality (Armstrong et al., 2010; Garssen et al., 2005; Huynen et al., 2001; Kovats & Jendritzky, 2005; Kovats & Hajat, 2008). Urban heat islands (UHIs) cause exposure to higher temperatures that increase the risk of heat-related adverse health effects during heat waves. Climate predictions indicate more frequent, more intense and longer lasting heat waves in the next decades (Meehl & Tebaldi, 2004), moreover, due to the urbanisation more people will become at risk in future heat waves. So, the impact of UHIs on human health is a matter of increasing concern.

UHIs can be reduced by adaptive measures. However, the sense of urgency among stakeholders in spatial planning is rather low. This is partly due to the complex process of urban heat island (UHI) risks and the challenging comparison between costs (of adaptive measures) and benefits (reducing risks).

Risk communication can help to explain UHI risks. However, communication of health risks is a very difficult task because there is no universal definition of a risk (Hampel, 2006). Due to the 'undefined' concept of risk, there is a permanent and fundamental difference between risk information presented by risk experts and the way society thinks about the presented risks (Leiss, 2004). Good risk communication should address the differences between scientific experts and society and facilitate an understanding of the risk (Leiss, 2004).

In this writing assignment 'communication of urban heat island risks' is studied. The main question of the assignment is:

How to communicate urban heat island risks?

To communicate this risk, it is necessary to gain insight into perceptions of risks. Furthermore, it is important to explain how we deal with risks and what the fundamentals of risk communication are.

The main question is divided in the below sub questions:

1. What is a risk?
2. How to deal with risks for societies?
3. How to communicate risks?

Additionally, a case 'how to communicate UHI risks?' was elaborated.

In chapter 2 understandings of the definition of risk and risk perceptions are described. The next chapter explains how risk managers deal with risks for whole societies. The fundamentals of risk communication in general and strategies to influence risk perception are given in section four. The case of communicating UHI risks can be found in chapter 5; in the last chapter results are discussed.

2. What is a risk?

To almost all activities a certain risk can be related. Therefore, there are large differences in risk perceptions. To show this, an explanation of the five different risk perception models distinguished by Renn (2004) is given:

- Risk as a fatal threat
- Risk as fate
- Risk as a test of strength
- Risk as a game of chance
- Risk as an early warning indicator

The perception of a ‘risk as a fatal threat’ is mostly seen by technological risks. These risks are consequences of man-made decisions and actions. Natural burdens are perceived as ‘fate’, these risk are often seen as ‘quirks of nature’ (Renn, 2004).

During some activities people take risks to test their own strength and to experience triumph over natural forces, for example when climbing high mountains. ‘The pursuit of such leisure activities is not about accepting risk as a ticket to the pleasurable benefits; instead, the benefit lies in the risk itself: the attraction of such activities is the fact that they involve risk’ (Machlis and Rosa, 1990). Games of chance involve loss or profit that is normally independent of the player’s ability. This perception model differs from ‘risk as a test of strength’ because the possibility of a big win induces the ‘thrill’ and not the process of playing/doing the activity (Renn, 2004).

The last perception model is in recent times more adopted. Environmental pollution and its impact on health indicate the lurking dangers and relationships between long-term exposure and effects. The probability of such an event cannot be explained by chance from the natural event, but rather as the degree of certainty between the relation of a cause and the effect (Renn, 2004).

2.1 Definitions of risk

A list of environmental risks in order of how many people they kill each year will largely differ from how alarming society thinks these risks are (Sandman, 1987). Hence, Sandman stated that ‘the risk that kills you is not necessarily the risk that anger and frightens you’. So, probably perceptions of risks are not only based on statistical facts, other factors play a role too.

In former times risk was defined as:

*Risk = probability * effect*

This is still a useful concept and mostly used in science. However, Sandman introduced in 1987 a new definition or risk:

Risk = hazard + outrage

He came to this formula because he noticed that experts only focus on the expected annual mortality, also called ‘hazard’. Society on the other hand paid little attention to hazard but more to other factors of risks, Sandman called these factors, collectively, ‘outrage’ (Sandman, 1987).

This definition of Sandman is in accordance with the theory of Slovic et al. (2004). According to Slovic et al. (2004) human beings can comprehend risks in two fundamental ways; risk as analysis and risk as a feeling. Risk as analysis is based on algorithms and rules; it is effortful and requires conscious control. The hazard in the formulae of Sandman corresponds to this risk. Risk as a feeling is intuitive, mostly automatic and not accessible to conscious awareness. It relies on associations and experiences to emotions and affect. People map affective information and hence create their own 'affect pool' with representations of positive and negative tags, with different degrees of value (Slovic et al., 2004). During decision-making processes individuals consult the 'affect pool' (Slovic et al., 2004). Outrage in the formulae of Sandman is comparable to risk as a feeling.

2.2 Outrage factors

The outrage factors in Sandman's formulae are main determinants of risk perception. These factors are no misconceptions in the perception of risks of people. According to Sandman (1987) they are intrinsic elements of our meaning of risk and explain why we worry more about one risk than the other. There are a lot of outrage factors identified; some important ones are list here:

- Benefits

From an analytical point of view risks and benefits differ; the nature of gains resulting from an activity varies from the nature of risk (Finucane et al., 2000). Risk-taking actions with low benefits will be low in risk and events associated with great benefits may be low or high in risk (Finucane et al., 2000). It is unlikely that one will perform an activity with higher risks than benefits. Thus, it can be stated that from an analytical point of view gain and risk are positively correlated in the environment as shown in figure 1.

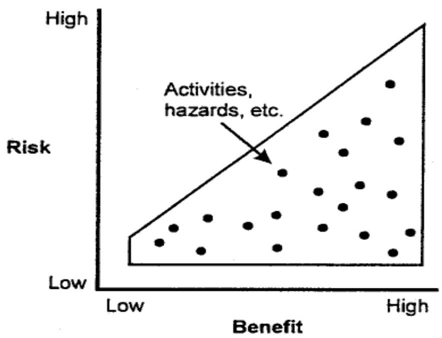


Figure 1. The positive correlation between risks and benefits from activities from an analytical point of view (Finucane et al. 2000)

However, the 'affect pool' in people's mind differs from the analytical point of view. One's affective feeling determines the perceived risks and benefits and plays an important role (Slovic, 2007). Risks of 'liked' activities will be judged as low and benefits as high and for 'disliked' activities the opposite is seen (Finucane et al. 2000).

In 1978 Fischoff et al. showed that the perceived risk was slightly decreasing when the perceived benefit was increasing. So, when the perceived benefit of an activity is 'high', the risk will be judged lower than when the benefit of the same activity is perceived as 'medium' or 'low'.

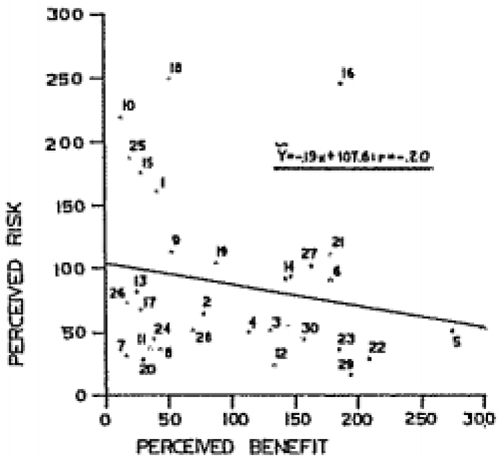


Figure 2. The relation between perceived risk and perceived benefit (Fischoff et al., 1978)

- Voluntary acceptance of the risk

Voluntariness of risk-taking activities can have strong correlations with perceived benefits of that activities. A risk voluntary taken is probably a risk with a certain degree of perceived benefit. However, the acceptability of a risk with a certain level of benefit is dependent on the voluntariness of the activity.

Starr (1969) studied the potential usefulness of revealed preferences by examining the relationship between the risk and benefit across a couple of common activities. Risk was measured by the statistical expectation of fatalities per hour of exposure to the activity. The benefit was assumed to be equal to the average amount of money spent on an activity by an individual participant, or to the average contribution that the activity makes to a participant's annual income (Starr, 1969). According to this analysis the public seems willing to accept risks from voluntary activities roughly 1000 times greater than it would tolerate from involuntary activities that provide the same level of benefit (see figure 3) (Starr, 1969). Moreover, he showed that the level of risk tolerated of voluntary activities is quite similar to the level of risk from disease.

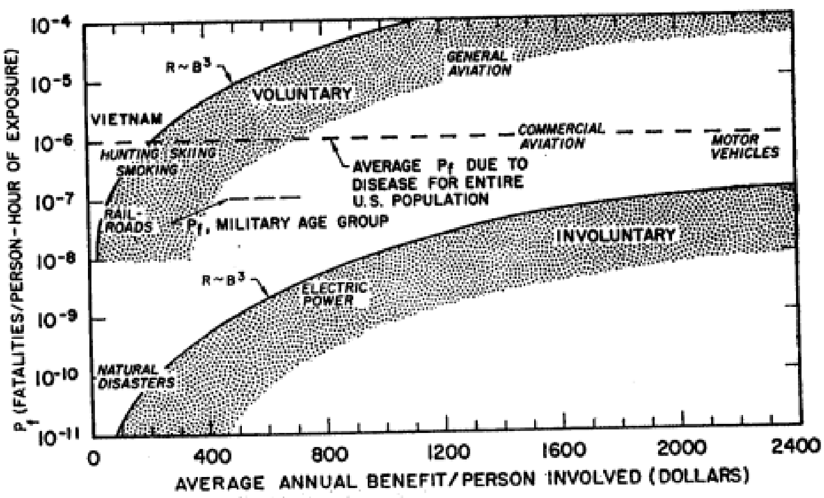


Figure 3. Risk plotted against relative benefit for various kinds of voluntary and involuntary activities (Starr, 1969).

- Origin

Perceived risks of natural hazards are lower compared to risks from technological (man-made) one's. This is due to random nature of events that poses a feeling of threat. Humans do feel more comfortable with predicted, foreseen risks (Renn, 2004). The unpredictability (random nature) of technological risks causes a higher degree of risk perceived by humans (Lofstedt, 2006). The probability of technological risk does hardly play a role in the perception of threat.

Although some natural disasters (e.g. earthquakes, volcano eruptions) are also unpredictable, their risk is perceived as fate instead of fatal. Possibilities for controlling and lessening the impact of natural disasters have not yet anchored in people's awareness to allow the risk caused by natural disasters to be assessed in the same way as other risks (Renn, 2004). People can flee from natural disaster risky areas or deny its existence. The rarer the natural disaster, the more people would deny the risk. The fear-triggering factor for natural disasters is not the random nature of the event, but the relative rarity (Renn, 2004). This perception causes a lower degree of perceived risk compared to technological risks (Renn and Klinke, 2004).

- Familiarity/knowledge

The risk of familiar events/activities is perceived lower compared risks of unfamiliar events (Leiss, 2004). When one knows the risk he/she is exposed, one accepts higher levels of that risk compared to a situation one does not know the magnitude of the risk, as shown in figure 4 (Fischoff et al., 1978).

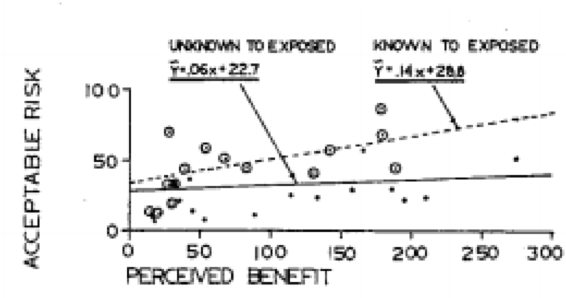


Figure 4. The relation between acceptable risk and perceived benefit of known (circled) and unknown exposed risk (Fischoff et al., 1978)

- Diffusion in time and space

A hazard that kills 50 anonymous people a year in the next ten years across an area is more readily accepted than a hazard that has a chance to occur once in ten years and kills 500 people in one week in one neighbourhood (Sandman, 1987). Although our 'hazard' assessment tells us that the harm of both hazards is equal, our 'outrage' assessment says that the hazard that occurs once in ten years is less acceptable (Sandman, 1987).

- Reversibility/fatality

Risks causing a reversible effect are more accepted and perceived as lower than risks causing an irreversible, fatal effect (Covello et al., 2001).

- Dread

Risks that evoke fear, like terrorism are less readily accepted than risk that do not generate that feeling (Covello et al., 2001).

- Control the degree of risk

When someone has the ability to control the degree of risk someone is exposed to, one accepts higher levels of risk (Sandman, 1987).

- Victim identity

Risk that cause identifiable victims are less readily accepted and are perceived as greater compared to risks that produce only statistical victims (Covello et al., 2001).

2.3 Misperceptions of risks

Probabilities of own risks are often misperceived. People do not judge risk the same to themselves, family members and in general (see figure 5). Most often people claim they are less subjected to risks than others. This phenomenon is called optimistic bias and is a very important feature in risk perception (Sjoberg, 2000).

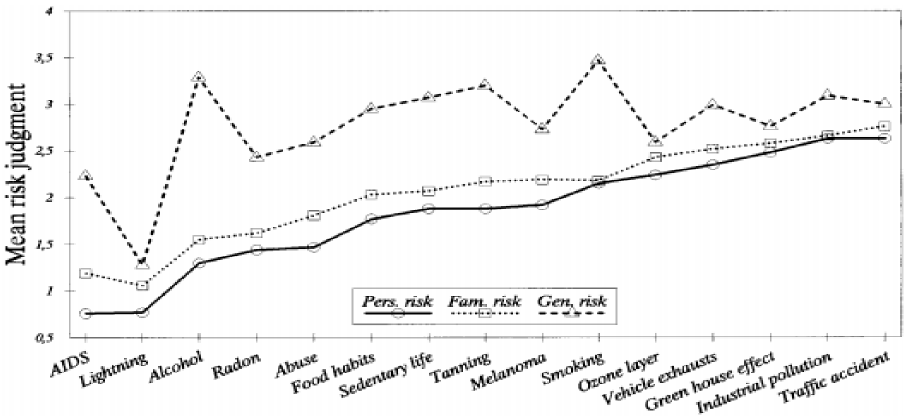


Figure 5. Average risk rating: personal, family and general risk (Sjoberg, 2000)

A lack of confidence in risk assessment makes judgement of risks controversial (Leiss, 2004). The risks of rare events are mostly overrated, while the hazard of more common events is underrated (Slovic et al., 2004). Besides, understanding cumulative risk is difficult (Glik, 2007).

3. How to manage risks for societies?

Risk managers have to deal with risks for populations. They do not focus on the causes and consequences for an individual. One can assume that every avoidable risk should be avoided and is unacceptable. However, risk managers consider risks as systemic risks. The range of the classical components of risk assessment (probability and effect) is in this term expanded by a larger concept of social, financial and economic risks and benefits (Renn and Klinke, 2004). It combines developments of various fields with policy-driven actions.

Important expanding components of the systemic risk concept according to Renn and Klinke (2004) are:

- Ubiquity: the geographical dispersion of potential damage
- Delay effects: the time between the triggering cause and the occurrence of the hazard
- Violation of equity: discrepancy between those who benefit and those who bear the risk
- The spill-over effects to other fields

Due to these elements it can be hard to make effective risk management strategies.

To explain the balance of dealing with systemic risks, the 'tolerability of risk' approach is important. This approach divided risks in three different areas: broadly acceptable, tolerable and unacceptable (Ball, 2002). Unacceptable risks are located in the upper part of the triangle in figure 6; acceptable risks can be found below the lower boundary. In the intermediate zone, risks should be reduced until 'as low as reasonable practicable' (ALARP) (Ball, 2002). If (social, financial and economical) costs are higher/disproportionate to the improved gain (risk reduction), risk managers will 'tolerate' risks in this region.

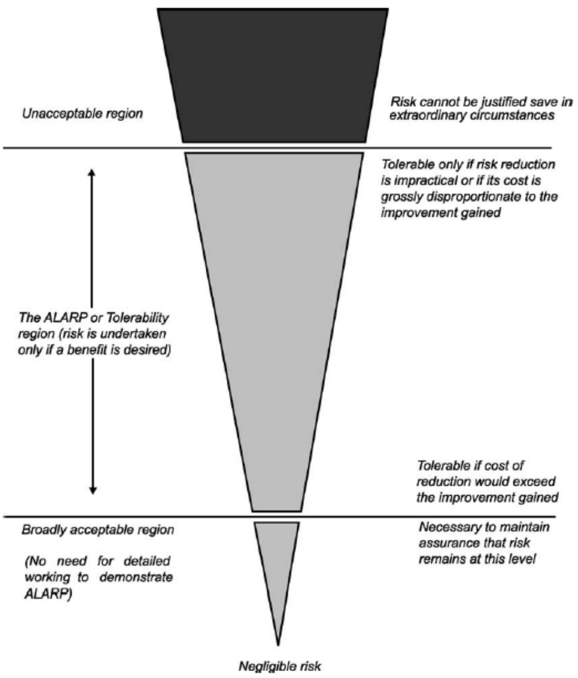


Figure 6. Fundamentals of the 'Tolerability of risk' approach (Ball, 2002)

The location (unacceptable/intermediate/acceptable) of a risk in figure 6 is dependent on risk perception. One can think as a risk as unacceptable while others do not bother about that risk. The degree of acceptance of a risk is hard to determine for societies. Outrage factors influence the perception of risks and probably the willingness-to-pay. When the acceptability of a risk decreases, for example due to a better understanding of the risk, the willingness-to-pay is likely to enhance. However, it is hard to compare benefits of reducing health risks with cost of actions (social, financial and economical).

4. How to communicate risks?

Communication of health risks is not only a process of transferring information between two or more parties. It is a contingent process, highly dependent on the context in which it takes place. Common signals and understandings of the transferred information are important elements in successful communication (Hampel, 2006). This can however not always be granted because of the divide between analytical facts and feelings about a risk.

4.1 Goal and motive of risk communication

Basically, two purposes of risk communication can be distinguished:

- Informing
- Motivating to take action/change behaviour

The exact goal of risk communicating is dependent on the purpose. According to Leiss (2004) the goal of risk communication is to address the fundamental and permanent divide between the way expert's present risks and the way society thinks about risks (Leiss, 2004). This divide will not disappear, but can be reduced when using the right communication. However, Sandman (1987) stated that since society is more focussed to outrage than to hazard, risk communicators should make serious hazards more outrageous and modest hazards less outrageous. Make outrage factors more outrageous will change risk perceptions and thus indirectly affect one's behaviour.

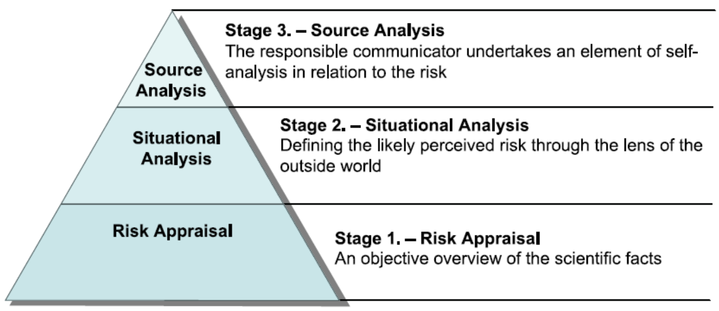
4.2 Fundamentals for effective risk communication

There are several theories and fundamentals for effective risk communication. The OECD (2002), Leiss (2004) and Smillie & Blissett (2010) indicate two steps that are more or less similar:

1. Give an objective overview of the risk (e.g. probability and extent of damage)
2. Understand the perception of risk of the audience.

These steps refer to respectively the hazard and the outrage in the definition of Sandman as described in chapter 2. Smillie & Blissett (2010) pointed out that in the last stage the communicator must analyse him-/herself. In this way the communicator can understand how he/she is perceived by the audience.

Figure 7. The proposed model for risk communication strategy. (Smillie & Blissett, 2010).



4.3 Communicating strategies to influence perception

To influence one's perception of risk there are different methods. Below some important strategies are described.

- To guide someone's perception of risks and benefits of an activity/event the 'affect heuristic' can help. Finucane et al. (2000) showed that the information provided about nuclear power influenced the risk and benefits judgements of persons (figure 8). Communicating the benefits of a certain risky action could in-/decrease the perception of the risk of the action.

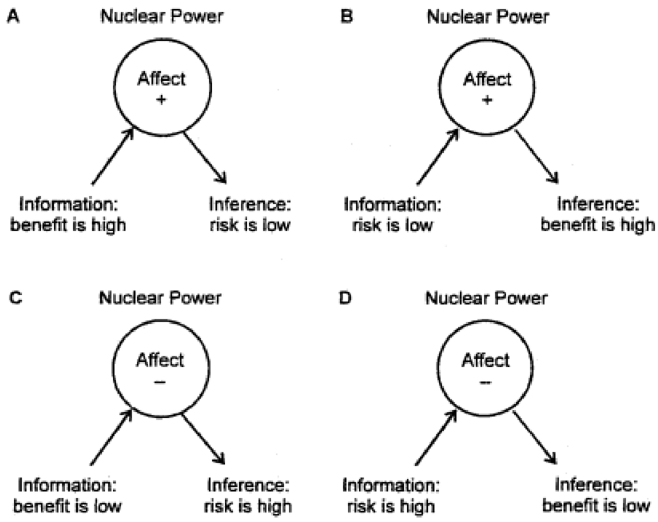


Figure 8. Model showing how information about risk or information about benefit could in- or decrease the affective evaluation of nuclear power and lead to inferences about risk and benefit that coincides affectively with the information given (Finucane et al. 2000).

Denes-Raj & Epstein (1994) also indicated the influence of beneficial effects. They showed that persons preferred to draw a red jelly bean to win $1 from a bowl with a greater absolute number of normal beans but a smaller proportion of red jelly beans (e.g., 7 in 100) compared to a bowl with higher probabilities of winning (e.g. 1 in 10). This is probably due to the fact that they neglect the denominator (total number) and only focus on the 'beneficial' numerator (number of red jelly bean). Images of benefits thus induce positive affects that motivates choices.

- Framing problems can influence perceptions and responses to risks. The intention of framing is to make gains seems like losses and vice versa (Kühberger et al., 1999). The framing manipulation intends people to adopt another reference point, below an example is given.

  In program A and B people adopt a '600 deaths' as a reference point. There is a sure (program A) and risky (program B) option who are both positively framed (saving lives). When choosing between program C and D the reference point is '0 deaths'. The sure (C) and risky (D) problem in this case are both negatively framed (number of deaths). Kühberger et al. (1999) showed that positively framed problems induce risk-aversive choices, negatively framed problems tends to induce risk-seeking choices. In a gain-presented problem, about

60% of participants choose the sure gain option (risk aversive), while in loss-presented problem, 60% choose the risky loss (risk seeking) (Kühberger et al., 1999). Irrespective to the influence of probability and impact, the belief of dealing with gains or losses is of major importance for choices in risky contexts.

Imagine that the United States is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimates of the consequences of the programs are as follows:

If Program A is adopted, 200 people will be saved.

If Program B is adopted, there is a 1/3 probability that 600 people will be saved and a 2/3 probability that nobody will be saved.

Which of the two programs would you favor?

Now consider this problem with a slightly different verbal description of the outcomes:

If Program C is adopted, 400 people will die.

If Program D is adopted, there is a 1/3 probability that nobody will die and a 2/3 probability that 600 people will die.

Which of the two programs would you favor?

Textbox 1. Framing a problem (Tversky & Kahneman, 1981)

- Another important factor in risk perception is evaluability. Slovic et al. (2002) showed for example that life-saving studies are dominated by proportion of lives saved relative to the population at risk than the absolute number of lives saved. Higher mean rated supported for purchasing life-saving equipment was determined by saving 85% of 150 people than saving 150 people, as showed in figure 9. This is due to the fact that saving 150 lives is diffusively good and hence hard to judge. Saving a high percentage is clearly very good because one can evaluate the 'score' which creates positive feelings.

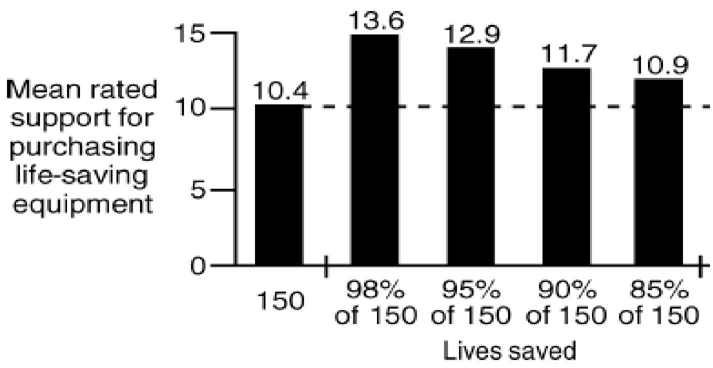


Figure 9. The mean rated support for purchasing equipment saving 150 lives (Slovic et al., 2002).

5. Communication of urban heat island risks

In section 5.1 an objective analysis of the UHI risk is given. Next, UHI outrage factors are described (section 5.2). These factors can help to determine the perceived UHI risk and to show which factors can possibly help to influence risk perception. The self analysis is not done because of it's not irrelevance for this writing assignment.

5.1 Objective analysis of the risk of Urban Heat Islands

The risk of UHIs is only present in warm periods. So, to place the risk of UHI in the right perspective, the excess mortality during heat waves is described first.

- **Excess mortality**

The 2003 heat wave caused 46.730 excess deaths in Europe (UNISDR, 2003). In the Netherlands, approximately 1400-2200 deaths in the 2003 summer may have-been heat related (Garssen et al., 2005). This high number is largely due to the 2003 heat wave that lasted from 31 July till the 14th August. The 2006 heat wave causes 1.000 excess deaths in the Netherlands and 940 in Belgium which yielded in a respectively fourth and fifth place of countries most affected by natural deadliest disasters that year (UN/ISDR, 2007, see figure 10).

Top 10

Natural disasters by number of deaths - 2006

Earthquake, May	Indonesia	5 778
Typhoon Durian, December	Philippines	1 399
Landslide, February	Philippines	1 112
Heat wave, July	Netherlands	1 000
Heat wave, July	Belgium	940
Typhoon Bilis, July	China, P Rep	820
Tsunami, July	Indonesia	802
Cold Wave, January	Ukraine	801
Flash Flood, August	Ethiopa	498
Typhoon Samoai, August	China, P Rep	373

Figure 10. Natural disasters by number of deaths in 2006 (UN/ISDR, 2007)

The general feeling that deaths of extreme heat are very elderly and frail people, who would have died within a couple of days or weeks after the warm period, may lead to a low urgency for adaptive measures to prevent heat-related effects (Garssen et al., 2005). This forward shift in mortality, also called 'harvesting effect', is found in some heat waves, but not in others (Garssen et al., 2005). Figure 11 shows the analysis of the average observed mortality of persons aged 80 years or older in 2003. Due to the fall of deaths after the 2003 heat wave (2nd red circle), one can state that a 'harvesting' effects has taken place. However, according to statistical analysis the fall is not counterbalancing the whole rise of deaths during the heat wave (1st red circle). So, not all the deaths during this heat wave would have died within a few weeks.

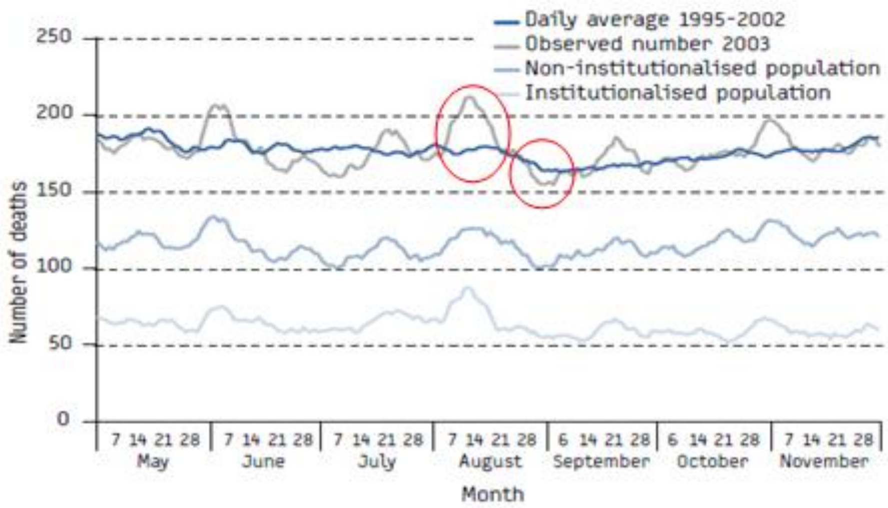


Figure 11. Observed and expected number of deaths in patients aged 80 years or more, The Netherlands, May-November 2003 (Garssen et al., 2005)

The increased mortality rate during the 2003 heat wave was not only seen in the 80+ aged population. An 11% higher number of deaths among persons 40-59 years of age than expected on the based data of 1995-2002 was determined (Garssen et al., 2005). In younger groups no higher mortality rates were seen.

Holstein et al. (2005) showed that the 2003 heat wave in France not only killed the frailest persons. Increased attention of medical staff among elderly intensive care patients showed lower mortality rates compared to patients with less attention. Moreover, people who died during the heat wave in France were often living alone, which implies that they were independent enough to live by themselves and would have lived for some more years without the heat wave. Of the 15.000 excess deaths two third of the victims could have been expected to live for another 8 years (Toulemon & Barbieri, 2005).

- **The extent of risks of urban heat islands**

Heat causes a risk when temperature exceeds the threshold temperature. In areas with a high UHI the temperature exceedance is higher compared to areas with low/no UHI. Hence, the risk of heat-related health effects is larger in areas with high effects. Vandentorren et al. (2006) showed that the temperature index of the urban area (radius of 200m) significantly increased the risk of premature mortality during the 2003 heat wave in France. Smoyer (1998) indicated that heat-related mortality rates during heat waves were generally higher in the warmer areas of St. Louis (Missouri) compared to the cooler parts. Smargiassi et al. (2009) also pointed out that micro-UHI can increase the risk of the people who live in that area.

A combination of geographical and epidemiological data can show the risk of UHI during heat waves. Steeneveld et al. (2014) simulated the Dutch heat wave of 2006 over different Local Climate Zones (LCZ). These zones illustrate urban areas that differ in all kind of aspects like emissivity, albedo and green that influence the UHI. Besides the below displayed climate zones, also an LCZcontrol was developed. This climate zone is an intermediate zone between LCZ3 and LCZ6.

Figure 12. The Local Climate Zones and their description (Stewart and Oke, 2012)

The UHIs determined by Steeneveld et al. (2014) are shown in table 1. The relative risk of heat is approximately 2,1% per degree Celsius above the threshold temperature (Armstrong et al., 2009). This temperature is approximately the 93rd centile of the mean summer temperature (Armstrong et al., 2009) and is set at 21,5°C in the below calculations according to Hajat et al. (2002). So, the excess risk of premature mortality caused by the UHI, is the UHI (°C) multiplied with the relative risk of 2,1%. The excess risks of the UHI per LCZ are shown in table 1.

Table 1. The vegetation, UHI and risk per Local Climate Zones

	LCZ2	LCZ3	LCZcont	LCZ5	LCZ6
Vegetation (%)	15	20	40	60	65
UHI (°C)	3,1	2,5	2,0	1,4	1,0
Excess risk	6,4	5,3	4,2	2,9	2,1

The simulated temperature of LCZ3 during the heat wave simulations of Steeneveld et al. (2014) is shown in figure 13. When the temperature threshold is 21,5°C, the excess risk caused by the UHI in LCZ3 is equal to the excess risk caused by the rural temperature. When a milder heat wave occurs and the UHI is assumed to be equal, the risk of the UHI exceeds the risk of the rural heat wave temperature.

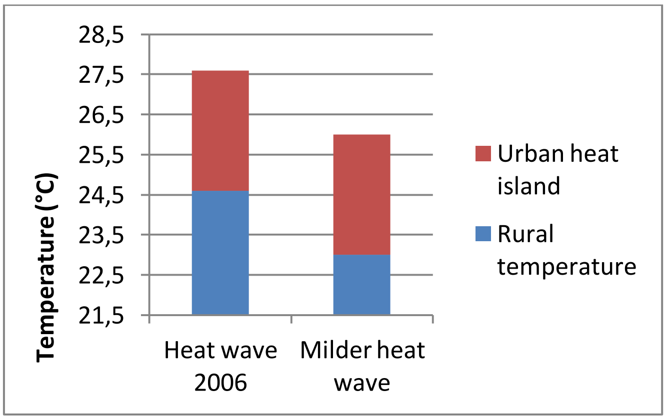


Figure 13. The influence of the UHI of LCZ3 on ambient temperature above the threshold temperature

- **Probability of occurrence/distribution of UHI**

The probability of a heat wave, defined to the Dutch standard, is low in the Netherlands. In the period 2004-2013 only five official national heat waves have been registered (2004, 2005, 2006 2x, 2013). However, Meehl and Tebaldi (2004) showed that future heat waves become more intense, more frequent and longer lasting.

The number of days the temperature exceeds the threshold temperature is affected by the UHI. To determine the influence of the UHI on the probability of the risk, the mean daily temperature data of the measurement location of the Dutch Meteorological Institute in Cabauw in the period 2004-2013 is used as rural temperature. UHIs shown in table 1 were added to the daily temperatures of Cabauw.

The threshold temperature was exceeded 78 days in Cabauw in this 10-year period. In an urban area with an UHI of 3,1°C (LCZ2), 257 extra warm days compared to Cabauw occurred. So, more than 75% of the days the temperature exceeds the threshold temperature in LCZ2 is caused by the building environment. For other urban areas this is less but still a substantial number of days (figure 14).

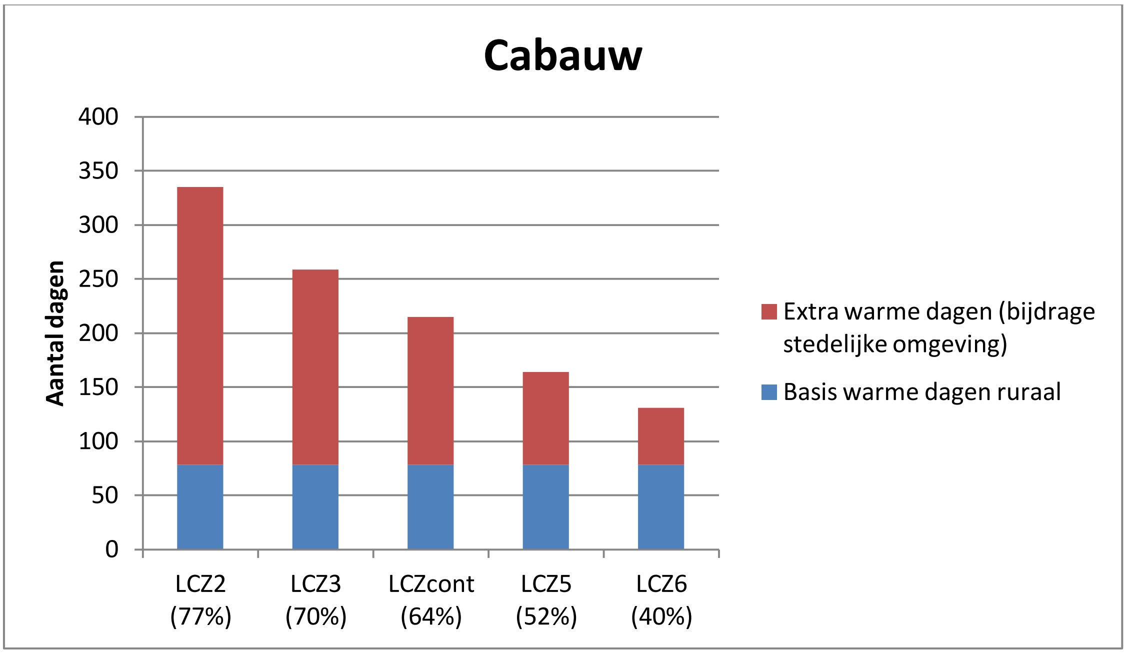


Figure 14. The number of days the temperature is exceeding the threshold temperature (warm days) in the different LCZs in the period 2004-2013

To explain the probability of the UHI risk will help to understand the risk and it gives insight in the unequal distribution of risks. People living in an urban area are not only exposed to a larger magnitude of heat, also the number of days exposed to risky temperatures is higher.

5.2 Outrage factors

As far as I know, there is no UHI risk perception study done. So, in this section I made an expert judgment of the most important outrage factors in the UHI risk perception. To influence one's UHI risk perception by risk communication, these factors will be useful. However, the influence of outrage factors on one's perception is hard to determine, to test my judgments further research is necessary.

- **Benefits**

UHIs cause higher temperatures in cities during the whole year. Especially during winters, higher temperatures will be perceived as beneficial and can result in a decrease in cold-related diseases/mortality. When temperature exceeds the heat-related threshold temperature, nobody will perceive the extra heat caused by the UHI as benefit. However, the period the UHI is beneficial is probably larger than the period the UHI causes a risk.

- **Voluntariness**

One can assume that exposure to extra heat caused by the UHI is not voluntary on warm days. Mobile people can flee from the UHI by going to a park or water body. However, immobile people (elderly or young children) do not have the choice whether or not to be exposed to the extra heat. Moreover, during night-time hours of warm days it is likely that everybody is exposed to the UHI of his/her living area. One cannot flee from his/her own home. Therefore, it can be stated that exposure to heat caused by the UHI on already warm days is involuntary.

- **Origin**

Heat is a natural event and thus the risk caused by heat can be assumed as a natural risk. Due to the rarity of heat waves in the Netherlands, it is likely that people deny the existence of heat risks. Moreover, humans feel probably comfortable with heat risks, because warm days are predicted and foreseen. However, heat caused by UHIs is the result of man-made buildings. So, when someone wants to influence risk perception he/she should emphasize the UHI risk is a man-made (technological) risk.

- **Familiarity/knowledge**

Heat is a familiar risk, and according to Slovic (2000) risks of common risks tend to be underestimated. However, not everyone knows the UHI of their living area, so there will be some uncertainty towards this risk. The unknown UHI risk will be less readily accepted.

- **Diffusion in time and space**

Heat waves are rare short-term periods that hit large parts of countries. However, short-term is relative concept. These events can last for more than a week and can be judged as long-term compared to other risky phenomena's (explosions, crashes etc.). The risk diffusion in space of heat waves is low; a couple of countries can be hit by a heat wave. However, the UHI differs in space as shown by table 1 and figure 15.

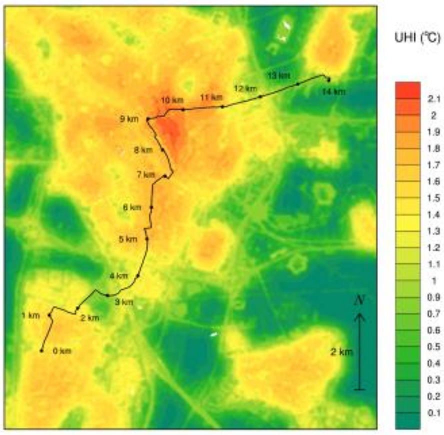


Figure 15. The diffusion in space of the mean night-time UHI intensity for the city of Utrecht and its surroundings (Brandsma and Wolters, 2012)

- **Potential to control**

The rural temperature increase during heat waves is unavoidable. So, there is no potential to control this risk. However, as showed in figure 13, the contribution of the UHI to the total harmful heat can be equal to the contribution of the rural temperature. The number of days one is exposed to temperatures above the threshold is also largely affected by the UHI (fig. 14). Thus, the total heat-related health effects are partly dependent on the UHI and can be prevented by adaptive measures.

The magnitude of the UHI is determined by the heat and energy-balance. The radiation (Q), anthropogenic heat (AH), sensible heat (H), latent heat (LE) and G (storage) are the five elements in this balance. Sensible heat is the heat we feel and causes heat-related health effects.

$$Q + AH = H + LE + G$$

These elements cannot be controlled by an individual. One does not have the ability to reduce the radiation or adapt a whole area to diminish the anthropogenic heat or storage, or increase the latent heat. So, there is very little potential to reduce the degree of the place-based risk he/she is exposed to.

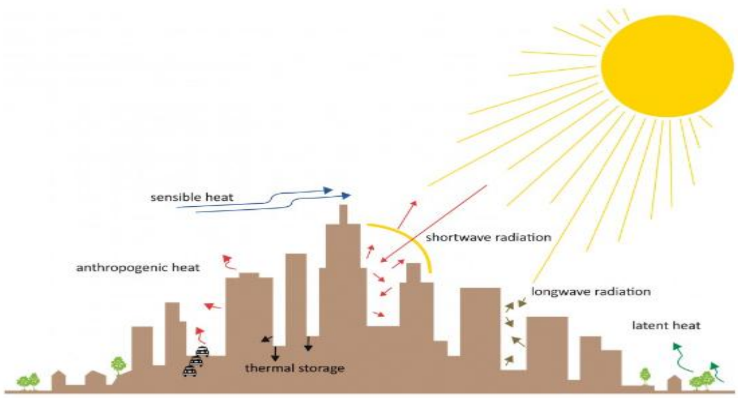


Figure 16. The elements of the heat and energy-balance (Environmental Protection Agency, 2008)

However, the UHI can be controlled to a certain degree by stakeholders/local governments. Reducing AH, Q and G, by adapting building materials, or increasing LE by increasing the amount of green in an area will lead to lower sensible heat (H). Although, one can assume that investing in urban areas is not that efficient for municipalities to improve health because of its indirect relation. One should know that reducing the magnitude of heat will lower the exposure to heat for the entire population of that urban area. Not only the amount of heat-related deaths will decrease, also the heat-related illness and heat stress will be lowered.

- **Reversibility/fatality of the risk impact**

The health effects of exposure to heat varies per person. During heat waves, the UHI will enhance the magnitude of heat. As shown in figure 17 exposure to heat can induce heat stress depedent on the factors affecting exposure. One's sensitivity to a given heat exposure determines if he/she gets ill. Heat-related illness can eventually cause heat-related death.

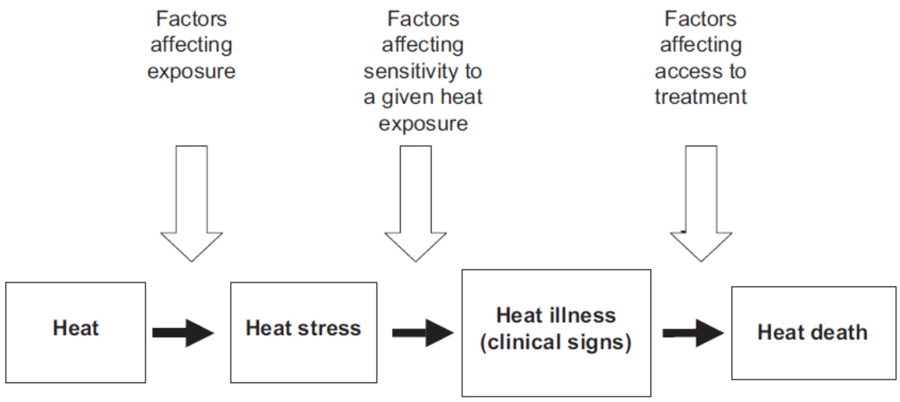


Figure 17. The relation between heat and the health effects (Kovats & Hajat, 2008)

During heat waves probably everyone experience a certain degree of heat stress. This stress is a reversible impact on humans and hence not perceived as threatening. Heat-related illnesses are heat strokes, -exhaustion, -syncope and -edema. Most of these illnesses are the result of a failure of the thermoregulatory system in humans.

A failure of the circulation to maintain blood pressure and supply oxygen to the brain can cause heat syncope (Koppe et al., 2004). Heat exhaustion is a first symptom of heat stroke in which extreme body temperature can lead to cellular damage. Heat edema is caused by vasodilatation and the concentration of salt (Koppe et al., 2004). Moreover, heat reactions of the human body can also affect health via the increased cardiovascular load and hence have an indirect effect. These illnesses are to a certain degree reversible. However heat stroke has a rapid onset (Donoghue et al.,1997) and can lead to mortality without urgent and proper treatment.

- **Dread**

Heat will not evoke fear or terror, therefore the risk of heat will be more readily accepted and perceived as lower compared to risk that do arouse such feelings.

- **Victim identity**

The excess deaths during heat waves are statistical deaths. It is hard to identify heat-related victims, deaths from for example heat strokes are probably underreported due to the similarity with other familiar causes of death (Koppe et al., 2004). Moreover, it is even harder to identify UHI-related victims.

6. Discussion

UHIs increase the temperature of urban areas and hence the risk of adverse heat-related health effects. Communicating the UHI risk can help to understand the risk and to show the urgency for adaptive measures. However, communication of health risks in general is a difficult task. There is no universal definition of risk which causes a permanent divide between the risks presented by expert and the way society thinks about the risk. The perception of risks is largely based on outrage factors; probability and extent of the harm are less important. So, to communicate the risks of UHIs, messages should focus on the hazard and outrage factors.

Although analytical facts show the impact of heat on human health, only a few studies indicated the relation between UHI and adverse health effects. This probably causes the low urgency for adaptive measures to reduce the UHI. However, geographical and epidemiological data showed the relative large contribution of UHI to the total harmful temperature. Outrage factors that can make the UHI risk less readily acceptable are: involuntary exposure, the technical origin and knowledge. Another important factor is the impotency to control the risk for individuals. Meanwhile, local governments have the potential to control the risk and can probably be held responsible for the UHI risks.

The general feeling that the excess deaths caused by the heat wave are frail and old people who would have died in couple of days/weeks without the heat wave is incorrect, but likely to affect the risk perception of heat. Other adverse health effects of heat are probably judged lower because they are almost all reversible. Moreover, UHI risks are more readily accepted because UHI will produce statistical victims instead of identifiable victims.

To show the urgency for adaptive measures one should give an overview of the statistical data of the UHI risk and make outrage factors more outrageous. This will affect the acceptability of the UHI risk and likely increase the 'willingness to pay' for adaptive measures. However, to adapt whole areas is very costly and because health cannot be expressed in money and vice versa, it is hard to weigh cost of adaptive measures against health benefits. Another factor that probably affect the willingness-to-pay is the material damage caused by the event. Cost of material damage can be compared to cost of adaptive measures. However, UHI risks (and heat waves in general) do scarcely cause material damage compared to other natural events like floods, earthquakes etc.

One can assume that due to its indirect relation, investing in urban areas is not that efficient for municipalities to improve health. However, the role of place in influencing health and health-inequalities is the last years becoming more important due to epidemiological, sociological, and geographical studies (Cummins et al., 2007). Developments of place-based health research in the last years showed conceptual models of causal relations by which place may influence health (Cummins et al., 2007). A place/neighbourhood context can affect health directly, for example when a depressing place leads to adverse health effects. But also indirect effects of a place, for example by environmental mechanisms (like UHI), can reduce health.

Adaptive measures to reduce UHI will decrease the extent of heat in that area. Such investments are focussed on the cause of health risks and therefore prevent people from being exposed to the harm. These investments can be assumed as more efficient than investments to cure people from heat-related illness. Moreover, all persons in the living area will benefit from these investments. Adaptations to decrease the UHI like more green, can also be beneficial for other health-related risks and may increase the liveability of an area. When one wants policy makers to take action to decrease the UHI, one should address these benefits.

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