Green Infrastructure for Health

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Master Thesis

Green Infrastructure for Health

Reviewing the evidence base for spatial planning

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Abstract

Objectives This study exposed what functions of urban green infrastructure can influence people's physical and mental health, namely why urban green infrastructure is important to people's health. After that, how city planners can plan and design urban green infrastructures in order to better improve health in the context of spatial planning.
Methods This study is based on a scoping study which represents a special kind of qualitative literature review. Over 100 studies were reviewed.
Results The relationships between urban green infrastructure and health were explored in the context of spatial planning. Urban green infrastructures influence people's physical and mental health through five functions, which are cleaning air, isolation of noise, providing space for physical activity, natural landscape and reduction of internal heat. Greenness, accessibility and size of green spaces were recognized as important characteristics of urban green infrastructure. The way planners design them determines how beneficial green infrastructure are to our health. According to results, both qualitative and quantitative guidelines of urban green infrastructure were proposed in order to better improve its health benefits.
Conclusion This study allows us to systematically describe the health contribution of green infrastructure, and meanwhile provides an overview of green infrastructure in the context of spatial planning. Concluded guidelines can be applied in future studies or planning cases as general instructions.

Summary

Green infrastructure is generally recognized as fundamental to provide comfortable and pleasant urban living environments (Takano et al, 2002). When people live at proximity to green area or walk in parks covered with amount of vegetation, people feel comfortable. Many surveys have shown the relation between comfortableness and physical environments by measuring people's preferences. Nevertheless, with increasing interest in improving citizens' quality of life, research on green space and human health expands beyond the concentration on landscape preference and is paying more attention to whether green infrastructure can promote human health, how it works and what are the factors of influences on human health.

This paper was performed on studying the importance of green infrastructure on human physical and mental health, and the relation between design of green elements and physical and mental health. Part 1 explains the importance of green infrastructure for human health. By collecting theories and evidences from literatures, this part supports that green infrastructure can directly influence human physical and mental health through providing five functions: clean air, space for physical activities, noise insulation, positive perception of land view and reduction of internal energy and heat. Part 2 exposes the relationship between the design of green elements and human physical and mental health. In this study, three characteristics of green infrastructure

were selected as the research focuses, which are: amount of greenness, size (or demission) of green space and accessibility. I will argue that the way that planners design these elements can significantly influence green infrastructure services and eventually influence human health as well. Through reviewing and interpreting previous knowledge, the relations between health and these elements were highlighted. Finally, the analysis and discussion of the results from part 1 and 2 provides both qualitative and quantitative guidelines for green infrastructure to have a positive impact on human health.

Introduction

Research background

Health issues are one of human's main concern. Science can help us to reach a better quality of life. Nowadays scientists pay more attention to the effects of our living environment on health and consider it an approach through which to improve our health conditions. The EU Strategy on Environment and Health (EC, 2003) and the European Ministerial Conferences on the Environment and Health Process recognize that economic and social factors are the main determinants to human health, and it also mentions that environmental factors are significant as well. This leaves us a question-how can we plan and design our living environment in order to get better life. Studies have already been performed to relate spatial planning and human health (Wilson, 2012; Hartz, 2012; Jenerrete, 2011; Thompson, 2011; Stavanovic, 2010; Wells, 2010, Thompson, 2012; Rodney, 2008; Abraham, 2010; Abranzabal, 2009; Opdam, 2009). Meanwhile, there is an increasing awareness that green vegetation is beneficial to human health (Gunnarsson, 2007; Nilsson, 2006; Wells, 2003) and better planned and managed green infrastructure is considered very important to promote living environment, health and quality of life (Kaplan, 1983 and 1987 and 2004; de Vries, 2003; Thompson, 2012; Takano, 2002 and 2003; Bowler, 2010; Peter, 2012; Jorgensen, 2010; Tzoulas, 2007). Recent studies about green infrastructure (GI) services are mainly focused on the static mapping and evaluation approaches which hardly provide dynamic thinking that supports green planning and further improves quality of life (Opdam, 2002). Besides, although there is a wide variety of a GI-health relationship in literature, only few researches focus on quantifying this relation with GI structure, which is crucial for spatial planning. In fact, kinds of characteristics of green infrastructure which are related with health and outcomes were researched. Are people healthier when they live in greener area (De Vries, 2003; Kaplan, 1987; Pretty, 2005; Morris, 2003 et al)? Does distance between green space and residential areas change the effects of green infrastructure on human health (Herzele, 2003; Neuvonen, 2007; Morris, 2011 et al)? Would more accessible and walkable green space serving human health better (Herzele, 2003; Karusisi, 2012; Maat, 2006; Schipperijn, 2010 et al)? Are people healthier while the valued green space is more aesthetic (Thomas, 2006; Pretty, 2005; Ulrich, 1986; Kaplan, 1987; Richardson, 2012; Herzeler, 2011 et al). With the aim to answer these questions, studies were carrying on. For example, De Vries investigated the influences of variable amount, distance and patterns of

green space on human health (de Vries et al, 2003). Studies have also provided evidence of the association between green space and physical activities (Booth et al, 2000, Pikora et al, 2003). Moreover, green infrastructure can negatively impact on human health as well. For instance, overgrown and unmanaged green area can be perceived unsafe because of fear of crime (Kuo et al, 1998). Wendel (2012) exposed that badly managed green spaces can sometimes feel unsafe for citizens because of potential crime or aggression, which could occur, and this is particularly true for female. On the contrary, Neuvonen (2007) and Morris (2011) claimed that only few people felt unsafe when they are in green space. This may lead us to question what characteristics green infrastructure influences positively citizens' view on them. Hence there is a need to review the current knowledge and interpret the relations between green infrastructure and human health and its application in landscape planning to help further research on this subject.

Research subject- green infrastructure and human health:
When talked about the word "infrastructure", people usually think about hospitals and schools which are actually called building infrastructure, or roads and utility lines which are called grey infrastructure. Nowadays, people are talking about another infrastructure-green infrastructure, which is significant to the continuance and growth of communities (Benedict, 2002). In 1999, the American Conservation Fund and the USDA Forest Service Fund formed a Green Infrastructure Working Group defined green infrastructure as being: "our nation's natural life support system. An interconnected network of waterways, wetlands, woodlands, wildlife habitats and other natural areas; greenways, parks and other conservation lands; working farms, ranches and forests; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life for America's communities and people." (Benedict, 2002). "Green infrastructure is comprised of all natural, semi-natural and artificial networks of multifunctional ecological systems within, around or between urban areas" (Konstantinos, 2007). According to these definitions, green infrastructure actually relates to human places of living and the various functions they provide for them. If green infrastructure can be well managed or maintained qualitatively or quantitatively, it would offer many opportunities for integration between urban development, nature conservation and public health (Konstantinos, 2007). However, green infrastructure is a very broad concept, and it can be almost every green place. For example, a forest which is located far away from an urban area can also influence urban life through various ways, but it should be noted that these influence are all indirect. This is true in the case of weather changes for instance in the Amazon forests, which may cause weather changes in Brasilia, but in turn people in Brasilia do not get influences from Amazon directly. In order to narrow down the research scope, this paper keeps focus on the green infrastructure that is closed to people and affect human health in or around urban regions. Therefore, green infrastructure hereby is considered to encompass parks, green spaces , green roads or some urban-closed green areas that affect city people directly (e.g. when people are directly exposed to green area, people

get rid of noise when they are in green space). It should be noted that family gardens are not included since there are too many unpredictable personal factors.

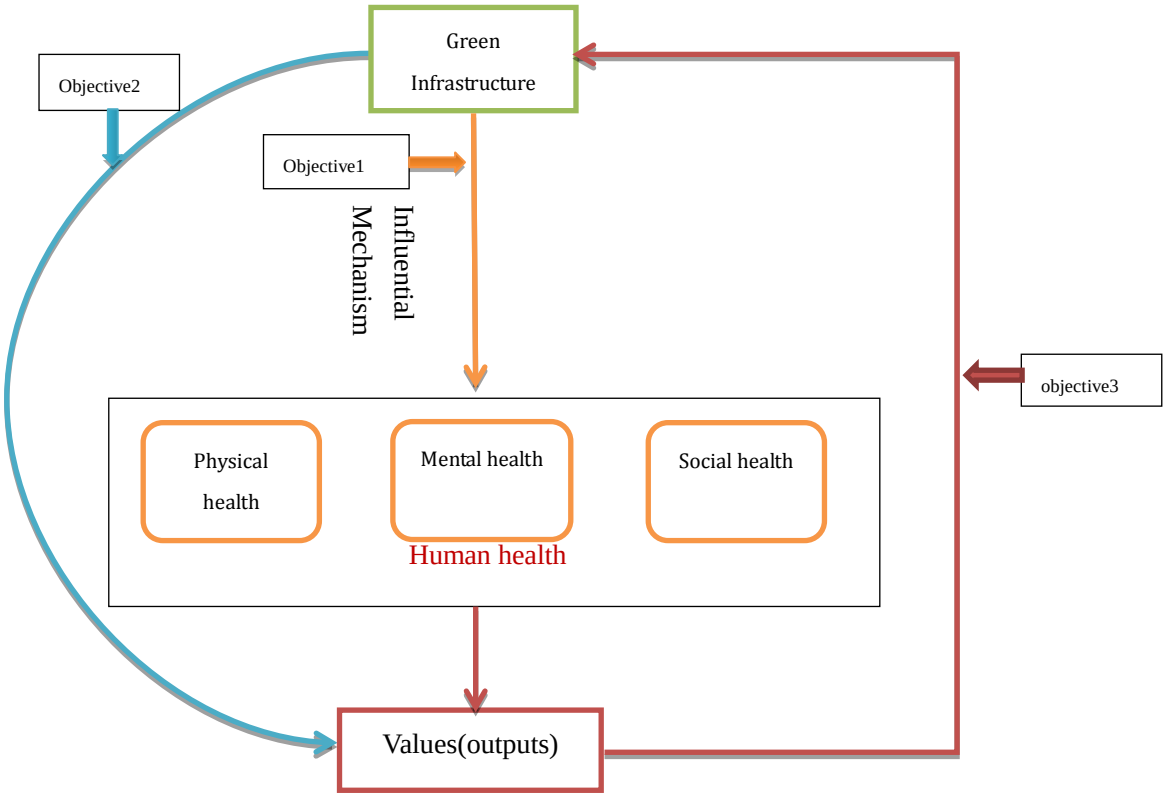
World Health Organization (WHO) defines Human Health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (WHO, 1948). Thus, human health can be associated with not only biological and medical factors. In facts, links between social and economic factors and human health has been established already. For example, structure of social relations is identified a crucial factor in shaping human health (Dunn, 2000). Neighborhood characters are also recognized as influential factors (Roux et al, 1997 and 1999). Moreover, such kinds of researches include investigation of relation between human health and safety, people’s income, social level, housing circumstance and so forth. The WHO also stated that physical, mental and social aspects should be treated as key approaches through which green infrastructure can influence human health. As a result of this claim, researchers have been concentrating on the relations between green infrastructure and physical health, mental health and social health. For example, in his survey, Tanaka investigated the relationship between senior longevity and green space (Tanaka et al, 2002). Kim and Kaplan suggest that residents’ feeling of attachment to the communities and the interactions with other neighbors are firmly related with the surrounding natural features (Kim and Kaplan, 2004). There are also evidences illustrating that being in green area can reduce psychological stress and contacting with nature is significant to psychological well-being and personal fulfillment (Kellert and Wilson, 1993). However, it is very difficult to encompass all of these three health aspects in one study. In order to limit research scope, this study only related the influences of urban green infrastructures to physical and mental health, but excluded the impacts on social health.

Research Objectives

(1) Exploring the ways in which green infrastructure influences human physical and mental health in order to illustrate the importance of green infrastructure functions on health.

(2) Quantification of the relationships between different characters or patterns of green infrastructure and various aspects of human physical and mental health in urban area.

(3) Providing both qualitative and quantitative guidelines for green infrastructure planning and design.



Methods

This research is mainly based on literature review. Data searching is conducted within "Scopus" database (http://www.info.sciverse.com/scopus). A range of green infrastructure functions and services/urban-associated searching words (e.g. green, park, physical activity, noise) were combined with a range of human health related words (e.g. physical, mental, activities, safety, depression, anxiety) to search for academic articles. Land use planning related words, especially for green infrastructure (e.g. vegetation amount/cover, distance, walkability, facility) are combined with human health related words for searching. Some references from selected articles were checked as well.

Articles were selected when it met the following criteria:

(1) English peer-reviewed papers published between year 2000 and 2012. A few of references were also selected and a symbol "R" was used to indicate this paper was from the references. Papers from references could be earlier before year 2000.

(2) Articles provided data or measures of human physical and mental health when people were directly exposed to green environment or synthetic environment. "Green environment" is defined in a limited sense to include sorts of natural environments within or around urban regions like parks, forests, woodland and college campus and so forth, but family gardens are excluded. "Synthetic environment" is only considered to be outdoor environment, and indoor environment is excluded. "Direct exposure" indicates physical presence within the environment (e.g. activities on green space) (Biana , 2010).

(3) Studies of observation and experiment are included.

(4) Excluded from the review were: Studies which only compared pictures, slides or views of natural and synthetic environments (Biana, 2010). Because this paper focuses on green infrastructure, and because overall environment is too big for the research. Meanwhile, pure comparison of pictures and slides is not sufficient enough to conclude guiding principles of urban green infrastructure. Studies only investigated social health. Studies focused on professional medical and biological research.

(5) This paper focuses on urban landscape so studies of rural regions were excluded. Rural regions are considered to have different conditions and context from urban regions such as larger green area, low population density and low Urban Heat Island effects.

Result

Part I Green Infrastructure Functions: Objective 1

Green infrastructure plays an important role in city life by providing kinds of services, which directly relates residents with their living environment. Parks, forests, woodlands, campuses, and all of these green spaces affect human health when they are exposed to it. Various studies are carrying on the relationships between green infrastructure and people's health. This chapter focuses on the green infrastructure's functions through which the "green" impacts positively or negatively people's physical and mental health. This chapter also explains the mechanisms through which these functions influence health conditions and why they are important to citizens. Functions (or services) of the researches and articles I reviewed generally encompassed five aspects: cleaning air (Thomas, 2012; Jim, 2008; Ningal, 2010; Oliver, 2011; Tallis, 2011), space for physical activities (Bolwer, 2010; Pretty, 2005 and 2007; Morris, 2003), isolation of noise (Laszlo, 2012; Godson, 2009; Chau, 2010; Gunnarsson, 2007), perception of land view (Kaplan, 1987; Ulrich, 1984 and 1986) and reduction of internal heat (Dominique, 2012; Smith, 2008; Gill, 2007; Wise, 2010).

In this study, those five functions of green infrastructure were divided into two categories. Category 1 functions with mechanisms that are triggered by the existence of the green infrastructure. It concerns the functions "cleaning air", "isolation of noise" and "reduction of internal heat". Category 2 functions with mechanisms, which are triggered by active or passive use of green infrastructure. It concerns the functions "provide space for physical activity" and "perception of natural landscape". These categories distinguished functions of green infrastructure that are related to a specific location (category 1) and functions that people are free to use (category 2).

This paper followed this above-mentioned categories is to discuss the objective 1, namely how can these green infrastructure functions influence or improve our health and how important it is to urban residents.

Cleaning Air

Picture 1: clean air (from Google Image)

Picture 2: polluted air (from Google Image)

Table. 1 Searching Terms: Green space, Infrastructure. Air quality, Pollution. Health, illnesses, Disease. Planning, Land use

Author	Year		Method	Description
Thomas	2012		experiment	effectiveness of green infrastructure for improvement of urban air quality
Oliver	2011		case study	relationships between respiratory and urban factors
Pataki	2011		review, framework	key urban biogeochemical regulating services
Tallis	2011		field work	deposition of trees and capacity of particulate removal
Ningal	2010		field work	association of tree size and carbon store
Canavagh	2009		field work, model	green path and particulate pollutant
Tiwary	2009		case study	vegetation in mitigating the effects of PM pollution
Currie	2008		fieldwork, model	air pollution mitigation and green plants
Manes	2008		review	the role of urban green to improve air quality
Jim	2008		field work	urban vegetation and pollutant concentration
Bailey	2004		case study	explore ways to improve environmental quality by green in ports
Ridder	2004		review, methodology	environment and socioeconomic aspects of green space
Boffetta	2001	R	field work	diesel exhaust and lung cancer
Dawson	2001		field work	diesel exhaust and lung cancer
Johnson	1996	R	case study	association of green roof and pavement and health

("R" indicates this article is from references of other selected article)

Negative impacts of urban air pollution on human health

With urban sprawling, Air pollution is increasingly becoming a pressing issue, which aggravates life quality, meanwhile decreases our health conditions. Urbanization negatively influences air quality in most of urban regions (Dhote, 2012; Ningal, 2010). Poor air quality in many studies is not only concerned with ambient aspect, but also take human health into account (Ningal, 2010; Cavanagh, 2009; Jim, 2008; Ridder, 2004; Oliver, 2011). Recently, scientists and city planners realize that besides technique solutions to abate air pollution, "green" elements should be utilized for the purpose of purifying urban air and further improve our health (Jim, 2008; Pataki, 2011; Ningal, 2010; Tallis, 2011). Trees are placed in cities, along roads and residences to absorb air pollutants, isolate traffic noise and, provide shelter (Ningal, 2010). People visit green area to relax and be surrounded by a peaceful environment. However, most of the urban green spaces are not well designed and developed to fulfill this functional use (Dhote, 2012). The following paragraphs are going to discuss the effects of negative air quality on people's health, how green infrastructure can promote urban air and what planners should keep in mind to maximize the benefits of green infrastructure.

Evidence shows that nearly 35,000-50,000 premature deaths happened every year in the U.K. because of outdoor air pollution, and this number could be more than 1 million worldwide (Thomas, 2012). In most urban regions, concentration of Nitrogen dioxide (NO_2) and particulate matter (PM) are the major sources of air pollutants, which cause mortality. Morbidity such as respiratory and cardiovascular illnesses (Oliver, 2011; Thomas, 2012; Tiwary, 2009; Manes, 2008) is often related to air pollution like nitrogen dioxide, ozone, sulfur dioxide and particulate (Thomas, 2012). In urban areas, air pollutants are mainly caused by traffic and industrial activities. Diesel exhaust is recognized to contain more than 450 compounds, 40 of which are listed as toxic air contaminants with negative effects on health (Bailey, 2004). People who are exposed to diesel exhaust reported eye and nose irritation, bronchitis, cough and abatement in lung functions (Bailey, 2004; Oliver, 2011). Meanwhile, lung cancer (Dawson, 2001) and other types of cancer (Boffetta, 2001) risks are also reported to increase with long-term diesel exhaust exposure. High concentration of particulates can cause asthma, chronic lung diseases, bronchitis, pneumonia and heart disease (Bailey, 2004). Inflammation and asthmatic reaction will threaten people when nitrogen dioxide levels are consistently high (Bailey, 2004). There are more disadvantages and illnesses caused by negative air quality. Clearing air seems to be an evitable mission in urban regions.

What can green infrastructure contribute?

In order to improve these air related health issues, a range of measures have been introduced over the lasts decades, for example tightening of vehicle emission standards and road pricing initiatives (Oliver, 2011). However, most of these measures are technical solutions which are costly (Jim, 2008; Pataki, 2011; Ningal, 2010; Tallis, 2011; Oliver, 2011). Only recently, has urban green infrastructure been considered to

play an important role in promoting air quality through well managed and planned "green" elements (Ningal, 2010; Tallis, 2011; Cvanagh, 2009; Jim, 2008; Ridder, 2004; Thomas, 2012; Schwitzguebel, 2009; Currie, 2008; Manes, 2008; Bailey, 2004). Urban trees and vegetation are recognized to offer mitigation against urban air pollution. Through capturing gases and particulates from atmosphere and releasing Oxygen, urban air quality can be effectively improved (Tallis, 2011). Both Taillis (2011) and Cavanagh (2009)'s studies showed that urban trees and vegetation can mitigate effects of particulate air pollutants and they suggested this green service should be considered in plans. Except for particulate matter, green infrastructure is capable to remove Sulfur dioxide, Nitrogen and Ozone out of atmosphere (Jim, 2008). But previous studies suggested the improvement of vegetation to urban air quality is very modest (<5%), Thomas (2012) provides evidences that increasing vegetation deposition can reduce Nitrogen dioxide concentration as much as 40% and 60% of particulates in cities. He strongly demonstrates that use of vegetation in dense cities can efficiently abate air pollution. Moreover, it is estimated that urban vegetation in the United States removed 214,900 tons of particulate pollution and 305,100 tons of Ozone per year (Manes, 2008). Johnson (1996) estimated that 2,000 m^2 of un-mowed grass could remove almost 4,000 kg of particulate pollutants, and 1 m^2 un-mowed grass would offer enough oxygen that meets the needs of one human for one year (Currie, 2008). Because urban green infrastructure is so important to promote air quality, planners are trying to find ways to instruct its utility and maximize the environmental benefits.

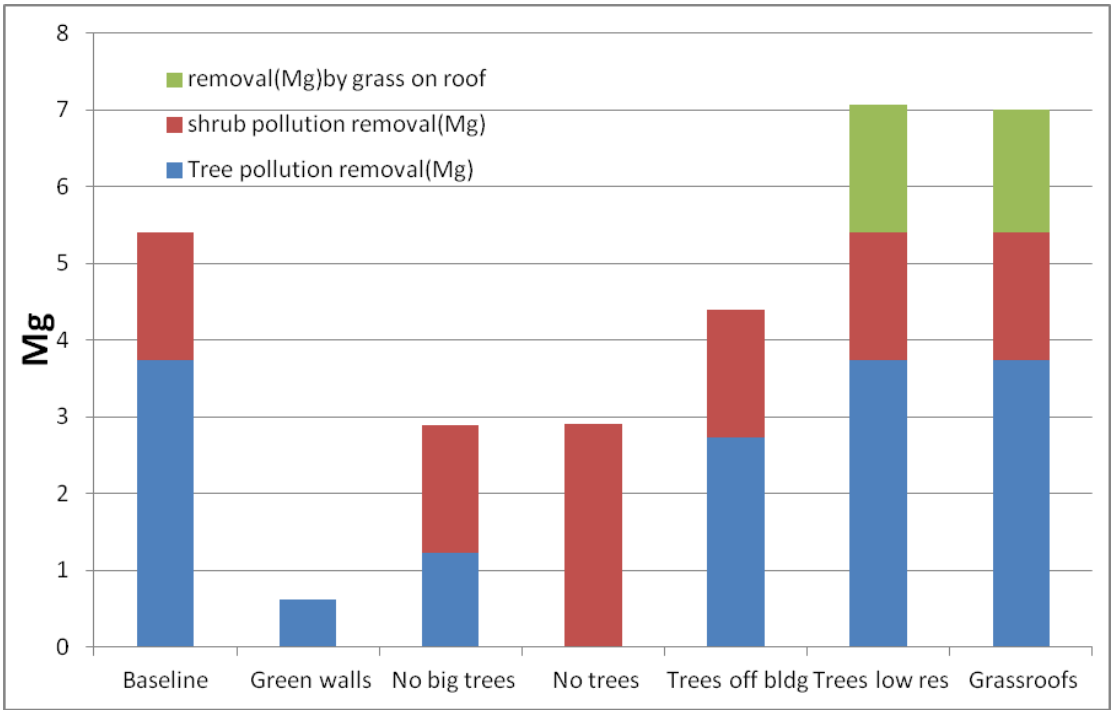


Fig. 1 Total NO2 removal (Mg) by trees, shrubs and grass in Midtown per Annum (Currie, 2008)

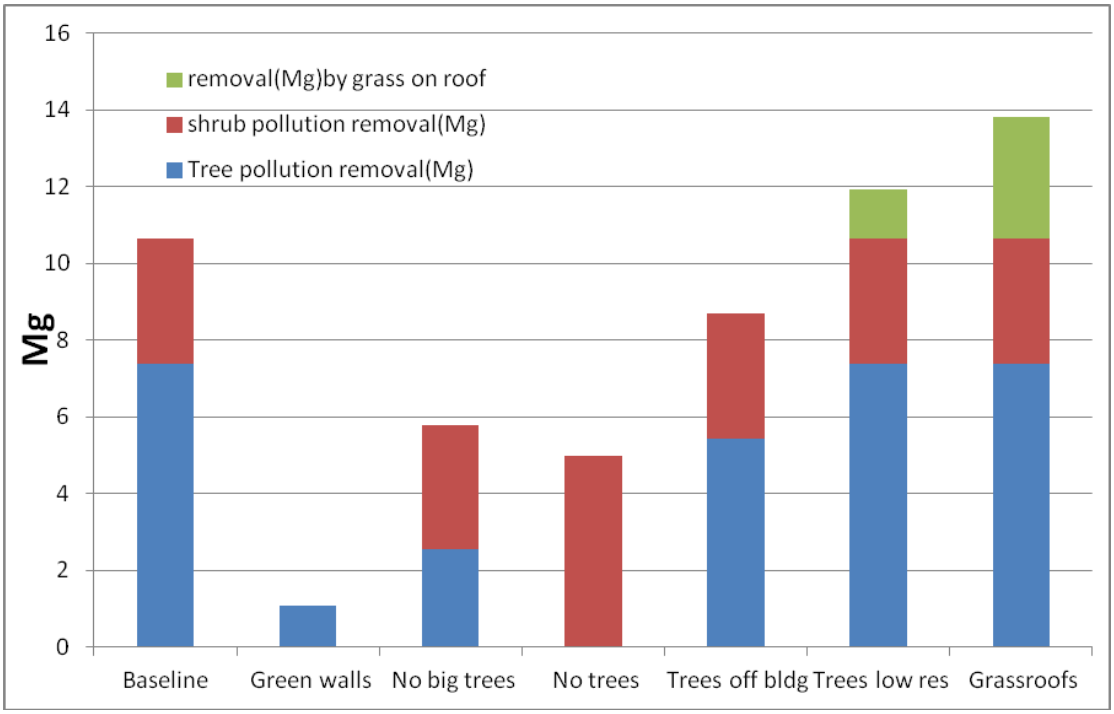


Fig. 2 Total O3 removal (Mg) by trees, shrubs and grass in Midtown per Annum (Currie, 2008)

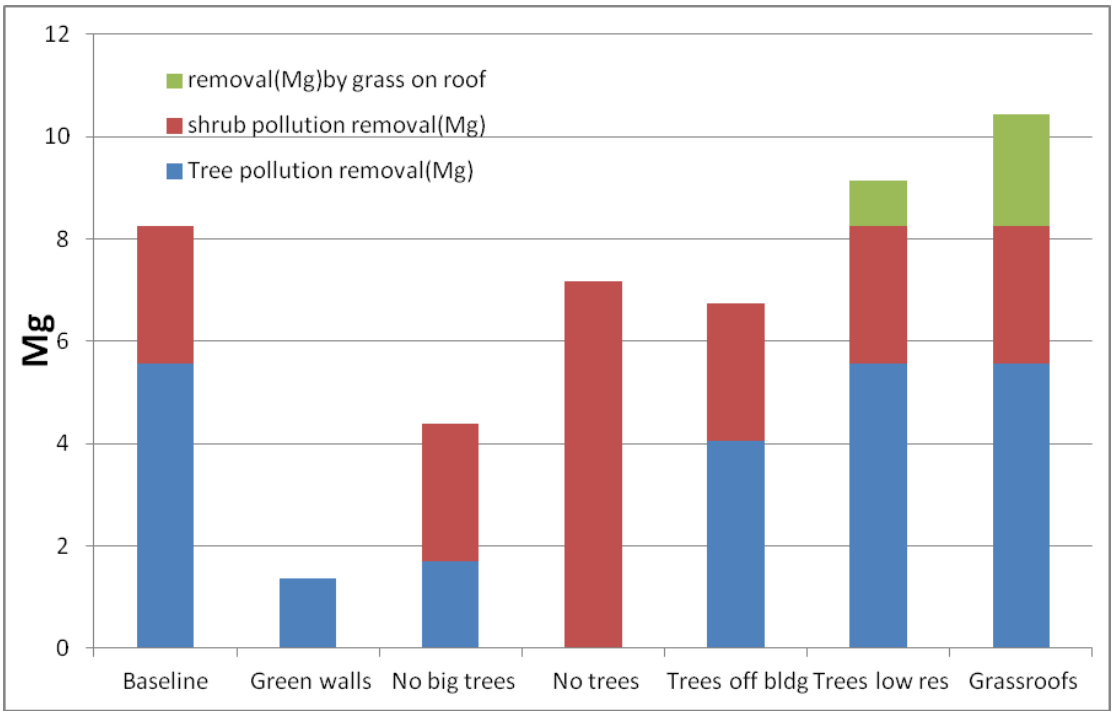


Fig. 3 Total PM10 removal (Mg) by trees, shrubs and grass in Midtown per Annum (Currie, 2008)

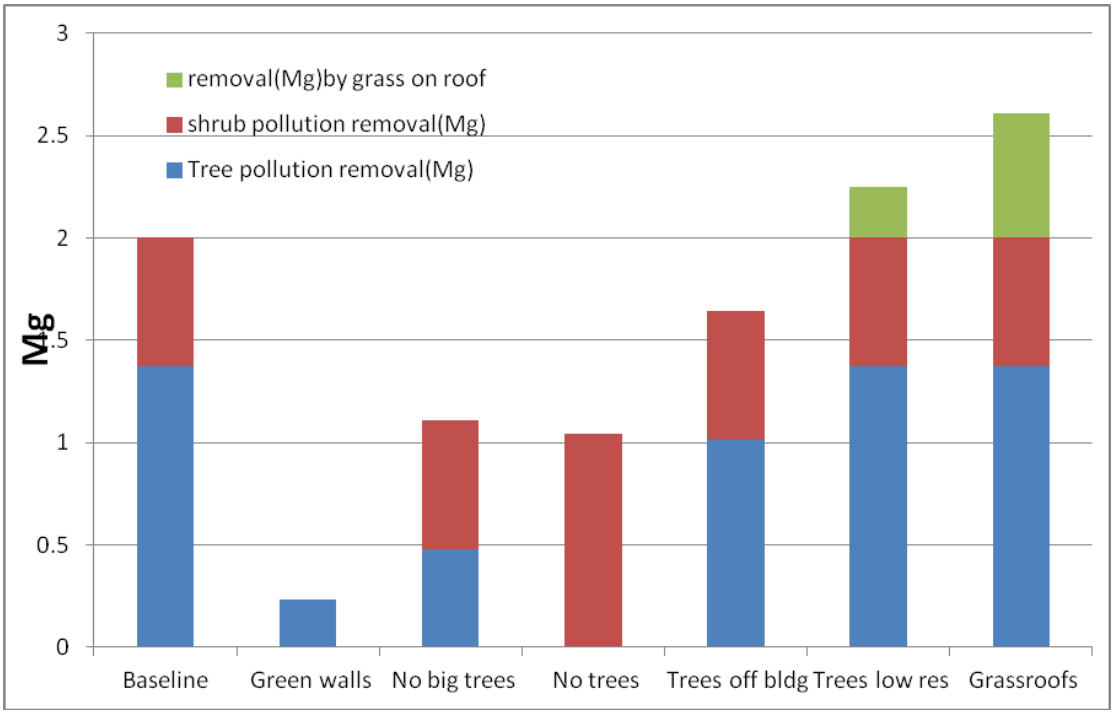


Fig. 4 Total SO2 removal (Mg) by trees, shrubs and grass in Midtown per Annum (Currie, 2008)

Recently, vegetation benefits on removing air pollutants have been linked to urban environment (Currie, 2008; Tallis, 2011; Thomas, 2012; Cavanagh, 2009). However, scientists found that different kinds of vegetation have different levels of efficiency. Curries (2008) tested the different capacity to remove pollutants from the air of tree, grass and shrub. Figures 1~4 above illustrate that in most of scenarios trees are the most important and efficient in removing air pollutants. Nitrogen dioxide, Sulfur dioxide, Ozone and particulates can be effectively absorbed by trees in urban scale. But Curries also points out that in the case of PM_{10} (Particulates diameter < 10um), shrubs were almost equivalent to trees in terms of air pollution removal, and compared with trees and shrubs, grasses contributed less to clearing air (Currie, 2008). Tallis (2011) also confirmed the important role of trees in removing air pollutants and suggested that planting trees in urban area would have the greatest benefit for future air quality. The data he collected and the experiment outcomes suggest that expanding urban canopy will promote the urban air quality through the reduction of PM_{10} and that coniferous vegetation in higher pollution areas offers the greatest PM_{10} mitigation potential (Tallis, 2011). Cavanagh (2009) experimented the impact of vegetation coverage on urban air quality and found that PM concentrations were much lower in a high tree cover area (~60%) compared with a low tree cover area (~40%). Furthermore, model results from study suggest that particulate removal is highest in urban regions if it was 100% tree covered. Relationships between categories of diameter breast height (DBH) and total carbon stored (kg per tree) are also presented, noting that carbon stored rate increases exponentially with size of tree. A large healthy tree (DBH>77cm) can store 1000 times more carbon than a small healthy tree (DBH<8cm) (Ningal, 2010). Jim (2008) systematically researched influences of vegetation on air quality in urban areas and provided several “green” guidelines that

may be helpful to urban planning. (1) Size, growth form and health condition of individual plant could affect the capacity of trees to remove air pollutants. For example, a large leaf area tree is estimated to remove 60 to 70 times more pollutants per year than small ones; (2) Better selection of vegetation species according to local situation could acquire more benefits. The table below shows types of species and their removal capacity for different pollutants; (3) Vegetation structure could influence the efficiency of trees in removing pollutants. For a given site, the availability of planting space and the designed configuration could function differently (Jim, 2008). Therefore, well-managed green elements could enhance the benefits of green infrastructure. However, to better improve urban air quality, planners should also consider interdisciplinary and interdependently. Many uncertainties remain such as wind speed, deposition velocities of air pollutants and street canyon environment (Thomas, 2012; Cavanagh, 2009; Jim, 2008), which forces us to involve more factors and not only green elements.

Table. 2 Selected common urban tree species and their air pollution tolerance

Species	Growth From	Family	Air pollutant tolerance		
			SO_2	NOxb	Particulate
Ficus microcarpa	E	Moraceae	Good	Good	Good
Cinnamomum camphora	E	Lauraceae	Good	Good	Good
Ailanthus altissima	E	Simarubaceae	Medium	Medium	Good
Fraxinus chinensis	E	Oleaceae	Good	Good	Good
Mimusops elengi	E	Sapotaceae	Good	—	Good
Morus alba	E	Moraceae	Good	—	Good
Platycladus orientalis	E	Cupressaceae	Good	Good	Medium
Sabina chinensis	EC	Cupressaceae	Good	Good	Good
Pittosporum tobira	E	Pittoporaceae	Good	Good	Medium
Lagerstroemia indica	D	Lythraceae	Good	—	Good
Magnolia grandiflora	E	Magnoliaceae	Good	Medium	Good
Gleditsia sinensis	D	Caesalpiniaceae	Good	—	Good
Celtis tetrandra	E	Ulmaceae	Medium	Medium	Good
Alstonia scholaris	E	Apocynaceae	Medium	Medium	Good
Hibiscus syriacus	E	Malvaceae	Medium	—	Good
Euonymus japonicus	E	Celastraceae	Good	—	Medium
Plumeria rubra	D	Apocynaceae	Good	—	Good
Sapium sebiferum	D	Euphorbiaceae	Good	—	Good
Livistona chinensis	EP	Palmae	Good	—	Good
Hibiscus tiliaceus	E	Malvaceae	Good	Good	Good

Source: Jim (2008)

D stands for deciduous, E for evergreen, C for conifer and D for palm

Space for Physical Activities

Picture 3: active people in green space (from Google Image)

Picture 4: inactive people at home (from Google Image)

Table 3. Searching Terms: Green space, Park, Forest. Health, Physical, Mental. Physical activity, Walking, Jogging, Cycling

Author	Year		Method	Description
Leyla E	2010		review	green benefits to physical and psychological active
J. Pretty	2007		cases study	green benefits to psychological active
Ralf Hansmann	2007		field work	green benefits to physical and psychological active
William et al	2007		health recommendation report	physical activity and health
Nick Cavill	2006		health report	green benefits to physical active
Ariane L	2005		a conceptual model	green benefits to physical active
J. Pretty	2005		field work and experiment	green benefits to physical and psychological active
Nina Morris	2003	R	review	green benefits to physical and psychological active
Renee	2003		multiple logistic regression	association of physical activity and mental health
Scottish Natural Heritage	2002	R	report	green benefits to physical active
Paluska	2000		controlled study	association of physical activity and mental health
Kenneth	1999		review	association of physical activity and mental health
Morris	1997	R	review	walking and health
Higgins	1995	R	literature and experience review	benefits of leisure and recreation to health
Esther Suter	1994	R	experiment, observation and assessment	walking, jogging and health
Thomas Stephens	1988	R	secondary analysis of surveys	association of physical activity and mental health
C.B. Taylor	1985	R	review	association of physical activity and mental health

("R" indicates this article is from references of other selected article)

Growing evidence supports the view that exposure to green spaces can strongly promote human health with different kinds of services, and one of these is that green infrastructure provides people space for physical activities. Physical activities are generally recognized to improve health conditions both on physical and mental aspects. Although people may exercise indoor or use exercise machines at home, some prefer outdoor physical activity. Professor J. Pretty in his book called these activities “green exercise” which stands for all sorts of physical activities within green area (Pretty, 2006). But why physical activities are so important to human health?

Consequences of inactive lifestyle and physical health improvement of GI

Many studies focus on the effects of different physical activities on human health. One of the EU (European Union) reports shows that in 2002 two thirds of the adults did not reach level of physical activities, and one in five European people did little or no physical activity at all. This leads to 600 000 deaths ever year in this region and a loss of 5.3 million of healthy life due to disability per year (WHO, 2006). Physical activity has become a public issue because it affects the health a lot and people are not quite aware of its importance. Evidences have shown that physical activities are related to physical health. More precisely, inactive people are twice as likely to contract heart disease than active people, and physical activities also help prevent from stroke and reduce the risk of high blood pressure (WHO, 2006). Overweight and obesity are strongly influenced by physical activities as well. Overweight and obesity occur when intake of energy exceeds total energy expenditure to which physical activity contributes a lot (WHO, 2006). Therefore, physical activities can reduce energy gains and further help control body weight. But less and less physical exercise makes people get more and more weight. Recent surveys show that childhood obesity affects over 17% of American children and causes all kinds of diseases. The fact that they spend more and more time indoors, playing with electronic media and dedicate less time to outdoor activities (Mccurdy, 2010). Moreover, the lack of physical activity can lead to diabetes, which kills many people every year. Evidences indicate that inactive people have 30% more risk of getting type II diabetes than active people (WHO, 2006). Physical activities also contribute to reducing rates of cancer and musculoskeletal related diseases. A recent review of research confirmed that physically inactive people carry higher risks of some forms of cancer than smokers, heavy drinkers or people with a poor diet (Scottish Natural Heritage, 2002).

Mental improvement of GI

Studies also illustrate that healthy physical activities can promote psychological health in many aspects. Outdoor activities help people get rid of the pressure of modern life and relax with nature and reduce mental stress or anxiety (Scottish Natural Heritage, 2002；Thomas, 1988). Pretty (2006) studied and measured the effects of 10 green exercises in four regions of the UK, and found physical activities within green spaces can promote human health and prevents mood disturbances (anger-hostility, confusion-bewilderment, depression and tension-anxiety). His other survey in Zurich, Switzerland also proved that practicing sports in green space have a

positive impact on respondents' level of stress and how balanced they felt. Moreover, sufficient evidence has proven that regular physical activity can help depression symptoms (Taylor, 1985; Kenneth, 1999). However, people who show signs of depression or anxiety more likely to be physically inactive. Paluska suggests that planned aerobic exercise and resistance training can significantly reduce depression symptom (Paluska, 2000). Although physical exercise promotes mental health, the extent to which it impacts people's mental health can vary. A study was carried out to examine the association of physical activities and many aspects of mental health in different population groups in the United States and Canada. The conclusion of the study pointed out to the fact that the influences of physical activity is particularly strong in the case of women and people who are over 40 years old (Thomas, 1988). A survey in the United States on a sample of population aged between 15-54 years old showed that the impact of doing physical activity differs between youth and old. At the same time, this survey provides some evidences that physical activity do effect on depression and anxiety symptom, but it is not quite associated with other psychological disorders (Renee, 2003). Besides mental illnesses or disorders, HEBS surveys demonstrates that physical exercise can also contribute to improve self-confidence and self-esteem, which are recognized as important factors in the individual development (HEBS, 2001b).

Sorts of physical activity in green space

Green infrastructure can provide space for physical activities. Usually, physical activities on green areas include walking, cycling, jogging, and various sports like soccer and skating and games for example flying kite, seesaw and swing. Walking is one of common outdoor physical activities. It is becoming more and more popular as a form of leisure and a valuable form of aerobic exercise (HMSO, 1998). It is strongly recommended to walk on a regular basis as it contributes to the body composition, muscular strength and endurance in adults (NHS Scotland, 2001). Walking and at any pace implies spending energy, which means that it is potentially an effective and long term method for weight control (Morris, 1997). As a clearly form of physical activities, cycling was identified as a means to achieving suggested physical activity level in report of the National Cycling Strategy in 1996, UK (Nick, 2003). But cycling can help improve health in specific ways. For example, the energy expenditure of cyclist depends on a range of factors including speed, weather and road conditions. Variable factors make different levels of activity, which are sufficient to improve physical fitness over a relatively short period of time (Nick, 2003). Except for walking and cycling, studies have been carried out to investigate the relations between human health and other types of physical activity within green space as well, and have proven the positive health benefits related to undertaking physical activity. (William et al, 2007; Suter, 1994).

Thus, physical activity can positively contributes to improving human physical and mental health. It can also reduce the risk of heart diseases, obesity and of the occurrence rate of cancer. In terms of mental health, physical activity mainly

improves the condition of people who are prone to depression and anxiety, but there is no strong evidence that exercise can improve other mental disorders. The method used people's mental condition could be to blame in this case. In fact, a wide range of studies used self-evaluation to measure the benefits of physical activity on the, which is thought not to be entirely objective. These infrastructures represent a better environment for people to undertake physical activity, which implies further has a more positive influence on people's health.

Isolation of Noise

Picture 5: quiet environment (Google Image)

Picture 6: noise pollution (Google Image)

Table. 4 Searching Terms: Green infrastructure, Space, Park. Health, Physical, Mental, Psychological. Noise, Annoyance

Author	Year		Method	Description
Di	2012		field work	influence of combined traffic noise on urban residents
Laszlo	2012		review	effects of rapidly changed noise on health
Nissenbaum	2012		cross-sectional study	influence of industrial wind turbines on sleep quality and general health outcomes
Paviotti	2012		field work	influence of Powered Two Wheelers noise on urban pedestrians
Yang	2011		questionnaire and emotional tests	psychological benefits of green infrastructure
Antonio	2010		field work, questionnaire	relationships between park size, tree cover and noise levels
Chau	2010		questionnaire	exploring the potential modifiers for annoyance
Godson	2009		cross-sectional study	influence of traffic noise on school people
Novak	2009		case study	promotion of green corridor on traffic noise reduction
Jarup	2008		sample tests, data collection	association of long-term noise exposure and hypertension
Gunnarsson	2007		questionnaire, review	association of nearby green space and long-term noise annoyance
Tyrvainen	2007	R	field work, questionnaire and GIS	association of urban woodland and land use planning
Jim	2006	R	questionnaire, field work	use of pattern and behaviour of green spaces
Klaeboe	2005	R	field work	impact of traffic noise on soundscape

("R" indicates this article is from references of other selected article)

Noise pollution is rapidly emerging in urban regions as one of the factors that negatively impact living environments and people's quality of life. Urban citizens are prone to noise pollution generated by industries nearby, transportation, recreation, and even coming from their neighbors. There was news about the noise's effect on human health: A picture shows a woman with depressive expression in a mental hospital, and the news said that this woman was used to work in a company but could not bear the daily noise from typewriter. Eventually, she got mad and was sent to mental hospital. However, is noise a factor influencing people's health? What are the consequences of excessive noise and noise pollution? What resources is noise from in cities? Finally, do green infrastructures contribute to helping people who suffer from noise pollution?

What damages noise can cause to us?

Early in the 1960s, traffic noise has been regarded as a predominant source of annoyance in London and major parts of England. Later, France started to pay attention to noise pollution and noise related problems in the 1970s. Besides, developing countries have been concerned with noise problems in the early 1990s. Nowadays, noise pollution is recognized as an issue worldwide (Mutairi, 2011). High levels of noise can cause physical damages such as hearing impairment and tinnitus, and low levels of noise pollution can also have an indirect impact on human physiological and psychological systems (Godson, 2009; Mutairi, 2011). Evidences usually have correlated noise pollution to higher rates of occurrences of cardiovascular diseases, hypertension, sleep disturbance and annoyance (Laszlo, 2012). For example, Babisch (2008) studied the relationship between traffic noise and myocardial infarction and suggests that noise from aircraft and road traffic may cause hypertension. Moreover, subjects that may cause annoyance and sleep disturbance have already been surveyed (Laszlo, 2012). Actually, many studies identified annoyance as the most important and common psychological impact of noise pollution (Mutairi, 2011; Marco, 2012; Di, 2012; Stansfield et al, 2000; Godson, 2009). In the last 50 years, noisy working and living environment have been identified as an emergent urban problem and are considered a hazard to human health (Stansfield et al, 2000). Besides, exposure to noise can make people irritable and promote depression symptoms, and inflict a sense of vulnerability (Mutairi, 2011; Godson, 2009)). Moreover, Mutairi's study gives evidence that compared with people who stay in a quiet environment; exposure to noisy environment can reduce their sense of vitality which also highlights the fact that people are highly influenced by their surrounding environment (Mutairi, 2011). Godson (2009) studied the effects of noise in campus and demonstrated that along with increasing stress, annoyance and other mental problems, being in a noisy environment can also decrease school performance and impact cognitive functions such as reading, problem solving, word discrimination, memorization and communication. According to these studies above, apart from physical consequences caused by the high levels of noise exposure, low levels of noise exposure in our daily life is considered to decline people's psychological conditions and may further lead to mental disorders and decrease performance. However, it is quite difficult for urban citizens to escape from such

noisy environment because people have to live and work there. The question is how green infrastructures can contribute to improve this situation?

What does location of GI contribute to reducing noise influences?

Many studies have studied ways in which noise can be controlled and some of these studies have focused on the physical control of environmental noise. One of the important ideas is that vegetation has been recognized as a cheap and natural material to reduce noise pollution in comparison with man-made materials such as metal, concrete and plastic. Meanwhile, vegetation barriers to control noise can promote relaxation, satisfaction and well-being (Yang, 2011). A study made hundreds of questionnaires that assessed their mental conditions. Results of this study indicated that green area nearby can significantly affect the noise annoyance and other potential annoyance modifiers includes age, education level, noise sensitivity and health status (Chau, 2010). Gunnarsson (2007) found by comparing two study groups, that the greater availability of nearby green areas plays an important in reducing lone-term noise annoyance and stress-related psychological symptoms. Further, J.A. (2010) explored the relationship between noise level and park sizes and tree density, and demonstrated that noise level can be reduced if the combination of park size and tree density can be taken into account. Vegetation hereby is regarded as an acoustic screen between noise producer and receiver. Another study looked at the psychological benefits of urban parks in reducing noise pollution. A comparison between two study groups revealed that landscape plants can act as a buffer to block noise. The author coined it under the terms of "psychological noise reduction". During the experiments, 90% of the tested subjects agreed that landscape plants reduce the negative influence of noise. Around 80% of participants thought vegetation were the most effective barriers to block noise, and only 10% participants preferred concrete or plastic as noise barriers (Yang, 2011). In fact, the benefits of green spaces at reducing surrounding noise are not only recognized in scientific research but have also been used in planning and construction projects. A green landscape concept has been implemented along the railway leading to the Ambassador Bridge, which is the major crossing point between the USA and Canada. This project aimed to improve both landscape and soundscape of this area through the use of vegetation barriers. While noise was reduced in some areas, it is not enough to bring it below the target of 55dBA, which is normally adopted from the Directive on Environmental Noise in 2002 (Novak, 2009). But the authors confirmed that city soundscape quality can be further improved with the implementation of vegetative planting. Based upon, green infrastructure improved soundscape and people are using these green areas as a break from noisy city life. City planners hereby are exploring ways to positively impact the landscape and reducing surrounding noise.

The importance of soundscape in GI

Studies found that according to the study participants, positive soundscape are usually those linked to hearing natural and human sounds such as birdsong and children playing (Gunnarsson, 2007). People always want to experience freedom from

unwanted sounds like traffic noise, construction noise, and this may indicate that a natural soundscape could contribute to improve living environment (Tryvainen, 2007). Gunnarsson (2007) also suggested that several natural sounds like birdsong, wind in trees and water flowing seem to evoke pleasant feeling, but mechanical sounds like traffic noise, mobile phone, construction and machinery trigger annoyance. It was also found that the more often one can hear children playing the more people trend to make a positive assessment of green areas because they feel this green area may fulfill important social functions by providing places to play, and for adults to meet and strengthen social ties (Gunnarsson, 2007). This may indicate planners that with respect to reducing the negative impact of noise on human health, lowering noise level is not enough. The natural sounds, which are associated with green infrastructures also an important role in the reduction of psychological problems. It is essential to have lower sound levels at residence but also in the close neighborhood to achieve healthy environment (Klaeboe, 2005). Although there are many physical measures implemented to reduce noise in cities like traffic-volume reduction measures, or the use of low noise asphalt, engine noise reduction, many of these measures are limited to political reasons. Therefore, it is necessary to develop accessible noise-free urban green areas close to residences so that people can easily get rid of stress and enjoy a noise-free environment. Elaborated approaches are suggested in the planning, design, management and conservation of green area (Gunnarsson, 2007). For example, planning should integrate the input of stakeholders (Jim and Chen, 2006). Tools like evaluation of green space quality and attitudes, GIS techniques and soundscape design and assessment should be applied to improve the further development of green space (Gunnarsson, 2007).

Perception of Landscape

Picture 7: beautiful landscape (Google Image)

Picture 8: bad-managed landscape (Google Image)

Table 5. Searching Terms: Green, Park, Space, Elements. Perception, Feeling, Preference. Landscape, View. Health, Physical, Mental

Author	Year		Method	Description
Thomas	2006		field work	people's perception and landscape
J. Pretty	2005		field work and experiment	green benefits to physical and psychological active
Maller	2005			
Rachel Kaplan	1987		sample, preference analysis	environmental preference effects
Ulrich	1986		models, controlled experiment	association with natural view and mental health and behaviour
Ulrich	1984	R	controlled experiment	association with natural view and mental health
Walker	1983		review	landscape of urban park
Kaplan	1983	R	case study questionnaire	psychological impact of natural experience
Schroeder	1982	R	field work, controlled experiment	preferred features of urban park and forests

("R" indicates this article is from references of other selected article)

When asked to rate the attractiveness of landscape, people generally prefer natural resource over man-made environment. Evidences of similar preferences for natural environment can be found in a broad range of cultures, which implies that culture does not influence people's visual perception, most can appreciate natural landscape scene (Kaplan & Herbert, 1987; Russ, 1987). But people who live in urban areas have less opportunity than rural people to enjoy such a natural landscape. Green infrastructures therefore provide them with a place to perceive nature. A lot of literature and research concerning the importance of urban parks and green spaces (Kaplan, 1983; Walker & Duffield, 1983) and works on psychological benefits are complemented as well (Kaplan & Talbot, 1983). In rural and urban areas, researchers are convinced that the value of nature is in its ability to offer a restful sanctuary from city life (Russ, 1987). How does one's perception of natural resources actually mean to human health? Studies are not strong enough to indicate that visual perception can directly affect physical health, but it does influence people's mental health, which can further influence their physical health as well (Kaplan & Talbot, 1983).

The benefits of natural landscape

Ulrich's (1984) test suggests that view of a natural landscape can help patients recover faster from illness (Russ, 1987). He compared two groups of cholecystectomy patients and found that patients had access to a view of a natural landscape needed shorter post-operative hospital stays, required fewer potent analgesics and received fewer negative evaluations than the patients who had the view of a brick wall from their hospital rooms (Russ, 1987). Another study examined the mental conditions of two groups of prisoners. Prisoners who could look out onto the yard or had view of nearby farmland and forested areas were reported to be healthier than the prisoners who could not benefit from such a natural view (Russ, 1987). Ulrich further tested the restorative effects of exposure to natural environments more experimentally. Stressed individuals were exposed to simulations of either natural or urban environment, and their recovery conditions were monitored. This research found statistically that the rates of recovery from stress depended on the type of environment exposure. Both physical and mental measures of stress indicate that recovery of stress can be quicker when people are exposed to natural environment (Ulrich, 1986). Today, stress and mental illness are becoming more and more common (Pretty, 2005). According to investigation of the World Health Organization (WHO), depression and depression related illness will become the greatest source of illness by 2020 (WHO, 2001). Fortunately, experiments and tests have strongly indicated that viewing from nature can release symptoms of stress and depression. A person who has view of natural scenes is more relaxed and tend to have more positive attitude than people who have just access to viewing urban landscapes (Russ, 1987). Evidence also shows that exposure to nature can reduce the rates of stress-related hormone (Russ, 1987). In conclusion, viewing natural landscape can promote people's mental health, which mainly includes stress and stress-related illness, depression and anxiety (Russ, 1987; Ulrich, 1986; WHO, 2001; Pretty, 2005). These mental illnesses are usually treated as factors that influence human and physical health as well.

These various research have proven that exposure to natural environment is healthy and many aspects of human being can be improved (Maller, 2005) and meanwhile people do not need to learn to enjoy nature to get these healthy benefits (Russ, 1987). Natural environment can provide relief from mental fatigue partly because they are fascinating and Kaplan also suggests that natural environments are restorative because they are pleasurable environments help to attenuate the pain generated by confusion and uncertainty that accompany mental fatigue (Russ, 1987).

Preference of landscape in GI

But what kind of natural landscape can attract people coming and enjoying the aesthetic? In his research, Pretty distinguished three levels of engagement with nature. The first one is viewing nature which can be physically (e.g. through a window) or through images (e.g. seeing a painting) (Pretty, 2005). Pretty's research group showed adults of different ages, more than 300 pictures of natural or urban scenes. Everyone agreed that the pictures which represented natural resources were more pleasant and attractive. Meanwhile, people preferred various and complex natural landscapes, for instance green vegetation with blue sky, clean water, different types of animals and most of them agreed that pictures which showed rubbish and pollution were unpleasant (Pretty, 2005). Thomas (2006) explored the relationship between landscape and people's perception of nature, in Chicago. His research showed that people prefer more diverse landscape which includes green, woody vegetation and species and is convinced that trees and vegetation contribute a lot to the aesthetic pleasantness and to a sense of wellbeing in the urban environment. Another study was proposed to discover what features make urban parks and forests more attractive. Responses illustrate that the most frequently mentioned features as attractive involved vegetation, and most particularly trees. Water resources, especially lakes, were the second feature most frequently mentioned. People often use the words "nature" "peace" and "quiet" to demonstrate their desirable attitudes. In contrast, the top one frequently mentioned that images featuring manmade objects were less attractive. Then poor maintenance of green areas is thought as unattractive. For example, trash and crowds of people ranked low in people's preferences. This study also showed another opinion of respondents. Although people generally like parks covered with more vegetation, they feel bored and unsafe if the park is too wild and overgrown. Apparently, when seeking to escape urban life in nature, people still keep in mind that forest may be a place where conflict and crime occur (Herbert, 1982). This leaves the suggestion that designers and planners should find a balance between the amount of vegetation found in parks and people's perception of risks.

Based upon these studies, the sight of natural environments can promote human mental health and protect them from mental illnesses, especially depression, anxiety, stress and stress-related illness. Although few evidences show that seeing nature can directly impact human physical health, people are convinced that bad mental condition can lead to physical disorder. Green infrastructures provide such a place for

people who are willing to escape from the hurried life and enjoy nature. A fascinating scenario should include a lot of trees, luxurious vegetation and an isolate, and at the same time this place should be well maintained with low population density and without pollution. On the other hand, overgrown and too wild natural environment can make people feel unsafe because of the potential threat of crime and conflict.

Reduction of Internal Heat

Picture 9: people exposure to sunshine (Google Image)

Picture 10: people enjoy shading under trees (Google Image)

Table.6 Searching Terms: Green infrastructure, Space, Park, Elements. Heat, Energy, Temperature, Urban Heat Island. Health, Physical, Mental

Author	Year		Method	Description
Dominique	2012		case study and experiment test	association of green infrastructure and heat stress
Masson	2012		case study	urban planning of green infrastructure and urban climate and people's health
Georgi	2010		case study	effects of vegetation on microclimatic conditions in urban areas
Wise	2010		review	multiple benefits of green infrastructure
Smith	2008		review	benefits of urban policy and planning to reduce Urban Heat Island
Gill	2007		case study site	exploring the important role of green infrastructure in adapting UHI
Rosenzweig	2004	R	field work, experiment	association of urban heat wave and related morbidity and mortality
Klinenberg	2003		review	urban heat wave and mortality in Chicago
McMichael	2000		review, report	multiple assessments of urban environment and health
Taha	1997	R	review	influences of vegetation cover on UHI
Lougeay	1996	R	field work, experiment	association of spatial temperature and landscape patterns

("R" indicates this article is from references of other selected article)

Urban Heat Island (UHI) is a phenomenon where the temperature in urban area is higher than in surrounding rural area. The temperature variation between city and country, in turn depend on the specific city characteristics. The UHI occurs because manmade construction materials retain energy in the form of heat at daytime, and release it, which keeps city temperature higher at night. Unfortunately, our cities are mainly constructed from these energy absorbing materials like concrete, cement, bricks and other kinds of construction materials (Dominique, 2012). In Melbourne the temperature difference was recorded to be around 3-4 degrees Celsius (Dominique, 2012) and in the UK this temperature difference was reported to reach up to 7 degrees Celsius (Smith, 2008), and the average annual temperature is suggested to increase by 5 degrees by the 2080s (Gill, 2007). Meanwhile, different seasons can influence the UIH phenomenon. A study shows that urban temperature can reach up to 10 degrees higher than in its surrounding rural areas in the summer, but this difference will be much lower in winter time (KIM, 1992). In contract, the effects of UHI are not obvious in rural areas because there are less manmade constructions, and even if it is warm at daytime, temperature will be cooling down during night.

Negative health impacts of high temperature

Recently, due to the increasing rates of urbanization, the impact of urban heat island has become a pressing issue for human health (Tan, 2009). The increased temperatures are associated with the UHI phenomenon and tend to exacerbate the threat to human health posed by thermal stress. Scientists point out that UHI can potentially increase the magnitude and duration of heat waves within urban areas, and by the same token mortality rates are higher during a heat wave. For example, the European summer heat wave in 2003 killed around 35,000 people (Gill, 2007). Moreover, evidence revealed that the UHI effect can be more harmful particularly at night because it deprives urban residents from a moment of cool, which people can get in rural area (Tan, 2009). A study in Italy in 2003 also found that people who live in urban region have higher risk of death compared with people who live in the countryside, and one significant reason is because of the higher temperatures in urban areas (Tan, 2009). Kinenberg (2003) pointed out that heat waves can cause heat stress. When people face heightened temperature, the body may lose its thermo-regulation ability, which leads to elevated body temperature and physiological function breakdowns and worse, death. Evidences show that heat waves are more threatening to vulnerable people in urban regions, such as infants, elderly people, ill people and disabled (Cynthia, 2005; Anthony, 2000). Population may exacerbate the UHI effect. Taha (1997) demonstrated that the UHI effect may increase according to the proportion of air pollutants (for example ozone) (Cythia, 2005). Furthermore, it can influence rainfall and pressure, which are regarded to reduce air pollutants, contributing to increase air pollution (Dominique, 2012).

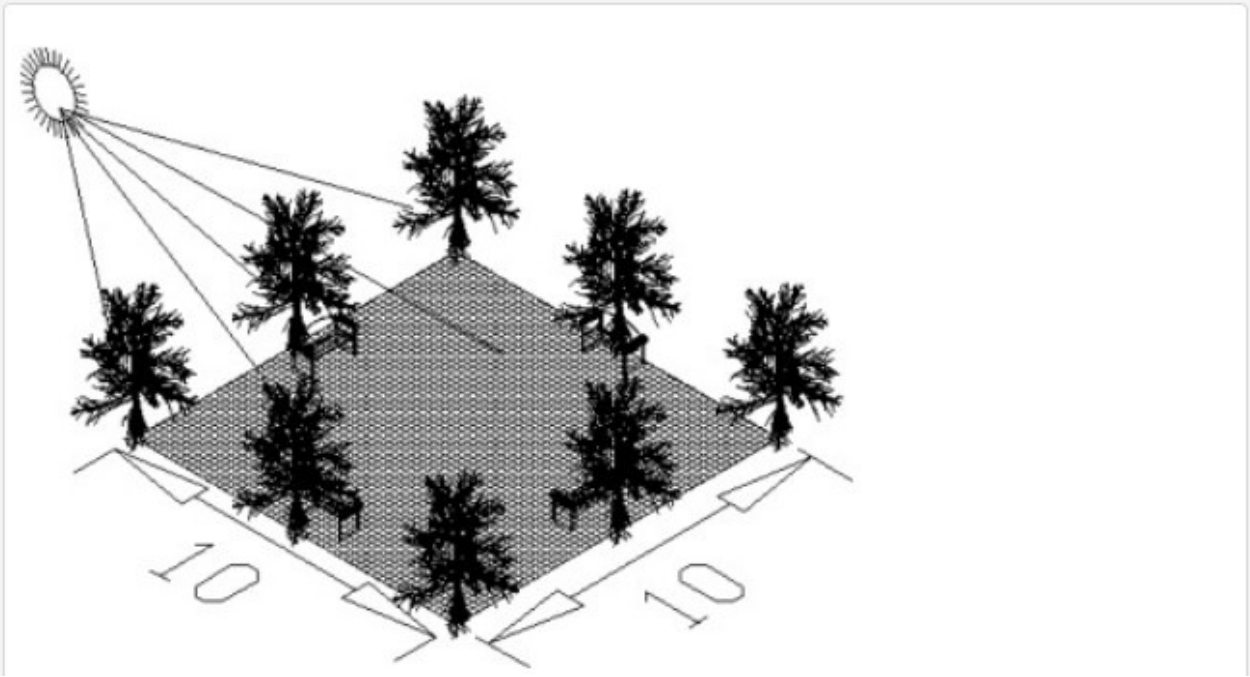
What GI helps

UHI occurs in areas with a high percentage of non-reflective, water-resistant surfaces and a low percentage of vegetation (Cynthia, 2005). Stones and concrete tend to trap

the heat on surface, and a lack of vegetation reduces heat losses because of low evapotranspiration (Lougeay, 1996). Research found that compare with non-reflective surfaces and other UHI factors, vegetation contributes more importantly to decreasing the UHI effect. Areas with more vegetation provide shading, and evaporative cooling effect, rainwater inception, storage and infiltration services within urban environment (Gill, 2007). These cooling functions reduce the negative effects of UHI and further reduce heat stress-related death. Various studies estimated the impact of trees and vegetation and compared non-green cities to greener cities which showed that temperature variation can be as high as 9 degrees. Another study evaluated the benefits of reducing heat events and estimated that 196 premature fatalities can be avoided in Philadelphia if 50% of trees and green infrastructure practices are well-managed in the city (over a 40-year period) (Wise, 2010). Gill (2007) especially mentioned the importance of mature tree (compare to grass and bushes) in playing an role in providing shading areas and cooling. While an individual tree has a negligible impact, overall green and vegetation space can influence city climate significantly (Wise, 2010). UHI also causes air quality to decline because increasing temperatures may elevate the emission of air pollutant through using air conditioning. Trees and vegetation contribute to improving air quality in multiple ways. For example, green areas absorb pollutants, intercept particulate matter and reduce energy consumption. Thus, bringing vegetation into cities may be an approach to decrease the negative effect of UHI and increase air quality and further promote habitats health conditions.

A study case in Paris suggests several ways of improving the UHI and air problems by developing green infrastructure, which integrate parks, trees on the streets and green roofs. Some 125 parks were studied and the research indicated that comparing with the neighborhood built-up areas, temperature in parks can be on average 0.94 degrees cooler during the day time and 1.15 degrees at night. Meanwhile, a park of about 150 hectares can positively impact within a distance of one kilometer (Masson, 2012). Trees on streets and green roofs contribute to the cooling effect, protect visitors from direct solar radiation and reduce energy demand from air conditioning, especially in the summer. Neorgi (2010) explored how vegetation, especially through evapotranspiration, affects people's appreciation of their environments. This study uses an example for green space planning, which is recognized to achieve desirable thermal comfort with creating a more pleasant environment and preventing visit from solar radiation and decreasing local temperature. Figure 5 below is the example of the design. Within an area of 100 m_2, 8 trees are suggested to be planted within 5 m from each other. It is hoped to help the use of green spaces in green planning with the aim to improve human health. But it should be noted that this recommended example is based on the case of Chania, Greece, which should be regarded as a model, which needs to be adapted to local conditions, which include for instance climatic conditions, population density and urban structure.

Figure 5



Part II Characteristics of Green Infrastructure in Planning: Objective 2 and 3

As part I showed, green infrastructure affects human health through five functions: Cleaning air, provide space for physical activity, isolate from noise, more pleasant landscapes and reduction of internal energy. However, characteristics and patterns of green areas are different, which implies that the functional effectiveness is different.

What characteristics of green infrastructure can promote its efficiency in improving human health? To answer this question, a review of recent literature was undertaken and this paper describes the characteristics of green infrastructure. These are generally divided into two categories: (A) relevant characteristics are those that simulate the working of functions of green infrastructure. (B) Relevant characteristics are those that enhance the attractiveness of green infrastructure. Planning and managing the characteristics of category A are actually adjusting the functions (or services) of green infrastructure, which directly influence people who are exposed to green area. For example, residents are reported easier to relax from mental anxiety in green space when there are more trees (Mackay, 2010), and amount of physical activity increases when the green area is larger (Rung, 2011). In terms of category B, people are more willing to visit green space when these characteristics are promoted, namely the visit frequency and number of visitors are influenced by these sorts of characteristics. For instance, with increasing of accessibility to green area, more visitors will more frequently visit green space, which means people probably have more opportunities to be healthy.

The following part is going to touch upon three main characteristics, which are amount of greenness at category A (Vries, 2003; Morris, 2007; Leslie, 2007 and 2010; Herzele, 2011), accessibility (Herzele, 2003; Morris, 2011; Neuvonen, 2007) of green infrastructure at category B and size of green space (Neuvonen, 2007; Maat, 2006; Hillsdon, 2006). Accessibility usually contributes to the frequency of visits of green spaces (Neuvonen, 2007; Wendel, 2012), and greenness is recognized as an important feature of green infrastructure (Almanza, 2012; Fin, 2011). Moreover, although a lot of people recognize that the size of green space is related with visitors' health (Neuvonen, 2007), there is still an ongoing debate about how this characteristic influences our health (Maat, 2006; Hillsdon, 2006). Therefore it is difficult to allocate size of green infrastructure into any category before a scientific agreement is reached.

It should be noted that green infrastructure characteristics are not limited to these three, and many others can be well-designed to promote healthy lifestyle. For example, facility management and quietness of green space are considered characteristics of green space to impact users' health as well. However, it is impossible to encompass all aspects in one study and this paper only focuses on above-mentioned three

characteristics. The following section aims to investigate the influence of these three characteristics on human health and discuss how planner should plan and design them (Grahn, 2010; Wardekker, 2012).

Amount of Greenness and Human health

Table.7 Searching Terms: Greenness, Greener, Amount, Degree. Physical, Mental Health, Stress, Anxiety. Planning, Design

Author	Year		Method	Description
Almanza	2012		GPS data, models, NDVI	physical activity of children and greenness exposure
Mytton	2012		cross-sectional study	between individual physical activity and green space
Paquet	2012		field work, NDVI	between the accessibility, greenness and open space
Pereria	2012		cross-sectional study, logistic regression, NDVI	association with greenness and cardiovascular disease
Richardson	2012		cross-sectional study	relation between coverage and selected morality rates
Fan	2011		modelling, case study	association with greenness and mitigation of stress
Herzele	2011		field work, self-report	relationship between greenness and health and well-being
Leslie	2010		mail survey, NDVI	between perceived and objective measures of greenness
Mackay	2010		quasi-experimental design	degree of greenness and state anxiety
Leslie	2007		mail survey, NDVI	between greenness and physical and mental health
Ralf Hansmann	2007	R	field work	green benefits to physical and psychological active
Thomas	2006		field work	people's perception and landscape
De Vries	2003		multilevel analysis	multiple effects of green space on health
Morris	1997		review	walking and health

("R" indicates this article is from references of other selected article)

Are people healthier when they live with more greenness? It has become a big issue both for residents and urban planners (Vries, 2003). Recent studies also believe that living in greener environment is good for one's health. Furthermore, few studies have aimed at providing a quantitative assessment of greenness, which may help improve spatial planning of green infrastructure. The following part reviews recent studies and answer two questions: will more greenness make people healthier? If so, what should planners do to improve this?

Physical health impact of greenness

The positive health effects of green environments have been found in many studies (Takano, 2002; Hartig, 2003; Mytton, 2012), and people living in green areas have reportedly been feeling healthier than people living with less greenness (De Vries, 2003; Almanza, 2011). In terms of the word "greenness", it is generally considered as the visual green level in green space. For instance, there is no doubt that a green space is greener than a desert area. Therefore, the green level can be different when comparing two green spaces, namely the greenness. Although green infrastructures promote health, recent studies claim that more greenness only brings mental health improvement (Fan, 2011; Mackay, 2010), whereas physical health is not so strongly related to greenness (De Vries, 2003; Leslie, 2007 and 2010; Almanza, 2011; Pereia, 2012; Herzele, 2011; Paquet, 2012; Richardson, 2011). De Vries (2003) systematically investigated the association between greenness and human health. He claims that people living in greener spaces are only found to have fewer symptoms, but did not report any improvement concerning their physical health. It is recognized that, in green spaces, physical health is mainly influenced by physical activity like recreational walking, jogging and cycling. However, more greenness has not been proven to lead to people undertake individual physical activities. Leslie (2010) examined the previous agreement between perceived greenness and an objective measure of greenness. This study compared different groups in variable levels of greenness and illustrates that outdoor space can promote physical activity without being very green. According to this study, individual choice of green space for the purpose of physical activity is not depended on whether it is greener or not. Except for physical activity, studies are performed on association between greenness and physical diseases. Greenness is not found to be significantly related with cardio metabolic health (Paquet, 2012; Pereira, 2012; Richardson, 2012), diabetes, lung cancer and stroke (Richardson, 2012). On the contrary, it is found that mortality rate is higher in greener cities in America (Richardson, 2012). It is estimated that any benefit that greenness offers can easily be destroyed by urban conditions such as greater levels of dependency on car. Similarly, De Vries (2003) also found that urbanization can impact negatively green infrastructure. After comparing the effects on health of three sorts of landscape: forests, blue (e.g. water, river and lake) and agricultural area, agricultural area is considered to be the most beneficial landscape in terms of improvement of health it provides. Unfortunately, urban residents have little opportunity to be involved in agricultural landscape since urban sprawling. There are also studies that argue the opposite (Mytton, 2012; Herzele, 2011; Hansmann, 2007;

Morris, 1997 and 2003). Generally, these studies relate natural environments with physical activity, and claim that more greenness can lead people to be more physical active and further promotes physical health. But evidences are not strong enough that physical active is directly influenced by greenness (amount of physical activity is often influenced by many factors such as dimensions of green space, accessibility)

Mental health impact of greenness

Although there is an argument that more greenness can improve physical health, greenness can significantly promote mental health has been already confirmed, and this is essentially the function of perception of land view of green infrastructure (see part 1: perception of land view). Studies support the evidence that perceiving natural landscape can promote mental health (Kaplan, 1987; Pretty, 2005; Maller, 2005), and recent studies found that more greenness can strengthen it (Herzele, 2011; Paquet, 2012; Leslie, 2007; Mackay, 2010; De Vries, 2003). In Mackay's report, there is a linear relationship between perceived greenness and anxiety reduction. Participants being in greener environments reported to witness a greater reduction in anxiety levels (Mackay, 2010). Moreover, perceived stress and ability to concentrate improve with increased amounts of greenness and meanwhile, citizens in general demonstrate a greater feeling of satisfaction when they are surrounded with more greenness (Herzele, 2011). In order to avoid negative socio-economic impact, Leslie (2007) adjusted these variables and still found that these who perceived neighborhoods as being highly green have 1.60 times more chances to be healthier mentally. People feel less stress, anxiety, and more positive emotion. It is not difficult to find studies relating mental health to natural elements and greenness (e.g. Kaplan, 1987; Ulrich, 1986; Russ, 1987; Pretty, 2007). More greenness seems to be correlated with an improvement of mental conditions in all aspects. This leads planners to explore approaches to improve this function of green spaces.

What city planners should do

Table 8 below shows a study of the amount of greenness in relation to citizens' health conditions. It is obvious that with an increasing number of trees (e.g. from 114 to 334), and associated increased in percentage of greenness (e.g. from 44% to 71%), people in turn tend to feel much healthier (e.g. 30% increase in overall perception of health), happier (e.g. 10% increase) and less prone to stress (e.g. 5% decrease). It should be noted that residents are much more satisfied (40% increase) with more greenness area (see the last line of table 7: amount of greenery). Meanwhile, this table also shows that the amount of time people spend doing physical activity per week increases if they are surrounded with greener spaces. This may because that the bigger and more numbers of neighborhood and city parks attract residents to do more physical activity (Herzele, 2011). According to the results illustrated, urban planners should take into account the influence of greenness when trying to promote residents' mental health. Street trees should be considered more efficient than other types of vegetation like flower bed and green facades. However, it is necessary to note that results of table 8 are based on the case of Ghent, Belgium. The health promotion which people in

Ghent achieve from greenness is probably different elsewhere. During this study, gender, age, education, income, current health conditions and many other factors were taken into consideration (for details, see Herzele, 2011). With so many uncertainties, planners should pay more attention to the local conditions before these recommendations are implemented. Moreover it does not only imply that greenness should infinitely increase. People have reported they felt bored and unsafe considering potential crime and conflict when surrounded with wild and overgrown natural environment (Herbert, 1982). Precisely, when people go to green areas to relax and enjoy nature, they prefer high quality features of vegetation, particularly trees (Thomas, 2006). This requires city planners to explore a balance between greenness, land view and human health and perceived safety.

Table. 8 study of relationship between neighborhood greenness and health (Herzele, 2011)

	More green		Less green	
Visible green elements				
	Number	% of street	Number	%of street
Street trees	334	71	114	44
Flower beds	12	32	9	17
Green facades	50	50	32	33
Accessible green spaces				
Neighborhood park < 1 ha	1		1	
Neighborhood park > 1 ha	1		0	
City park >5 ha, <800 m	1		0	
City park >10 ha, <1,600 m	1		0	
Health and well-being				
	Rating		Rating	
General health (lower is better)	22.9		33.2	
Bodily functioning (lower is better)	1.65		1.68	
Happiness (lower is happier)	1.8		2.06	
Possible mediators				
Overall physical leisure activity, hours per week	1.74		1.61	
Walking and gardening hours per week	1.38		1.22	
Perceived stress	5.29		5.57	
Ability to concentrate (lower is higher ability	5.08		5.13	
Neighborhood satisfaction (lower is higher satisfaction)	1.74		2.12	
Amount of greenery (lower is more satisfied)	1.98		3.32	

Accessibility of Green Infrastructure

Table.9 Searching Terms: Green infrastructure, Space, Area. Accessibility, Access to. Intervention, Barrier. Health. Planning, Principle, Guiding

Author	Year	Method	Description
Bennet	2012	models, field work	accessibility to green space and social interaction
Lottrup	2012	questionnaire	benefits of access to green space at workplace
Wendel	2012	field work, observation, interview	barriers of accessibility of green space
Coombes	2011	GIS, second-hand data	physical activity and obesity and accessibility
Dai	2011	GIS, two-step floating catchment area method, models	measuring the accessibility of green space and disparities
Lwin	2011	remote sensing, GIS, Spatial Web Technology	scoring green space walkability
Morris	2011	review	barriers to accessibility of woodlands and forests
Coutts	2010	cross-sectional study, GIS	accessibility of green space and morality
Kessel	2009	quantitative analysis with GIS, ethnographic research	accessibility of green space and public health
Yin	2009	GIS, case study	measuring the accessibility of parks in Shanghai
Neuvonen	2007	case study	accessibility and the frequency of visits
Hillsdon	2006	GIS	recreational activity and access to green space
Herzele	2003	case study, GIS	qualitative and quantitative monitoring accessibility

Environmental consideration often concern human health and accessibility to public green areas (Neuvonen, 2007). This is regarded as an important approach, which can be planned and improved to promote health conditions. Many recent studies are trying to explore the healthy benefits of the accessibility to green space and the relationship between physical and visual access to green spaces in relation to decreased levels of stress (Lottrup, 2012; Paquet, 2012; Hansmann, 2012), association of physical activity and overweight to green space accessibility (Coombes, 2010; Cavill, 2006; Heritage, 2002; Hillsdon, 2006). Most of them are convinced that more accessible green areas would significantly promote the surrounding residents' health.

The importance of accessibility of GI

Despite the great benefits green infrastructures can provide and important role in improving human health, more and more people fail to achieve these. Studies claim that one important reason is the low levels of accessibility to green infrastructure (Coomdes, 2010; Kessel, 2009; Hillsdon, 2006). Obviously, people achieve nothing if they are not in green space. Therefore, many potential diseases might happen. For instance, more and more people get overweight and obese because of their lack of physical activity (Coombes, 2010). People are stressed more easily concerning work-related issues in urban areas (Lottrup, 2012). Different kind of unexpected unhealthy consequences could come (for details see part 1 green infrastructure functions). Therefore, it is suggested that the increased access to green areas is quite helpful in promoting health in urban regions (Coombes, 2010). Accordingly, many studies were performed on measuring the accessibility of green spaces and the results indicated that although there has been lots of improvement on this issue, it still cannot meet people's demand in many instances. For example, based on GIS technologies, Yin (2009) measured the accessibility of green space in Shanghai, China and indicated that during period of 1986-2002, accessibility was improved. However, there are still residents who cannot access green areas. Similar outcomes have been found in many countries (Wendel, 2012, in Latin America; Lwin, 2011, in Japan; Kessel, 2009, in UK; Coutts, 2010, in America). This requires government and city planners to find solutions concerning ways to increase accessibility of green infrastructure. Generally speaking, the accessibility to green areas means that people are able to see and visit this area without difficulty or barriers (Lottrup, 2012). Several factors are considered to influence the accessibility to green areas. Distance from outdoor green areas is considered to be the most important one (Lottrup, 2012; De Vries, 2003; Coombes, 2010; Kessel, 2009; Hillsdon, 2006; Xu, 2009, Herzele, 2003). Meanwhile, safety in green areas has been reported to significantly affect people's willingness to visit green areas (Morris, 2011; Herzele, 2003; Neuvonen, 2007) and other factors include weather, lack of facilities, costs of visiting and so forth (Herzele, 2003). The following paragraphs concentrate on these factors of accessibility, and explore the planning possibilities to improve accessibility to green infrastructure in urban regions.

How planners should design distance to increase the accessibility of GI

Herzele (2003) stated five important guiding principles in the monitoring of urban green spaces provision. One of these is "*Preconditions for use*" : "The preconditions for use (proximity, accessibility, surface, safety, etc.) should first be considered. If these are not fulfilled, people won't be attracted to green spaces.'' He explains that the deciding factor for people to actually visit green spaces is depending on these preconditions. For example, people who live close to green areas are visiting more

frequently these areas than people who are far away from a green space. Figure 6 below shows the results of a study on the distance to park in relation to the frequency of use (Schipperijn, 2010). The results show that the percentage of daily users drops between 28.8 and 36.9 when the nearest green space is more than 300 m away from home. Moreover, when the green area is 1 km away, the percentage of daily users drops by 2.8 % to 8.5 %. According to most of previous studies, neighborhood green spaces should be located within a 5 minute' walk from people's home, correspondingly within 400 meters (Herzele, 2003; Vries, 2003; Dai, 2011). Task Force (2002) suggests that everyone should live less than 300 m from the nearest green area. Meanwhile, many authors consider that different green spaces have a different walkable area which is partly depending on its size, and it is necessary to consider the amount of green space when evaluating distance of green from residents (Petestio, 2009; Herzele, 2003). After systematically comparing green areas in different countries (the Netherlands, UK, Germany and US), Herzele pointed that city planners should relate the distance to access green spaces to its size and type. Table 8 below illustrates the recommended distances between different sizes of green space and residence, noting that it is based on the minimum requirement according to which every resident should be able to reach at least one green area at each level of the indicated distance and surface (Herzele, 2003).

Figure. 6 (Schipperijn, 2010)

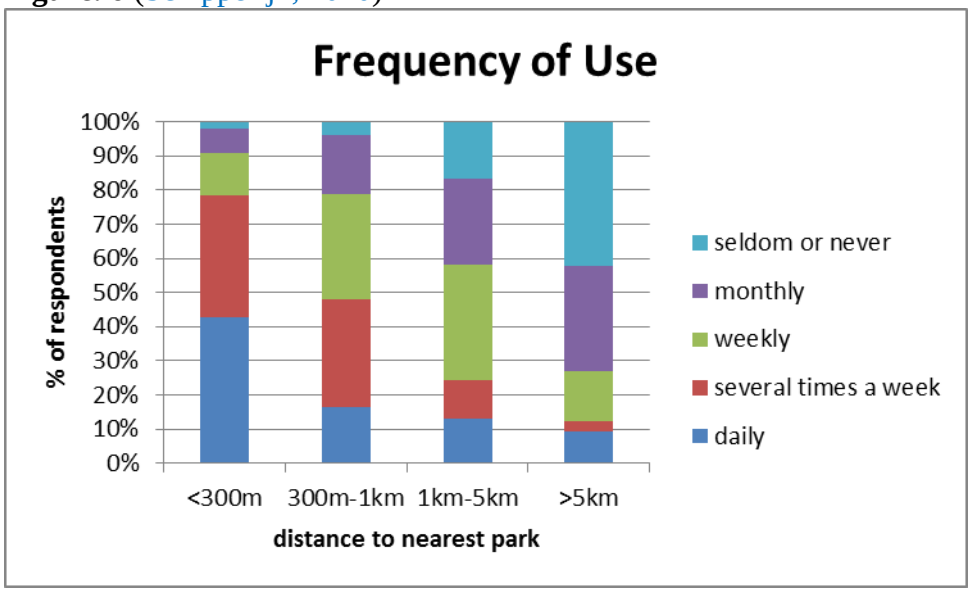


Table.10 Minimum standards for urban green spaces (Herzele, 2003)

Functional level	Maximum distance from home (m)	Minimum surface (ha)
Residential green	150	
Neighborhood green	400	1
Quarter green	800	10 (park: 5 ha)
District green	1600	30 (park: 10 ha)
City green	3200	60
Urban forest	5000	>200 (smaller towns)
		>300 (big cities)

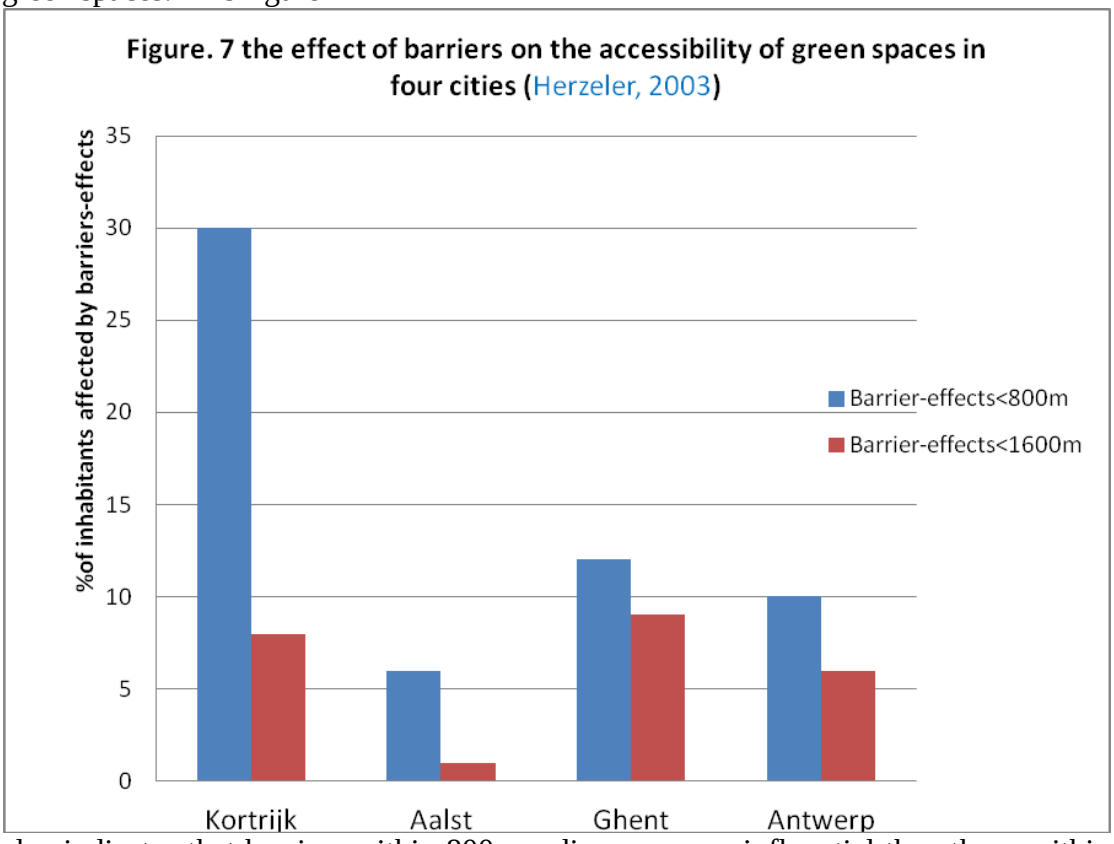
But these references are general standards, which should be adjusted to local specificities (Herzele, 2003; Coutts, 2010). For example, groups of users and

travelling time are suggested to be involved in setting a proper distance (Herzele, 2003; Potestio, 2009; Morris, 2011). Residents who own cars spend less time on the way to green space than students who usually walk or cycle. Studies found that the previous recommended maximum distance of 400 m is not a sufficient criterion to students in primary school, and one of the reasons is that children have less freedom because of increasing traffic (Herzeler, 2003). Besides, planners are suggested to consider many other factors like the age of the users, gender, health condition, educational level, population density and economic conditions (Hofman, 2012; Petestio, 2009; Hillsdon, 2006; Wendel, 2012; Dai, 2011; Herzele, 2003; Neuvonen, 2007). This leads city planners to firstly figure out who are the users of the green spaces before setting the required distance.

How planners should manage urban barriers to increase the accessibility of GI

Although the distance from home is recognized as the main factor that influences accessibility, studies claim that the effects of many other barriers would also seriously prevent people from going to green spaces, especially in urban areas. Figure 7 below shows a study of the effects of barriers on accessibility to green spaces in four cities. We can clearly see that there is a maximum of 30% of urban residents who are affected by barriers, and this significantly decreases the benefits people can reap from green spaces. This figure

Figure. 7 the effect of barriers on the accessibility of green spaces in four cities (Herzeler, 2003)

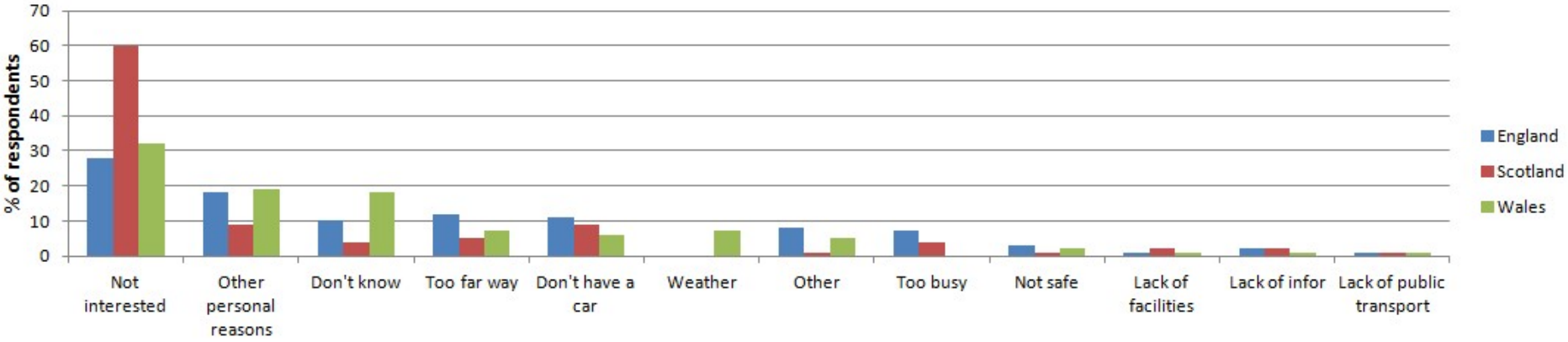


also indicates that barriers within 800m radius are more influential than those within 1600m. This criterion instructs planners to pay more attention to barriers which are situated within a distance of 800 meters from residences. Generally, besides distance, barriers on accessibility are divided into physical and socioeconomic ones. Herzele (2003) considered main linear infrastructures such as railways, navigable waterways, high ways and main roads as physically effective barriers. Meanwhile, traffic intensity, traffic speed and road width are considered to determine effectiveness of physical

barriers on accessibility. In order to solve these problems, urban stucture is recognized the key element. According to figure 6, Kortrijk demostrates a highly inaccessible city, worse than the other three cities and the author's study illustrates this is caused mainly by the results of different urban stuctures. Unlike Antwerp which has a "finger-shaped" urban structure that allows green spaces to be situated closely to the city centre, the "ring-shaped" structure of Kortrijk results in all green spaces being located on the outside of a ring of highways at a distance from urban core (Herzele, 2003).

In terms of socioeconomic influences, Morris (2011) investigated why people do not visit green areas in England, Scotland and Wales. Outcomes are shown below in Figure 8. Except for the top 2 of "not interested" and "other personal reasons", not knowing sufficient green spaces prevents people from benefiting from green areas. Sometimes, people have reported that they are willing to go to green spaces but do not have any idea where they can find a satisfying spot to enjoy nature. Correspondngly, planners should keep in mind that publicizing locations and characters of green spaces is also very important to promote its use frequency. Moreover, it is interesting to note that based upon Morris' s study, a feeling of safety seems not to be a big barrier preventing people accessing green space in England, Scotland and Wales. In fact, less than 5% of respondents reported they are influenced by safty concern. Similar outcomes were conducted by Neuvonen as well. His survey does not show a correlation between the frequency at which people visit green spaces and the notion of safety concerns (Neuvonen, 2007). However, Wendel (2012) claims that feeling unsafe in green spaces will seriously decrease the rates of use, especially for female because they are easier targets of crime such as robbery and violence. This is probably because of different contexts of these cases (Morris, 2011, in England, Scotland and Wales; Neuvonen, 2007, in Helsinki, Finland; Wendel, 2012, in Latin America). Culture, security, legislation, education, social structures and many other factors may make residents feel different about visiting green areas. Further, it leads to variable degrees of accessibility to green area. In most cases, it is a big challenge for city planners to involve such complex relations with accessibility design. Although distance from home mainly determines the accessibility to green space, improving the management of other physical and socioeconomic barriers such as improving access information and tackling the safety issues related to green spaces can play an important role in increasing access to green spaces.

Figure 8. Barriers to visiting woodlands in England, Scotland and Wales (Morris, 2011)



Size of Green Infrastructure

Table.11Searching Terms: Size, Dimension, Parameter, Accessibility, Attractiveness of green space and infrastructure. Health, Physical, Mental, UHI. Planning, Design, Guideline.

Author	Year	Method	Description
Karusisi	2012	Record Cohort Study, models	environmental characteristics and jogging
Rung	2011	case study	features of park and the visitation
Grahn	2010	questionnaire	perceived dimension in nature and stress restoration
Schipperijn	2010	case study	factors influence the use of green space
Schipperijn	2009	case study	factors influence the use of green space
Neuvonen	2007	case study	accessibility and frequency of visits
Hillsdon	2006	GIS	relationship between access and quality of green space with physical activity
Maat	2006	models, data basement	influence of amount of green space on its use
Herzele	2003	case study, GIS	accessibility and attractiveness of green space

An argument about the size of green space and its health influences

Although accessibility to green space is very important to influence the frequency of visits, size of green space also needs to be considered in urban planning. Evidences reveal that by increasing the size of parks, urban residents tend to visit them and more frequently use green infrastructure that are close to their homes. Rung (2011) led an investigation on 37 parks and 154 green activity areas and claimed that characteristics of activity area influence activities within it, and one of these is the size of green spaces. Respondents were found more physically active when they are in bigger green areas. More precisely, Karusisi (2012) explored the relationships between quality of green spaces and jogging behaviors. The size of green spaces was found to influence the probability of people going jogging and the practice of jogging. Compared with people who were close to big green area, people who had access to small green spaces were reported being less willing to go jogging. Moreover, even when they are jogging, the time and energy they spend were less than for those exercising in bigger-green areas. There are more studies that illustrate the positive association between size of green infrastructure and human health both on physical and mental aspects (Grahn, 2010; Schipperijn, 2009 and 2010; Hillsdon, 2006; Refshauge, 2012; Neuvonen, 2007; Herzele, 2003). However some of these studies are very limited in proving the benefits of access to bigger green space, it is mainly because of the complex factors. For instance, Rung (2011) argues that the size of parks is not the only factor to take into account but that others such as the type of activity area, supporting features, genders and the day of use also plays a role. But the results were not conclusive enough to reveal a linear relationship between physical activities in relation to the size of green spaces. Karusisi's (2012) study also includes many social and personal factors like the age and educational level, and this shows that the results of this study can only support the positive relationship between jogging and the presence and quality of green space, but benefits of size of green spaces was not proven separately. Maat (2006) investigated whether people's use of parks and other green recreational facilities was influenced by the amount of green spaces and found there is no obvious connection between the frequency of use and the size of the green area. Similar outcomes came out of Hillsdon' study (2006). With GIS measurement, there was non-significant association between the two factors. He claimed that size of green spaces does not appear to be correlated with population levels of physical activity. It is hard to say which theory is correct since different studies have variable researching contexts and influential factors. One study that shows a positive relationship between the size of green spaces and human health could lead to opposite outcomes if reproduced under different conditions. Therefore, there is still an argument whether the size of green infrastructure is definitely relevant in improving human health. This should be regarded as a further potential research.

Guiding principles of planning size of green space

Although scientists and planners have not reached an agreement on the benefits of big size of green infrastructure, some guiding principles are already put forward to improve urban planning in integrating it. This part temporarily leaves the

above-mentioned argument aside, and discusses the proposed guidelines for the size of green infrastructure. Herzele (2003) suggests that space of green areas is a main quality which should be perceived in a way that "one moves freely without being aware of the limited dimension of green space." A case study in Odense, Denmark reveals the influence on the use of urban green space (Schipperijn, 2010). Table 12 below shows

Size nearest UGS	%	Sig	Odds ratio	N
<1 ha	47.6	0		612
1-2 ha	53.5	0.3	1.31	68
2-5 ha	55.5	0.01	1.53	242
>5 ha	68.4	0	2.55	225

Table 12 potential predictors of the nearest UGS also being the most used UGS (Schipperijn, 2010)

the results, which illustrate the relationship between frequency of use of green infrastructure and size of nearest urban green spaces. The odds ratio for using the nearest UGS being the most used UGS is 2.54 times higher for UGS over 5 ha than area under 1 ha. The outcomes of this study indicate a general trend for the size of green infrastructure. The frequency of visits on a 5 ha green space is much higher than for those who only have a size of 1 ha. Planners should firstly consider setting green spaces that are more than 5 ha to promote the benefits of green elements. However, urban planning is sometimes restricted by many factors such as policy, economic constraints and size of urban areas. Green spaces between 2 and 5 ha could be considered the second alternative when it is difficult to build spaces that are bigger than 5 ha. Moreover it should be always noted that the frequency of use of green is related with the distance to which they are located in relation to residencies. Based on a GIS map, studies reveal that urban green spaces should be at least 5 ha to attract visitors to go past a smaller green space closer by, but this effect starts to decline if the bigger green space is more than 600 m far away from residents (Schipperijn, 2010). Herzele (2003) also argues that the association of size and distance of green space increases the frequency of use. Table. 10 (see part 2: accessibility) indicates the general standars for size and distance of green space. When the park is 5 ha, the maximum distance from residents'home should be less than 800 m (in Schipperijn's study, this number is 600m). Therefore, 5 ha green spaces within a ditance of less than 600m (or 800m) seems to be a guiding principle in planning green infrastracture.

However, this guideline is geared towards cities that have similar contexts and conditions as Odense. In order to implement this guideline elsewhere in the planning of green infrastructure, planners should take into account local contexts. For example, a case study in Shanghai (China) showed that there are not enough green infrastructure in Shanghai to meet citizens' increasing demands (Yin, 2009). Although there are more and bigger green spaces in comparision to Odense, people in Shanghai still feel unable to enjoy the benefits from green spaces. This might be related to the fact that there is higher population density, heavier traffic condition, different urban

structure, higher costs of travelling to green space and so forth. Moreover, the difference of suggested distance between green space and home in Schipperijn and Herzeler's studies may also indicate the influence of local context (Schipperijn, 2010, Odense, Denmark; Herzeler, 2003, Belgium). Therefore, this above-mentioned guideline should be considered as an instruction, and planners should combine it with practical situation to try and fulfill people's interests as much as possible with ultamate aim of improving the benefits of green infrastructure, then further promoting human health in urban regions.

Discussion and Conclusion

Main Findings

This study exposed the relationship between urban green infrastructures and human health, meanwhile proposed both qualitative and quantitative guidelines in order to positively promote health benefits of green infrastructures in the context of spatial planning. In order to achieve those targets, this study firstly explains why green infrastructure is so important to our health. Precisely speaking, what functions (or services) of green infrastructure are beneficial to physical and mental health. Then, three characteristics of green infrastructure were selected and analyzed to help concluding guidelines of green infrastructures planning.

Green infrastructures mainly influence citizens' health through five functions: clean air, noise insulation, provide space for physical activity, perception of natural landscape and reduction of internal heat. People are physically and mentally influenced when they are exposed to green spaces because of those functions. Physical heath, such as physical active and different kind of diseases (e.g. heart disease, lung function etc.al), and mental health such as psychological diseases, were found to improve. Meanwhile, greenness, accessibility and size of green infrastructure should be taken into account for urban planning, because these characteristics are important to greater improve human health if they are well planned.

To scientific research, this study produced an overall of urban green infrastructure in relation to people's health in the context of spatial planning. Studies have already related human health to green infrastructures, but most of them were limited to medical or biological realms and the contributions of spatial planning were rarely considered. And most of these studies focused on very specific aspect of green infrastructure, few of them provided an overall concept on planning of green infrastructure. Therefore, this study bridges the gap between specific influences of urban green infrastructure on health and general overview of urban planning. In realistic, guidelines proposed in this study are expected to serve practical planning situation. For example, the proposed distance of 1 hector green space is less than 300~400 meters from residents, this number can be adopted when planners are going to design the distance of a green space. Moreover, planners might act differently according to this study. They may integrate different functions of green infrastructure together and treat the influences systematically, but not only concentrate on individual ones.

State of This Study

Functions of green infrastructure in this study were divided into two categories (1) functions with mechanisms that are triggered by the existence of the green infrastructure. It concerns the functions 'cleanning air', 'isolation of noise' and 'reduction of internal heat' and category (2) functions with mechanisms that are triggered by active or passive use of the green infrastructure. It concerns the functions

'space for physical activities' and 'perception of land view'. These categories distinguished the five functions of green infrastructure between the contribution to the working conditions of the function and the contribution to the level of use of the function.

Health effect of functions of green infrastructure

According to category 1, urban residents are getting negative influences of health from polluted air, noisy environment and increased temperature, which are considered the production of urbanization. Industrial activity and heavy traffic are the major causes of these environmental issues. These environmental conditions further contribute to greater risks of contracting respiratory, cancer and cardiovascular illnesses. Although many measures (e.g. tightening of vehicle emission, vehicle noise control) have already been implemented, most of them are often restricted to social, economic and political factors. For example, a measure of relieving threat from traffic emission may be difficult to implement because people pay more money for this. Moreover, technical solutions sometimes negatively influence environment as well (e.g. using concrete or plastic materials to isolate noise and reduce effect of UHI can also damage our environment). However, green infrastructures are considered beneficial both to our health and environment (Thomas, 2012). Urban trees and vegetation can sufficiently offer mitigation against urban air pollution through absorbing air pollutants (Nitrogen dioxide, Ozone, Sulphur dioxide and particulates) and releasing Oxygen at the same time. People living close to green area are reported having lower risks to be negatively impacted through urban air pollution, and having more benefits of clean air. Urban green spaces are usually used as barriers and screens located between noise producer and receiver to reduce impact, meanwhile natural soundscape in green spaces can make visitors more easily get relaxation from daily stress. Moreover, high temperature has been found to cause different kinds of diseases such as losing ability to thermo-regulation and heart attack. Direct solar radiation can also cause damages to our health as well such as skin cancer and heat stroke. When being exposed to green space, people can enjoy a cool environment and get rid of influences of solar radiation.

The benefits of "physical activity" and "natural landscape" are depended on whether people actively use green infrastructure. The more frequently they do physical activity and enjoy natural landscape in green spaces, the more benefits they will achieve. Active lifestyle is relevant with both physical and mental health and being exposed to natural is related to mental health. For example, lack of physical activity can lead to heart disease, obesity and diabetes, and beautiful natural landscape can prevent people from depressive mood, annoyance and stress, meanwhile contribute to individual performance.

However, there is still an argument about the benefits of green infrastructure providing space for physical activity. Although studies show that physical activity contributes to our health and green infrastructure provides space for doing this,

evidence is not strong enough to prove that people always prefer doing physical activity in green area. Reviewed studies show that not all of people prefer doing physical activity outside instead of indoor activity. It is reported that some people would like to exercise inside with machines and the reasons that they do not go outside are very complicated and include factors such as the weather, age, gender, free time and so forth. Meanwhile, some studies illustrate that doing physical activity indoor has more benefits than outdoor, and reasons can be professional guidance of cough, special-purpose machines and lower risks of getting hurt during exercise. On the other hand, some studies encourage people to do physical activity outdoor in green spaces, because of the combination of physical and mental health improvement. Therefore, whether indoor physical activity is better than outdoor activity on green area should be further investigated.

Picture 12: light pollution (Feng Tian, author's father, 2013)

What I expected to find

- **A potential function of green infrastructure**

A potential function of green infrastructure can be treated as further research interests–association between light pollution and green infrastructure. Picture 12 above presents such a situation: there is a new-built shopping mall located opposite to my room. Neon lights are kept on every night. Dazzle light seriously declines my sleep quality. With rapid sprawl of urbanization, city residents are getting more and more impacts by artificial light, which is thought to cause both physical and mental damages such as declining eyes sight, insomnia, depression and exhaust. Unfortunately, few studies are found to relate this potential benefit of green

infrastructures in reducing artificial light pollution. According to picture 12, green space might be situated between the lights and house as a barrier, and people can escape from artificial light and enjoy the natural landscape at the same time.

- **Can results of this study be applied elsewhere**

Table. 13 Evidence Assessment of this study

Evidence Score	Evidence Assessment
1	Effect Unknown
2	Effect demonstrated in 1~3 studies
3	Broad evidence for general effect of GI
4	Quantitative relations to urban planning have been found in 1~3 studies
5	Broad evidences to construct spatial planning rules

Characteristics	Reviewed studies	Qualitative relations in studies	Quantitative relations in studies	Score
Greenness	**14**	**9**	**0**	**3**
Accessibility	**13**	**6**	**6**	**5**
Size of GI	**15**	**8**	**2**	**4**

The third research objective of this study is to generate and conclude both qualitative and quantitative guidelines for green infrastructure planning based upon reviewed studies. However, planners should clearly figure out how strong evidences are before they implement those guidelines in practical cases. Therefore, according to table 13 above, reviewed evidences were assessed and scored into five levels, and this method was adopted from Wardekker (2012). For instance, the score of accessibility is 5, which means reviewed evidences are strong enough to instruct urban green infrastructure planning. On the contrary, no quantitative relations between spatial planning and greenness were found in studies but broad evidences for general GI effect, which implies that the proposed guidelines of greenness are qualitative.

Moreover, it should be noted that uncertainties can influence the results of this study. Uncertainties can be numerous. The age, gender, health condition, income, culture, education and even weather can influence the use of green infrastructure. Therefore, city planners should always keep in mind relating these guidelines to practical situation. The method of evidence assessment (table 13) can be also used for uncertainties. For example, impact of health condition of users can be scored according to evidences. The higher the uncertainty is scored, the more attention city planners should pay to its influences.

How can results be applied in planning?

Box 1. General guiding principles for the planning of urban green infrastructure (Herzele, 2003)

> "Citizen-based": As green spaces are intended to support urban population's quality of life, they have to be considered in connection with the places where people live and in a way that reflect their point of view.
>
> "Functional levels": Green spaces inside and outside the city are no substitutes for each other and both are perceived in different ways. Urban greening should be evaluated in relation to the relevant functional scales, ranging from street to city level.
>
> "Preconditions for use": The preconditions for use (proximity, accessibility, surface, safety, etc.) should first be considered. If these are not fulfilled, people won't be attracted to green spaces.
>
> "Variety of qualities": A variety of qualities ensures an array of activities and experiences related to urban green within close proximity to homes and workplaces. Variety is a general aim, if not within one green space separately, at least for the total supply on the different functional levels.
>
> "Multiple use": People use open landscapes, such as parklands, playing fields, forests or farmlands, in and around the cities freely and often without regard to their original purposes. Urban green spaces are seen in a wide scope and include all the open areas, which can be perceived by citizens as contributors to their quality of life.

Box 1. Above is quoted from Herzele (2003) as general guiding principles for the planning of urban green infrastructure. City planners should consider these five guidelines as overall instructions before they design green infrastructures.

More detailed guidelines from reviewed studies both on qualitative and quantitative aspects are listed in table 14 below.

Table 14. Concluded guidelines and the suggested ways of application in this study

Qualitative Guidelines	Ways of Application	Quantitative Guidelines	Ways of Application
Trees are more sufficient to remove urban pollutants	Make people aware	Within an area of 100 meters, 8 trees are suggested to be planted within 5 meters from each other	Incorporate rules into planning

In case of particulates pollutants, shrub is almost equivalent to tree	Provide insight into the effect of adapting GI	1hector GI is suggested to be located less than 300 meters (table 10)	Incorporate rules into planning
Size, growth form and health condition of individual tree are important	Provide insight into the effect of adapting GI	Barriers within a radius of 800 meters should get more concerns	Provide insight into the effect of adapting GI
Selection of vegetation species should be related to local context	Make people aware	"Finger-shaped" urban structure is better than "ring-shaped" urban structure	Provide insight into the effect of adapting GI
Vegetation structure can help acquire more benefits	Make people aware	5 hectors is suggested as the top standards for the size of green space. 2~5 hectors can be the second option	Incorporate rules into planning
Birdsong, water flowing, wind in trees and children playing should be used to create a natural soundscape	Provide insight into the effect of adapting GI		
People prefer various and complex natural landscape	Provide insight into the effect of adapting GI		
Children, women and old people are more vulnerable to high temperature	Make people aware		
the evergreen is more sufficient than deciduous, and palm species are better than conifer	Incorporate rules into planning		

Applications of guidelines in this study are classified into (1) Make people aware, which means the corresponding guideline only aims at increasing people or city planners' awareness but it is difficult to be related to practical planning case. For example, "selection of vegetation species should be related to local context" is not

able to tell how planners should exactly do in planning. (2) Provide insight into the effect of adapting GI. Corresponding guidelines are suggested to provide city planners an overview when they are designing green spaces. For example, “size, growth form and health condition of individual tree” tells planners that the effect of green infrastructure is relevant with these three characteristics of individual tree and selection of trees should be based on them. (3) Incorporate rules into planning. Corresponding guidelines are suggested to provide concrete standards or criterions for green infrastructure planning. For example, the suggested distance of green spaces around 1hector can be considered an instruction for specific planning case.

How could studies be more useful for providing the information I was looking for?

Most of studies I reviewed only provide general and qualitative concepts in urban planning, from which I could hardly conclude specific criterion or standards. On the contrary, some studies focus on field work or case study, and the results of those studies are limited to the contexts of corresponding cases and lead to a question-can these be applied elsewhere? Study would be more useful to my research if it kept a balance between general information and guiding principles of too specific planning case. Moreover, some studies relate human health to green infrastructure and some of them relate green infrastructure to spatial planning. But what I am expecting is that study treats human health, green infrastructure and spatial planning as a whole system and integrates one with each other.

Limitation of this study

This paper frequently mentioned a question: how important it is to relate planning of green infrastructure with local context. What this paper got from reviewed studies might be different if they were reproduced elsewhere. Therefore, proposed guidelines in this paper are not suggested to be directly implemented because of the influences of uncertainties.

Numbers of reviewed articles are very limit. The author is the only reviewer, which means some useful studies might be missed. Meanwhile, it is inevitable to involve some misunderstood views concluded from reviewed studies and sbjective concepts of author himself.

Conclusion

This study allows us to systematically describe the health contribution of green infrastructure, and meanwhile provides an overview of green infrastructure in the context of spatial planning. Concluded guidelines can be applied in future studies or planning cases as general instructions, which should be related to conditions of practical situations.

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