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Article

Engendering Creative City Image by Using Information Communication Technology in Developing Countries

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Abstract

Creativity has been a major key word in the city planning and urban marketing policies all over the world. Arguably, it ensures an image that can ensue marketable branding of a city. Thus, a creative city has major socio-economic implications. However, the question remains how a creative environment in a city can be engendered and an attractive image be built. In the contemporary age, Information Communication Technology (ICT) apparently has increasingly been influencing every sphere of the city functions, and it is hypothesized that it will assist in building a creative image of a city. Therefore, the objectives of the paper are (1) to map the theoretical insights on the concepts of creativity, city image building and branding; and (2) to explore the influence of ICT on developing the image of a creative city. The investigation was conducted by using both qualitative and quantitative research methods. A stimulating mix of literature review and case study analyses were done to develop the concept of a creative city and image building. Besides, using a survey research method and by considering two cities (Bloemfontein in South Africa and Bhubaneswar in India) two case studies were performed to examine how ICT can engender a creative image of a city in developing countries. Findings suggest that although urban creativity is not a revolutionary approach towards urban policies, and there are criticisms against such a concept; distinct images of cities are enforced by (a) economic variables, such as, business environment, entrepreneurship and innovation, availability of knowledge workers and ICT activities; (b) socio-cultural variables, such as, art, culture, receptive attitude, safety and tolerance; and (c) environmental variables, such as, cleanliness, greenery, quality public spaces and tourism. It is also revealed that ICT can play a catalytic role in creative image building as it contributes extensively in the form of enabling a better business environment, bringing social cohesion and multicultural tolerance, promoting tourism and engendering a clean environment. However, the image of every city could be unique depending on the attributes being focused on and reinforced in the development of a city.

Keywords

creative image; city branding; entrepreneurship; environment; ICT; socio-cultural

Issue

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1. Introduction

Of late a unique phenomenon in the city development process is apparently seen across the world. With the inculcation of globalisation and market economy, competitiveness has been engendered among the cities in the globalised world. Cities are found to often compete directly with their peers at both regional and global level (Jiang & Shen, 2010). While certain global cities such as New York, London, and Tokyo compete with each other and their international competitors (Sassen, 1991), cities of Europe become more concerned and alert about the opportunities and competitions arising out of increased European integration. Similarly, cities in the Asian continent such as Beijing, Hong Kong, Singapore and more recently Dubai are seeking to establish themselves at the global level (Jessop & Sum, 2000; Lever, 1993; Shen, 2008; Xu & Yeh, 2005). Furthermore, at a regional level, certain rising cities like Guangzhou and Shanghai in mainland China, and Delhi, Mumbai, Ahmadabad, Pune, Bengaluru, etc., in India, face competition from each other (Jessop & Sum, 2000; Jiang & Shen, 2010; Shen, 2007; Xu & Yeh, 2005). The competition is basically with respect to (but not limited to) attracting foreign direct investment (FDI), national projects, creation of an economic image, attracting tourists, and more recently to becoming smart (Gold & Ward, 1994; Vanolo, 2008). Consequently, many national and local governments have come under intensifying pressure and in turn vigorously responded by incorporating a variety of policies aimed at creating the image of cities, building marketable brands and enhancing their competitiveness (Jiang & Shen, 2010; Shen, 2004, 2007). Even the relatively smaller and provincial cities have entered in this race of image building—particularly in developing countries like India and South Africa. As a result, image building, branding, preferential policies, competition and competitiveness have become important topics of study in the urban planning and development study.

However, many studies have equated urban competitiveness with economic success such as economic outputs, income and employment generation (Jiang & Shen, 2010). Accordingly, efforts were made to create an image and brand of the cities, keeping economic success in view. Besides, spatial development engendering aesthetic appeal and enhancing tourist attractions; social cohesion through encouraging cosmopolitanism; and creativity by inspiring research, innovation, knowledge creation and enhancing art and culture, were loosely integrated in the development process (Florida, 2002, 2003, 2005; Jiang & Shen, 2010; Sassen, 1991, 1999; Vanolo, 2008). However, the scenarios changed with the advent and introduction of Information Communication Technology (ICT). Over the last two decades ICT has invaded almost all spheres of life—particularly in the urban areas. Not only has it blurred the time distance relationship and changed the way almost all the urban activities—including economic and social activities used to be accomplished, but it has also influenced the physical and spatial environment of the cities. Moreover, art, culture, music, sports, research and innovation, to name a few, are also largely influenced by ICT. It is also an accepted fact that ICT will be strengthened further, and more and more urban activities are expected to be performed with the aid of ICT (Van der Vyver & Marais, 2015; Das & Emuze, 2014; Giffinger et al., 2007; Ponelis & Holmner, 2015). As a result, ICT will become pivotal in the overall city development process and realization of creative images of the cities. Besides, as suggested by Batty (2012), the building of cities is a highly complex process and is open to embrace many ideas, elements and technologies. Technology, particularly ICT, has been observed to be—and also testifies in some cases (e.g., Dubai, Osaka, New York, and Singapore) as the symbol of development, power and creativity. Incidentally, extensive research has been done at individual and aggregate level with regards to the domain of ICT as a technology, the use of ICT, and the influence of ICT on socio-economic, recreational and entertainment, tourism and transportation activities. The majority of these studies have been confined to larger cities and to the developed world, although sporadic studies have been conducted by considering lesser cities in the developing or underdeveloped world. Nevertheless, not much investigation has been seen related to the influence of ICT on the development of a creative city image—particularly in smaller and medium cities in the developing world. Thus, understanding of the influence of ICT on developing a creative city image—particularly in lesser known cities in the developing world, is warranted, as such cities also keep similar aspirations. Therefore, this study first mapped the theoretical insights on the concepts of creative city image building and then explored the influence of ICT on developing the image of a creative city. The contributions of this paper are that (1) based on literature, it developed a discourse on creative city image and identified a set of attributes that influence engendering a creative city image, and that (2) it ascertained that ICT is a major influential factor in creating a creative city image—even in relatively not so well known and smaller cities and—thus need to be an important criterion to be considered while developing policies for image building of such cities.

The following sections of the paper elicit the approach of the investigation, mapping of the theoretical insights of an image of a creative city, comprehending the influence of ICT on the creative city image building, discussions and concluding remarks.

2. Approach of the Study

To realize the objectives, both qualitative and quantitative research methods were used. The concept of creative city image and branding was developed through critical review of literature and case study analyses. In addition, a survey research method was used to collect data, followed by quantitative statistical analyses. For this purpose two cities—Bhubaneswar in India and Bloemfontein in South Africa—were taken as case studies.

Bhubaneswar located in the eastern region of India, is one of the fastest growing medium sized cities of the country. An unprecedented demographic, spatial, economic, commercial and industrial growth has been experienced in the city during the last decade and a half. More importantly, the city has gradually transformed from being a small provincial administrative capital to being a hub of higher education and ICT based industrial activities. A significant number of institutions engaged in knowledge creation and industries engaged in ICT oriented activities and knowledge economy is located in the city. Consequently, the city has become one of the major urban centers in the eastern region of the country, and the Government of India has recently declared it to be developed as one of the smart cities of the country. Bloemfontein is the capital of Free State province and one of the three national capitals—judicial capital—of South Africa. In 2012, the erstwhile Mangaung (the native name of the Bloemfontein city) municipality has become the Mangaung metro municipality with the incorporation of the two towns such as Thaba 'Nchu and Boshabelo as well as other smaller settlements in and around Bloemfontein. Consequently, Bloemfontein has become the largest constituent of the newly formed metro municipality. The city encompasses two large universities and a number of well-known schools and health facilities. It is the hub for knowledge oriented activities and health facilities of the central region of the country. Besides, a significant amount of ICT oriented activities are being incorporated in the city. Moreover, the city development authority—the metro municipality—has envisaged to transform the city into a vibrant and sustainable world class city. Although, these two cities do not have any kind of noteworthy image and are not well known internationally, they have become competitive at the national level in their respective countries. Furthermore, their city development authorities have envisaged transforming these two cities to world class cities in a foreseeable period (IDP, 2015; City Development plan, Bhubaneswar, 2006). Therefore, these two cities become ideal candidates for this investigation in the wake of similar aspirations of a number of cities in developing countries.

To collect data, a survey was conducted among the stakeholders and common people by using pre-tested questionnaires and by applying a random sampling process. The stakeholders constitute academicians, urban planning professionals, engineers, architects, city development officials, students, business men, merchants, personnel from ICT industry, people from advertising and image building industry, politicians, and municipal councillors. Besides, common people aware of the city development and image building process were selected for the survey. The selection of respondents was done by personal contacts after initial scrutiny of their awareness of and engagement in the city development and image building process. During initial scrutiny, care was taken to observe the personal profiles and professional activities of respondents and their engagements with regards to city development, creativity and creative city image and to avoid personal bias, prejudices and affiliation with the investigator. The searching of profiles was done by using online search engines like Google, contacting relevant organisations and institutions, and examining various promotional materials, and advertisements available at the study area level. Then, from the search and subsequent scrutiny, a list of 550 people (prospective respondents)—which includes both professionals and common citizens who are either aware of or engaged in the city development process, creative activities and the creative image of cities—was drawn by using a random sampling process. Once the list of prospective respondents was drawn, they were contacted via telephone, e-mail (if available) or personal contacts visiting them, to determine their suitability for the survey and to invite them to participate in the survey if found suitable. While selecting respondents, care was also taken not to discriminate against or exclude any person based on his/her race, gender, religion, social and economic status, occupation and similar attributes. Of the total contacts made, about 378 people (68.72%) responded positively and gave their consent to participate of which 38 people later withdrew. Eventually, the survey was conducted among the willing participants (with total sample size of 340–210 from Bhubaneswar and 130 from Bloemfontein) by using a pretested questionnaire. Table 1 presents the various demographic and professional attributes of the respondents. Of the total number of respondents about one third are professionals and the remaining two thirds are common citizens. The gender, age and professions of respondents are also proportionately distributed, thus avoiding any bias in the sampling process towards a particular segment of people in both cities.

The various variables to be investigated were compiled from the established literature and scrutinised for their relevancy both to the investigation and the study areas. The variables investigated include economic variables, such as business environment, entrepreneurship and innovation; availability of knowledge based activities as well as knowledge workers; socio-cultural variables, such as architecture, heritage, culture, receptive attitude, social cohesion, safety and tolerance; and environmental variables, such as cleanliness, greenery and tourism, quality of public spaces and spatial hotspots (Batty, 2012; Florida, 2005; Gertler, 2004; Gold & Ward, 1994; Giffinger et al., 2007; Kavaratzis & Ashworth, 2005; Lalli, 1992; Landry, 2006; Landry & Bianchini, 1995; Moser, 2010; Peck, 2005; Sassen, 1999; Shields, 1991; Vanolo, 2008). As mentioned earlier, ICT has also gained significance in every sphere of life including social, economic, transportation, education, health, tourism, recreation and entertainment activities to name a few. Availability of ICT facilities and services—particularly in urban areas—has become an essential requirement for smooth functioning of daily urban life. Internet connectivity such as broadband, wi-fi (wireless internet connectivity), internet hotspots, and associated digital technology related equipment and accessories such as computers, laptops, smart mobile phones, tablet computers, GPS instruments, smart watches, and similar gadgets have become an integral part of human life through which the majority of socio-economic and related urban functions are being performed by people. The presence of such ICT related facilities and equipment and their service quality also develop an image of a place. The availability of technological variables such as ICT facilities, penetration of ICT in urban activities, quality of ICT facilities, and level of use of ICT facilities in urban areas as well as how ICT influences the economic, socio-cultural and environmental variables in building a creative image of a city (Van der

Table 1. Profile of respondents.

Profession		
	Share	
Category	Bhubaneswar	Bloemfontein
Academicians	12 (5.7)	6 (4.6)
Urban planning professionals	5 (2.4)	3 (2.3)
Engineers	4 (1.9)	4 (3.1)
Architects	5 (2.4)	2 (1.5)
City development officials	6 (2.9)	4 (3.1)
Students	16 (7.6)	12 (9.2)
Business men, and merchants	5 (2.4)	4 (3.1)
Personnel from ICT industry	6 (2.9)	4 (3.1)
People from advertising and image building industry	3 (1.4)	2 (1.5)
Politician, municipal councillors	7 (3.3)	3 (2.3)
Total professionals	70 (33.3)	44 (33.8)
Common citizens	140 (66.7)	86 (66.2)
Total	210 (100.0)	130 (100.0)

Gender		
	Share	
Category	Bhubaneswar	Bloemfontein
Male	134 (63.8)	81 (62.3)
Female	76 (36.2)	49 (37.7)
Total	210 (100.0)	130 (100.0)

Age		
	Share	
Age group	Bhubaneswar	Bloemfontein
15–24	34 (16.2)	18 (13.8)
25–35	71 (33.8)	51 (39.2)
36–50	62 (29.5)	40 (30.8)
51–60	38 (18.1)	16 (12.3)
> 60	9 (4.3)	5 (3.8)
Total	210 (100.0)	130 (100.0)

Note: The numbers in brackets show values in percentage.

Vyver & Marais, 2015; Das & Emuze, 2014; Giffinger et al., 2007; Ponelis & Holmner, 2015; Yang & Meng, 2001) were investigated. The data collected was quantitatively analyzed by use of descriptive statistics, development of a perception index (PI) (Das & Emuze, 2014; Lambsdorff, 2006; Nardo et al., 2005; Saltelli, 2007), and significance tests. In addition, qualitative discussions with some stakeholders such as urban planning professionals, decision makers, academicians and people engaged in image building and branding were done through non structured interviews to corroborate the findings of the study and understand the threshold of the indices.

The perception index (PI) was measured by using the model given in Equation 1:

$$PI = \frac{\sum W_i \times N_i}{\sum N_i} \tag{1}$$

Where W_i is the perception index values assigned by the respondents for each variable in a scale of 0 to 1. N_i is the number of respondents assigning a particular index value.

3. Theoretical Insights to Creative City Image

According to Batty (2012) and Miller and Page (2007), the science of building cities is highly complex; yet sufficiently open to embrace many different approaches and ideas. It has been recognised that cities accept innovation—rather they are the crucibles of innovation and engender surprises (Batty, 2012). The functions of the cities in space and time are based on a multitude of processes of spatial choice in which individuals and groups in the population locate with respect to one another and their wider activities in the form of land use types. These activities are apparently controlled by trade-offs between economic and non-economic activities. Consequently these trade-offs lead to patterns of activity that reflect different spatial, socio-economic and environmental images and also develop spatial patterns (Batty, 1971, 2012; Shields, 1991; Vanolo, 2008). The image creation attributes not only include the visual images, but also many other elements such as aspects relating to the symbols embodied in the material components of the city (roads, monuments, and buildings). In addition, many immaterial components such as the habits, routines, institutions and organizations regulating the life of the inhabitants are part of this image. Furthermore, discourses about the city, typecasting of the attitudes of the inhabitants, and descriptions in tourist guides, movies, slogans, and local marketing campaigns also enforce the creation of a city's image. These spatial patterns, socio-economic and environmental attributes and metaphorical attributes create different images of the cities by which they are identified in the longer run. Moreover, the construction of images of cities is generally analysed from perspectives such as (1) the internal image: perceived and reproduced by the local actors of the city, those who identify with the geographical identity of that particular place (Lalli, 1992); and (2) the external image: the perception and representation of the city by (and for) people and organizations more or less extraneous to local life and symbols (Entrikin, 1990; Shields, 1991; Vanolo, 2008). However, it is argued that the external images are frequently regarded as vague, abstract, and simplistic (Entrikin, 1990; Shields, 1991; Vanolo, 2008). Conversely, these images are essential as they enable the urban planners and city development authorities to organize information, formulate generalizations and expectations, and guide further actions like the choices made by tourists and investors (Entrikin, 1990; Shields, 1991; Vanolo, 2008). More importantly, these considerations have given rise to interests and efforts of many cities in branding (i.e., building positive and charming images) (Kavaratzis & Ashworth, 2005), which could act as an important tool to attract flows of tourism and investments, to name a few, and to promote local development (Gold & Ward, 1994; Vanolo, 2008).

According to Gertler (2004), many cities in the post-industrial era attempted to make places attractive to a target audience, for example, to the artistic communities, who have a preference for vibrant artistic networks, who seek a climate that offers support to their arts and offers a good and affordable quality of life. Creative image of cities is an outcome of such processes depending on the activities they perform and attributes they possess (Shields, 1991; Vanolo, 2008). For example, New York is known as the financial capital of the world; more recently Dubai is acknowledged as the world's top immigration hub (Benton-Short, Price, & Friedman, 2005) as its rulers sought to make this condition a brand of the Middle-Eastern metropolis (Acuto, 2010); Osaka is known as the intelligent city; Amsterdam caught the attention for its ports and capacity to conduct world trade; Florence captivated people through its painting, sculpture, crafts and even the technology of the era (Hall, 1998; Savitch, 2010); and most recently Putrajaya in Malaysia reflects the changing national priorities and understandings of national identity (Goh & Liauw, 2009; Moser, 2010).

Towards the end of the last millennium and start of this millennium, classical works of Florida (2002, 2003, 2005), Landry (2006), and Landry and Bianchini (1995) emphasized the idea of the 'creative city'. Later on, with the passing of time, creativity has become an important buzz word in urban planning and more importantly in urban-marketing policies across the world. In its simplest form it is argued that capitalist development has moved to a new distinct phase, where the driving force of the economy is no more technological or organizational, but human (Peck, 2005; Vanolo, 2008). According to Peck (2005), in such a framework a key question for urban planning refers to the possibility of promoting creative environments and 'cool city' images. Central to this framework remains the availability and presence of creative professionals, and formation of an attractive and inviting environment for these professionals, which include knowledge workers, researchers, innovators, artists, and so on. For example, ICT professionals and knowledge workers who remain as the backbone of ICT activities that influence economy and society through business, productivity, social contacts, education and creativity, to name a few, have distinct aspirations, needs and ways of life. They also act as a driving force to transform the society, enable socio-economic growth of a city and also engender a creative city image (Van der Vyver & Marais, 2015; Castells, 2000; Das & Emuze, 2014; Andoh-Baidoo, Osatuyi, & Kunene, 2014; Ponelis & Holmner, 2015; Rantanen, 2001; Yang & Meng, 2001). Thus, the availability of ICT professionals and knowledge workers in cities offers distinct images to the cities. Therefore, it is argued that creative professionals possess unique characteristics and their motivations are different from normal people of the cities. They are the actual producers of new values that reshape the world, and place their cities at the cutting edge of change (Friedmann, 1986; Sassen, 1991). Such creative professionals are not merely motivated by material rewards of economic and financial benefits but seek to live in quality, creative, tolerant and exciting places (Peck, 2005; Vanolo, 2008). Scholars like Florida (2002, 2005), affirmed that this creative class is attracted by such places, thus development of such places fit within the theoretical framework of building cities based on external and internal images.

Florida (2002, 2005) argued that creative city policies should aim at the construction of desirable environments for the creative class and the display of the creative image of the city; although such policies may be elitist selective policies, which include speculative real estate development, gentrification, enhancement of specific neighbourhoods, and construction of landmarks designed by famous architectural stars (Peck, 2005). On the contrary, Sandercock (2003) argued that creative in terms of promotional policies and urban branding means a set of practices of selective story telling aimed at creating an intended understanding and impression on the potential visitors, investors or even inhabitants (Vanolo, 2008). Thus, the issues emerge that engendering creativity, development of a creative city image and city branding have become part of the city development process. Creativity is related to economic development, attracting investment (FDI), enhancing tourism and attracting skilled and creative workforce to a city. Many cities across the world and in developing countries like India and South Africa keep the aspirations to transform their cities and build a creative image, which is evidenced from their policy and programmes (IDP, Mangaung, 2015; City Development plan, Bhubaneswar, 2006). However, efforts to develop such images and branding are being made based on the core theoretical arguments of creative city approach, although these theoretical approaches have often been criticized as elitism, ambiguous and being based on incongruent data (Peck, 2005; Scott, 2000, 2006; Vanolo, 2008). Besides, despite the incorporation of the influence of ICT and consequent rapid change in urban activities in cities, approaches by considering ICT as a core element in creative city image creation and branding are scarce. Therefore, although creative image implies the creation and representation of environments perceived as suitable for creative industries, both by city users and external actors (Vanolo, 2008), there is yet a necessity to explore how ICT should act as a catalyst to engender a creative city image in developing countries.

4. Results and Discussion

The images of creative cities were evaluated by considering the various influential economic, socio-cultural, environmental and technological variables that prompt a creative image of a city. Consequently, the evaluation was conducted under two aspects such as (1) the influence of economic, socio-cultural, environmental and technological attributes of the city in engendering a creative city image, and (2) the influence of ICT in reinforcing the economic, socio-cultural and environmental attributes to induce a creative city image. The analysis of a creative city image scenario was done based on the measured perception indices (PI); significance tests (p-values based on t-tests) between the perception indices of various economic, socio-cultural, environmental and technological variables and perception indices obtained from evaluation of responses received from the survey on the overall image of the two case study cities considered in the study. The analysis of both cities was first done separately and then in combination to obtain an overall picture.

4.1. Influence of Economic, Socio-Cultural, Environmental and Technological Variables on Creating an Image of Cities

Table 2 presents the level of influence of socio-economic, environmental and technological variables in developing an image of a creative city for both Bhubaneswar and Bloemfontein separately and then in combination. The high Cronbach α values (ranging between 0.84 and 0.89) of the different variables indicate that the data is reliable and can be used for further analysis. The low SD values (ranging between 0.12 and 0.23) indicate the consistency in the responses, so eliminating the prejudices and biases. A perception index higher than 0.6 is also considered as the threshold value for enforcing a positive creative city image based on the opinions of the stakeholders[1].

Under economic attributes it is found that in Bhubaneswar city, business environment, availability of knowledge based activities, and availability of knowledge based workers (with PI>0.6 and p-values for both one-tailed and two-tailed <0.05 for α<0.05) create a positive image of a creative city. However, lower PI values

[1] Based on the perception of urban development professionals, experts and decision makers.

Table 2. Level of influence of socio-economic, environmental and technological variables in developing an image of creative cities.

Attributes	Bhubaneswar		Bloemfontein		Overall	
	%	Perception index (PI)	%	Perception index (PI)	%	Perception index (PI)
Economic attributes						
Business environment	59.3	0.62*	47.6	0.49**	54.8	0.57**
Entrepreneurship	57.8	0.59**	45.8	0.48**	53.2	0.55**
Innovation	37.6	0.33**	46.6	0.48**	41.0	0.39**
e-Commerce	43.2	0.45**	41.6	0.44**	42.6	0.45**
Availability of knowledge based activities	72.4	0.76*	54.3	0.56**	65.5	0.68*
Availability of knowledge based workers	68.4	0.72*	52.7*	0.54**	62.4	0.65*
Activities relating to arts	62.5	0.66*	57.4	0.60*	60.6	0.64*
Cultural activities	75.8	0.79*	61.2	0.64*	70.2	0.73*
Availability of architectural elements	84.7	0.88*	55.6	0.57**	73.6	0.76*
Socio-cultural attributes						
Inclination of people towards building and architectural elements	67.6	0.69*	74.2	0.76*	70.1	0.72*
Creation of symbolic elements	72.7	0.74*	72.9	0.75*	72.8	0.74*
Receptive attitude	67.4	0.71*	66.8	0.69*	67.2	0.70*
Tolerance	69.8	0.73*	65.7	0.67*	68.2	0.71*
Safety	71.6	0.74*	56.3	0.59**	67.6	0.70*
Environmental attributes						
Clean environment	58.3	0.62*	75.2	0.79*	64.8	0.69*
Availability of greenery	54.7	0.57**	68.9	0.71*	60.1	0.62*
Level of tourism activities	84.8	0.87*	36.6	0.39**	66.4	0.69*
Availability of quality public spaces	62.5	0.65*	60.4	0.61*	61.7	0.63*
Availability of spatial hotspots	56.3	0.58**	57.6	0.59**	56.8	0.58**
Technological attributes						
Availability of ICT facilities	68.7	0.69*	76.9	0.79*	71.8	0.73*
Penetration of ICT in urban activities	62.6	0.64*	75.8	0.78*	67.6	0.69*
Quality of ICT facilities	48.6	0.50**	65.8	0.68*	55.2	0.57**
Level of use of ICT facilities in urban activities	45.5	0.47**	72.7	0.74*	55.9	0.57**

Notes: Cronbach α range: (0.84 to 0.89), SD range of PI: (0.12 to 0.23); *p (one-tailed and two-tailed) <0.05 for α<0.05, statistically significant; **p (one-tailed and two-tailed) >0.05 for α<0.05, statistically insignificant.

of innovation, entrepreneurship and e-commerce do not portray such an image, which is corroborated by the significance test results (p-values for both one-tailed and two-tailed >0.05 for α<0.05) (Table 2). In Bloemfontein, none of the variables under economic attributes indicate that they foster any positive image of a creative city (PI values for all variables <0.6 and p-values >0.05 for α<0.05). Moreover, in the current state, the overall status of business environment, entrepreneurship, e-commerce and innovation are barriers against developing a creative city image (Table 2).

In Bhubaneswar, all the socio-cultural variables such as activities relating to arts, cultural activities, availability of architectural elements, inclination of people towards building and conserving architectural elements, creation of symbolic elements, receptive attitude, tolerance and safety have higher perception indices (PI values >0.6). Besides, the relationship between the creative image indices and PI of these variables is statistically significant (p-values for both one-tailed and two-tailed<0.05 for α<0.05). However, in Bloemfontein all the socio-cultural variables other than safety and availability of architectural elements convey a creative city image (PI values >0.6; p-values for both one-tailed and two-tailed <0.05 for α<0.05). Perceptions of poor safety and lack of architectural elements in the city do not symbolise the city as a creative city (PI< 0.6; p-values for both one-tailed and two-tailed >0.05 for α<0.05). Overall, the socio-cultural attributes promote an image of a creative city.

Environmental attributes show mixed indications in both the cities. Lack of availability of adequate greenery and lack of spatial hotspots in Bhubaneswar, and lack of significant tourism activities and lack of availability of spatial hotspots in Bloemfontein (PI values <0.6, supported by p-values >0.05 for α<0.05) act as challenges in fostering an image of creative cities. However, tourism activities, clean environment, and quality of public spaces in Bhubaneswar engender a creative city image. Similarly, clean environment, availability of greenery and quality of public space are the most notable variables which prompt the creative city image in Bloemfontein.

Under the technological attributes, all the four variables such as availability of ICT facilities, penetration of ICT in urban activities, quality of ICT facilities and level of use of ICT facilities in urban activities (PI values >0.6, p values for both one tailed and two tailed <0.05 for α<0.05) are found to posit a creative city image in Bloemfontein. In Bhubaneswar in contrast the quality of ICT facilities and level of use of ICT facilities in urban activities (PI<0.6, p values >0.05 for α<0.05) act as barriers against building a creative city image in the city.

As both the cities are similar in characteristics and have similar aspirations, it is found that overall the availability of knowledge based activities, and knowledge based workers under economic attributes; all the socio-cultural attributes; clean environment, availability of greenery, level of tourism activities and availability of quality public spaces under environmental attributes; and availability of ICT facilities and penetration of ICT in urban activities create an image of a creative city. However, challenges remain in other variables with respect to business environment, entrepreneurship, innovation, e-commerce, availability of spatial hotspots, quality of ICT and level of use of ICT facilities in urban activities. Thus, as evident from this analysis, both cities have significant potential to create an image of a creative city respectively despite a few challenges.

4.2. Influence of ICT on Creative Image of Cities

As both cities have significant potential to develop the image of a creative city, and in recent years ICT has become an influential factor in every urban activity, it was essential to explore how ICT is engendering a creative city image in both the cities. Before evaluating the influence of ICT on a creative city image, data was checked for consistency and reliability. The high Cronbach α values (ranging between 0.84 and 0.89) and low SD (ranging between 0.11 and 0.24) of different variables indicate that the data is reliable and consistent and can be used for further analysis. Table 3 presents the level of influence of ICT on the different economic, socio-cultural and environmental attributes, which enable a creative city image. The evaluation was made by considering to what extent ICT is enhancing or enabling or reinforcing the various attributes in the cities. The results revealed that ICT reinforces economic attributes such as knowledge based activities and assists in attracting knowledge based workers to both the cities. Additionally it enables a better business environment in Bloemfontein (PI values >0.6; p-values one-tailed and two-tailed <0.05 for α<0.05). On the other hand ICT does not have much influence on enhancing entrepreneurship, encouraging innovation and enhancing e-commerce (PI<0.6; p-values one-tailed and two-tailed >0.05 for α<0.05) in both cities.

Besides, ICT is found to augment activities relating to arts, boost cultural activities, stimulate creation of symbolic elements, develop receptive attitude, imbibe tolerance, and enhance social cohesion (PI values >0.6; p-values one-tailed and two-tailed <0.05 for α<0.05) in both cities. However, it does not have much influence in promoting architectural elements, encouraging people towards building and conserving architectural elements and improving safety in both cities as seen from the PI values and significance tests (PI<0.6; p one-tailed and two-tailed >0.05 for α<0.05).

Environmentally, ICT assists in encouraging tourism activities, promoting public spaces and creating spatial hotspots in both the cities (PI values >0.6; p-values one-tailed and two-tailed <0.05 for α<0.05). Additionally, ICT also fosters greenery and clean environment in Bloemfontein. A discussion with stakeholders such as municipal officials, councillors and ICT professionals corroborated this finding as information transferred through ICT regarding environmental protection, assists in creating cleanliness and engendering greenery[2]. Contrary to this, ICT does not promote a clean environment and greenery in Bhubaneswar as people remain unmindful of the promotional activities related to environmental protection[3].

A close examination of the influence of ICT on various attributes show that ICT has a similar influence in both cities but for a few exceptions. The performance of the majority of attributes indicates that ICT is pivotal in developing a creative city image in both cities. As seen from the overall evaluations, ICT enables a better business environment, reinforces knowledge based activities, and attracts knowledge based workers under economic attributes. It promotes almost all socio-cultural attributes except promoting architectural elements, offering encouragement to people for building and conserving architectural elements and improving safety. It also assists in engendering a clean environment, encouraging tourism activities, promoting public spaces and creating spatial hotspots, although fostering greenery remains as a challenge. Thus, it is evident that ICT has significant influence on drawing a creative city image. However, it is also evident that despite the similarities between the two cities with regards to their attributes in creating a creative city image, the presence of certain distinctive attributes and the varied level of influence of ICT on these attributes prompt for unique images of the cities based on the policies and paths they follow. For example, whereas ICT influences extensively in enabling business environment and promoting greenery and cleanliness in Bloemfontein, it attracts knowledge workers to- and promotes tourism significantly in Bhubaneswar.

[2] Opinion of common people and municipal officials.
[3] Opinion of municipal officials and councillors.

Table 3. Level of influence ICT in developing a creative image.

Attributes	Bhubaneswar		Bloemfontein		Overall	
	%	Perception index (PI)	%	Perception index (PI)	%	Perception index (PI)
Economic attributes						
Enabling better business environment	55.3	0.58**	72.7	0.76*	62.0	0.65*
Enhancing entrepreneurship	54.2	0.56**	55.7	0.58*	54.8	0.57**
Encouraging innovation	42.6	0.46**	56.4	0.58**	47.9	0.51**
Enhancing e-commerce	56.8	0.59**	54.9	0.57**	56.1	0.58**
Reinforcing knowledge based activities	87.4	092*	86.3	0.88*	87.0	0.90*
Attracting knowledge based workers	78.4	0.82*	68.2*	0.72*	74.5	0.78*
Socio-cultural attributes						
Augmenting activities relating to arts	68.5	0.69*	71.3	0.75*	69.6	0.71*
Boosting cultural activities	65.7	0.67*	68.3	0.71*	66.7	0.69*
Promoting architectural elements	44.9	0.48**	39.4	0.43**	42.8	0.46**
Encouraging people towards building and conserving architectural elements	48.3	0.53**	47.9	0.51**	48.1	0.52**
Stimulating creation of symbolic elements	67.4	0.72*	65.9	0.68*	66.8	0.70*
Developing receptive attitude	62.3	0.64*	64.7	0.67*	63.2	0.65*
Imbibing tolerance	65.8	0.70*	68.2	0.71*	66.7	0.70*
Enhancing social cohesion	73.2	0.77*	63.4	0.66*	69.5	0.73*
Improving safety	57.4	0.59**	54.6	0.56**	56.3	0.58**
Environmental attributes						
Engendering clean environment	55.4	0.58**	59.8	0.63*	57.3	0.60*
Fostering greenery	52.3	0.54**	58.9	0.62*	54.8	0.57**
Encouraging tourism activities	77.4	0.79*	56.7	0.60*	69.5	0.72*
Promoting public spaces	64.3	0.68*	66.3	0.69*	65.1	0.68*
Creating spatial hotspots	68.4	0.72*	63.4	0.66*	66.5	0.70*

Notes: Cronbach α range: (0.84 to 0.89); SD range of PI: (0.11 to 0.24); *p (one tailed and two tailed) <0.05 for α<0.05, statistically significant; **p (one tailed and two tailed) >0.05 for α<0.05, statistically insignificant.

4.3. Discussions

Technology has become a symbol of power and competitiveness with enormous socio-economic and environmental consequences (Acuto, 2010; Callon, 1986). Technology—particularly ICT—has been able to control the economic development, social articulation and environmental consequences and created either positive or negative dynamics among the various attributes. The interaction of ICT and all these attributes coexist in a plurality of competing, complementary and overlapping, symbolic and spatial orders that define the socio-economic and environmental texture of cities (Acuto, 2010; King, 2004, p. 3). Creative city image is an offspring of these interactions. The integration of ICT in every sphere of cities, which is envisaged to dictate the spatial organization as well as the socio-economic functions and practices, can engender an explicit image (Acuto, 2010; Florida, 2002, 2003, 2005; Sassen, 1999). As seen from the evaluations of the attributes of both the cities and the influence of ICT, it is emanated that ICT has a significant presence and is largely influencing every sphere of city life tending to create a distinctive image in both the cities. The findings of the two case studies suggest that ICT has become an enabler for enhanced knowledge based activities, and to attract knowledge based workers under economic attributes. According to certain stakeholders such as businessmen and people engaged in ICT industry activities as evidenced from this study, knowledge based activities and knowledge based professionals have significant presence in both cities and ICT has been able to reinforce these activities as well attract knowledge based workers—particularly to Bhubaneswar, although to a relatively lesser extent to Bloemfontein—and ICT also enables a better business environment, particularly in Bloemfontein[4]. This study also suggests that ICT enhances the majority of socio-cultural attributes like arts, culture, tolerance, social cohesion, safety and symbolic creation. It also enhances tourism activities, promotes public places and assists in creation of spatial hotspots in both cities[5], which can promote a creative environment and create exciting places corroborating the findings of

[4] Opinions of businessmen and ICT professionals.
[5] Opinions of majority of stakeholders.

scholars like Florida (2002, 2003, 2005), Peck (2005) and Sandercock (2003). However, ICT also influences differently on different elements, based on context, type and functions of the cities as evidenced from the two cities. For example, ICT acted as an enabler of the creation of a congenial business environment in Bloemfontein although the same can not be true for Bhubaneswar. Similarly, while ICT engenders a clean environment and greenery in Bloemfontein, it does not suffice to creation of such elements in Bhubaneswar. Consequently, it suffices to argue that both the cities have the potential to develop as creative cities and develop their own stories which they can tell through their promotion and branding, based on the creative city image they pursue to craft, and it is envisaged that ICT can play a catalytic role in engendering a creative city image in developing countries.

5. Conclusion

Creative city has become a buzz word in many parts of the world. The creation of an image and promotion and branding of cities to attract investment, tourists, skilled professionals, knowledge based workers and creative people to cities have become a key objective of decision makers of many cities in the world. Not only the large and world renowned cities, but also relatively smaller cities in the developing world—like in India and South Africa have nurtured the aspiration to develop their cities to exciting places and to create an explicit image to make them attractive. Although Florida's work (2002, 2003, 2005) opened a debate on creative city image, it is observed that not much headway has been made in this field as evidenced from the literature so far. Besides, many scholars have criticised the concept as being non-realistic, elitist and ambiguous. Despite these pitfalls more and more cities are inclined towards developing a creative city image and using technology as a symbol of power and image. ICT in recent years has entered every sphere of city life and is found to be influencing every urban activity. Thus, it is imperative that ICT is expected to play a pivotal role in the image building of cities in the future. Since not much study has been devoted to this particular aspect, this study attempted to comprehend how ICT can engender a creative city image in the cities of developing countries. Looking at the aspirations of the two case study cities—Bhubaneswar and Bloemfontein—to transform into world class and smart cities, such a study was considered imperative. A survey research methodology was pursued to realise the aim of the study. The findings suggest that both the cities have the potential to engender creative city images respectively. ICT is found to be significantly influential to create this image. Overall, ICT enables a better business environment, reinforces knowledge based activities, attracts knowledge based workers under economic attributes and promotes almost all socio-cultural attributes except promoting architectural elements, encouraging people towards building and conserving architectural elements and improving safety. ICT also assists in engendering a clean environment, encouraging tourism activities, promoting public spaces and creating spatial hotspots. Thus, it is evident that ICT has a significant influence on drawing up a creative city image.

The investigation has certain limitations as it is based on primary survey data in all attributes in the absence of structured statistical data, which would have provided critical insights in the issues—particularly with regard to economic attributes. Nevertheless, at its current state, it is construed that ICT can significantly engender and reinforce an image of a creative city.

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Conflict of Interests

The author declares no conflict of interests.

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Article

The Role of Planning in Minimizing the Negative Impacts of Global Climate Change

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Abstract
Climate change is one of the most salient challenges to society, both today and in the near future. Considering the complexity, uncertainties, and scale of possible global climate change (GCC) impacts, there is agreement that urban planning has the capacity to facilitate the development and implementation of adaptation as well as mitigation strategies. The land use planning system provides a framework to reduce greenhouse gas emissions considerably by addressing central issues such as community design, transportation networks and use, and increasing development density. Planning can also play an important role in impacting public behavior, thus slowing the pace of GCC and allowing the development and implementation of adaptation measurements. The purpose of this article is to examine the important role of the planning profession in developing and successfully implementing mitigation and adaptation strategies. There is a growing sense that planning will receive increasing attention as an important policy instrument for addressing both the causes and impacts of climate change. This work also supports the argument that climate action plans can be a vital instrument in confronting the challenges of climate change and that planners need to be more involved in the development and implementation process of such plans.

Keywords
adaptation; global climate change; mainstreaming; mitigation; urban planning

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1. Introduction

A great amount of political intervention, public behavioral change, and support for climate action planning will be necessary in the next decade to mitigate the causes of global warming, predominantly human-induced greenhouse gas (GHG) emissions. As of 2008, more than half of the world's population lives in an urban environment (United Nations, 2015) and the majority of the world's energy consumption either occurs in cities or as a direct result of the way cities function. Cities consume about 75% of the world's energy and are responsible for more than 71% of energy related GHG emissions (UN Habitat For A Better Urban Future, 2016). Comprehensive changes in numerous aspects of society and the built-up environment will also be required in order to reduce the effects of global climate change (GCC) that are already unavoidable. These actions, collectively known as adaptation and mitigation of climate change, present a challenge to local decision makers and urban planners. However, the two approaches are not independent and, in fact, mitigation and adaptation are driven by the same set of problems (Smit & Wandel, 2006) and the more mitigation takes place, the less adaptation will be needed (Huq & Grubb, 2003).

Considering the complexity, uncertainties, and scale of possible GCC impacts, there is agreement that urban planning has the capacity to facilitate the development and implementation of adaptation as well as mitigation strategies (American Planning Association, 2011). The land use planning system provides the framework to reduce GHG emissions considerably by addressing central issues such as community design, transportation networks and use, and increasing development density (Friesecke, Schetke, & Kötter, 2012). Planning can also play an important role in impacting public behavior, thus slowing the pace of GCC and allowing the development and implementation of adaptation measures. The highly influential Stern Review (Stern, 2007) argues that planning can be an important tool for promoting private and public investment in locations that are less vulnerable to climate risks. Moreover, planning is distinctively qualified to provide comprehensive and long-term approaches that are required to reduce these vulnerabilities through various land use and infrastructure adjustments, and zoning. Although the discussion about the role of spatial and urban planning for responding to GCC is still in its early stages, there is a growing sense that planning will receive increasing attention as an important policy instrument for addressing both the causes and impacts of climate change (Greiving & Fleischhauer, 2012; Wamsler, Brink, & Rivera, 2013).

The way urban environments develop will have an impact on whether or not a low carbon, climate resilient future, and worldwide sustainable development can be achieved. The increasing extreme weather events caused by GCC demand the development of new strategies which improve the resilience of cities and their inhabitants and identify new innovative opportunities for a sustainable development pattern (Jabareen, 2013). Planners have to make sure that new developments and long-term infrastructure such as commercial and residential buildings, roads and ports, or water and transport networks are constructed to endure possible negative climate impacts and weather hazards. In addition, long-lasting infrastructure also needs to be designed to decrease the energy consumption and GHG emissions of the built environment (Hallegatte, Henriet, & Corfee-Morlot, 2011).

Therefore, the purpose of this article is to examine the important role of the planning profession in developing and successfully implementing mitigation and adaptation strategies. The literature review carried out in the present work emphasizes the important role, responsibilities, and challenges planners face when dealing with the issue of GCC. Throughout this study, only literature from scientific books, peer reviewed journal articles and reports published by research institutes or governmental organizations are considered. With the exception of foundational literature that discusses fundamental concepts related to planning and climate change, the study's literature review focuses on the period between the late 1990s and 2016. Considering the fact that the United States is among the main contributors to GCC and recently witnessed the emergence of planning strategies such as New Urbanism, Smart Growth, and Transit Oriented Development, the literature review also focuses primarily on studies carried out in North America. In particular, a combination of terms such as climate change mitigation and adaptation, urban planning, transportation and the built environment, smart growth, new urbanism, transit oriented development, and greenhouse gas emissions were used for the literature search.

By examining mostly journal articles, the literature analysis is presented and organized in different sections. Following an introduction on mitigation and adaptation, particular planning strategies and approaches to reduce the causes and impacts of GCC are discussed. After the planning for mitigation and adaptation sections, the importance of mainstreaming relevant policies is discussed, as are the benefits of climate action plans as a tool for planners to confront the challenges created by GCC. The final part of this paper provides a discussion of the reviewed literature and ends with concluding remarks and an outlook on required future research.

2. Planning for Mitigation

Mitigation planning is mainly considered as a tool for influencing energy demand and GHG emissions in two ways: first, through the design of new developments and urban retrofitting, and secondly through policies on location and access (Bulkeley, 2006). Policies include, for example, the promotion of energy efficiency, passive solar gain and advancing renewable energy alternatives. The built environment and urban form significantly influence levels of energy use and, thus, GHG emissions levels, which are the main cause of GCC (IPCC, 2013). A good example for a progressive energy strategy, linking policy and design, can be found in the city of Freiburg, Germany. The city's strategy to reduce GHG emission consists of three pillars: a) energy saving, b) efficient technology, and c) renewable energy sources (Beatley, 2012; Gregory, 2011). As a result, the city enforced strict design standards for new buildings in 1992, and also invested in insulation and energy retrofits, which has reduced heat oil consumption significantly. Furthermore, Freiburg relies heavily on combined heat and power plants (CHP), which produce both electricity and heat by capturing the waste heat from electricity production. Regarding renewable energy, Freiburg is, in particular, known for having solar installations throughout the city and the energy plus homes in the Vauban neighborhood.

The term 'urban form' describes the spatial characteristics of fixed elements within a metropolitan region (Anderson, Kanaroglou, & Miller, 1996). Urban form not only includes land uses and their structure and density, but also the spatial design of the transport and communication infrastructure. As noted by Calthorpe (2011), however, urban design is still often neglected as a strategy against GCC. Moreover, he argues that without more sustainable development patterns, mitigating and adapting to global climate change will be impossible. Nevertheless, urban planning has recently been receiving increasing attention as an instrument for changing urban forms and promoting a more sustainable development pattern. In the past two decades, planning approaches such as New Urbanism, Traditional Neighborhood Design, Smart Growth, Sprawl Repair and Transit Oriented Development have emerged as alternatives to conventional patterns of urban design. Influential literature and advocates of these planning strategies (Newman, Beatley, & Boyer, 2009; Tachieva, 2010) argue for introducing design features that, when implemented, will reduce energy and car use. These principles comprise the mixing of land uses, compact urban development, walkable neighborhoods, and transportation alternatives, as well as shorter trip lengths and improved accessibility. Starting in the mid–1970s, one of the first cities in the United States that implemented New Urbanism and Transit Oriented Development principles was Sacramento, California. During this time the city started to develop the Capitol Area Plan which established a light rail transit system, a mix of low-rise and high density housing, the restoration of historic buildings, and the construction of new energy-efficient office buildings (Calthorpe, 2011). Today, the efforts undertaken by the city of Sacramento can be considered a prime example of the type of urbanism needed to mitigate climate change. Overall, the existing literature underscores the importance of urban form and household energy use, as well as underlining the increasing responsibility of planners for advocating and implementing more sustainable development patterns, which reduce energy uses and thus GHG emissions (Fraker, 2013; Newman & Kenworthy, 2015).

2.1. Urban Form and Transportation

In one of the first studies addressing the link between land use and transportation and its implications for planners, Kelly (1994) argues that decisions made in the transportation sector influence land use patterns and vice versa. This conclusion was based on a comprehensive literature review covering six decades of research, examining case studies, practical recommendations, and mainly theoretical work. Due to the strong focus on theoretical literature and thus the lack of available data on the relationship between urban form and travel behavior, the study did not allow the validation of the benefits of the theories presented, designing ideas, and policies. Early studies, which were mostly theoretically-based, were not able to show conclusively to what degree particular settlement structures and urban design features systematically reduce car use and daily miles travelled and thus reduce transportation related GHG emissions. Instead, uncertainties and conflicting conclusions remained (Berman, 1996; Cervero & Gorham, 1995).

An example of this is the study by Crane and Crepeau (1998), which emphasized the uncertainty regarding the relationship between urban form and transportation. Acknowledging the growing popularity of smart growth and similar planning concepts as tools to reduce the negative environmental impacts of urban development, the authors emphasized that the impact of any specific neighborhood feature on travel behavior is still based on unproven hypotheses. The literature review published by Crane in the year 2000 followed up on the question of whether neighborhood design can improve traffic conditions (Crane, 2000). Here, the author argues that the literature has made significant progress in terms of identifying key questions to understand the complex relationship between urban form and transportation. Crane's study suggested that while the body of research is improving, strong evidence that transit—or pedestrian-oriented neighborhood plans—can effectively reduce the use of the automobile is still missing. Nevertheless, Crane acknowledged that existing research (Boarnet & Crane, 2001) at the time provided some evidence that certain street patterns along with commercial concentration result in fewer non-working automobile trips. Still, the scientific foundation for accepting that urban design can change travel behavior had not yet been fully accomplished.

Among the first publications that showed significant progress in reducing he uncertainty regarding the impact of land use on travel behavior was Ewing, Bartholomew, Winkelman, Walters, and Anderson's (2008) study. The research focused on two important questions in terms of successfully mitigating global warming. First, to what degree can vehicle miles traveled be reduced through compact development patterns instead of continuing urban sprawl? Secondly, what is the impact of less vehicle miles traveled on the total amount of GHG emissions within the transportation sector? Based on multiple studies and methodologies, the authors concluded that the average vehicle miles traveled could be reduced by 20%–40% by implementing design principles and guidelines which foster more compact development. Ewing, et al. (2008) pointed out that a 7–10% reduction in GHG emissions could be achieved by the year 2025 through appropriate urban form. The article also emphasized that a compact development pattern would not only reduce GHG emissions in the transportation sector, but also reduce the amount of harmful emissions in other sectors of the economy. Although a 7–10% reduction does not seem much at first, it is worth the effort for a number of reasons. First, the authors discount improved vehicle and fuel technology alone. They argue that if the current development pattern is continued, every improvement in technology will be offset by the growth of car dependency and vehicle miles traveled. Khattak and Rodrigues (2005) also concluded that traffic reduction can be achieved in well-planned and developed neighborhoods that follow the guidelines advocated by New Urbanism, Smart Growth, or Transit Oriented Development.

Another key publication on the relationship between the built environment and transportation was the National Research Council's (2009) report *Driving and the Built Environment: The Effect of Compact Development* *on Motorized Travel, Energy Use, and CO_2 Emissions*. The study concluded that a higher residential and employment density probably results in less vehicle miles traveled. In the best case scenario, a reduction of 25% could be achieved. However, the report only expected a reduction of about 5% to 12% vehicle miles traveled. Furthermore, the paper confirmed that compact mixed-use development can directly and indirectly reduce energy consumption and CO_2 emissions. The authors pointed out numerous obstacles that make the implementation of a more sustainable land use development pattern difficult, such as the aversion of many local governments to revising their zoning codes and the lack of power within regional governments to regulate land use. Overall, the National Research Council report encourages the implementation of more mixed-use development to reduce vehicle miles traveled, energy consumption, and GHG emissions. However, the report is not without criticism. Scholars such as Ewing, Nelson and Bartholomew (2009) criticized the projection by the National Research Council as too conservative. Instead, they points to their own studies, summarized in the book Growing Cooler (Ewing, Winkelman, Walters, & Chen, 2008). The results in this book suggest a 20% to 40% reduction of vehicle miles travelled through compact development. Moreover, the publication identifies five key factors of urban design that reduce travel and emphasize the important role of urban planning in decreasing energy use and GHG emissions. These guidelines are now often referred to as the 5Ds (Hamin & Gurran, 2009; National Research Council, 2009). The first D represents density, which captures the level of population and employment per square mile or per developed acre. The second D is diversity, and is an indicator for the mix of different land uses in an area. Design, the third D, addresses the features enabled by the overall neighborhood layout and street design that enhance walkability and bicycle-friendliness. The fourth D stands for destination accessibility. This indicator assesses the effort needed for the population to travel between trip origins and desired destinations. The final indicator and fifth D is the distance of transit, which examines the accessibility of transit.

Social aspects and public attitudes towards living in traditional, more walkable, and transit-oriented neighborhoods also need to be considered when discussing the benefits of specific urban designs for reducing energy use in the transportation sector. Lund (2006) conducted a study, surveying households located in communities characterized by transit-oriented development. Lund pointed out that households moved into these neighborhoods on the basis of a wide range of motivations. A significant factor, however, is that one third of the households surveyed named access to transit as one of the top reasons for living in a transit-oriented development. Other responses that were equally or even more frequent pointed to lower housing costs and the overall quality of the neighborhood. Lund argued that people's attitude and lifestyle preferences influence significantly their choice of residential location. However, the author stated that it was not clear to what extent those attitudes and preferences impacted the resident's daily routine, such as travel behavior, compared to the opportunities provided by their household's location. Nonetheless, the results of the study showed that residents of transit-oriented developments use public transit more often when compared to people living elsewhere.

2.2. Urban Form and Household Energy Use

Holden and Norland (2005) pointed to population density as well as size, age and type of housing as key factors in energy demand. Their study showed that with regard to compact urban form, the type and grouping of housing are likely to be the two most important land use characteristics impacting energy consumption related to heating and cooling. The authors also concluded that multi-family housing is more energy efficient than single dwellings. Residents of larger and older buildings in particular had a higher energy demand than their counterparts living in smaller, but also newer units based on the latest building designs, materials, and technologies. These findings were echoed by Ewing and Rong (2008) as well as by Lehman (2015). Furthermore, the energy required for establishing electricity transmission and distribution is higher in sprawling communities than in high-density neighborhoods. In the United States alone, the residential sector is responsible for more than 20% of the country's energy consumption (Ewing & Rong, 2008). Thus, retrofitting buildings to improve energy efficiency, assigning higher energy standards in new developments, or releasing stricter insulation regulations will all be important tools for planners hoping to decrease energy demand in the building sector and mitigate GCC. A recent study by Liu and Sweeney (2012) examined the relationship between household energy demand and urban form using both energy and land use models. The results supported the findings of previous studies, showing that residential urban form has a significant impact on energy demand. Furthermore, type, age and size of housing and household density were once again identified as key characteristics for reducing energy consumption when cooling or heating households. Moreover, the output of the computer models suggest that compact cities can decrease energy consumption by up to 16.2 percent per household compared to cities which are characterized by urban sprawl with low density developments.

Guided by the question of whether the physical form of today's cities impacts private energy use at home, the study by Ko (2013) provides an extensive review of the existing literature in the fields of architecture and planning. In particular, the study examines the relationships between particular urban forms and energy use primarily for space conditioning (heating and cooling). The urban form elements considered included: a) size and type of housing; b) density with regard to physical compactness, dwelling units, and population; c) community layout such as street orientation or building configuration; and d) natural elements in the form of trees and other vegetation. With regard to housing type and size, the study confirmed the results of previous research, arguing that low-density settlements with predominantly detached housing use more energy for cooling and heating as multi-unit developments or attached housing. Furthermore, the author demonstrates that the increase in the average house size since 1978 has outpaced any improvement in energy efficiency over the same time span. In terms of density, research suggests that in densely populated inner city areas with mainly multi-family housing, the energy consumption per capita is lower than in the single family-dominated housing of the suburbs (Pitt, 2013). However, more research is needed to fully evaluate the potential trade-offs between high-density developments in different climates. The aspect ratio of building height to street width can have a significant impact on energy use. On the one hand, in hot and dry conditions studies show that narrow twisting streets aligned with the usual wind direction and compactly spaced buildings with staggered heights are most energy efficient (Aggarwal, 2006). This type of aspect ratio supports natural ventilation, while simultaneously diverting strong winds and enabling buildings to provide shade for each other. On the other hand, in cold regions compact form can lead to an increase in energy use for heating due to reduced solar access (Steemers, 2003). In addition, compact urban environments can minimize heat loss from buildings and contribute to the urban heat island effect (Krishan, Baker, Yannas, & Szokolay, 2001) as well as limiting the opportunities for on-site solar energy generation (Cheng, Steemers, Montavon, & Compagnon, 2006). Another key element affecting energy use for space conditioning addressed by Ko (2013) is the community layout. Solar neighborhood guidelines, for example, advocate an east–west street orientation, which would result in lots being oriented north–south. This would allow more south-facing buildings to maximize solar access in a neighborhood. Again, more research and data are needed to quantify the impact of urban form elements on residential energy use.

Another important dimension of urban form and household energy is the presence of natural systems within the settlement structure. In respect to plant and surface coverage, research often points to the beneficial impacts of trees and urban parks in reducing energy consumption for heating and cooling. Tree planting efforts can improve the control of solar access, evapotranspiration, natural ventilation, and the urban heat island effect (Maimaitiyiming et al., 2014; McPherson & Simpson, 2003; Middel, Häb, Brazel, Martin, & Guhathakurta, 2014). The climate inside parks tends to be cooler than in its urban surrounding. Studies have proven that the vegetated park is a cool patch in the built-up city. This phenomenon is often referred to as the "Park Cool Island" effect or "Oasis Effect" (Saito, Ishihara, & Katayama, 1990). Observations conducted by Spronken-Smith and Oke (1999) also confirmed that vegetated urban parks are often cooler than their surroundings. Various climate studies related to urban parks show the magnitude and spatial distribution of the park cool island effect. Upmanis, Eliasson and Lindqvist (1998) analyzed and compared parks in different cities throughout the world and noted that the cold park climate often extends beyond the park and therefore influences the temperature in surrounding urbanized areas. Yu and Hien (2006) examined the thermal benefits of city parks. In order to analyze the cooling effect of green areas, they measured temperatures at vegetated and non-vegetated locations throughout the city. Notable cooling effects of parks were reported within the vegetated urban areas, but also in the surrounding urban environment. Thus, lower temperatures in the park and in the nearby built environment prove the cooling impact of city parks. According to their research and simulations, arranging green urban parks and additional evaporating surfaces throughout the whole urban settlement structure can alter the energy balance of an entire city. As a result, the urban temperature will be reduced because more heat can be dissipated (Yu & Hien, 2006). Meier (1991) also acknowledges the energy-saving potential of trees and other landscape vegetation. Meier's (1991) study points out that vegetation can mitigate urban heat islands directly by shading heat-absorbing surfaces, and indirectly through evapotranspiration cooling. Furthermore, the author's research shows that vegetation consistently lowers wall surface temperatures by about seventeen degrees Celsius and reduces air conditioning costs by 25 to 80 percent. Moreover, urban parks support city ventilation, which is an important aspect for the mitigation of the urban heat island effect, especially during the night. The park breeze plays an important role in city ventilation. The theory of park breeze is based on temperature differences as a driving force for the divergent outflow of cool air at a low level (Oke, 1988).

3. Planning for Adaptation

Even in the case of successful mitigation, the impact of GCC will continue affecting the least developed countries and poor population the hardest (IPCC, 2013). Rapid population growth in cities, especially in developing countries, paired with the increasing impact of GCC is adding significant pressure on existing infrastructure, and will eventually cause it to fail. This requires institutional, technical, and spatial measures to adapt to the impacts of GCC in urban areas, where most of the world's population lives today (IPCC, 2014). Planning for adaptation, however, is not an easy task. Global climate change is characterized by high levels of uncertaintys and the requirement and adaptation capacity of a region is often difficult to recognize. As a result, there is no single strategy at the local or (inter)national level to adapt to the impact of GCC or reduce the GHG emissions (Biesbroek, Swart, & van der Knaap, 2009). In terms of adaptation, uncertainty results from the nature of GCC itself, its associated extremes, their effects, the vulnerability of systems and regions, conditions that influence vulnerability, and many attributes of adaptation, including the costs, feasibility of implementation, consequences, and effectiveness (Hamin & Gurran, 2009).

Global climate change adaptation also requires urban planners to more efficiently communicate with policy makers and the public in new and different ways (American Planning Association, 2011). Planners will need new communication tools to explain the possible impact of GCC and to ensure that the public and decision-makers maintain the focus on long-term adaptation and mitigation responses. Engaging the public to participate in the adaptation and mitigation process is vital to its success. Many people are not aware of the precise nature, causes, and possible negative impact of GCC (Hagen, 2016; Leiserowitz, 2010). The way the public processes information and new scientific findings regarding GCC has a significant effect on how and to what degree mitigation and adaptation strategies are supported. GCC has to be communicated in a way that motivates the public to change their behavior and support adaptation or mitigation policies (Wolf & Moser, 2011).

Spatial and urban planning presents a strategic framework in which adaptation, as well as mitigation measures can be integrated as a part of a broader perspective on sustainable development (Uittenbroek, Janssen-Jansen, & Runhaar, 2013). Due to their expertise in adapting the urban environment to the impact of GCC, urban planners are in a position to usefully engage local stakeholders, policy makers, and decision-makers to advocate for urban adaptation strategies. The following section examines the role of the local planner in terms of adapting the built environment to reduce the impact of the potential hazards of GCC. Based on the existing literature, the question of how planners should think and plan for adaptation, as well as how planners should consider incorporating climate adaptation strategies into existing and new policies are discussed. Any incorporation of climate adaptation strategies should be based on in-depth impact assessments or risk analyses considering local circumstances.

3.1. Vulnerability Assessment

Different aspects need to be addressed by planners in order to assess the vulnerability of built-up environments to possible GCC risks and impacts. One key aspect of vulnerability assessment, especially for urban planners, is to identify vulnerable populations. Since the poorest countries of the world are those who will suffer disproportionately from its consequences, GCC raises issues of equity and social justice (Grasso, 2007). As seen in the case of Hurricane Katrina in New Orleans, however, not only populations in poor countries are vulnerable to extreme weather events, but also the most disadvantaged in wealthy nations (Van Heerden & Bryan, 2006). Although Katrina cannot be linked directly to GCC, it represents the type of GCC impact that we can expect in the future and thus need to be prepared for. However, in order to plan and adapt to such events appropriately, equity issues need to be addressed. Planning and policy approaches need to consider local inequalities and injustice, reflected in disparities in wealth, health, education and job opportunities (Saavedra & Budd, 2009). Planners are well-suited to the task of overcoming these issues by identifying and addressing the root of inequities, promoting policies to reduce the problem, empowering communities, working across agencies and departments, recognizing and respecting cultural differences, and aiming for strategies for long-term, permanent change (Friesecke et al., 2012; Jabareen, 2013).

In addition, planners need to determine to what degree specific systems such as the transportation infrastructure, the built-up environment, threatened ecosystems, or public health will be affected by the previously assessed impact of GCC. Following the climate impact assessment, the first step in the vulnerability assessment process should be the evaluation of the exposure of specific systems or groups within the population to the impact of GCC (UKCIP, 2010). For example, infrastructure in coastal areas or near rivers might be exposed to flooding due to projected sea level rise or increasing precipitation. As in climate impact assessment, climate models play an increasing role in this part of the vulnerability assessment (Abraham, 2009). Geographical Information Systems (GIS) can produce high resolution maps at the local scale to illustrate the exposure of urban areas to sea level rise or the Urban Heat Island Effect (UHI). Such specific information leads to diminishment of uncertainties and support of urban planners in their development of appropriate adaptation strategies.

Three interrelated factors stand out in the literature with regard to determining vulnerabilities (Lowe, Foster, & Winkelman, 2009). These factors are exposure, sensitivity and capacity to adapt to the impact of GCC. Sensitivity to this impact refers to the degree to which resources, population, infrastructure, or other important components of the urban environment respond to incremental changes in the impact of GCC. This concept allows urban planners to identify the sectors which will be influenced earliest by GCC and consequently will need to be addressed first by adaptation strategies. According to the IPCC Working Group II (IPCC, 2014), adaptive capacity describes the 'potential or ability of a system, region, or community to adapt to the effects or impacts of GCC. On an urban scale, this means that by increasing their adaptive capacity, settlements are more likely to cope with changes and uncertainties in climate. As a result, a high adaptive capacity also increases the resiliency of cities and encourages sustainable development (Smit & Wandel, 2006).

The idea of resiliency as a policy and planning goal has its origin in ecosystem theory (Holling, 1973) and is now commonly used in the context of GCC adaptation (Meerow, Newell, & Stults, 2016). Resiliency to GCC from a planning perspective can be understood to improve the ability of urban systems to bounce back after suffering a negative environmental event. Since future GCC is already built into the earth's atmosphere and its short-term effects cannot be avoided anymore, thus making adaptation a necessity, it is important that planning strategies not only address the identified vulnerabilities of a city and its population but also improve the ability to recover from negative GCC induced events. Still, the need to adapt to GCC is not fully acknowledged by all countries or administrations (Wamsler et al., 2013). Moreover, the countries that do recognize GCC adaptation as a significant planning challenge have only implemented very few adaptation policies (Carmin, Nadkarni, & Rhie, 2012; Greiving & Fleischhauer, 2012). Overall, the important role of urban planning in the success of GCC adaptation is still not recognized strongly enough among policy-makers. Policy action on planning for the adaptation of cities and towns is just now emerging and thus many adaptation strategies have not yet been translated into planning practices. Nevertheless, several adaptation strategies have already been implemented in communities worldwide.

3.2. Strategy Development

According to an extensive review of current adaptation practices worldwide (Wamsler et al., 2013), most policies that are currently proposed are quite similar and not highly focused on local circumstances. The most frequently employed measures include updating infrastructure and disaster plans to include and acknowledge projected forecasts for GCC, considering larger floodplains for areas with possible increased storm events and precipitation, establishing wildlife corridors, and adjusting building codes to support more natural cooling while contributing less to the UHI effect (Hamin & Gurran, 2009). Most adaptation strategies focus on the physical structure of the built environment with the aim of reducing the vulnerability of buildings and infrastructure to the impact of GCC. The main focus of authorities in terms of urban adaptation seems to be the reduction of flood risks, the risk of landslides, extreme temperatures, urban drought and urban heat island effects. In addition, there is a preference for adaptation policies which also have a beneficial impact in terms of GCC mitigation and GHG emissions reduction. This is especially the case in Europe, where so called "climate planning" is an emerging trend which combines GCC mitigation and adaptation (Davoudi, Crawford, & Mehmood, 2010a).

A major criticism of current adaptation approaches is that most policies address physical factors separately from related non-physical factors (Wamsler et al., 2013). This means that the close interrelationships between the social, cultural, economic, political and institutional characteristics of cities on one hand and the physical features of the urban fabric on the other are not addressed appropriately. As a result, current policy frameworks do not allow urban planning to show its full potential in terms of GCC adaptation, which can lead to a further reduction in the resilience of cities rather than improving it. As a result, Wamsler et al. (2013) provide a conceptual framework to reduce urban risks through adaptation measures and strategies, while acknowledging the missing links between physical assessment and social/contextual issues. Depending on the local circumstances and the results of previously performed impact and vulnerability assessments, urban planners might need to address various sectors. For example, adaptation strategies might need to consider biodiversity and habitat, infrastructure, rising sea levels, public health, water resources and management, or forestry and agriculture. During the development process of adaptation strategies urban planners need to evaluate possible adaptation options according to their costs, benefits, efficiency, and implementability. They also have to be aware of potential tradeoffs and conflicts with mitigation strategies. For example, on the one hand, mitigation of GHG emissions on an urban scale focuses on densification of the built-up environment to reduce vehicle miles traveled and the energy use of buildings. On the other hand, adaptation strategies often rely on open spaces to address storm water, species migration, urban cooling, and other goals. Thus, planners need to develop strategies that minimize this conflict and find the right balance between minimizing the causes and impact of GCC. Despite the fact that planners are considered well placed to address GCC risks and adaptation, it remains unclear what exactly their role is, how their responsibilities relate to those of city authorities, and how national adaptation policies can be translated into local planning strategies (Greiving & Fleischhauer, 2012).

3.3. Mainstreaming

In order for planners to incorporate climate adaptation strategies successfully, the issue of climate change and adaptation in particular has to be integrated or mainstreamed into existing government policy (Wamsler et al., 2013). The aim of mainstreaming is to make adaptation to climate change a part of other well-established programs. Otherwise, urban planners do not have the tools or the political support necessary to implement the appropriate adaptation measurements into their regular planning routine (Huq & Reid, 2004). In terms of urban planning, planners need to integrate climate change risks into development policies and patterns. Thus, any decision-making process dealing with urban planning, relevant issues such as urban design, water supply, and capital investments in agriculture, urban form, energy, and transportation, or any other infrastructure should consider its impact on and resilience to climate change. This can only be achieved if adaptation becomes an inherent part of urban planning practices, which requires the suitable use and mixture of a set of different mainstreaming strategies.

Several measures exist to promote mainstreaming of adaptation, including the integration of climate information into environmental data sets, vulnerability or hazard assessments, broad development strategies, macro policies, sector policies, and development project design and implementation (Huq, Rahman, Konate, Sokona, & Reid, 2003). Nevertheless, there are also constraints for successfully mainstreaming climate change risks and its impact into development and urban planning. The five major constraints are the relevance of climate change information for development-related decisions, the uncertainty of climate information, compartmentalization with governments, segmentation and other barriers within development-cooperation agencies, and trade-offs between climate and development objectives (Hay & Mimura, 2006).

To integrate climate effects and risks into the decision-making process of urban policy and development, many cities have developed Climate Action Plans (CAP) (Basset & Shandas, 2010). The plans range from theoretical or motivational documents to highly detailed documents stating concrete goals with thoroughly designed methods. The first generation of Climate Action Plans focused mainly on improving municipal operations in terms of energy use and GHG emissions (Millar-Ball, 2010). Today, these plans are also addressing jurisdiction-wide policies such as land use planning focusing on supporting public transport, compact development, and green building codes. In general, CAPs seem to get the most support from policy makers if the development strategies provide immediate or highly visible results (Basset & Shandas, 2010). Climate Action Plans and their recommendations present a great opportunity to change current planning and developments patterns. Climate Action Plans can provide the framework and the political power to change current development patterns, improve the position of the planner in the decisions making process, and establish a sustainable way of living in the future, which reduces vulnerability to GCC and increases the adaptive capacity of communities.

However, so far, planners seem to play only a small role in the development of CAPs. Instead, municipalities tend to rely more on environmental engineering, and environmental departments (Boswell, Greve, & Tammy, 2011). Furthermore, only a very limited number of completed climate action plans address the need to develop and implement adaptation plans. Considering the type of policies presented in existing CAPs and the lack of adaptation strategies, planners need to take a leading role in the development and implementation process. Planners have the expertise to improve CAPs significantly. Many climate action plans focus on strategies that are already part of various sustainable urban planning practices, such as compact and energy saving development patterns or extensive green spaces throughout neighborhoods. Furthermore, planners have the tools necessary to improve the resiliency of urban environments and improve their adaptive capacity regarding potential negative impacts of GCC.

4. Discussion

The existing literature suggests that planning strategies have great potential for achieving significant GHG emission reductions as well as decreasing the vulnerability and increasing the adaptive capacities of urban environments. However, with regard to mitigation, the existing body of knowledge is not sufficient to come to definitive conclusions and more research is needed either to validate the benefits of compact and transit-oriented development patterns, or to avoid unforeseen negative consequences resulting in even higher energy use and GHG emissions. As long as questions remain, reliable predictions of the impact of land use and design strategies on travel behavior will remain elusive. The existing body of knowledge does not suggest that planning approaches implementing a development pattern based on the 5Ds are mislead. Rather, it demonstrates that success in terms of reducing GHG emissions and energy use is not self-evident. Nevertheless, it is undeniable that the built environment is a primary contributor to GCC as current development patterns make driving a necessity in many places, resulting in high energy consumption and GHG emissions. Although the impacts of land use on modal split remains unclear, planners must play a key role in promoting energy efficiency in the existing built environment and changing development patterns, transportation systems, and regulations in ways that reduce GHG emissions. At the very least, planning strategies promoting more sustainable development patterns offer various commuting choices.

Even when the potential risks and impacts are understood, the perceived long timeframe of climate change presents a significant barrier to the development and implementation of place-specific strategies. Nevertheless, more tools, resources, and ongoing efforts are becoming available to planners to provide guidance for adaptation planning. The concept of adaptation is not entirely new. Instead, it includes well-established practices from disaster risk management, coastal management, resource management, spatial planning, urban planning, public health, and agricultural outreach. However, several aspects of GCC adaptation are new. Among the new challenges are unprecedented extreme climate conditions, the rate of change, knowledge and methodological challenges, as well as new actors related to climate-sensitive resources, such as water planners, forest managers, urban and spatial planners, architects, tourism managers, and health care providers (Füssel, 2007).

The diversity of adaptation challenges emphasizes the fact that it is impossible to develop a single and globally applicable approach to assessing, planning, and implementing adaptation measures. Any risk assessment and discussion about adaptation measurements has to allow flexible methodological approaches in order to produce knowledge that is relevant in a particular decision context. Therefore, planned adaptation to climate change means foremost the use of information about present and future climate change to examine the appropriateness of current and planned practices, policies and infrastructure.

Traditional approaches such as making decisions based on worst case scenarios do not apply to the highly complex and uncertain issue of climate change. Instead, a more flexible framework is required that allows decision makers to develop strategies based on many different possible scenarios with feedback loops. This approach is referred to as advanced scenario planning and is a key component of the anticipatory governance framework. The concept of Anticipatory Governance can be described as "a system of institutions, rules, and norms that provide a way to use foresight for the purpose of reducing risk, and to increase capacity to respond to events at early rather than later stages of their development" (Fuerth, 2009, p. 29). It presents a new model for decision making while dealing with great uncertainties such as in the case of climate change. Current research suggests that Anticipatory Governance consists of three steps: anticipation and futures analysis, the creation of flexible adaptation strategies, and monitoring and action (Quay, 2010).

Eventually, the role of planners is about giving recommendations regarding who should do what more, less, or differently, and to determine the resources needed. Moreover, planners have to pay close intention to possible trade-offs between the considered adaptation strategy and already-existing mitigation policies. These two response options can sometimes be mutually reinforcing, but they can also work against each other. Thus, the appropriate adaptation strategies have to be determined on a case-to-case basis, taking the local circumstances into consideration as best possible (Hagen, 2016).

5. Concluding Remarks and Outlook

Policy makers, decision makers, and planners agree that mitigating GHG emissions and adapting the built environment to cope with the possible negative consequences of GCC are among the most difficult and important challenges faced by the planning profession today (Davoudi, Crawford, & Mehmood, 2010b). The increasing awareness of GCC is not only increasingly dictating the sustainable development debate, but is also supporting the critiques of the current predominant development patterns characterized by urban sprawl, separation of uses, and the necessity of owning and operating a private automobile. The need for planners addressing alternative development strategies on different scales and in different places is increasing (Liu & Sweeney, 2012). The available scientific data emphasizing the complexity, uncertainty and irreversibility of GCC in the near future is also impacting the nature and framing of spatial planning. Planners need to be more involved in the development and implementation process for climate policies and action plans. As a result, planners will be expected to resolve or even overturn short-term and long-term development expectations. Their work will be increasingly guided by questions such as what low carbon, 'climate proof' settlement will look like in terms of urban form and infrastructure; what barriers there will be to effective planning for such development; what the implications for governments will be, from transnational to local levels, and what the relationship between these levels will be; and who will bear the risk and what will the implications be for equity and social development.

Furthermore, as emphasized by Bulkeley (2006), climate change is a global public good that includes complex planning issues that not only exceed the traditional planning framework, but also the policy objectives of local authorities. One of the main issues is the limited availability of climate change impact data at the regional and local scale. Unfortunately, existing models predominantly provide insights only in terms of average changes in climate parameters on a very large geographical scale and over a long time frames. Likewise, compared to mitigation policies which are easy to assess by measuring the change of GHG emissions over time, measuring the effectiveness of adaptation planning, which focuses on avoiding future negative effects of climate change, is much more difficult. The effectiveness of adaptation strategies is still influenced by the high level of uncertainty. More research is needed to improve understanding of the multifaceted relationships between important issues such as energy demand and consumption, land use changes and climate change. It will take an interdisciplinary approach—in which planners will play an important role—to fully understand the environmental, urban, and social problems caused by climate change.

Conflict of Interests

The author declares no conflict of interests.

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Bjoern Hagen holds a M.Sc. in Spatial and Environmental Planning from the University of Kaiserslautern, Germany, and received his Ph.D. in Environmental Design and Planning from Arizona State University. Dr. Hagen has conducted research in the areas of climate change mitigation and adaptation, public risk perception and risk communication. By studying the nature of public perceptions of global climate change in different countries and over time, his research contributes to improving climate change communication efforts to reduce greenhouse gas emissions and to increase the adaptive capacity and resiliency of urban environments.

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Article

Cool City Design: Integrating Real-Time Urban Canyon Assessment into the Design Process for Chinese and Australian Cities

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Abstract
Many cities are undergoing rapid urbanisation and intensification with the unintended consequence of creating dense urban fabric with deep 'urban canyons'. Urban densification can trap longwave radiation impacting on local atmospheric conditions, contributing to the phenomena known as the Urban Heat Island (UHI). As global temperatures are predicted to increase, there is a critical need to better understand urban form and heat retention in cities and integrate analysis tools into the design decision making process to design cooler cities. This paper describes the application and validation of a novel three-dimensional urban canyon modelling approach calculating Sky View Factor (SVF), one important indicator used in the prediction of UHI. Our modified daylighting system based approach within a design modelling environment allows iterative design decision making informed by SVF on an urban design scale. This approach is tested on urban fabric samples from cities in both Australia and China. The new approach extends the applicability in the design process of existing methods by providing 'real-time' SVF feedback for complex three-dimensional urban scenarios. The modelling approach enables city designers to mix intuitive compositional design modelling with dynamic canyon feedback. The approach allows a greater understanding of existing and proposed urban forms and identifying potential canyon problem areas, improved decision making and design advocacy, and can potentially have an impact on cities' temperature.

Keywords
performative urban design; real-time design; sky view factor; urban canyon; Urban Heat Island

Issue
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1. Introduction

Many of the world's cities are undergoing rapid urbanisation and intensification (Brenner & Schmid, 2014; Koolhaas, Obrist, Boeri, Kwinter, & Tazi, 2001; Rode, 2013) with the unintended consequence of creating dense urban fabric with deep urban canyons. This urban densification can trap longwave radiation having a profound impact on the local atmospheric conditions in particular, the Urban Heat Island (UHI) which can increase temperatures within urban centres considerably when compared to surrounding rural areas (Basara, Basara, Illston, & Crawford, 2010; Mills, 2004; Oke, 1981, 1988). This heat retention in urban centres has been understood and documented since the late 1960s (Bornstein, 1968), and can cause temperature differences between central urban areas and nearby rural areas ranging from 2 °C to as much as over 6 °C on a clear and calm night (US Environmental Protection Agency, 2008).

Heatwaves are among the deadliest of natural disaster types (Li & Bou-Zeid, 2013). The death toll in the European heat wave of summer 2003, probably the hottest in Europe since AD 1500, resulted in around 70,000 heat related mortalities (Lass, Haas, Hinkel, & Jaeger, 2013). Even more extreme heat waves are experienced in Australian cities with recent recorded temperatures in excess of 40 °C for over five consecutive days (Bureau of Meteorology [BOM], 2013). The already finely balanced climate of Australian cities make them particularly susceptible to impacts of climate change brining heat waves of increased frequency, duration and intensity (Akompab et al., 2013; Patz, Campbell-Lendrum, Holloway, & Foley, 2005).

Studies by researchers in Nanjing and Shanghai, China found that UHI is directly responsible for heightened heat-related mortality in urban regions in and around Shanghai (Tan et al., 2010). UHI is a critical issue particularly for cities along the Yangtze River Valley such as Nanjing, which is considered, along with Chongqing and Wuhan, to be one of the "Three Furnaces of China".

UHI is a key consideration in the design for the growth of cities in the future. As global temperatures are predicted to increase, there is a critical need to better understand urban form and heat retention behaviour in city centres, and to integrate rapid analysis tools into the design decision making process to create cooler cities.

The modelling of UHI is complex (Shao, Zhang, Mi, & Xiang, 2011) with a great number of variables such as wind, material colour, street orientation, tree coverage, permeability of ground surfaces and building heights in relation to street width or "urban canyon" (Oke, 1988). The urban canyon is where, in dense urban environments, buildings on each side of a street enclose a space obscuring the sky and therefore restricting the amount of long-wave radiation that can escape, a phenomenon particularly acute at night (US Environmental Protection Agency, 2008) (Figure 1).

The urban canyon is considered by many to be the most important contributing factor to the UHI effect (Ibrahim, Nduka, Iguisi, & Ati, 2011) due to the strong correlation between them (Brandsma & Wolters, 2012; Kakon & Nobuo, 2009; Unger, 2009), and is a critical variable considered by microclimate researchers in the study of Urban Heat Island (Ewenz, Bennett, Chris Kent, Guan, & Clay, 2012). It is the measurement of this variable that is the focus of this paper.

The urban canyon is the degree to which the sky is obscured at a given point commonly calculated as Sky View Factor (SVF) (Johnson & Watson, 1984), a dimensionless measurement of openness between 0 and 1, representing totally obscured $\Psi_{sky} = 0$ and totally open spaces $\Psi_{sky} = 1$ where the sky is completely unobstructed allowing all outgoing radiation to radiate freely to the sky (Brown, Grimmond, & Ratti, 2001).

SVF modelling used to infer UHI is critical to understanding the impact of densification of urban form and if incorporated into the urban design process, has great potential for mitigating future UHI in developing cities (Grant, Heisler, & Gao, 2002).

This paper describes the application and validation of a novel three-dimensional modelling approach to calculating SVF, an important indicator used in the prediction of UHI for existing as well as proposed urban design scenarios. A rapid SVF, calculated using a modified daylighting system in a digital modelling and visualisation environment allows iterative design decision making in-

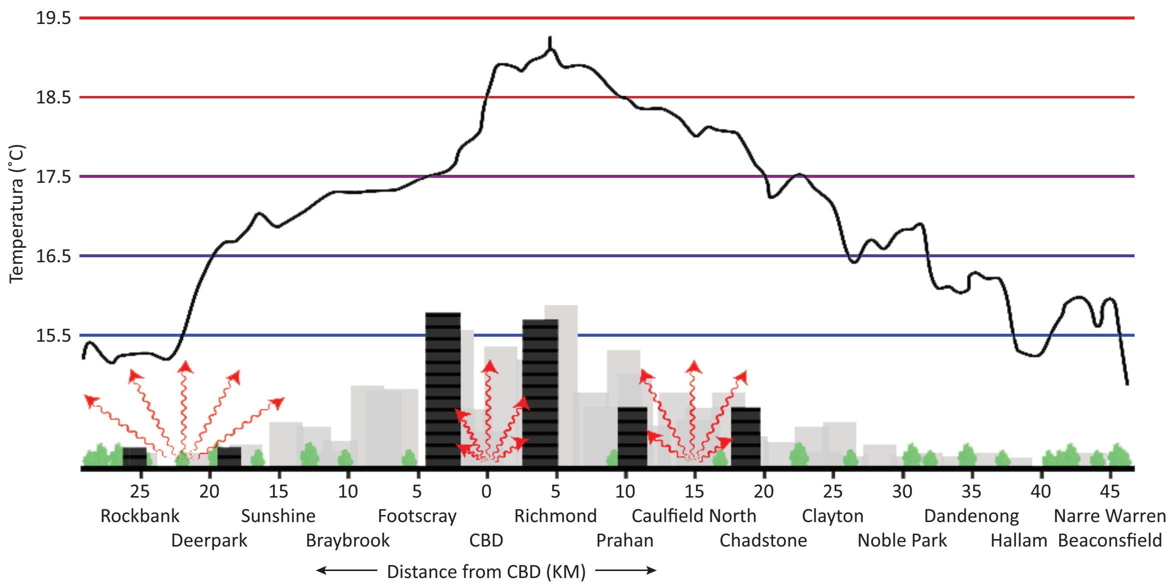


Figure 1. This diagram shows temperature and urban form relationship by way of a longitudinal cross-section through Greater Melbourne overlaid with temperature readings (taken on a clear summer night) from outer western suburbs, through the CBD to the outer south-eastern suburbs (based on diagram from City of Melbourne's Urban Forestry Strategy (Melbourne, 2012)).

formed by UHI and SVF impacts on an urban design scale. This modelling and analysis approach is tested on urban samples from cities within Australia and China which experience climatic extremes and provide a range of different urban morphologies.

2. SVF Modelling: Current Methods

SVF has traditionally been very difficult to measure (Grimmond, Potter, Zutter, & Souch, 2001). There are however several methods for modelling and assessing SVF manually such as scale model (Oke, 1981), angle measurements, (Bottyan & Unger, 2003; Johnson, 1985; Johnson & Watson, 1984), evaluation of fisheye photos (Blankenstein & Kuttler, 2004; Bradley, Thornes, & Chapman, 2001; Holmer, Postgård, & Eriksson, 2001) and evaluation using GPS signals (Chapman & Thornes, 2004).

SVF can also be calculated computationally using digital elevation model (DEM) databases describing surface geometric elements (Brown et al., 2001; Lindberg, 2005; Souza, Rodrigues, & Mendes, 2003), and raster-based three-dimensionalisation of two-dimensional data using Digital Elevation Models in GIS (Kokalj, Zakšek, & Oštir, 2011; Ratti, Baker, & Steemers, 2005; Ratti & Richens, 1999). This analysis can be computed rapidly, though as they are two dimensional with a height attribute (2.5D), they cannot assess more complex three dimensional urban forms such as where a street has weather protecting canopies at lower levels or have elements of buildings that may cantilever or protrude from a building at an upper level.

Fully three-dimensional analysis is possible with microclimatic modellers such as SOLWEIG and Envi-Met which can be used to analyse a low detail street canyon to a resolution of 0.5m (Levermore & Cheung, 2012); by using ESRI ArcGIS™ with the additional add-on package 3D Analyst™ where hundreds of rays are projected from a series of points (Chen et al., 2012; Kastendeuch, 2013; Kidd & Chapman, 2012) or by using a similar approach in Rhino with a purpose-built Grasshopper script (Wu, Zhang, & Meng, 2013). Though effective in analysing complex 3D urban geometry, these methods have been computationally intensive—taking considerable time to assess a precinct (Gal, Lindberg, & Unger, 2009; Unger, 2009). Though there have been recent improvements in speed, these assessment tools are more suited to simple 3D geometry and are not well integrated with design modelling tools.

3. Method

3.1. GPU and CPU Approach Within Design Modelling Software

For this study we have used a common 3D design, animation and visualisation program, Autodesk's 3ds Max™. This software was chosen due to its flexible parametric modelling capabilities, integrated daylight modelling system, and common use in the architectural design industry. Within the program we have developed two variations of a rapid three-dimensional SVF analysis approach which uses a 'hacked' Mental Ray™ photometric daylight modelling system to create a 'sky dome light'. Our approaches extend Ratti and Richens' (2004) concept of shadow casting on DEM reversing the modelling logic of the aforementioned computational systems, instead of starting with the point of interest and projecting rays outwards to intersect with surrounding geometry and then a hemisphere beyond (Unger, 2009), we use a hemispherical light source—a "sky-dome" or "Skylight Illumination" which projects and traces photons (light) from the globe towards the point of interest. We modified the typical daylight modelling system setting the intensity of the sun to zero (no direct light from the sun as though the sun was turned off), set an artificially low uniform intensity light from the sky (dome). Using this approach, surface areas of the model that received full global illumination (full 180 degrees of light from the hemisphere) appeared white ($\Psi_{sky} = 1$). Where the surface is in shadow it appeared as a shade of grey depending on the amount of shadowing of the sky-light by other objects or black where it receives no light ($\Psi_{sky} = 0$) (see Figure 2).

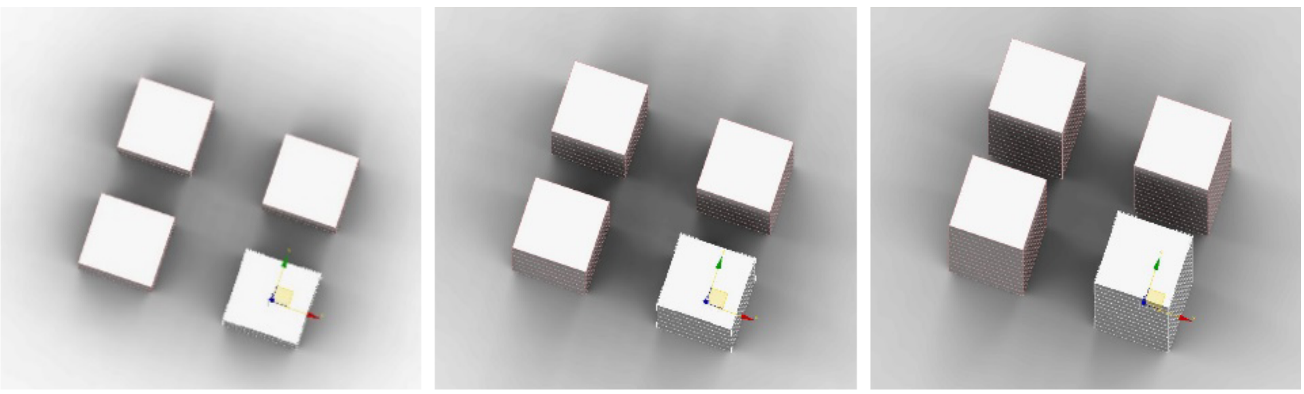


Figure 2. This figure shows a sequence of screen-grabs of four boxes (buildings) with their height parameter changed. As the box's height parameter is increased, the shadows become darker representing a lower SVF reading (less sky is visible where the shadow is darker).

As the Mental Ray™ render engine within Autodesk 3ds Max™ is able to trace millions of photons (Grosch, 2005) this system not only has the advantage of being more accurate but also faster than previous methods, in that we can choose to perform the calculation either using the Central Processing Unit (CPU) or Graphic Processing Unit (GPU).

For numerically quantifiable calculations we used the CPU method which involved reconfiguring a lux level light meter grid calculation system (Reinhart & Breton, 2009) so as to measure the total amount of sky-dome light hitting each grid point—giving a numeric SVF value (from $\Psi_{sky} = 0$ to 1), as this value can be exported to a .CSV file and opened in Microsoft Excel™ (or similar spreadsheet program) for further data analysis and quantifiable comparisons of design options (Figure 3 and Figure 4).

This method has been verified through a series of experiments using hemispherical geometry with known percentage areas subtracted comparing expected SVF values with measured SVF values. To verify the accuracy of the SVF meters (reconfigured lux meters), we modelled a series of large mesh domes of different scales and openings. The dome experiment examples included in this paper were modelled with a 300m radius. Each of

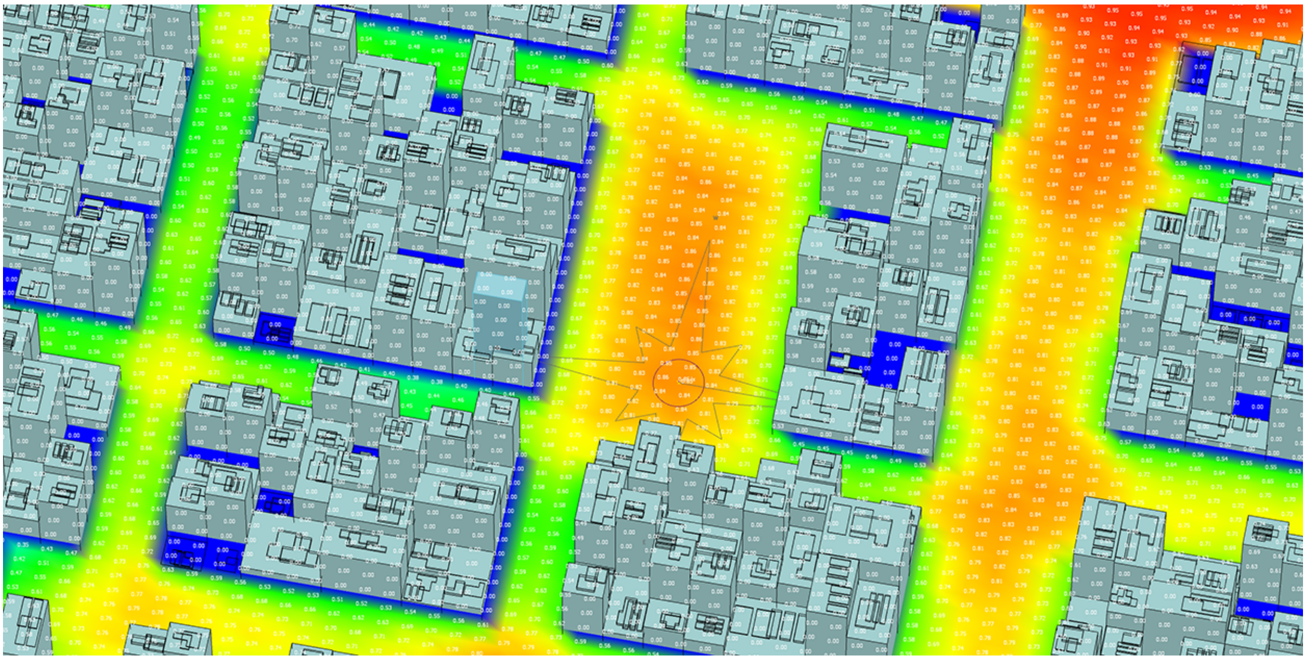
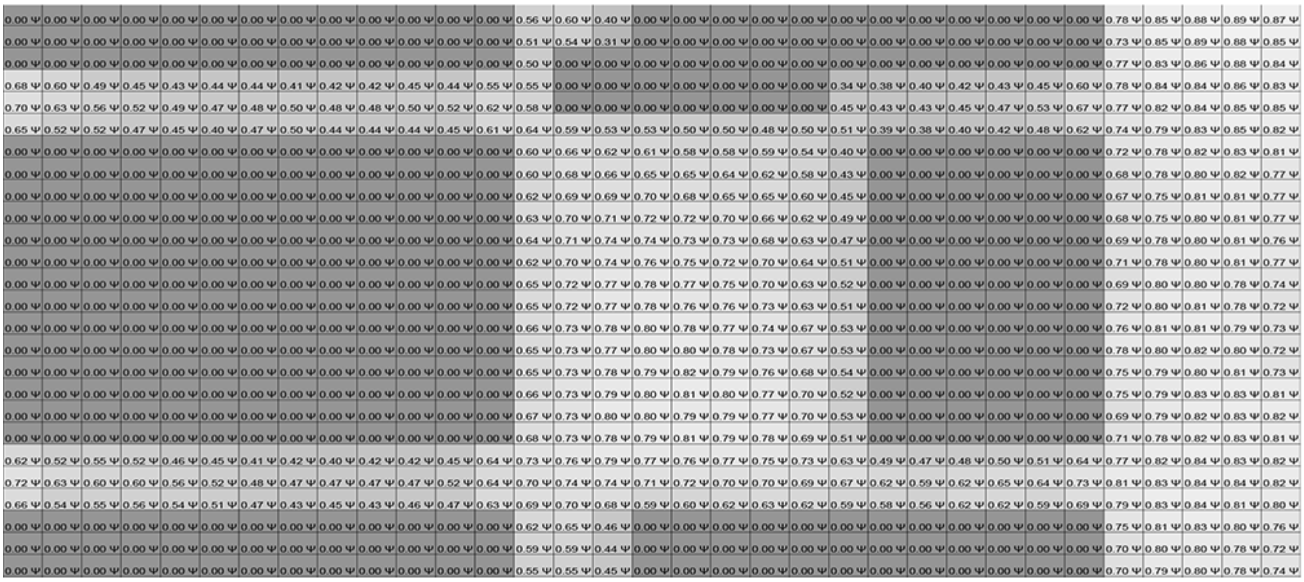


Figure 3. This figure shows a screen grab of the grid of lux meters configured to read SVF levels for a large urban precinct.



0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.56 Ψ	0.60 Ψ	0.40 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.78 Ψ	0.85 Ψ	0.88 Ψ	0.89 Ψ	0.87 Ψ
0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.51 Ψ	0.54 Ψ	0.31 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.73 Ψ	0.85 Ψ	0.89 Ψ	0.88 Ψ	0.85 Ψ
0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.50 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.77 Ψ	0.83 Ψ	0.86 Ψ	0.88 Ψ	0.84 Ψ
0.68 Ψ	0.60 Ψ	0.49 Ψ	0.45 Ψ	0.43 Ψ	0.44 Ψ	0.44 Ψ	0.41 Ψ	0.42 Ψ	0.42 Ψ	0.45 Ψ	0.44 Ψ	0.55 Ψ	0.55 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.34 Ψ	0.38 Ψ	0.40 Ψ	0.42 Ψ	0.43 Ψ	0.45 Ψ	0.60 Ψ	0.78 Ψ	0.84 Ψ	0.84 Ψ	0.86 Ψ	0.83 Ψ
0.70 Ψ	0.63 Ψ	0.56 Ψ	0.52 Ψ	0.49 Ψ	0.47 Ψ	0.48 Ψ	0.50 Ψ	0.48 Ψ	0.48 Ψ	0.50 Ψ	0.52 Ψ	0.62 Ψ	0.58 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.45 Ψ	0.43 Ψ	0.43 Ψ	0.45 Ψ	0.47 Ψ	0.53 Ψ	0.67 Ψ	0.77 Ψ	0.82 Ψ	0.84 Ψ	0.85 Ψ	0.85 Ψ
0.65 Ψ	0.52 Ψ	0.52 Ψ	0.47 Ψ	0.45 Ψ	0.40 Ψ	0.47 Ψ	0.50 Ψ	0.44 Ψ	0.44 Ψ	0.44 Ψ	0.45 Ψ	0.61 Ψ	0.64 Ψ	0.59 Ψ	0.53 Ψ	0.53 Ψ	0.50 Ψ	0.50 Ψ	0.48 Ψ	0.50 Ψ	0.51 Ψ	0.39 Ψ	0.38 Ψ	0.40 Ψ	0.42 Ψ	0.48 Ψ	0.62 Ψ	0.74 Ψ	0.79 Ψ	0.83 Ψ	0.85 Ψ	0.82 Ψ
0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.60 Ψ	0.66 Ψ	0.62 Ψ	0.61 Ψ	0.58 Ψ	0.58 Ψ	0.59 Ψ	0.54 Ψ	0.40 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.72 Ψ	0.78 Ψ	0.82 Ψ	0.83 Ψ	0.81 Ψ
0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.60 Ψ	0.68 Ψ	0.66 Ψ	0.65 Ψ	0.65 Ψ	0.64 Ψ	0.62 Ψ	0.58 Ψ	0.43 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.68 Ψ	0.78 Ψ	0.80 Ψ	0.82 Ψ	0.77 Ψ
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0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.63 Ψ	0.70 Ψ	0.71 Ψ	0.72 Ψ	0.72 Ψ	0.70 Ψ	0.66 Ψ	0.62 Ψ	0.49 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.68 Ψ	0.75 Ψ	0.80 Ψ	0.81 Ψ	0.77 Ψ
0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.64 Ψ	0.71 Ψ	0.74 Ψ	0.74 Ψ	0.73 Ψ	0.73 Ψ	0.68 Ψ	0.63 Ψ	0.47 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.69 Ψ	0.78 Ψ	0.80 Ψ	0.81 Ψ	0.76 Ψ
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0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.65 Ψ	0.73 Ψ	0.77 Ψ	0.80 Ψ	0.80 Ψ	0.78 Ψ	0.73 Ψ	0.67 Ψ	0.53 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.78 Ψ	0.80 Ψ	0.82 Ψ	0.80 Ψ	0.72 Ψ
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0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.66 Ψ	0.73 Ψ	0.79 Ψ	0.80 Ψ	0.81 Ψ	0.80 Ψ	0.77 Ψ	0.70 Ψ	0.52 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.75 Ψ	0.79 Ψ	0.83 Ψ	0.83 Ψ	0.81 Ψ
0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.67 Ψ	0.73 Ψ	0.80 Ψ	0.80 Ψ	0.79 Ψ	0.79 Ψ	0.77 Ψ	0.70 Ψ	0.53 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.69 Ψ	0.79 Ψ	0.82 Ψ	0.83 Ψ	0.82 Ψ
0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.68 Ψ	0.73 Ψ	0.78 Ψ	0.79 Ψ	0.81 Ψ	0.79 Ψ	0.78 Ψ	0.69 Ψ	0.51 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.71 Ψ	0.78 Ψ	0.82 Ψ	0.83 Ψ	0.81 Ψ
0.62 Ψ	0.52 Ψ	0.55 Ψ	0.52 Ψ	0.46 Ψ	0.45 Ψ	0.41 Ψ	0.42 Ψ	0.40 Ψ	0.42 Ψ	0.42 Ψ	0.45 Ψ	0.64 Ψ	0.73 Ψ	0.76 Ψ	0.79 Ψ	0.77 Ψ	0.76 Ψ	0.77 Ψ	0.75 Ψ	0.73 Ψ	0.63 Ψ	0.49 Ψ	0.47 Ψ	0.48 Ψ	0.50 Ψ	0.51 Ψ	0.64 Ψ	0.77 Ψ	0.82 Ψ	0.84 Ψ	0.83 Ψ	0.82 Ψ
0.72 Ψ	0.63 Ψ	0.60 Ψ	0.60 Ψ	0.56 Ψ	0.52 Ψ	0.48 Ψ	0.47 Ψ	0.47 Ψ	0.47 Ψ	0.47 Ψ	0.52 Ψ	0.64 Ψ	0.70 Ψ	0.74 Ψ	0.74 Ψ	0.71 Ψ	0.72 Ψ	0.70 Ψ	0.70 Ψ	0.69 Ψ	0.67 Ψ	0.62 Ψ	0.59 Ψ	0.62 Ψ	0.65 Ψ	0.64 Ψ	0.73 Ψ	0.81 Ψ	0.83 Ψ	0.84 Ψ	0.84 Ψ	0.82 Ψ
0.66 Ψ	0.54 Ψ	0.55 Ψ	0.56 Ψ	0.54 Ψ	0.51 Ψ	0.47 Ψ	0.43 Ψ	0.45 Ψ	0.43 Ψ	0.46 Ψ	0.47 Ψ	0.63 Ψ	0.69 Ψ	0.70 Ψ	0.68 Ψ	0.59 Ψ	0.60 Ψ	0.62 Ψ	0.63 Ψ	0.62 Ψ	0.59 Ψ	0.58 Ψ	0.56 Ψ	0.62 Ψ	0.62 Ψ	0.59 Ψ	0.69 Ψ	0.79 Ψ	0.83 Ψ	0.84 Ψ	0.81 Ψ	0.80 Ψ
0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.62 Ψ	0.65 Ψ	0.46 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.75 Ψ	0.81 Ψ	0.83 Ψ	0.80 Ψ	0.76 Ψ
0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.59 Ψ	0.59 Ψ	0.44 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.70 Ψ	0.80 Ψ	0.80 Ψ	0.78 Ψ	0.72 Ψ
0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.55 Ψ	0.55 Ψ	0.45 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.00 Ψ	0.70 Ψ	0.79 Ψ	0.80 Ψ	0.78 Ψ	0.74 Ψ

Figure 4. This figure displays a screen grab of a portion of data grid readings exported to Microsoft Excel™ with cells shaded based on SVF value. Note that inside buildings, SVF = 0 (this is due to windows and internal walls not being modelled in the test scene).

these domes was then altered to remove portions of the polygon mesh to a known area percentage—beginning with 50%. We activated the SVF meter and the resulting SVF readings were each within ± 0.01 of the expected 0.50Ψ reading (0.51, 0.50 and 0.51) shown in Figure 5 (b), (c) and (d) and Table 1.

We performed the final test with a more complex 3D mesh with a simulated skyline to either retain or remove the dome's polygons (Figure 5 (e)). The area of the full dome was measured and compared with the modified skyline dome area. The area comparison showed that 38.883% of the polygons of the mesh dome retained, thus the SVF meter should result in a SVF = 0.61Ψ. In this case the reading was within ± 0.03 (Table 1). This was seen as an acceptable range of error for urban scaled modelling and though a higher degree of accuracy would be possible by increasing the number of photons or the quality of the rendering by increasing the density of light photons, we believed this was not worth the potential sacrifice in speed of feedback.

For more iterative real-time feedback, we used the GPU method which uses the Nitrous™ viewport drivers (Murdock, 2012) providing a kind of ambient occlusion meaning that this SVF analysis was able to be employed directly within a 3D design modelling environment with real-time viewport feedback (Figures 6 and 7).

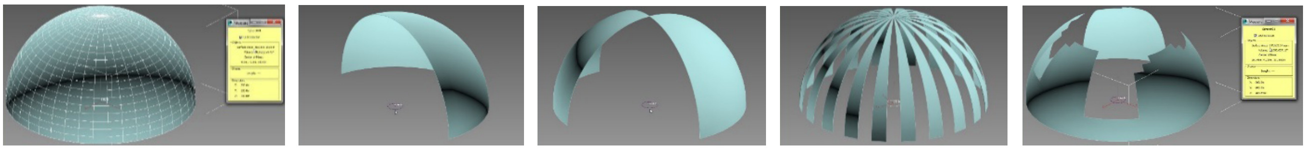
3.2. Urban Sample Studies: Application in Different Urban Conditions

In this study we examine the validity of the approach by applying the CPU SVF method to four sample areas of existing cities to test speed and ability to produce visually comparable results in vastly different urban conditions. The data can be exported numerically for more detailed analysis or comparison of specific portions of these sample areas. However, this lies outside the scope of this study.

Urban fabric samples of 1000 × 1000m were selected from areas of the rapidly growing city of Nanjing, China, and one from a growth area in Melbourne, Australia. Sites were chosen that embodied a wide range of urban typologies including tower, towerpodium, slab-block, low-rise high-density (traditional Chinese "hutong" urban form), low-rise low-density (traditional Australian urban form). The sites were also chosen as they are suscep-

Table 1. This table shows the results of verification test examples given in Figure 5, tabling extent of enclosure (as a % of dome coverage) with expected SVF results against actual SVF point readings. These results suggest a SVF reading accuracy of ± 0.03.

	(a)	(b)	(c)	(d)	(e)
Measured enclosure (%)	100.00	50.00	50.00	50.00	38.88
Expected SVF (Ψ)	0.00	0.50	0.50	0.50	0.61
Point reading SVF (Ψ)	0.00	0.51	0.50	0.51	0.64



(a) 0.00 Ψ **(b)** 0.51 Ψ **(c)** 0.50 Ψ **(d)** 0.51 Ψ **(e)** 0.64 Ψ

Figure 5. This figure gives examples of part of verification testing showing a 300m radius dome with known surface area compared with domes of the same radius but different percentages of surface area removed, measuring each with single SVF meter (in the central point of the dome).

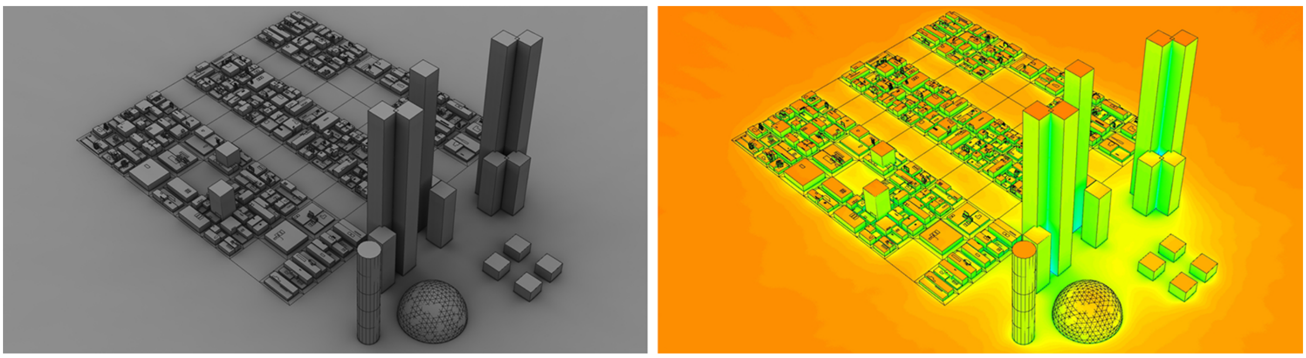


Figure 6. This figure shows screen grabs of a simple precinct model with partially restrictive height limits (low buildings) (left image) with GPU based viewport feedback for sky view factor (urban canyon) of the model on the (right image).

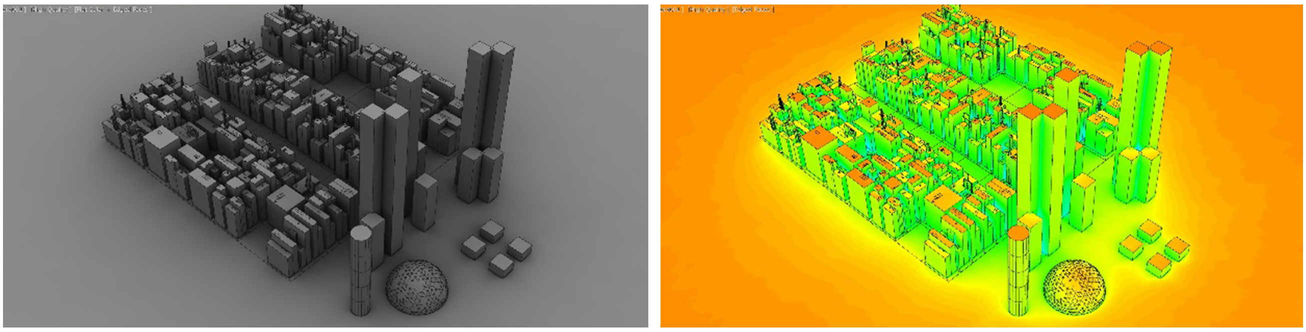


Figure 7. This figure shows screen grabs of a simple precinct model with less restrictive height limits (taller buildings) (left image) with GPU based viewport feedback for sky view factor (urban canyon) (right image).

tible to substantial heat waves (BOM, 2013) and suitable geospatial data was available.

In the second part of the study, we then use the GPU approach on a large urban renewal project testing the method's suitability for comparing existing conditions with the currently proposed master plan, and then compare potential variations of height restrictions and different setback options. For this study we chose Beenleigh, a suburb outside Brisbane, Australia, as it currently in the process of undergoing major urban renewal at a rate and scale similar to Chinese city densities. The chosen site also shares similar climatic heat and humidity conditions to Nanjing China and is therefore a site where increased urban canyon is worthy of consideration in the master planning design process.

3.2.1. CPU Based SVF Calculation Method Applied

To test the CPU based SVF calculation, 1000 × 1000m 3D samples of urban form were extracted from existing digital geo-spatial city models of Nanjing, China and Melbourne, Australia. We sampled Longjiang, a residential area developed in the 1990's adjacent to the Nanjing city, Chengnan, an inner historical area of inner city of Nanjing, Xinjiekou, an inner city Nanjing, and Arden-Macaulay, an inner northern suburb of Melbourne.

We set up a template file with an adapted 1000 × 1000m SVF measurement grid set to take measurements at 10m intervals. The different square samples were then linked (externally referenced) into the template and the SVF was calculated for each site.

The SVF calculations based on the 10m interval settings were obtained extremely rapidly within 10–16 seconds. Light meter intervals at 5m were also then tested, generating results within 20–35 seconds and 1m intervals generating results within 1.45–3.55 minutes. The site that took the most time to calculate SVF was Changnan, due to the higher polygon mesh density used to represent the finer grain urban form (Figure 10 and Figure 12).

The resulting graphic representational outputs of the analysis draw attention to potential problem urban

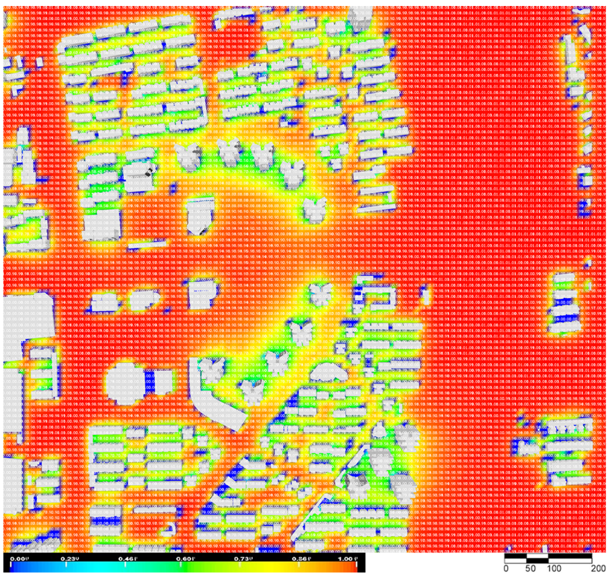


Figure 8. This figure shows Longjiang, a residential area developed in 1990's adjacent to city in Nanjing, China, SVF calculated at 10m intervals.

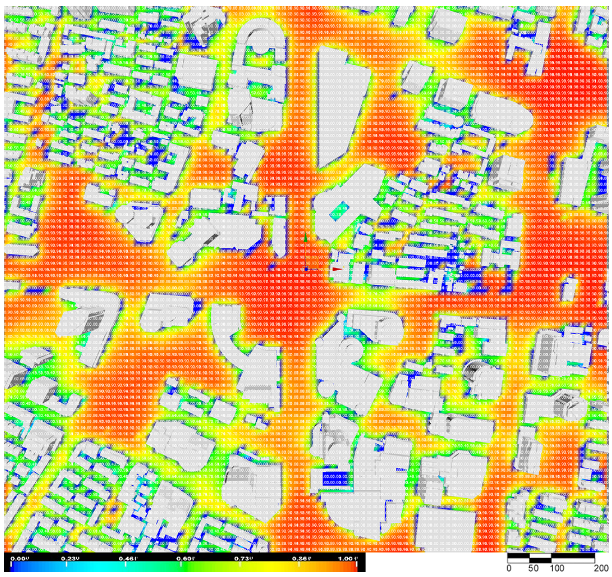


Figure 9. This figure shows Xinjiekou, an inner city Nanjing, China, SVF calculated at 10m intervals.

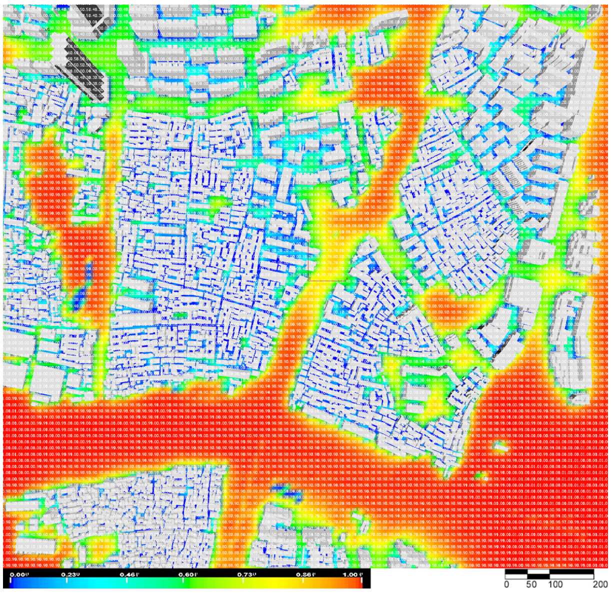


Figure 10. This figure shows Chengnan, an historical area of inner Nanjing, China, SVF calculated at 10m intervals.

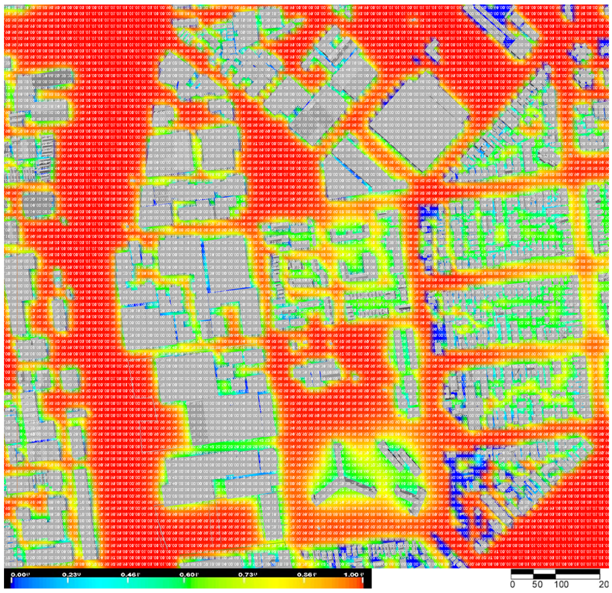


Figure 11. This figure shows Arden-Macaulay, an inner suburb of Melbourne, Australia, SVF calculated at 10m intervals.

canyon areas. The visual outputs also allowed quick visual comparisons both between and within the samples. As would be expected in a study of diverse urban forms, a great range of SVF readings were found, with the lowest SVF in the traditional Chinese high-density low-rise urban form in the Chengnan area (Figure 10); the highest readings found in the comparatively low-density low-rise Arden-Macaulay site in Melbourne (Figure 11) and the 1980's modernist developments of Longjiang precinct in Nanjing, China.

As expected, we also found there to be a great variety within each site sample—particularly obvious in the Chengnan site (Figure 10 and Figure 12) where traditional low-rise informal Chinese urban forms are contrasted with 1960's Soviet style housing slab-blocks which, somewhat unexpectedly given their heights, achieve considerably better SVF results due to the large adjacent open spaces.

3.2.2. GPU Based SVF Calculation Method

The above description of the CPU method shows that the approach is good for analysis of existing conditions and can provide both visual and numeric data output for fur-

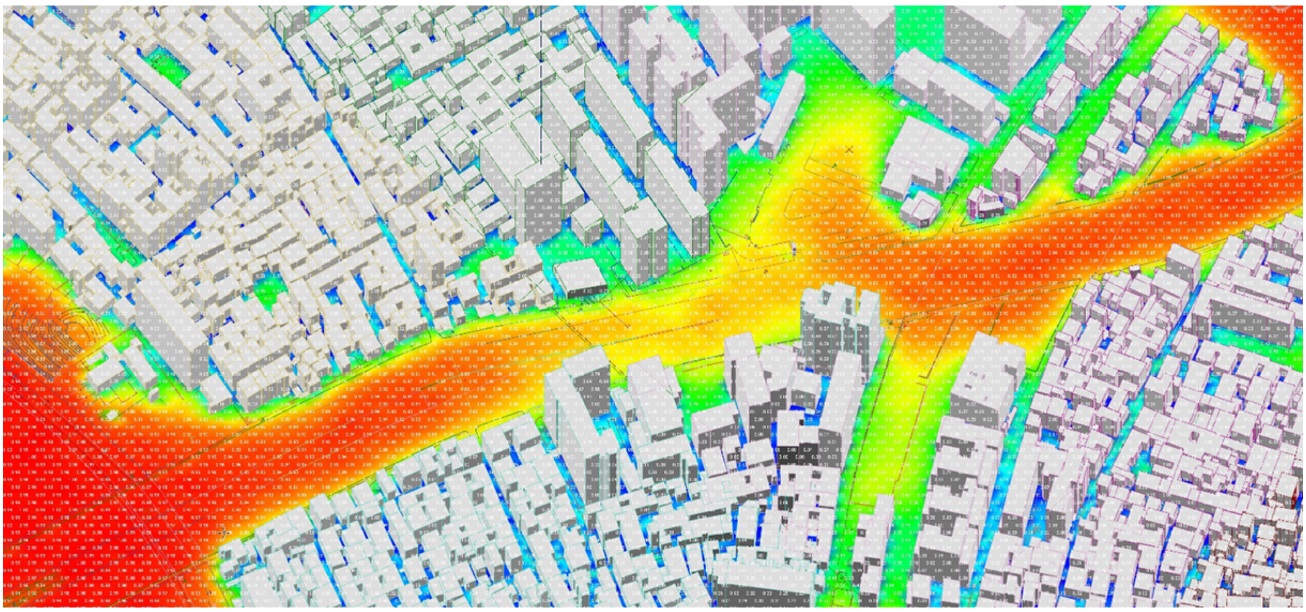


Figure 12. Detailed aerial view of the Chengnan precinct showing contrast between traditional and informal development with Soviet style slab-block development.

ther analysis, but we hypothesised that a quicker, more iterative process might be more useful for analysis during the design phase of a project.

To test the suitability of the GPU based calculation, we used a used the area of Beenleigh in Queensland, Australia, which is currently undergoing major urban renewal. We tested the existing urban conditions by building a flexible procedural based digital model utilising data from the Logan City Council, and from the online e-research tools of the Australian Urban Research Infrastructure Network (AURIN) (Figure 13, left). We then modelled the potential urban form based on the current government master plan documentation (Figure 13, right).

In this case we embedded (as opposed to externally referenced) the geometry into a single file and managed the existing and proposed design iterations using a 'Scene States' feature which allowed light, cameras, materials, visible layers and geometry parameters to be saved as a 'state'. We set up the GPU based SVF analysis settings on the existing conditions model and saved the Scene State. We then compared the existing conditions with the currently proposed master plan (Figure 14). The GPU based SVF modelling instantly revealed a dramatic reduction in SVF throughout the central activity area in currently proposed master plan option, with the existing urban fabric showing high levels of SVF at both street level and overall building level (shown in red), whereas the proposed master plan model shows low levels at street level (shown in green) and very low levels on façades where proposed high-rise buildings are set out with close proximity (Figure 14).

We then followed on with a series of design variations, changing height parameter restrictions and setback options by adjusting the geometry parameters (Figures 15 and 16). As the 3D model had been set up in a flexible, procedural way, we could rapidly adjust parameters using spinner controllers and receive real-time viewport feedback of not only the impact on SVF, but also on what the new geometry looked like at eye height (visual impact) using perspective cameras and by toggling between Scene States from SVF state to textured viewport state. As we were calculating SVF with the GPU method, the analysis was considerably faster than the CPU method, that would allow for a more integrated and iterative design workflow whilst developing planning controls for the site. The analysis also calculated SVF for not only the ground level as would be the case for other SVF analysis methods mentioned earlier, but also assessed façades and building roofs (Figure 16).

4. Conclusion

In this paper we have outlined preliminary findings of a new method for modelling SVF that extends the applicability of the metric by proposing two analysis methods—a CPU based calculation and GPU base calculation. Both of these methods dramatically increase speed of analysis, addresses limitations of 2.5D methods of SVF calcu-

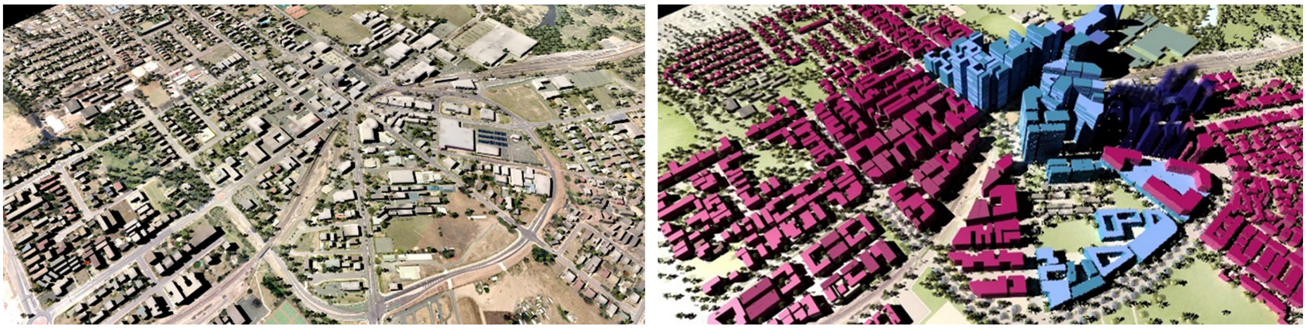


Figure 13. Left image shows render of 3D digital model of existing urban form. Right image shows render of flexible 3D digital model of master plan's potential urban form, used for visualisation; communication; solar impact analysis; and design advocacy.

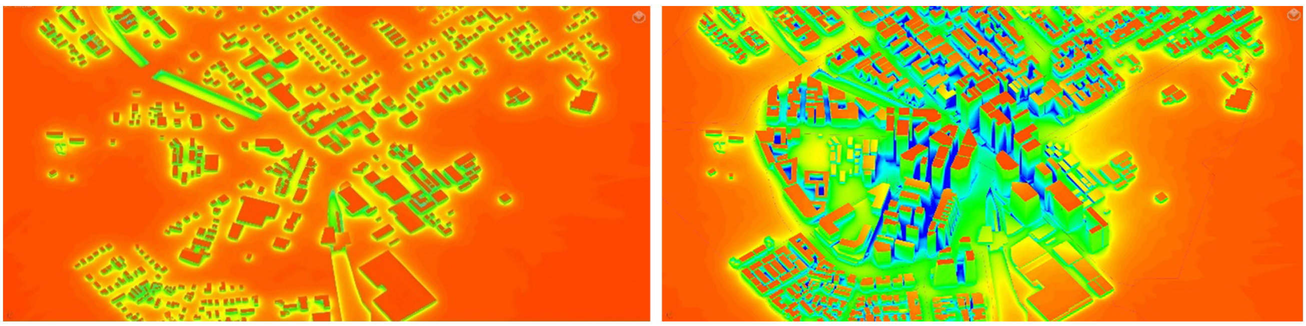


Figure 14. Left: screen grab of GPU based SVF calculation performed on the town centre of Beenleigh, in the City of Logan, Queensland, Australia. Right: GPU based SVF calculation performed on currently proposed master plan height and setbacks, resulting in clearly visible increased urban canyon (low level of SVF shown in blue).

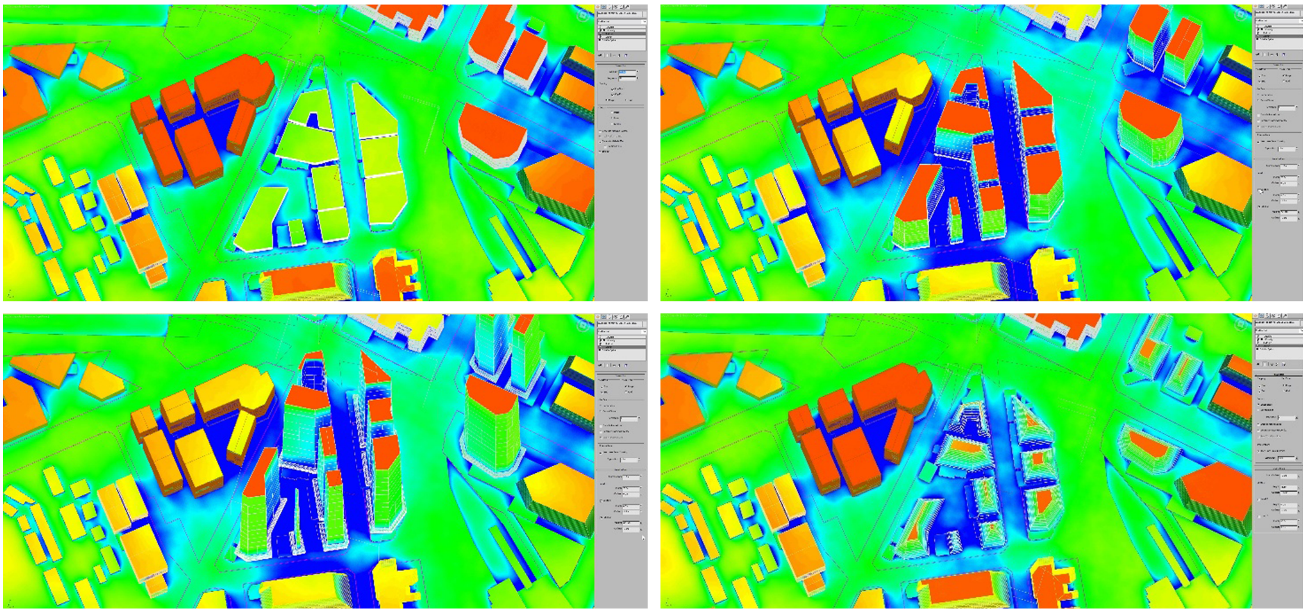


Figure 15. A series of screen grabs showing GPU based SVF calculated in real-time whilst adjusting height, podium size and setback, and tower taper parameter 'spinners' controlling potential urban form.

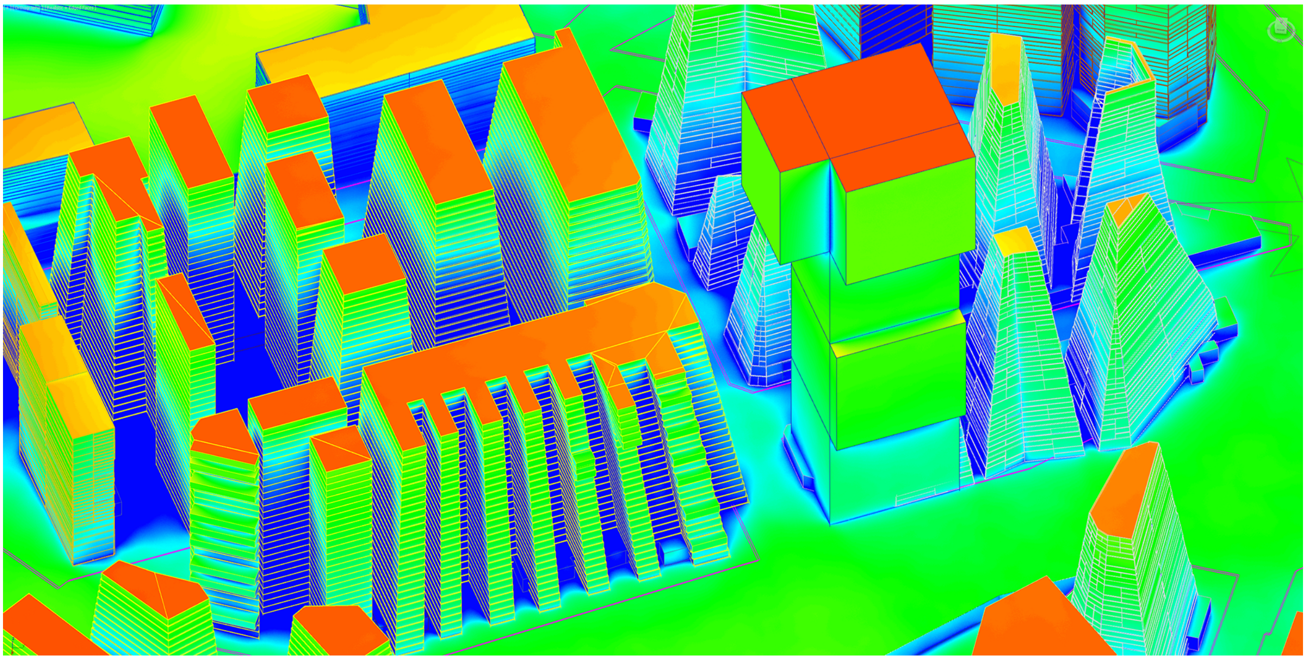


Figure 16. This figure shows a screen grab illustrating the detailed 3D SVF calculation on potential urban form with tapering setback profiles, as well as more complex cantilevered balconies and building masses. The SVF is not only calculated at the ground level, but also across building façades (potentially useful for assessing view quality within buildings).

lation and integrate the analysis into design software to provide rapid design feedback.

The CPU based calculation was shown to be useful in studies of existing urban fabric, where a known physical condition can be tested and compared with other existing urban fabrics (Figure 8 to Figure 11). Though typology was not the focus of this study, the SVF modelling approaches rapidly exposed the large variation in openness in each of the study areas with particularly interesting resulting comparisons with low-rise traditional Chinese areas compared with modernist mid-rise slab block housing (Figure 10). The results of these initial tests suggest further investigation of urban morphology and typological impacts of SVF looking at each of the sites in more detail and comparing numeric SVF data outputs with microclimatic readings. Though SVF is only one piece of the puzzle of UHI modelling, it is an important element to understand and be able to analyse at a large but detailed scale. The modelling approach outlined provides city designers and researchers potential for complex and detailed comparative studies of large scale SVF readings against environmental behaviour within test areas using temperature and humidity sensor data logging (Ewenz et al., 2012; Kakon & Nobuo, 2009) and is part of ongoing parallel micro climatic research by the authors (White & Kimm, 2015) as well as vegetation impact modelling research (White & Langenheim, 2014a).

The CPU method appears useful in identifying key problem areas in existing urban conditions, suggesting where urban design interventions or solutions might be most effectively targeted either through modification of urban form, or where this is not possible, through strategically located vegetation.

The GPU based calculation method proved to be useful in a more fluid and tactile way due to its real-time feedback combined with real-time model manipulation. By providing dynamic visual (viewport) SVF feedback for complex three-dimensional urban scenarios, it permits new ways of engaging feedback during design processes, effectively integrating the design analysis with the design process. As this method remains within the design modelling and visualisation environment, it lends itself to mixing intuitive compositional design gestures, cultural understandings and conceptual design ideas with meaningful environmental impact feedback. This differs from other algorithmic optimisation modelling approaches (Panão, Gonçalves, & Ferrão, 2008; Yu, Austern, Jirathiyut, & Moral, 2014) in that it does not attempt to remove the human element of design. There is however potential for further investigation of using either CPU or GPU based SVF analysis methods in the exploration of optimisation algorithms using MaxScript or Max Creation Graph, or by porting the approach to Rhino 3D with Grasshopper.

In large scale urban renewal projects, we see great potential for designers to use both the GPU and CPU based analysis as an integrated part of their design process. GPU based SVF can be used whilst 'form finding' as urban form is manipulated and 'sculpted' to maximise SVF whilst meeting a variety of other design criteria. Urban planning control options can be compared visually with GPU method, and when design options are refined, the CPU based numeric analysis can be used to calculate tangible numeric evidence that can be used in the advocacy of design propositions.

Both CPU and GPU approaches have the potential to inform existing and new planning controls for renewal areas. The above studies suggest that planning controls such as site coverage, building setbacks and building heights might be informed using these approaches in cities that experience extreme heat conditions where urban canyon is considered a critical decision making factor such as those cities sampled above.

The method described also has potential for assessment of other aspects of urban comfort. As mentioned above, the GPU method calculates SVF at ground level as per the CPU method and other commonly used SVF analysis methods, but also assesses façades and building roofs. There is potential for further research into the impact of SVF on the quality of view within high density development. This raises questions such as: does the amount of sky visible from a façade (apartment windows or balconies) impact on property prices; and does the amount of visible sky from within a hospital room impact on patient recovery times?

In conclusion, the new approach extends the applicability in the design process of existing methods by providing 'real-time' SVF feedback for complex three-dimensional urban scenarios in a variety of diverse urban contexts. The modelling approach enables city designers to mix intuitive sculptural, compositional and tactile design modelling with dynamic urban environmental modelling feedback, and output numeric data when required.

The approach allows a greater understanding of existing and proposed urban forms and identifying potential UHI problem areas; improved decision making, community engagement and design advocacy; and can potentially have an impact on cities' temperature thus reducing cooling energy load costs, and more importantly, potentially reduce heat related mortality.

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Conflict of Interests

The authors declare no conflict of interests.

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Article

Governing Uncertainties in Sustainable Energy Transitions—Insights from Local Heat Supply in Switzerland

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Abstract
The governance of sustainable energy transitions (SET) is facing multiple technological, economic, societal and political uncertainties. In practice, these energy-related uncertainties play a role not only at the level of "major politics," but also in the policymaking of local decision makers and planners. This paper seeks to attain a more differentiated understanding of how uncertainties concerning the energy transition play out and are dealt with in policymaking and planning "on the ground." To do so, the paper combines conceptual reflections with an explorative empirical study on local heat supply policy in Switzerland. In conceptual regards, it proposes some distinctions of types of uncertainties related to energy transitions, and a typology of strategic decision options for dealing with uncertainty. On this basis, the paper reveals similarities and differences regarding the perception of uncertainties and ways of dealing with them in a number of Swiss cities. These insights evoke further questions about the causes and effects of different sensitivities to uncertainty and ways of dealing with them.

Keywords
energy transition; governance of uncertainty; sustainability; sustainability governance; uncertainty; urban heat supply

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1. Introduction

Energy systems all over the world are currently facing two major challenges. On the one hand, the existing infrastructures in many countries are reaching the end of their technical lifespans. On the other hand, the discourse about sustainable development (and its energy-related storylines such as "peak-oil," "climate change," and "Fukushima") is questioning the effectiveness and legitimacy of the incumbent energy systems and has brought about political pressure to reform these systems (Araújo, 2014; Solomon & Krishna, 2011). In light of these challenges, some countries have begun fostering sustainability-oriented transitions of their energy systems. For this purpose, they have set up concerted governance efforts that cut across various policy domains and levels (Laes, Gorissen, & Nevens, 2014). In Switzerland, for example, the federal government has come up with an overarching energy strategy, which includes goals such as the reduction of energy consumption, a further substitution of fossil fuels with renewable energy, and the reduction of CO_2 emissions. While this strategy promotes a general national policy framework for the envisioned energy transition, the Swiss federalist system renders sub-national actors, such as cantons and municipalities, important players for the realization of the goals. In fact, these actors dispose of the main legislative and administrative competences in energy policy and planning (see Schubert, 2015) and, therefore, have to deal with the concrete challenges that come with the energy transition and its governance "on the ground."

One of the main challenges related to the governance of sustainable energy transitions is uncertainty (Meadowcroft, 2009; Meijer & Hekkert, 2007). Generally, such uncertainty results from both the long-termism and complexity of the endeavor. For example, energy infrastructure involves long-ranging investment cycles which deal with making projections up to 60 years in advance. Yet it remains uncertain which societal developments and technological innovations—not to mention what changes in political dynamics as well as individual behaviors—might take place within these time horizons (Monstadt, 2004). In addition, the envisioned transitions are highly complex in nature, as they refer to the entire energy chain (from production through distribution to consumption) and cut across various technological, economic, social, and ecological domains involving multiple actors at different levels. The various linkages among the different subsystems and levels virtually guarantee uncertainty.

These kinds of uncertainty are also relevant in the field of energy for heat demand. As heat constitutes a major component of residential energy demand (up to 80%, including hot water, in northern European countries) and the integration in renewable energies slows (compared to the pace of their development in power supply during the last ten years), this field is assumed to bear a crucial potential for realizing a sustainable energy transition (e.g., BMWI & BMU, 2010). At the same time, there is an urgent need to transform the urban infrastructure in light of ambitious political goals in energy and climate politics. As the planning related to urban heat supply takes place at the local level, where the existing infrastructure requires major investments for renovation and where political goals for integration of renewable energies into the heat supply have to be transformed into concrete measures, it is the local policymakers and planners who are facing uncertainties and have to deal with them in concrete decisions.

While decision-making in the face of uncertainty is probably most prominently discussed in the field of psychology with a focus on individual behavior (Tversky & Kahneman, 1974), the topic is also a recurrent "classic" in various fields of research focusing on collective decision-making—ranging from organization and management studies (Courtney, Kirkland, & Viguerie, 1997; Weick & Sutcliffe, 2015) to policy research (Arentsen, Bressers, & O'Toole, 2000; Renn, 2008). More recently, the issue has gained prominence in the interdisciplinary field of environmental and sustainability studies, reflecting a core challenge of sustainability governance (Berkes, 2007; Grunwald, 2007; Polasky, Carpenter, Folke, & Keeler, 2011). Some accounts even refer to uncertainty as a core element of a more general problematic that modern (reflexive) governance has to deal with (Beck, 2006; Voss, Newig, Kastens, Monstadt, & Nölting, 2007).

These governance-oriented literatures have provided valuable conceptual and empirical insights into the types of uncertainties and strategies of dealing with them in terms of collective action. However, we see two important knowledge gaps. First, there is little conceptual and empirical knowledge regarding the concrete meanings and manifestations of uncertainty in specific practice fields such as energy transitions. Second, existing research tends to focus on rather aggregate arrangements for dealing with uncertainty on a strategic level of collective choice. Yet, there is only little knowledge about how uncertainty is perceived and dealt with by actors on a more operational and individual level of decision-making on the ground.

With our paper, we seek to address these knowledge gaps and shed light on variations of uncertainty and ways of dealing with them in the particular policy field of local heat supply in Switzerland. To do so we ask the following question: *How are uncertainties perceived and dealt with in local heat policymaking and planning in Switzerland?* Following this question, we aim to contribute conceptual and empirical insights to the study of uncertainties in energy transitions as well as uncertainty-oriented governance and policymaking more generally. In conceptual respects, we bring together the general notion of uncertainty with the complexity of energy transitions proposing a nuanced understanding of energy transition-related uncertainties. Furthermore, we provide a typology of basic strategic decision options for dealing with uncertainties, which can guide further governance-oriented uncertainty research. In empirical respects, we explore how uncertainties are perceived and dealt with in the context of different governance arrangements. These conceptual and explorative empirical insights shall provide the ground for further systematic inquiries on the relationship between uncertainty and policymaking.

We begin by outlining a conceptual understanding of uncertainty that takes account of the complexities of sustainability-oriented energy transitions (Section 2). After critically reflecting on an established distinction of three "classical" uncertainty-related governance strategies, we propose a generic typology that captures options for dealing with uncertainty on the ground (Section 3). We illustrate our conceptual propositions with empirical observations regarding the perception of energy-related uncertainties and the strategies for dealing with these uncertainties in policymaking in three Swiss cities (Section 4). In the concluding Section 5, we summarize the results and discuss their implications for research and practice regarding the governance of energy-related uncertainties on the ground.

2. Uncertainty in the Context of Sustainable Energy Transitions

2.1. Conceptualizing Uncertainty

Uncertainty is a much-debated term that scholars from different disciplines define and delineate from other concepts, such as risk, ambiguity or ambivalence, in different ways (Gross, 2010, p. 53ff.; Jeschke, Jakobs, & Dröge, 2013; Smithson, 1989, 2008; van Asselt & Rotmans, 2002). According to a prominent definition by Walker et al. (2003, p. 5), uncertainty refers to "any deviation from the unachievable ideal of completely deterministic knowledge of the relevant system." As this definition suggests that basically all situations are characterized by uncertainty, its inclusivity comes at the expense of its clarity. Other definitions allow for more differentiation. Gross (2007), for example, locates uncertainty between two ideal typical situations: certainty on the one hand and the unknown on the other. While "certainty" implies that there is only one possible consequence of an action, a situation in which we do not know about the consequences of an action at all can be qualified as "unknown." Uncertainty refers to all situations with multiple possible consequences of one action which are only partly known (Gross, 2010, p. 3).[1] Below the level of definition and delineation, the literature provides us with different typologies of uncertainty stemming from different disciplines and referring to different (more or less specific) contexts of application (Enserink, Kwakkel, & Veenman, 2013; Grunwald, 2007; Milliken, 1987; Smithson, 2008).

First, cutting across the current literature, there are different understandings of the *object of uncertainty*, i.e. answers to the question of *what* exactly is uncertain. Various authors distinguish between ontic and epistemic uncertainties (van Asselt & Rotmans, 2002; Walker et al., 2003). Ontic uncertainty refers to given contingencies and variabilities in the behavior of real world systems (nature, human behavior, society, technology). In contrast, epistemic uncertainty refers to some incomplete or limited knowledge about a certain situation. This means that our propositions and beliefs are uncertain. In the realm of epistemic uncertainty, one can further distinguish between factual and normative uncertainties. For example, Christensen (1985) distinguishes between the (un-)certainty of normative goals and instrumental means in decision situations; Mazouz (2003) explicitly points to the uncertainty of normativity. However, most frequently, epistemic uncertainty relates to some form of factual knowledge (Grunwald, 2007; Smithson, 2008; Voss et al., 2007). And we see good reasons to follow that line, since there are other concepts that denote contingent normativity (such as "ambivalence").

Below the distinction between ontic and epistemic uncertainty, there are several more specific suggestions to differentiate objects (and sometimes also locations) of uncertainty. In the context of integrated assessment and modelling, for example, van Asselt and Rotmans (2002) distinguish between states, processes, functions, outcomes, and impacts of uncertainty. In the context of organizational action, Milliken (1987) differentiates between state, effect, and response uncertainty.

A second fundamental dimension of uncertainty refers to the *mode of uncertainty*, that is, *how* or in what respect something is (regarded to be) uncertain. According to a common understanding, there are different levels of (epistemic) uncertainty. Some authors distinguish between non-fundamental uncertainty (as a lack of knowable knowledge) and fundamental uncertainty (as a lack of unknowable knowledge). Other authors suggest more differentiated conceptualizations that cover various interim steps such as inexactness, lacking measurements, immeasurability, conflicting evidence, reducible ignorance, indeterminacy, and irreducible ignorance (van Asselt & Rotmans, 2002). In whatever form, the levels and types of uncertainty express the assumption that some situations are essentially uncertain due to fundamental problems in discerning knowledge about the quality or extent of an incident. In contrast, situations of non-fundamental uncertainty are *in principle* describable by probabilistic statements: if there was enough knowledge, they could turn into calculable risks or even certainty (in case of deterministic relationships).

A further analytical differentiation regarding the mode of uncertainty refers to its contestation. Uncertainties can be agreed on by the actors who are involved in a decision situation, or they can be contested (Gottschick, 2014). Whether at all or to what extent a situation is seen as certain or uncertain can become part of a dispute. Some can hold the knowledge that constitutes the understanding of a situation as certain while others doubt about it. These differences regarding the perception of uncertainty may have different causes, such as different "ways of knowing" or framings (Brugnach, Dewulf, Pahl-Wostl, & Taillieu, 2008). This understanding promotes a notion of (epistemic) uncertainty, which is essentially subjective and constructed.

We follow this manner of reasoning and regard uncertainty as a concept that organizes an actor's interpretation of a situation (Brugnach et al., 2008; Enserink et al., 2013; Smithson, 2008). However, for analytical purposes, we suggest maintaining the distinction between objective and subjective uncertainty (Milliken, 1987; Renn, 2008). Referring to objective uncertainties does not imply that these uncertainties are "objectively" true (i.e., ontic uncertainties). Rather, objective uncertainties denote situations in which actors are confronted with assertions and diagnoses of uncertainty (e.g., in the public or scientific discourse) that have not (yet) entered their individual action space. Accordingly, subjective uncertainties are interpreted objective uncertainties: uncertainties that have been perceived as being relevant by a cer-

[1] This definition is helpful to clarify the relationship between uncertainty and risks—two terms which are very often used in confusing ways. Following the classical understanding (quality of an incident multiplied by the probability of its occurrence), risks can be seen as representing a specific kind of "known" uncertainty, that is, an uncertainty, which is calculable with regard to the quality and the probability of a certain incident (mostly conceptualized in terms of "damage") (see Gross, 2010, p. 60ff.; Renn, 2008). In contrast, uncertainties proper are characterized by the lack of knowledge with regard to one of the two dimensions of risks, while a third category, the "unknown" (non-knowledge), refers to a situation where neither the probability nor the extent of an incident is known.

tain actor. They have become a subjectively relevant reference point for his or her actions.

2.2. Specifying Uncertainty for SET

In light of these general conceptual considerations, how can we make sense of uncertainty in relation to sustainability-oriented energy transitions? More specifically, what uncertainties arise from the endeavour of transforming energy systems toward more sustainable ones? Traditionally, energy systems have been conceptualized in terms of technological infrastructures mediating between supply and demand. More recently, scholars have strived for more comprehensive analytical representations of the energy systems taking account of further societal dimensions of energy production, distribution, and use (Guy & Shove, 2000; Monstadt, 2009; Schippl, Grunwald, & Renn, 2012). This expansion of perspective toward socio-technical energy systems is of particular relevance for studying sustainability-oriented energy transitions (Everett, Boyle, Peake, & Ramage, 2012; Kern & Smith, 2008; Meadowcroft, 2009). And it has major consequences for thinking about uncertainties related to energy transitions.

A socio-technical system perspective implies that the physical components of energy systems (such as power plants, grids, steering devices and storage, etc.) are intertwined with institutions and networks of actors who shape technology through social interactions and practices. The technological domain defines a corridor for human action which creates opportunities as well as restrictions for innovation and change (see e.g. Raven, 2007; Verbong & Geels, 2007). Monstadt (2009) emphasizes that technological infrastructures are both society-shaping and shaped by society. It is human actors—providers, users, and regulators—who construct, manage, and change technical artifacts and coordinate the provision of infrastructure services. From a socio-technical system perspective, energy systems are characterized by specific knowledge, skills, norms, a deep formal organization, and a highly integrated and interconnected structure (Araújo, 2014; Goldthau, 2014). Changing this system means having to reconfigure infrastructures and services and to overcome established actor constellations, norms, values, and power relations (Kuzemko, Lockwood, Mitchell, & Hoggett, 2016; Stirling, 2014).

Based on such a general understanding of complex socio-technical energy systems, uncertainties in relation to sustainable energy transitions have multiple sources that can be located in various technological, economic, societal, and political spheres of the system and the interplay of these spheres (Meijer & Hekkert, 2007).

- Uncertainties in the *technological sphere* relate to the development and application of technologies for extracting and producing, distributing, and using energy resources as well as the future availability of these resources. Technological uncertainty refers to, but is not limited to, aspects such as future developments in combustion and transformation technology, the appropriate degree of (de)centralization of the energy system, the availability of future storage, and regulation technologies. Furthermore, it extends to future energy availability and the feasibility of exploring and exploiting new technologies like deep geothermal energy or fuel cell power (Akademien der Wissenschaften Schweiz, 2012);
- The costs and benefits of envisioned transition pathways and individual decisions regarding these pathways are at the core of uncertainty in the *economic sphere*. Usually these economic uncertainties stem from dynamic technological and market developments on both the supply and demand side. For example, there is uncertainty related to the strategic dynamics between competing energy providers. Moreover, related to cultural change and political dynamics, there are uncertainties regarding the development of energy demand;
- The *societal sphere* of SET-induced uncertainty includes and goes far beyond questions of social protest and public acceptance related to the innovation and development of new technologies and infrastructures. It extends to the manifold actors connected to the system, whether governing, regulating, or being directly affected by such a system. Hence, the interplay as well as the development of interests and practices of these multiple actors are relevant sources of uncertainty. For example, it is impossible to definitively predict how values and norms will change in the future, which lifestyles are or will be commonly shared, or how societal developments will influence consumption patterns. All this leads to high uncertainty regarding future behaviors and actions of individual and collective societal actors;
- *Political uncertainties* regarding the energy system and sustainable energy transitions relate to all kinds of collective decision-making and implementation processes that affect public discourses and policy frameworks, which, in turn, impact private decisions of companies or consumers. Corporate decision makers, for example, regularly point to the need for certain, if not stable, policy frameworks in order to be able to assess the risks and opportunities of investments in new technologies, etc. (Meijer & Hekkert, 2007). In modern democratic societies, political uncertainties stem from open political competition among parties and interest groups. To a certain extent, political struggles are channeled by political institutions and defined procedures. However, in an ever-globalizing and increasingly complicated world (Willke, 2014), these political institutions might themselves become fluid, less reliable, and less important compared to more dynamic political discourses (Hajer, 2003).

3. Governing Uncertainty

3.1. Three Governance Strategies for Dealing with Uncertainty

Strategies for dealing with uncertainty have been widely examined by different strands of governance-oriented literature with a policy and implementation (Arentsen et al., 2000; Bressers, 1997; Jänicke & Jörgens, 1999; Morgan, Henrion, & Small, 1990), organizational (Milliken, 1987), or planning focus (Christensen, 1985). Within these diverse literatures, three ideal typical approaches for dealing with uncertainty can be identified.

The traditional approach for dealing with uncertainty is through planning. In fact, uncertainty is one of the main reasons for planning and the emergence of planning theory (Camhis, 1979; Christensen, 1985). From a planning perspective, uncertainty is something that can be overcome by means of rational calculation and by "sorting things out" (Arentsen et al., 2000). More specifically, a plan can be regarded as a tool for substituting uncertainty with a promise of certainty in two ways. First, efforts can be made to fill existing knowledge gaps regarding the present and the future; second, this informational basis can be used to define goals and means that guide future actions and thereby bridge remaining uncertainties. Planning is about influencing the future (and its uncertainty) by means of decisions that rely on a comprehensive informational basis. This idea of planning has been criticized from many sides, both by those who are skeptical about the possibility of processing comprehensive information and by those who regard fixed goals and means as inappropriate for dealing with dynamic environments and reacting to emerging surprises that result from uncertainties (Meadowcroft, 1999).

Given the shortcomings of the classical planning paradigm, an alternative model of incrementalism has been suggested that rests on step-by-step decisions and actions that take account of the information that is available at a certain point in time (Braybrooke & Lindblom, 1963; Lindblom, 1969, 1973, 1999). Decisions are rather short-term, made in the light of available means and information. They refer to the terrain that can in fact be overseen at a certain point in time from a certain point of view. This incremental approach to decision-making ensures that the information basis is constantly being extended as the decision process evolves. It rests on an experimental trial-and-error logic that allows for cautious and stepwise exploration of uncharted terrain. Incrementalist approaches have not only been celebrated for their empirical adequacy, but also for their normative strength in dealing with complex issues. However, they are also criticized for being biased to conservative positions as they promote a vested interest in the status quo and hinder the kind of fundamental change advocated by sustainability proponents (see Meadowcroft, 1999).

With regard to the shortcomings of both planning and incrementalism, a third way is supposed to integrate the strength of both approaches and, at the same time, avoid their shortcomings. This third way has been called "directed incrementalism" (Grunwald, 2000; Kemp & Loorbach, 2006; Steurer & Martinuzzi, 2005). At the core of this approach are flexible strategies rather than fixed plans. These strategies are supposed to be constantly adapted to dynamically changing conditions without neglecting overall visions. From the perspective of directed incrementalism, policymaking is thus about maneuvering through a dynamic landscape towards an overall goal. Within an approach of directed incrementalism, uncertainties are not controlled once and for all; rather, uncertainties are constantly reduced through continuous learning and the adaptation of an overall strategy.

These three ideal types provide important theoretical insights and illuminate empirical forms of dealing with uncertainty. However, when it comes to understanding how policymakers on the ground deal with uncertainty, at least two limitations become visible. First, the three types refer to patterns of meso-level (i.e., organizational) action courses; however, they do not capture uncertainty-related actions by individual actors within these organizations. Second, these overall strategies come with normative-prescriptive implications of how to adequately and effectively deal with uncertainty, rather than analytically capturing how uncertainties are actually dealt with.

3.2. Dealing with Uncertainty "On The Ground": A Typology of Strategic Options

In what follows, we provide a complementary conceptual framework for understanding how uncertainties are dealt with in policymaking and planning. Compared to the rather general and aggregate (meso-)strategies that become manifest at an organizational level, this framework is supposed to capture, in a more differentiated way, how uncertainties are dealt with at the micro-level of individual actions and practices (Moore, 2008). We assume that individual policymakers can choose from a "menu" of ideal typical strategic options for dealing with uncertainties. This menu is represented in our framework. We have developed it through a method of literature-informed rational imagination (Byrne, 2005) from the perspective of policymakers. This process was guided by the following question: *How would rational policymakers deal with some form of objectively given uncertainty?*[2]

By imagining strategic action options from the perspective of rational policymakers, we depart from other approaches that seek to identify strategies for managing uncertainties from the perspective of different scientific disciplines (Bammer, Smithson, & Goolabri Group, 2008). However, our efforts do not start from scratch, but take

[2] This implies that we do not engage with *all kinds* of imaginable uncertainty-related actions, such as actions to create, impose, or foster uncertainty (Smithson, 2008). Rather, we are interested in ways of *dealing with* some form of *objectively given* uncertainty.

account of the rich literature pertaining to strategies of dealing with uncertainty (such as the rich material in Bammer & Smithson, 2008; Polasky et al., 2011; Weick & Sutcliffe, 2015). Therefore, what we did was reconstructing and sorting the strategies mentioned in the literature along a process of rational imagination from the perspective of allegedly rational administrative actors.

Referring to *rationality* neither implies that the identified options would necessarily entail rational results, nor does it mean that actors do *in fact* rationally choose these options. Rather, it reflects our assumption that actors are interested in overcoming the objective uncertainties they are confronted with in ways, which they can present as being rational. More specifically, we assume that actors, in particular in an administrative context, feel urged to frame their actions in terms of rationality, that is, they present themselves *as if* they acted in a rational way (Gross, 2010; Schimank, 2005).

The strategic options captured in the framework do not represent fully developed strategies. Rather, they take the form of basic "strategic postures" describing the "intent" or basic rationale, "but not the actions required to fulfill that intent" (Courtney et al., 1997, p. 74). The framework takes the form of a binary decision tree: At each level of decision there are two alternative options which are related to a certain rationale.

In the following, we describe the framework along the different strategic action options. While Figure 1 provides an overview of the basic structure of the framework, Table 1 illustrates the rationales behind the different strategy options:

(1) At the most fundamental level, actors are confronted with some form of objective uncertainty (e.g., in the form of uncertainty claims made by other actors, such as scientific studies), and have the choice between two alternative approaches for dealing with it. *Acknowledging* uncertainty means that actors translate objective uncertainty into subjective uncertainty, i.e., a form of uncertainty that becomes relevant for their own perception of an action situation. This translation implies that actors become aware of uncertainty and decide to deal with it in one or the other way in their further actions. *Neglecting* uncertainty implies that objective uncertainty does not translate into a subjectively perceived challenge. For whatever reasons, actors turn a blind eye on uncertainty and do not take account of it in their subjective perception of an action situation. Accordingly, uncertainty is neither taken into consideration in further decisions and actions, nor is it seen as something that would require further action.

(2) As soon as uncertainty is acknowledged as a subjectively relevant challenge, there are two basic options for dealing with it. First, actors can decide to actively engage with uncertainty or to passively cope with it. A strategy of active uncertainty *management* implies that an actor perceives uncertainty as relevant challenge that he/she should actively engage with in one or the other way. In contrast, a strategy of passive *coping* means that uncertainty, though acknowledged as subjectively relevant, is regarded as a challenge that cannot or should not be treated actively by the actor him-/herself. This consideration could be based on the impression (or assertion) that an active uncertainty management would overwhelm an actor's own capacity, that it lies beyond his/her institutionally legitimized action realm, or that it produces outcomes which worsen the situation.

(3) A strategy of passive coping can be further distinguished by two more specific options. First, actors who are unable or unwilling to actively manage uncertainties by themselves might decide to shift the responsibility for dealing with the uncertainty to

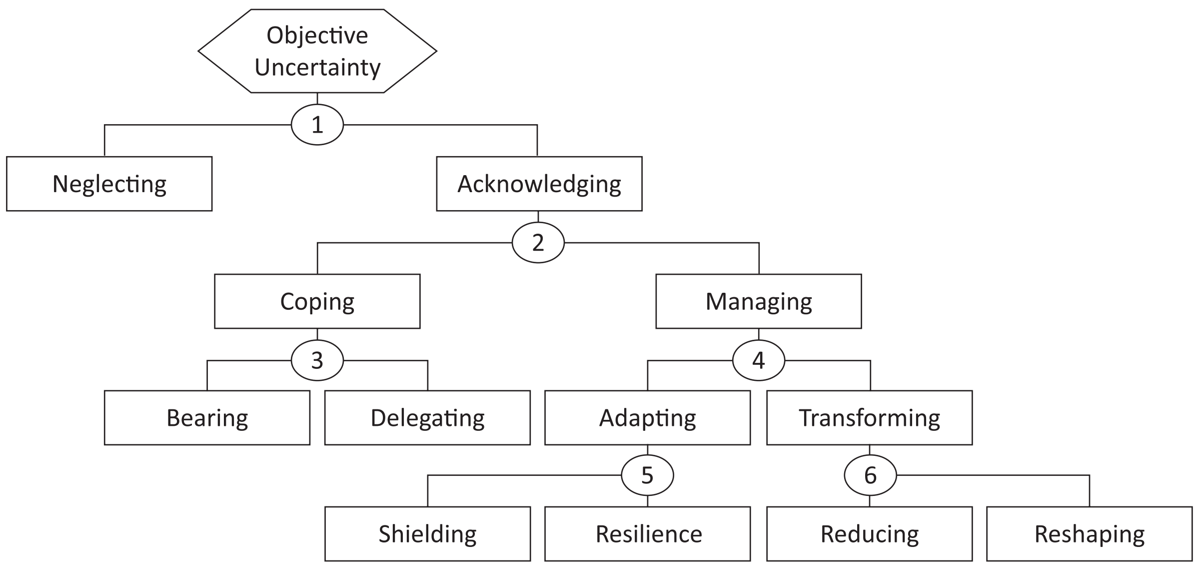

Figure 1. Overview of strategic options for dealing with uncertainty.

Table 1. Strategic options and related rationales.

Strategy	Rationale
Neglecting	We do not believe that there is uncertainty at all.
Acknowledging	We know that there is uncertainty.
Managing	We know that there is uncertainty, and we have to actively engage with it.
Coping	We know that there is uncertainty, but we cannot do anything about it.
Bearing	We know that there is uncertainty, but we have to live with it.
Delegating	We know that there is uncertainty, but somebody else should deal with it.
Adapting	We know that there is uncertainty, and we can actively face it by developing our own capabilities.
Transforming	We know that there is uncertainty, and we can actively engage with it by transforming it.
Shielding	We know that there is uncertainty, and we can actively protect ourselves against its potential effects.
Resilience	We know that there is uncertainty, and we can actively prepare ourselves against its potential effects.
Reducing	We know that there is uncertainty, and we can actively reduce it by producing more knowledge.
Reshaping	We know that there is uncertainty, and we can actively influence it.

other actors. This *delegation strategy* builds on the assumption (or assertion) that other actors are better prepared, that is, more capable, eligible, or entitled, to deal with an uncertainty at hand. A second option for passively coping with uncertainties, which are regarded relevant, but appear to lie outside an actor's action realm consists in accepting them. From a rational point of view, this *bearing strategy* builds on the idea that uncertainty cannot, at least for the time being, be dealt with by any actor at all: it is a "given" reality that one has to live with in a "wait and see" manner.

(4) Strategies to actively manage uncertainty can take on two forms, which can be distinguished with regard to the object of management. An *adaptation strategy* addresses the actor him-/herself as the object of management and involves actions of self-management. Based on whatever considerations, an actor comes to the conclusion that it is not the uncertainty itself to be managed (since it, for example, might lie beyond the realm that can be effectively steered by the actor); it is rather the actor him-/herself who is in need of management in order to deal with uncertainty in a rational way. In contrast to this strategy of active self-management by adaptation, a *transformation strategy* builds on the assumption the uncertainty itself can and should become the object of management. Rather than adapting oneself toward uncertainty, the actor regards actions directed at changing the uncertain situation to be more promising and suitable to deal with a given uncertainty.

(5) Strategies to actively manage uncertainties in a mode of self-adaptation ideally take two different forms. A first option of adaptive uncertainty management is to adopt a *shielding strategy* that protects against a given uncertainty and its potential consequences by establishing protective means (such as insurances). A second option for dealing with uncertainties in a self-managing way is to build up capacities that allow for reacting to uncertainties as soon as their consequences become real. This *resilience strategy* includes the development and maintenance of open and responsive structures, that is, the improvement of buffer capacities by assigning resources for dealing with future events (Kaufmann & Blum, 2012; Longstaff, 2012).

(6) An actor who decides to actively transform a given uncertainty has two further options to do so. First, following a *reduction strategy* implies that actors foster the production or acquisition of new knowledge in order to fill the knowledge gap that makes up for the uncertainty. This strategy presupposes that uncertainties are conceived of as a lack of knowledge and thus can be eliminated or alleviated by more or different knowledge and increased diagnostic and prognostic capacities, for example, by involving experts. An alternative to this reduction strategy is to take actions that are directed at the situation which is regarded as uncertain. These *reshaping strategies* can be either of a symbolic nature (i.e., reshaping uncertainties by reframing or retelling them) or of a substantial nature (i.e., changing a situation that is perceived as uncertain in terms of material reconfiguration).

4. Uncertainty "On The Ground": Local Heat Policies in Switzerland

4.1. Approach and Methods

To find out about perceptions of energy-related uncertainties and ways of dealing with them, we conducted a qualitative study on local heat supply policymaking and planning in Switzerland. The study was not designed to generate systematic generalizable (or even explanatory) knowledge; rather it aimed at illustrating our conceptual considerations with empirical forms. In a first step, we analyzed 16 energy plans and energy concepts of Swiss towns to reveal how uncertainties are considered and treated in these official plans. Second, three in-depth case studies—Basel, Berne and Winterthur—were carried out to learn how the uncertainties are perceived and dealt with on the ground by local policymakers and planners. These case studies draw on data from qualitative expert interviews with employees of the administration, urban planners, and municipal energy providers (see "Empirical Data" in the Annex). Aside from the specific issue of uncertainty, the interviews covered multiple aspects of local energy planning practice, such as institutional conditions, coordination procedures, and planning instruments (see Schubert, 2015). We analyzed the interview transcripts by looking more closely at passages that referred to uncertainty and their treatment in policy and planning practice. Based on our two conceptual schemes—types of energy-related uncertainties on the one hand, and strategic options for dealing with uncertainties on the other—we interpreted the relevant passages to identify empirical correlates to our concepts. We discussed and further condensed our observations in a step-by-step manner accompanied by group discussions among the authors.

The three cases for in-depth analysis were selected based on their specific combination of similarities and differences. First, all three cases expose similar long-term time horizons of their energy policy rendering uncertainty a potentially important topic.[3] Furthermore, the cases are similar regarding two basic organizational matters: While the overall responsibility for energy policy and planning lies with the energy department of the municipality or, in the case of Basel, with the canton, the local energy supply companies are public-law companies in municipal or cantonal ownership.

Second, the cases differ regarding their overall governance arrangements in energy planning (for details see Schubert, 2015). In fact, each of the three cases approximates one particular (meso-level) governance strategy for dealing with uncertainty (see 3.1). In Berne, energy planning follows a rather holistic approach and is established in a comprehensive and cross-cutting governance arrangement of spatial planning ("Richtplanung"). The city of Basel can be regarded as representing an incremental approach, renouncing an overall planning scheme for future urban heat supply. In Winterthur, energy planning is mainly organized in a sectoral manner with some interfaces to overall spatial planning; therefore, it represents a middle way between the holistic arrangement of Berne and Basel's incrementalist approach.

Since these governance schemes can be regarded as "typical" in the sense that they can be expected to occur in multiple different contexts, the case selection paves the way for some modest generalization of the empirical insights beyond local heat policy in Switzerland. At least, the selection of three cases with different governance schemes allows for reflections on the nexus between individual strategies to deal with uncertainties and overall governance arrangements (4.3). Before we come to that particular point, however, we focus on the two basic questions, how uncertainties are reflected in planning documents and perceived by actors (4.1) and how they are dealt with (4.2).

4.2. How is Uncertainty Reflected?

Our empirical analysis reveals that uncertainty is a constant and relevant topic in local policymaking and planning for future heat supply. Yet, there are important qualifications to be made. First, within the analyzed official energy planning documents of 16 Swiss cities, uncertainty does not play a very prominent role. Some documents do not explicitly mention the term uncertainty (e.g., Geneva; Schlieren; La Brillaz; Bulle). Rather, uncertainty is an implicit topic that shines through the efforts made in data collection about demand and heat potentials, prognosis, and finally defined strategies, which reflect gaps of knowledge and missing forecasting reliability. Nevertheless, in some of the analyzed planning documents, uncertainty is explicitly mentioned as a relevant factor and occurs in different ways which reflect the above mentioned SET-induced types of uncertainty. The availability of energy resources is the most obvious source of uncertainty in energy planning, referring to such aspects as the usable heat potential from drinking water, the amount of economically usable geothermal energy, the prospective potential of synthetic natural gas, and the usable amount of wood for heat purposes, not at least due to its dependence on developments and decisions in other policy fields, especially landscape management (e.g. Arlesheim; Berne; Thun). The availability of industrial waste heat is further mentioned as an uncertain energy source, since it depends on continuance in industrial processes and the long-term existence of industrial waste heat suppliers in the specific location (e.g., Boedeli). The availability of resources relates to the economic as well as the technological sphere of uncertainty, since the economic viability of extraction or production technologies is crucial in this context. However, the political sphere also plays a part, since the politically defined legal framework conditions set guidelines for the use of available resources. Some planning documents (e.g., Aarau; Kloten) seem to refer to societal uncertainties, for example, when reflecting on the development of heat demand for residential as well as industrial use, and thereby take account of changing consumption behaviors.

In contrast to the official planning documents, the interviewed actors involved in planning processes and decision-making for local heat systems refer to uncertainty more explicitly and in more diverse and nuanced ways. First of all, technological development and especially viability thresholds of (new) technologies for heat

[3] The energy plan of Berne targets the year 2035 (Stadt Bern, 2012, p. 4). Winterthur adopts the same time horizon (Stadt Winterthur 2011), but has an additional underlying energy concept with target values for 2050 (Stadt Winterthur, Umwelt- und Gesundheitsschutz, 2011). The energy concept of Basel refers to the year 2050 (Kanton Basel-Stadt, 2013, p. 8).

supply are frequently named as relevant uncertainties, e.g., in cases of fuel cells, geothermal energy, and energy storage technology. The viability threshold of these technologies is not regarded as stable, but rather it is seen as depending on the users' acceptance and willingness to pay. How users—primarily private homeowners—will respond to new technologies and what they will be willing to invest is also named as an uncertain dimension (IP 1, 2 and 3).

With regard to diverse technologies for heat supply, interdependencies between different energy related sectors are also mentioned as a crucial source of uncertainty (IP 1 and 4). How will electricity production from renewables develop in general, and how about heating technologies that depend on electrical energy (such as heat pumps)? How will this affect the electricity rate in the heating sector? How will electro mobility develop and impact the demand for power, including its consequences for cheap power available for heating purposes? Further, the uncertain development of demand for cooling appliances, depending on future comfort demands, is mentioned as a source of uncertainty regarding the societal sphere and changing consumption patterns (IP 4, 5 and 6). Reflecting on these interdependencies inside the energy sector, actors pay attention to the high complexity arising from dynamic developments which generate uncertainty in their concrete decision-making processes. The political sphere of uncertainty is described by the experts in terms of changing political priorities relating to environmental problem awareness and interest, e.g., increasing awareness of environmental and health problems from fine dust created by wood combustion (IP 1 and 4)—all of them coming along with possible changes in legal framework conditions.

Overall, uncertainty is referred to in various sources in the context of policymaking and planning for future urban heat supply. While planning documents on the one hand mention uncertainties only marginally and mostly implicitly, focusing on technological and economic uncertainties, the interviewed experts seem to reflect on uncertainties in a more differentiated and complex way also considering political and societal sources of uncertainty.

4.3. How Is Uncertainty Dealt with?

According to our analysis, local policymakers in Swiss towns adopt a variety of strategies to deal with energy-related uncertainties occurring throughout the planning and policymaking process. These strategies can be interpreted as approximations to the ideal typical strategic postures we have introduced above. While some strategies play a role with regard to all governance arrangements, i.e. holistic planning, incrementalism, and directed incrementalism, other strategies can be observed only in relation to particular arrangements.

The most obvious approach for dealing with uncertainties involves simply neglecting them, i.e., not including objective uncertainties into the subjective action realm. Many uncertainties that are arguably relevant for future heat supply systems and are regularly referred to in the scientific debate, such as uncertainties resulting from shrinking demands due to renovation of the building stock, the development status of technology, and changing and competing political priorities (DENA, 2010; DLR, IWES, & IFNE, 2012; UBA, 2007; Wuppertal Institut für Klima, Umwelt, Energie, 2010) are not reflected or even named in the analyzed energy planning documents.

Another strategy of passively coping with uncertainties consists of accepting once acknowledged uncertainties but leaving them respectively untouched and unaddressed in the course of planning and decision-making. Such a strategy of bearing—or in practice "wait and see"—becomes evident when uncertainties are mentioned in planning documents but are not addressed by further actions. In the case of Aarau, for example, some sources of uncertainties (e.g., energy consumption patterns) which had been acknowledged in the process of setting up energy plans were not mentioned in argumentation for the final decisions for heat supply (Stadt Aarau, 2012). This strategy seems to result from both established energy policy and the pressure from higher administrative levels that force municipalities to actually act and transform their local infrastructure with an awareness of its long lifespan and the high costs of investing in it.

A different way of dealing with uncertainties arising from the complex interplay between heat sources and transformation technologies is the reference to overarching policy goals, such as cantonal orders concerning the application of energy sources, as named in the energy plans of Berne and Wädenswil for example (Stadt Bern, 2012; Stadt Wädenswil, 2009). Such a strategy comes with a simplification of the interdependencies in energy supply and doesn't consider local characteristics in the existing infrastructure or patterns of demand. This reference to cantonal priority lists for the application of heat sources without analyzing their implications and usefulness for the local situation can be considered a strategy of passive coping in the form of delegation of responsibility.

An important strategy for actively dealing with uncertainty in all governance arrangements is the involvement of external experts – yet to a variable extent. In the making of the most integrated spatial energy plan of Berne, for example, a rather broad pool of different experts on energy supply, spatial planning, communication processes, visualization, and data modelling have made significant contributions (Stadt Bern, 2012, pp. 3f.). In the sectorial energy planning of Winterthur, primarily experts like energy engineers and planners were involved (IP 7). This involvement of experts can be interpreted in terms of an active uncertainty management that aims at reducing uncertainty by producing additional knowledge and thereby closing a knowledge gap. Such a strategy was chosen mainly to address technological and economic uncertainties (e.g., biogas potential and geothermal energy sources).

Besides involving experts, the process of making spatial energy plans featured intense communication and cooperation with political decision-makers (e.g., the municipal parliament, agents of the executive) from almost all administrative departments and public enterprises. In the case of Berne's holistic energy planning arrangement, even a public participation process has been established to accompany the development of the plan, although usually the public is only asked to participate in later planning steps (Stadt Bern, 2012, p. 3). This effort to shift uncertainties to political decision-making and public debate may be qualified as form of coping-oriented delegation that shifts responsibility for action to another (more capable or legitimate) decision-making body. However, it could also be an expression of active uncertainty management that aims at reshaping an existing state of uncertainty by means of collective decisions. This just illustrates that the motivation for different strategies in practice is more complex than the theoretical categories suggest.

Some local energy plans remain unspecific when it comes to the definition of goals or measures to implement a certain goal. Rather than setting definite targets and measures, the plans stay flexible to be able to react to future developments while postponing definite decisions that may allow deep transformation processes of the local infrastructure. In Winterthur, for example, the new small district heating systems currently running on a wood basis were designed in a way that they can deliver a similar amount of energy also on a lower temperature level. Such a "flexible" system allows for future conversion to other energy sources, if wood burning becomes out of date once (IP7).

Such an approach of postponing decisions can be classified as a strategy of passive coping by means of delegating decisions to the future. Yet, when it involves preserving resources for future activities, it can also be interpreted as an active adaptation strategy that is directed at achieving resilience. This example illustrates that the empirical qualification in some respects depends on additional information to be gathered from other sources.

Other local energy plans define very concrete targets and measures, e.g., by deciding to build new technological infrastructure systems or to rebuild existing ones *in spite* of acknowledged uncertainties regarding future technological developments. In Berne, for example, the political goal is to dismantle the gas grid and abandon gas-fired stand-alone systems in the long-term. To reach this goal, the transformation of the heating infrastructure is initiated and pushed now—even though the experts acknowledge that there are many uncertainties and open questions with regard to technological development and the availability, "which can't be answered today". However, in order to initiate a "rebuild" and not just a "conversion", decisions have to be made anyway (IP 2). This strategy entails the possibility that a once-adopted solution might turn out to be suboptimal in the future (in view of technological developments that had not been foreseen). Yet, it can be qualified as an active management of uncertainty since it involves a reshaping of the existing technological landscape/material infrastructure, and thereby the grounds on which a certain situation had been described as uncertain.

A closer look at the substantial decisions made on future urban heat supply in light of uncertainties reveals that specific technological infrastructures, namely district heating and especially small heating networks, are the prioritized solutions (e.g. Winterthur; Pratteln; Schaffhausen). In practice, actors justify these solutions by referring to their flexibility with regard to both the use of various heat sources (an argument that applies especially to urban areas where integration of renewable energy sources in heat supply is difficult) and of temperature levels to react to changes in demand. District heating and small heating networks can be fed by different energy resources, using different transformation technologies. Such a distribution structure provides the potential to either grow to a central system or to remain in decentralized heat islands, depending on what might be most reasonable and sustainable in the future and most appropriate with regard to urban development. Going back to the typology of uncertainty strategies, these decisions toward flexible technical infrastructures can be interpreted as efforts to actively create adaptive capacities to deal with uncertainties in terms of resilience.

4.4. Dealing with Uncertainties in Different Governance Arrangements

As mentioned before, the three more deeply analyzed empirical cases differ with regard to their overall governance arrangements. Winterthur and Berne address future urban heat supply in an overreaching strategic planning instrument, with a more holistic approach in the case of Berne and a more sectorial design in the case of Winterthur. In contrast, Basel considers future heat supply in a project-oriented, incremental way.

In examining how uncertainty is dealt with under these different conditions, one might conclude that the more holistic or comprehensive a planning scheme, the higher the probability that uncertainties are addressed and dealt with as an important topic. Strategically oriented arrangements like sectorial or more holistic spatial planning seem to support the identification of uncertainties and the specification of individual strategies for dealing with them. In the two cases of Berne and Winterthur, which dispose of some strategic planning instruments (either holistic or sectorial), the official planning documents address uncertainties with regard to future resource availability and development of consumption. In the more holistic planning arrangement of Berne, uncertainty concerning the future energy sources for heating purposes is discussed in more detail than in Winterthur's sectorial energy plan. The case of Berne, with its holistic planning scheme, shows that the range of identified uncertainties and the variety of strategies to deal with them is even higher than in Winterthur's sector planning arrangement.

In Basel, which adopts an incremental approach, it is apparent that, due to the absence of an overall spatial plan and a process of consolidation, uncertainty is not an explicit topic in local energy decisions related to heat supply. The likelihood of neglecting uncertainty in a project-oriented, incremental context seems higher than in the cases with more strategic orientation. Some sources of uncertainty only become obvious within the overall picture created by a governance arrangement that involves planning, while an incremental project view (like in Basel) is less prone to capture a situation's complexity and to identify related uncertainties.

However, three important qualifications need to be made. First, the existence of spatial energy plans does not guarantee that uncertainties are reflected at all. In fact, our broader sample of cases also includes energy plans where uncertainty is not mentioned (e.g. Schlieren; Farvagny). Second, strategic planning does not imply a comprehensive coverage of uncertainties. The two analyzed arrangements with a more strategic orientation (Winterthur and Berne), for example, do not integrate their reflections on uncertainties into a broader context relating to technological and economic conditions and developments or being influenced by societal aspects and users' behaviour. Third, there seems to be an important informal sphere where uncertainties are perceived and dealt with. In fact, all analyzed cases show that uncertainties are reflected by the experts more comprehensively than in the official planning documents. Even in the case of Basel, interviews with experts reveal that uncertainties related to technological developments, the consumers' future demands (e.g., for electro mobility) and ongoing political discussions do play a role in planning and investment decisions of the municipal supply company (IP 6). In fact, in the case of Basel, these uncertainties and the absence of a strategic planning arrangement have created a situation where the supply company plans for two alternative systems—one based on the existing gas grid and one under the conditions of a dismantled grid (IP 4 & 5).

In all arrangements the inclusion of experts seems to be not only a way to identify uncertainties but also an important strategy to deal with them. Interestingly, such a strategy of active management to reduce uncertainties by filling knowledge gaps also plays a role in the incremental arrangement of Basel. Here, the department responsible for energy affairs commissioned the expert study "Basel on the way to a 2000-watt-society" to address the many interdependencies and uncertainties resulting from the political decision to shift to a renewables-based energy supply (IP 4). The strategy to involve external experts at this point can be interpreted as a strategy to gain knowledge and reduce uncertainty as far as possible. However, in the case of Basel, these efforts are not resulting in commonly defined planning documents and decisions to transform the existing infrastructure, as is observable in the two cases with a sectorial or holistic planning approach.

Apart from the identified similarities and differences among different governance arrangements, the three cases that we have looked at in more detail suggest that there might be a correspondence between types of uncertainty and strategies for dealing with them. Uncertainties regarding technological development and resource availability are mainly handled in terms of active management—be it by a strategy of reduction that involves experts to close knowledge gaps, or by some form of self-adaptation or resilience strategy that aims at creating an open adaptable structure by deciding for a flexible technology in terms of district heating systems which are open for different energy sources, but create new path dependencies to the same time (Magnusson, 2012).

While technological uncertainties are managed in an active manner, societal and political sources of uncertainty, like changes in users' behaviour and political or legal dynamics are handled, if at all, by passive coping. Actively managing these uncertainties, e.g., by including experts, seems to be an ineffective strategy. One might speculate that there aren't experts on these topics around or that the relevant experts are not included in the planning and decision-making processes that are dominated by natural scientists and technicians. Therefore, one also has to acknowledge the limitations of existing spatial planning instruments for dealing with uncertainty. In their given forms, they might not be sufficiently prepared to face the complexity that arises from the interdependencies among different energy uses and sectors and the dynamics of technological development and norm setting of energy policy. These kinds of complex webs of uncertainties can be neither identified nor solved by local spatial energy plans in their given form.

Finally, and expanding the perspective from planning to implementation, one may speculate whether and how certain strategies for dealing with uncertainties defined in energy plans might have repercussions on the implementation of these plans, creating an additional layer of uncertainties. For example, rebuilding gas grids, as planned in the holistic case of Berne, might be an adequate strategy of adaptation to technological uncertainties. However, the implementation of such a highly invasive strategy can also come with a number of follow-up uncertainties in the societal and political domain, such as unpredictable opposition and protest against the rebuilding of a socially well-entrenched energy infrastructure.

5. Conclusions and Perspectives

Uncertainty is widely regarded as one of the most pressing challenges of sustainability governance in theory and practice. This is particularly true for the governance of complex energy systems. With our paper, we have added to the debate on the governance of energy-related uncertainty in three respects. First, we related general conceptual understandings of uncertainty to complex energy systems. The proposed "spheres of energy-related uncertainties" provide a comprehensive framework for thinking about and detecting uncertainties related to energy transitions. In particular, this allows for scrutinizing the links between the physical components and the social organization of the energy system and thus widens the analysis beyond a focus simply on technology. Second, we provided a differentiated conceptual framework regarding the ways uncertainties are dealt with by policymakers and planners on the ground. By identifying various ideal typical strategic postures, we have highlighted strategic options underneath the (meso-)level of aggregate governance strategies, such as planning, incrementalism and directed incrementalism. The framework can serve to empirically illuminate and interpret individual decisions with regard to uncertainty and disentangle the prevailing aggregated view on uncertainty governance. Third, our empirical analysis of urban heat supply policies in Switzerland shows that our conceptual investments are suitable to detect representations of uncertainty and ways uncertainties are dealt with on the ground. On this conceptual level lies the main potential for generalizing our observations: we have good reasons to believe that our frameworks capture relevant empirical phenomena and thereby have the potential to illuminate uncertainties and ways of dealing with them in different contexts.

Aside from this validation of the usefulness of our conceptual considerations, it is possible to draw some preliminary empirical conclusions regarding the micro-governance of uncertainty. We would like to highlight four general aspects, which can be expected to "travel" beyond the Swiss context. First, it seems to be the case that different governance schemes allow for the consideration of uncertainties. In fact, uncertainties do play a role in all types of arrangements—ranging from planning to incrementalism. Yet this does not mean that every single case takes account of uncertainty—not even all cases with holistic spatial energy plans. Put differently, given that there are also energy plans where uncertainty is not addressed at all, there is no guarantee that, under any conditions, uncertainties do come into view, not even within holistic planning schemes. The particular (in-)sensitivity towards uncertainties is not explained by the existence (absence) of an energy plan. Second, it can be concluded that some kinds of uncertainties are more salient than others. Technological and economic uncertainties tend to be more prevalent than societal and political uncertainties. Put differently, there is a tendency to take account of technological and economic uncertainties while neglecting others. Some dimensions of uncertainty, e.g., the complexity related to interdependencies between the different energy uses and sectors and the dynamics of technological development and energy policy, are not reflected in the analyzed documents. Whether or not this holds true for different governance schemes remains an open empirical question. Third, concerning strategies for dealing with uncertainties, we have not found evidence that all kinds of ideal typical strategies do in fact play a role. There is a proclivity towards strategies of technological reshaping to deal with uncertainties. Investing in and bringing out "flexible technologies" is a rather dominant strategy to deal with uncertainty. Another dominant strategy consists in reducing uncertainties via the production of knowledge and expertise. Including experts is a prioritized strategy when it comes to dealing with technological aspects, resource availability, and development of demand. Furthermore, there is a tendency to delegate actions regarding uncertainties from the local to the cantonal or federal level. Fourth, some forms of uncertainty, i.e., the societal and political ones, seem to be addressed by means of passive coping rather than active management. In other words, uncertainties such as changes in users' behaviour as well as dynamics in political and legal settings, etc., seem to lie outside the action realm of local policymakers and planners. As there is no clear evidence that the various governance arrangements differ in that respect, the neglect of societal and political uncertainties might turn out to be a more fundamental tendency in the practice of energy-related policymaking and planning.

Based on the proposed conceptual frameworks and our preliminary empirical findings, we suggest the following routes for future research. First, more empirical studies in various political administrative contexts (and at various policy levels) can further substantiate and enrich the empirical picture regarding the perception and representation of uncertainty and ways of dealing with it. More particularly, comparative research might reveal more general patterns of uncertainty representation and how these patterns are related to different strategies for dealing with uncertainties (see also Arentsen et al., 2000). Furthermore, more empirical studies will have to further explore the link between overall governance arrangements, such as planning, incrementalism, and directed incrementalism, the representation of uncertainties within these schemes, and more specific strategies for dealing with different kinds of uncertainties. Longitudinal empirical analyses might also reveal the dynamics within the governance of uncertainty: the evolution of understandings of uncertainties and practices for dealing with them over time. Drawing on these reconstructions of empirical patterns, one could attempt to develop more robust explanatory approaches. Under which conditions do which forms of uncertainty emerge? And what factors and conditions explain the various ways uncertainties are dealt with? Furthermore, additional empirical analysis on the success and failure of strategies to deal with uncertainties can be carried out. This kind of analysis would require the development of sophisticated evaluative criteria to assess the performance of uncertainty strategies. Finally, in practical respects, these kinds of analysis might inform policymakers and planners about "working" strategies for dealing with uncertainty: What works when and where in order to deal with what kind of uncertainty? And they might support governance designers in their efforts to set up governance arrangements that allow policymakers and planners to develop tailor-made strategies for dealing with different kinds of uncertainties in a reflexive manner.

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Conflict of Interests

The authors declare no conflict of interests.

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Susanne Schubert has studied urban planning at the HafenCity University of Hamburg, Germany, and holds a doctoral degree in civil engineering from the Technical University of Darmstadt, Germany. Her research focus is on the interface of sectoral infrastructure planning and overall spatial planning, on sustainable solutions for urban heat supply and their development in urban energy regimes. She is further interested in planning instruments and their relevance for environmental protection. Currently Susanne is working for the German Environment Agency in the section for sustainable spatial development and environmental assessment on urban environmental management.

Annexes

Empirical Data

Table A1. Planning and policy documents.

Case	Document(s)
Aarau	Stadt Aarau (2012). Kommunaler Energieplan der Stadt Aarau. Aarau.
Arlesheim	Gemeinde Arlesheim (2009). Energiesachplan Arlesheim. Arlesheim.
Basel	Kanton Basel-Stadt, Bau- und Verkehrsdepartement (2009). Kantonaler Richtplan. Basel.
	Kanton Basel-Stadt (2013). Basel auf dem Weg zur 2000 Watt-Gesellschaft. Basel: Department für Wirtschaft, Soziales und Umwelt, Amt für Umwelt und Energie.
Berne	Stadt Bern (2006). Energiestrategie der Stadt Bern 2006–2015. Bern.
	Stadt Bern, Direktion für Sicherheit, Umwelt und Energie (2012). Richtplan Energie der Stadt Bern.
Boedeli	Gemeinden Bönigen, Interlaken, Matten, Unterseen, & Wilderswil (2011). Überkommunaler Richtplan Energie ”Bödeli”, Erläuternder Bericht mit verbindlichem Richtplantext und Massnahmenblättern. Bönigen, Interlaken, Matten, Unterseen, Wilderswil.
Bulle	Ville de Bulle (2001). Plan communal des énergies. Bulle.
Farvagny	Commune de Farvagny (2011). Le plan communal des énergies. Farvagny.
Geneva	Ville de Génève (2009). Politique énergétique et climatique de la Ville de Genève. Genève.
Kloten	Stadt Kloten (2008). Kommunaler Energieplan der Stadt Kloten. Kloten.
La Brillaz	Commune de La Brillaz (2011). Plan communal des énergies. La Brillaz.
Pratteln	Gemeinde Pratteln (2011). Energiesachplan Pratteln. Pratteln.
Schaffhausen	Stadt Schaffhausen (2007). Energierichtplan Stadt Schaffhausen. Schaffhausen.
Schlieren	Stadt Schlieren (2012). Kommunaler Energieplan der Stadt Schlieren. Schlieren.
Thun	Gemeinden Heimberg, Steffisburg, Uetendorf und Stadt Thun (2010). Überkommunaler Richtplan Energie. Heimberg, Steffisburg, Uetendorf, Thun.
Wädenswil	Stadt Wädenswil (2009). Kommunaler Energieplan der Stadt Wädenswil. Wädenswil.
Winterthur	Stadt Winterthur, Umwelt- und Gesundheitsschutz (2011). Grundlagen Energiekonzept 2050. Winterthur.
	Stadt Winterthur (2011): Kommunaler Energieplan Winterthur. Winterthur.

Table A2. Interviews.

Number	Institution	Date and Place
IP 1	Head of the Divison “Energy and Technology”, Departement of Building and Construction, City of Winterthur	18.04.2013, Winterthur
IP 2	Head of the Division “Environment and Energy”, City of Berne	07.05.2013, Berne
IP 3	Head of the Divison “Energy Services”, Energy Water Berne (EWB)	21.05.2013, Berne
IP 4	Head of the Division “Energy”, Office of Environment and Energy, City of Basel	24.04.2013, Basel
IP 5	Staff member of the Divison “District Heating”, Industrial Plants Basel (IWB)	15.05.2013, Basel
IP 6	Head of the Divison “Strategy and Cooperation”, Industrial Plants Basel (IWB)	15.05.2013, Basel
IP 7	Head of the Division “Energy Contracting”, Municipal Utilities Winterthur	26.06.2013, Winterthur

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Commentary

Sustainability Planning as Paradigm Change

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Abstract
The theme of the next issue of *Urban Planning* will be Paradigm Shifts. To make the link between "sustainability" and "paradigm change," the following commentary analyzes the former concept as a main example of the latter. Although it is often applied to rather modest planning initiatives, "sustainability" can be seen as requiring shifts in cognitive paradigm that are transformational, radical, and not yet fully appreciated by most of those who use the term. Specifically, this term implies a proactive, results-oriented approach (e.g. initiatives to actually meet GHG reduction targets), a long-term viewpoint (e.g. planning for 50 or 100+ years in the future), and a holistic or ecological mindset able to understand dynamic, evolving systems. This last change is the most difficult and requires thinking across scales of action, across time frames, across issue areas and goals (e.g. the "Three E's" of environment, economy, and social equity), and across communities. It also means integrating different types of actions into a broader program of social change. Though challenging, these cognitive shifts can lead to radically different outcomes than past urban planning.

Keywords
paradigm change; sustainability; sustainable development; urban planning

Issue
This commentary is part of the issue "Sustainable Planning and Technologies", edited by Hatem Ibrahim (Qatar University, Qatar), Ahmed Khan (Université Libre de Bruxelles, Belgium), Steffen Lehmann (University of Portsmouth, UK), Dellé Odeleye (Anglia Ruskin University, UK) and Atiq Zaman (Curtin University, Australia).

The topic of "paradigm shifts" is a great one for this journal, and challenges us to come up with new ways of thinking so that planners can address many problems of the twenty-first century. As one contribution to this conversation I would like to reflect on the concept of "sustainability planning." In the current era almost every institution has some actions it can point to as proof of its sustainability commitment. Is "sustainability" just a meaningless buzzword or planning fad that has already played itself out? Or does it connote a fundamental paradigm shift with relevance far into the future? In this short commentary I will argue that "sustainability" refers to shifts in worldview that are transformational, radical, and not yet fully appreciated by most of those who use the term.

Let me start with an example of how the term can be used uncritically. While preparing for a trip recently I read an English-language summary of the city of Oslo's sustainability planning, which to be sure includes many impressive achievements and accolades including a European Sustainable City Award in 2003. However, the website argued that:

> "Oslo has already successfully been a sustainable city for 1,000 years and with the plans and actions put forward in the realization of goals [it can be] more sustainable for the next 1,000 years." (Sustainable Oslo, 2016)

Fractured English aside, this rather self-congratulatory statement epitomizes some common interpretations of "sustainability" that detract from its potential paradigm shift role. First of all, the author equates "sustaining" with "surviving," when I think most of us would wish for something considerably more than mere survival. In its thousand-year history Oslo was destroyed multiple times by fire and decimated by the plague; arguably it is lucky to have survived at all. Its restrictive nineteenth-century society helped inspire artist Edvard

Munch's world-famous painting "The Scream," not something that most cities would want to brag about. Just having survived to date is no guarantee that communities are healthy and livable places, or that they will thrive in the future. Seeing sustainability as mere survival is a cop-out.

The statement's focus is also just on Oslo and not on its relation to the rest of the world. However, given Norway's role as a leading oil producer and arms exporter, never mind the ecological footprints of some 1.7 million Oslo-area residents, its impacts on other places are certainly sizable. These links must be taken into account. Sustainability should not just be about preserving one relatively well-off place in isolation.

Lastly, this website seems to assume that developing plans, actions, and goals primarily on environmental topics is enough to address sustainability problems. Instead, social dynamics and values must be considered as well. Oslo was in fact forced to reevaluate its own social health after July 22, 2011, when a right-wing Norwegian set off a car bomb downtown and then opened fire at a camp outside the city, killing 77 people in all. These events were a wake-up call that tensions existed regarding immigrants, rapid population growth, inequality, and alienation. Those tensions have led to the growth of sometimes violent right-wing movements in many countries. So moving toward sustainability requires dealing with fundamental social, political, and economic issues, not just adoption of environmental policies.

One of the mantras I repeat to undergraduate classes is that "sustainability is not simple." Sustainability planning does not mean doing just enough to brag about, or considering a limited set of environmental issues in one place. Rather, it requires deeper re-examination of all facets of "development" using different cognitive lenses than previously.

Three paradigmatic lenses are particularly important. First, "sustainability" requires a proactive, results-oriented focus. To take the most obvious example, we have no choice but to reduce greenhouse gas emissions to virtually nothing within a generation or two if we want to have a livable planet. That will require radical changes in economies, societies, and lifestyles. Other needs are nearly as dramatic. In a world filled with weapons including nuclear and biological agents, we must commit ourselves to reduce violence. In a world in which growing inequities, conflict, and economic despair produce potentially dangerous social upheaval, we must address social injustices. With such sustainability threats, Charles Lindblom's "muddling through" philosophy of mid-twentieth century planning is no longer possible (Lindblom, 1959). Instead, new forms of advocacy planning seem needed within government, civil society, and academia. Planners and other professionals need to actively frame alternatives that will lead to greater long-term social and ecological well-being, and to work with all possible constituencies in order to move in those directions.

A second cognitive shift behind "sustainability" involves adopting a more long-term perspective. As has been pointed out by many, including the Brundtland Commission, author of the most widely used if imperfect definition of sustainable development,[1] sustainability connotes a long-term approach to problem-solving. That's radical in modern societies that are heavily oriented towards the short term. It means, among other things, that we have to be more strategic in establishing institutions, social movements, inspirational examples, and collective understandings that will support long-term change. We also need to figure out ways to work around existing incentives for short-term thinking, many of them produced by economics, capitalism, and current forms of political economy. Many of our analytic tools must also be changed. Due to the existence of discount rates, for example, economic cost-benefit analysis has little ability to consider project costs and benefits more than 20 or 30 years into the future. Yet much longer-term analysis is important for sustainability planning. Also, within individual building projects the habit of separating construction costs from operating costs makes it difficult to incorporate long-term savings from resource efficiency up-front. Such structural impediments need to be changed.

Perhaps the most challenging cognitive shift is toward what might be called holistic or ecological thought—the ability to understand the dynamic, evolving, radically contingent, and interdependent nature of human and natural systems. This worldview is very different than that promoted by twentieth-century modernity, which embraced a more atomistic, mechanistic view of reality often labeled as "Cartesian" thought (Capra, 1996). Postmodernism began to deconstruct the misplaced modernist faith in scientific objectivity, pointing out the cultural relativism of many beliefs, but failed to propose anything else in its place (Norgaard, 1994). But an ecological worldview can supply both a sophisticated cognitive outlook, emphasizing the dynamic coevolution of systems, and a moral framework, based on those values necessary for all species to thrive on a small planet (see Table 1 and Figure 1).

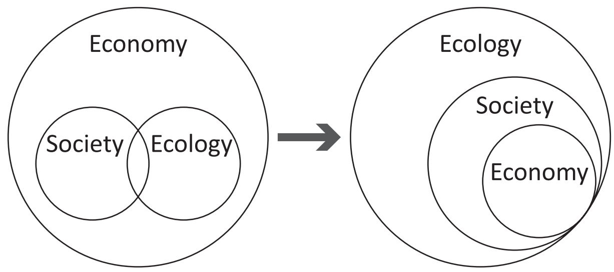

Figure 1. Sustainabilty as a transition from the modernist paradigm grounded in economics towards ecological thought.

[1] Development that "meets the needs of the present without jeopardizing the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987).

Table 1. Modernist, postmodernist, and ecological worldviews.

	Modernist Worldview	Postmodernist Worldview	Ecological Worldview
Values	Universal values based on modern science	Pluralistic values based on cultural and cognitive traditions	Acknowledges pluralism but also a shared core value set based on common problems
Cognitive Approach	Atomistic (break problems down into constituent parts; view world as collection of individual elements)	Acknowledges multiple ways of viewing the world	Focuses on interrelationships and dynamic, evolving systems
Core Influences	Newtonian physics; neoclassical economics	Twentieth century physics (relativity, uncertainty principle)	Ecological science; chaos theory; systems theory; many social theories
Political Implications	Reinforces centralized authority	Undermines centralized authority	Emphasizes flexible and evolving relationships between many different institutions
Preferred Planning Modes	Rational, comprehensive planning	Decentralized local planning to meet pluralistic community needs; communication to gain consensus on directions	Emphasizes communication and education to help evolve understanding; advocacy planning to achieve shared goals; evolving incentives and mandates between different levels of government

Such an integrating, ecological mindset can be seen at work within the somewhat simplistic trope of the "Three E's"—environment, economy, and social equity—which has been a mainstay of the sustainability discourse since Donella Meadows and others first surfaced the term in 1972 (Goldsmith, Allen, Allaby, Davoll, & Lawrence, 1972; Meadows, Meadows, Randers, & Behrens III, 1972). It can also be seen within recurrent attempts to link different scales of professional action (the building, site, neighborhood, district, city, region, state, nation, and world) within recent movements like the New Urbanism. Academic efforts to promote interdisciplinary or transdisciplinary sustainability-related courses likewise rest on this foundation of ecological thought, though such initiatives often founder within the silo-based environment of academia. The ecological perspective is still in its infancy. Twentieth century modernity was heavily about specialization of disciplines, compartmentalization of knowledge, and the rise of supposedly objective experts, and it will take a long while to overcome these unfortunate norms. But this outlook is gaining ground and can be practiced by students and professionals alike.

Many smaller paradigm shifts may follow from these three fundamentals of the sustainability perspective. Developing "biophilic cities," which Timothy Beatley has proposed, means learning to see cities as a dynamic balance of green and gray landscapes and figuring out creative ways to improve this balance (Beatley, 2011). "Guerilla urbanism" or "tactical urbanism," championed by a number of community activists worldwide, means seeing urban contexts such as streets as an opportunity for short-term, grass-roots interventions that can challenge a stuck and dysfunctional business-as-usual (e.g. The Street Plans Collaborative, 2012). Seeing cities as places that are friendly for women, children, the elderly, people of color, LGBT communities, and the differently abled all require their own broadening of perspectives as well.

To sum up, sustainability planning requires three fundamental paradigm shifts: results-oriented problem-solving, a long-term perspective, and holistic or ecological thought. These new cognitive lenses may sound simple, but are highly challenging to bring about in practice. They themselves require a supportive framework of institutions, incentives, peer networks, and education. They require professionals to work collaboratively and openly with communities of all sorts in pursuit of collective learning and communication. They require resisting the siren lure of many incentives of modernity: academics avoiding the seduction of overly rarified theory and impenetrable language that will make their work irrelevant to practice; engineers moving away from the safety of outdated rulebooks and instead changing them; developers resisting financiers' desires to see them build what has been built before; and public officials developing a creative culture of governance rather than adhering to rigid bureaucratic rules. Moving towards sustainability will place new cognitive demands on professionals of all types. But it also offers new potential rewards, not least of which is the excitement that comes from creating a global community of social change agents actively responding to the challenges of the time.

Conflict of Interests

The author declares no conflict of interests.

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