Can We Have It all? Exploring the Relationship between Ecological Health and Quality-of-Life: From City to Neighbourhood

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Abstract

This paper examines the question, is it true, at a wide range of scales, that localities with high environmental quality and ecological health also make strong positive contributions to quality-of-life? The paper reviews the literature that may illuminate this question, looks for useable data within existing city rankings for quality-of-life and ecological health, and considers how the question may be approached at finer resolutions – districts and neighbourhoods. Key factors include commonly measured aspects of environmental quality such as species diversity and pollution levels, and common considerations for human wellbeing including thermal comfort, noise, visual quality, health and safety. Less frequently discussed measures such as diversity of experience, excitement, and opportunity for self-expression are also considered.

1 Introduction

Urban ecology has become a major field of research in recent years. Cities are increasingly keen to be seen as green both in terms of their resource consumption and their direct ecological aspects such as tree cover (Melbourne, Australia has plans for 40 % coverage) and the health of waterways. At the same time, residents seek a good quality of life (QOL) and aspects of this quest become part of international liveability indices.

However, few studies seek to bring these two aspects of the urban environment together. Recent exceptions are a conceptual framework for exploration of the relationship by BANZHAF et al. (2014) and a very pragmatic look at the claims and realities of urban stream restoration by COCKERILL & ANDERSON (2014). The latter conclude that "Protecting the built environment is often a legitimate reason to manipulate an urban stream, but shrouding this relationship under the idea of improving the ecology perpetuates a problematic idea that we can 'have it all' − our comfortable urban environment and ecologically healthy streams within that environment."

Landscape architects often have objectives of enhancing both the ecology of their site and the QOL of those who visit the site. This relationship is promulgated at the local level in specific landscaping projects. This paper asks the question, is it true at a wide range of scales, and across both private and public lands, that localities with high ecological health (EH) also make strong positive contributions to QOL? Can we have it all?

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We review the literature that may illuminate this question, look (at city level) for answers within existing urban rankings for quality of life and ecological health, and consider how the question may be approached at finer resolutions – districts, neighbourhoods and even individual sites. More specifically, drawing on the literature, we identify key factors that are important at finer resolutions. These include commonly measured aspects of environmental quality such as species diversity and pollutions levels, and common considerations for human well being including thermal comfort, noise, visual quality, health and safety. Less frequently discussed measures such as diversity of experience, excitement, and opportunity for self-expression are also considered. In general, it appears, the smaller the area the more factors can be meaningfully included in analysis. In all instances it is necessary to "consider both the *city on the ground* and *the city in the mind"* (PACIONE 2003). That is, both objective measures of the urban condition and subjective perceptions and reflections of residents are important, especially in quality of life estimation.

This paper does not answer the question. Published data at the city scale is used for a preliminary comparison of cities on a greenness index and another index built from social and economic liveability factors. Data from metropolitan Melbourne is used as a case study for analysis of mapped physical and social attributes at city and district level. In considering the neighbourhood, the City of Shanghai is used as a framework within which to review some recent contributing studies and to illustrate the possibilities of (a) crowd-sourced data on specific physical attributes (e.g. noise) as well as localised perceptual responses and (b) controlled virtual reality experiments to explore the relationship at site and neighbourhood levels.

2 Quality Indices

Urban quality indices can be estimated through objective statistical measures or through the subjective impressions of residents or visitors, or some combination of both. This proposition has been disputed by some authors (e.g. ANDREWS & WITHEY 1976) but strongly defended by others (e.g. CUMMINS 2000). However, as Cummins points out the relationship is complex and people's perception of their QOL tends to be shaped by their expectations and to be independent of objective factors unless stressed. The complexities of this relationship are beyond the scope of this paper and here we take the view that increases in the quality of objective indicators cannot diminish QOL and are likely to increase QOL for some part of the urban population. We are also limiting consideration of QOL factors to those directly related to the physical environment. We do not consider, for example, income levels, health services, the social or political environment or access to education (see Figure 1). Our interest is in the features of the physical environment that contribute to QOL and that may, or may not, be linked to ecological health (EH).

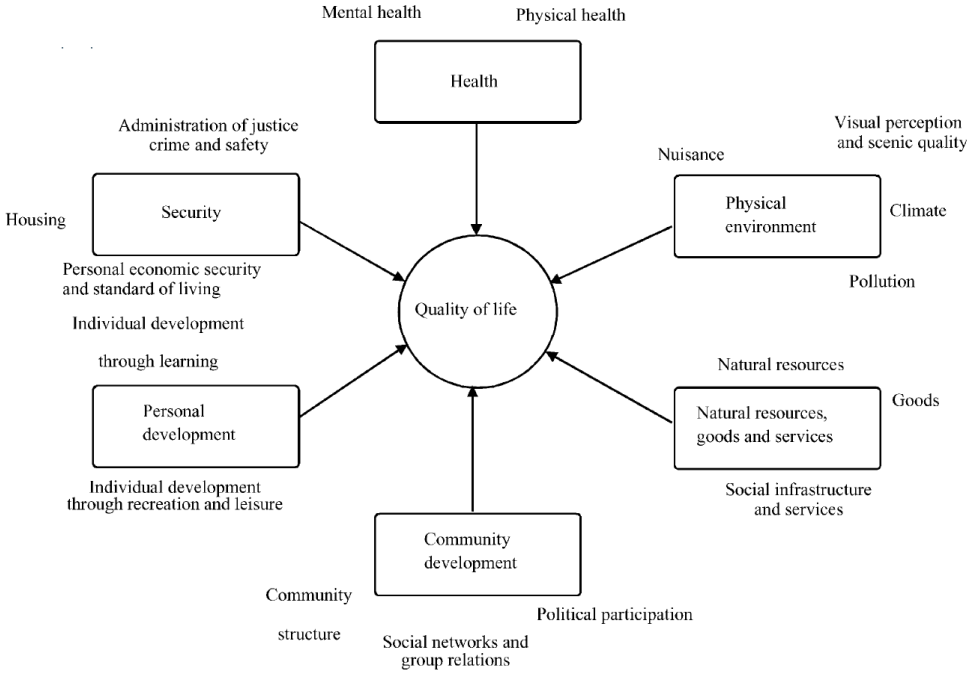

Fig. 1: Components of quality of life (from MITCHELL 2000, 74)

MARANS (2012) proposed a model in which quality of life is a combination of satisfaction levels at a range of scales: housing/dwelling, neighbourhood, city/town and country. He suggests that overall quality of life experience depends upon satisfaction with elements of the environment (social and environmental) at each of these scales. Different factors, both objective and subjective, apply at each scale and indices can be computed from these factors. For example, Figure 2 is the MARANS (2002) model showing how various factors contribute to neighbourhood satisfaction. It is notable that this model includes both the objective measures 'distance to nearest park' and 'amount of parkland', and the subjective factor 'awareness of parkland'. However there is no recognition of the quality of the parkland except in that this may influence the awareness factor. In the context of this paper key questions emerge at this point. Does the quality of the parkland affect perceived satisfaction? Is EH a major element in perceived parkland quality – or is perception influenced more but other factors such as facilities, aesthetics or noise within the parks?

We have not yet undertaken the all the experiments necessary to answer our primary question – can we have it all? The remainder of the paper is a combination of findings derived from already available indices relating to QOL and EH (City Scale), new preliminary findings based on on-line data (District Scale) and our ideas about how to best pursue the key questions (Neighbourhood Scale) drawing on our recent work in this domain.

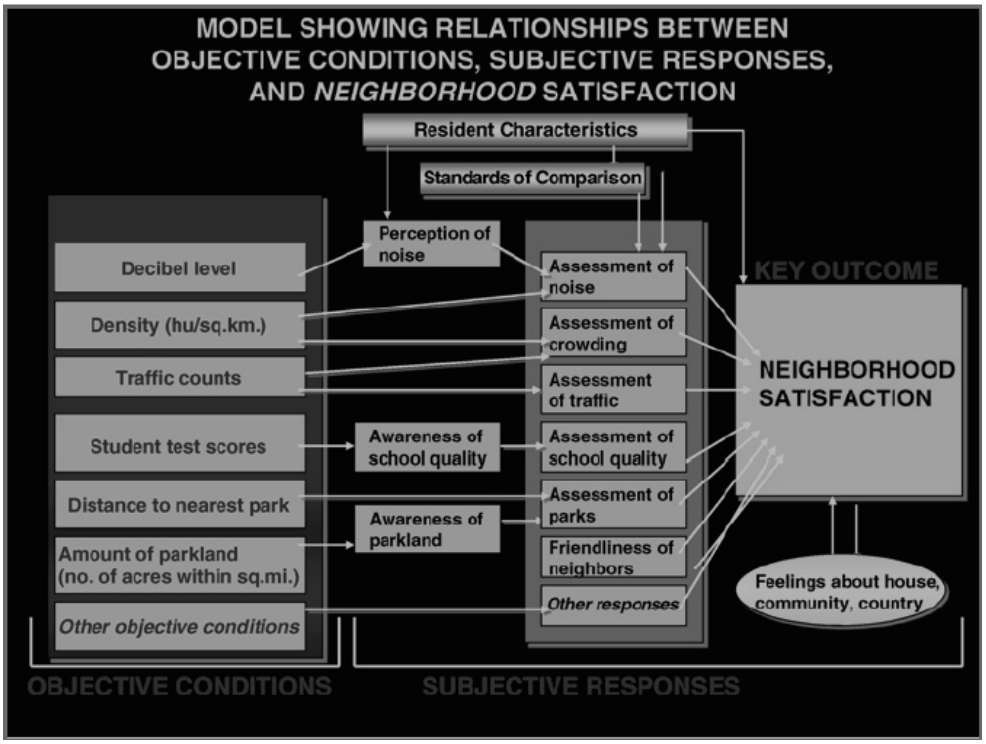

Fig. 2: The combination of objective and subjective responses to estimate satisfaction (from MARANS 2002)

3 City Scale

To compare cities in terms of greenness and livability, we used the Economist Intelligence Unit (EIU) livability data and their subsequent spatial adjustments. The later were available for 70 cities around the world (ECONOMIST INTELLIGENCE UNIT 2012). We deemed some factors to relate to greenness and formed one index from those, and another index from all the other factors (Table 1). We then tested the correlation between these (N = 70, correlation = 0.801, $p<.001$). Despite the strong correlation, the rank ordering changes considerably according to factor-set. For example Munich ranks first for greenness but only 19th on other factors. By contrast, Osaka is first on the other factors but only 15th for greenness. The full distribution of the cities is shown in Figure 3. Cities below the line score better on 'other' factors, those above the line score better on 'greenness'. Very noticeable is the concentration of Asian cities with large negative greenness residuals (especially the major Chinese cities Beijing, Shanghai, Guangzhou, Tianjin) while positive residuals included clusters of European (Munich, London, Madrid) and South American (Bogota, Caracas, Rio de Janeiro) cities. In the USA there is a clear distinction between green San Francisco and New York and not-so-green Miami and Atlanta. Most of the Africa cities in the survey are well above the line even though they rank fairly low on both indices.

Table 1: Factors in EIU livability assessment and spatial factors introduced in EIU (2012) divided into two groups – those that relate to ecological health (greenness) and others that relate to quality of life

	Factors included in Greenness Index	**Factors used in 'Other' index**
Original EIU factors	Culture and Environment	Stability Healthcare Education Infrastructure
'Spatial' Factors (EIU 2012)	Green Space Sprawl Natural Assets Pollution	Cultural Assets Connectivity Isolation

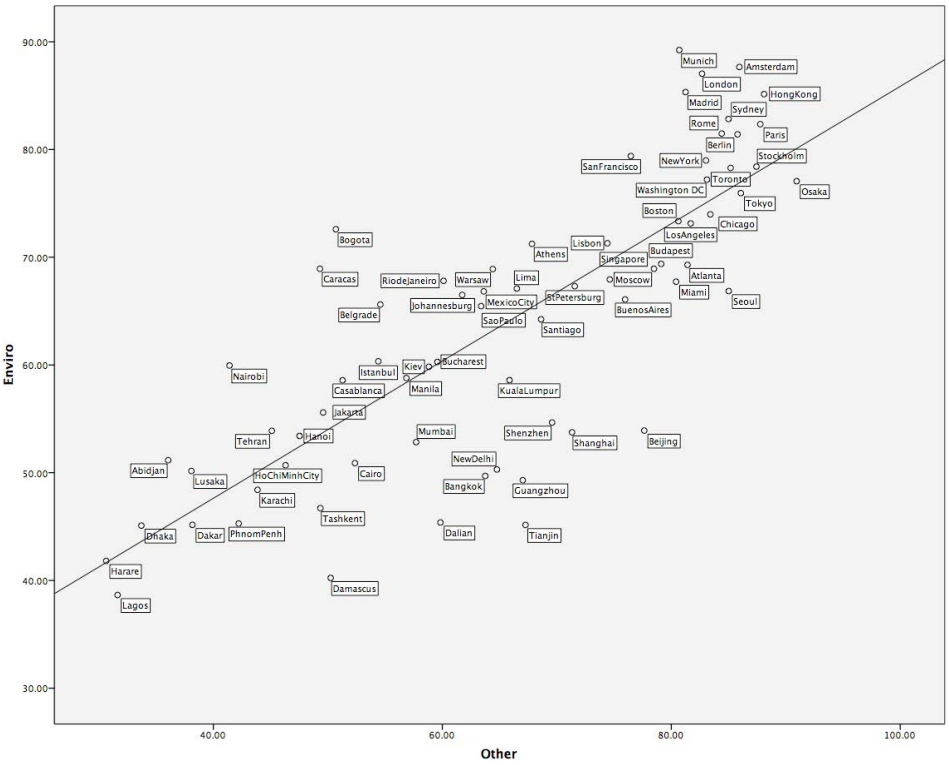

Fig. 3: The distribution of cities on a group of environmental/greenness factors (Y) and a group of other (QOL) factors (X)

4 District Scale

A city is not uniform. MILLER et al. (2013) argue that highly aggregated city-wide indicators often fail to capture nuanced spatial effects since they mask heterogeneity in the underlying disaggregated distribution. Also, a large number of disaggregated spatial distributions can be consistent with the same aggregated state, meaning it is impossible in principle to

untangle competing explanations and policy interventions (O'KELLY 2010). A city may have good overall indicators but high levels of inequality in QOL.

While there are various studies of both greenness and QOL at the city scale, and very local studies of ecological value, there is much less literature on spatially distributed QOL. SAITLUANGA (2013) mapped liveability across a mid-sized city in northern India. He mapped both objective and subjective measures and used principle components analysis to resolve these into five factors: three objective and two subjective. As with OKULICZ-KOZARYN (2013) he found no significant relationship between objective and subjective dimensions. In relation to the spatial distribution of liveability, Saitluanga concluded that location has significant importance in the pattern of liveability but some districts could not translate their locational advantages (such as proximity to the CBD) into resident satisfaction because of their unsuitable topographies or inadequate infrastructure. SAKAMOTO & FUKUI (2004) recognized the importance of perceptions and developed a system that allowed on-line users to define utility functions associated with a range of factors in their living environment. Users then weighted these liveability factors using their personal preferences in fuzzy structure modelling. The weights and utility functions were then applied to on-line spatial data to generate maps of liveability in Tokyo.

We have used the situation of Melbourne Australia to take a preliminary view of the spatial distribution of EH and QOL. In this case we have available a subjective QOL estimation couched as an index of Wellbeing. This was derived from an extensive random survey of households (25,075 participants) which included questions about satisfaction with standard of living; health; achievements in life; community connection; personal relationships; safety; and future security (VICHEALTH 2011). The results are available by Statistical Local Area (SLA). SLA's vary considerably in size (range roughly 10 to 2000 km2 in the selected urban and periurban areas) and population (range approximately 3000 to 100,000).

A city wide disaggregated estimation of EH is harder to find. However there are some datasets that can be used to create a preliminary index. To illustrate this we have simply used a tree distribution mapping in which tree cover is defined by woody vegetation greater than 2 meters in height and with a crown cover (foliar density) greater than 10%. Tree cover is mapped down to a minimum area of one hectare. This layer was derived by the State Government of Victoria from LANDSAT TM digital data. We downloaded the dataset from the on-line portal of the Australian Urban Research Infrastructure Network (AURIN), loaded it into ArcGIS, rasterized the polygons and then created a Euclidean distance map. Finally a zonal analysis gave the mean distance (in degrees) to the nearest mapped trees within each SLA. The distance was subtracted from 1.0 to give an index of 'tree-access'.

As Figure 4 shows there is a significant negative correlation ($R = -0.417$, $N = 97$, $p < 0.001$) between subjectively assessed wellbeing and objective tree-access. In other words people who live nearer the treed areas tend to have a greater sense of wellbeing. There are many possible reasons for this, including selection of a residence in nicer areas by those with greater purchasing power and consequent sense of wellbeing. Establishment of a district level relationship depends on negation of such confounding variables.

The associated spatial distributions are evident in Figure 5. A clear outlier in this relationship is Cardinia (Shire) – South, which is in the lower right of the maps. This SLA has a very high wellbeing estimate but the treed area access is only moderate. Other factors, such as access to the sea, appear to be influential.

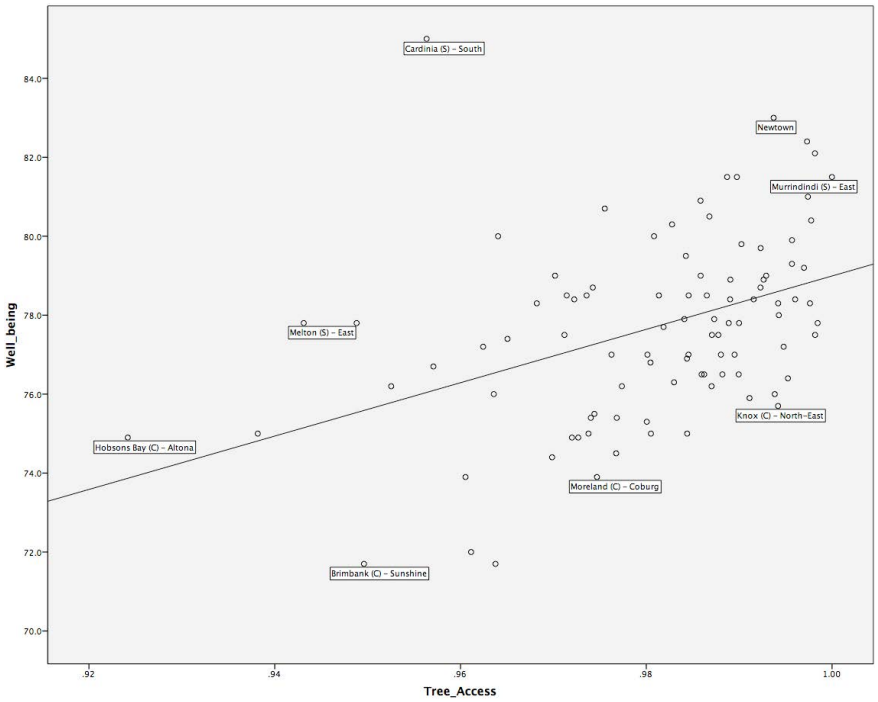

Fig. 4: Distribution of SLAs (Districts) in terms of subjective wellbeing and distance to treed areas

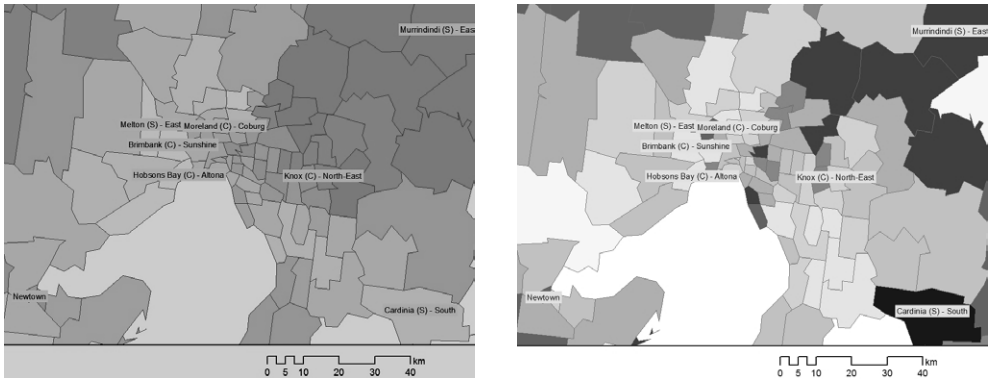

Fig. 5: Spatial distribution in the Melbourne area of access to green areas (left) and subjective well-being (right). Labels correspond to the labeled points in Fig. 4.

5 Neighbourhood Scale

Scoring multiple factors of QOL and EH at the neighbourhood level would be an immense undertaking requiring very substantial spatially disaggregated data sets. As this is not practical in most cities, a process for sampling is necessary. BANZHAF et al. 2014 used high, medium and low income neighbourhoods for stratified sampling; another key dimension

would be distance from city centre. Random sampling within stratifications would then give good comparative data.

In this case we have several examples from existing literature, especially our own work as applied to Shanghai, China. However each of these refers to a particular factor and the results have not been integrated as they typically do not apply to common or even overlapping neighbourhoods.

CHE et al. (2011) studied the urban waterways of Shanghai and particularly the Suzhou Creek and its distributaries from the perspective of public accessibility based on the premise that "the accessibility of urban riverfronts is significant in terms of realizing ecological and social benefits" (p80). In the view of Che et al., ecological and social benefits are inextricably linked. They used a definition of accessibility from NAVARRO (2000) that referred to the "possibilities of realizing recreational, aesthetic, and educational values, as well as protecting wildlife and habitats in waterfront redevelopment." (p81). Using 12 indicators related to spatial accessibility, visual accessibility, corridor continuity and amenity, the study found that both ecological and social aspects were of low quality largely because of uncontrolled development along the waterways. In this case there was clearly scope for improvement of both aspects (EH and QOL) but only the implicit assumption that they are closely linked.

Within the domain of thermal comfort, CHEN & NG (2012) argue that both subjective (human knowledge) and objective (climatic knowledge) are important to understanding how urban spaces become supportive of human behaviour and how this awareness can contribute to improved urban design. In relation to climatic knowledge, a related study by NG et al. (2012) explored the ways in which 'greening' can contribute to thermal comfort. From a Hong Kong based study, they concluded that: "The amount of tree planting needed to lower pedestrians level air temperature by around 1 °C is approximately 33% of the urban area." (p256). While this kind of hard data is a good starting point, there is still a knowledge gap regarding the kinds of changes that affect human perceptions and behaviours and also more detailed information about the detail of the vegetation needed. While NG et al. (2012) concluded that trees were more effective than grass, there was no attempt to distinguish between different tree species, to include the role of understory or to consider the optimal spatial distribution of the vegetation. Other authors have begun to study these questions (e.g. NORTON et al. 2015) but there is little literature on how this relates to ecological health.

Both access to waterways and thermal comfort may contribute to the desirability of walking as a mode of mobility within a city. LIN & MOUDON (2010) studied the factors (both objective and subjective) that contribute to the walkability of a neighbourhood. They found that while several objective measures – such as proximity to grocery stores and schools were good predictors of walking behaviour at neighbourhood level, their subjective counterparts were less effective. The focus in this study was however on accessibility factors rather than amenity factors. There is clear scope to explore further the relationships between amenity, including aesthetics and comfort, and the ways in which these factors intersect with measures of EH.

Consideration of noise as a QOL factor is a recent addition to the Shanghai work. An interesting phenomenon in Zhongshan Park in central Shanghai is the presence of large screens displaying current noise levels (Fig. 6). The interplay of subjective and objective measures are especially important in this context as evident also in Zhongshan Park where music for dancing is often played. The presence of the displayed meters could make people more

sensitive to noise, while the music will be pleasant to some and noise to others. VAN RENTERGHEM et al. (2014) discuss a number of studies that suggest that the role of vegetation in relation to noise may be more important subjectively than objectively.

Fig. 6: Scenes in Zhongshan Park, Shanghai. Public noise monitors (left) and sources of sound which might be noise to some but not to others (right). Photographs by Changjiang Gou.

While GOBSTER et al. (2007) explored the relationship between aesthetics and EH from a number of conceptual perspectives; there has been little empirical research into the relationship – especially in the urban context. The main exception is research into the role of urban nature in human psychological health (recently reviewed by BRATMAN et al. (2012)) but this does not explicitly consider aesthetic responses.

It is clear from this brief review that there are extensive gaps in the literature about the relationship between QOL factors derived from the physical environment and EH. In particular there are very few empirical studies. As BIELING et al. (2014) say, "this remains a heavily underexplored field" (p20). The next section explores the potential of emerging technologies to help fill this knowledge gap – especially the subjective aspects of the neighbourhood experience.

6 Technology and QOL Factors

Since GOODCHILD (2007) reviewed the potential of volunteered geographic information there have been considerable changes in available technologies and also rapid expansion of social media. Collecting information from the 'crowd' has become a great deal more diverse than simply building new maps (e.g. open street map). LEAO et al. (2014) created a smartphone app (called 2Load?) for monitoring and then reporting noise levels to a project server. This app was made available to residents near a busy road in Melbourne, Australia. Over a seven week period, 27 residents used the app to compile spatially explicit noise statistics (over 1000 h of readings) in and around their homes.

In addition to information about the purely physical environment, the crowd can provide information about the emotional environment – which is potentially an excellent indicator for QOL. For example, RESCH et al. (2014) describe three different techniques for mapping emotional responses: 1) detecting emotions using wristband sensors, 2) "ground-truthing" these measurements using a smartphone-based survey in real time 3) extracting emotion information from crowd-sourced data like Twitter (detecting the type of emotion). Despite this potential, there do not seem to be any instances yet in the literature of crowd sourcing used specifically to extract QOL information. Closely related however is the real-time

monitoring of subjective wellbeing using the Mappiness app by MACKERRON AND MOURATO (2013).

Another approach to public input is through experimental exploration of people preferences or behaviours in virtual reality (VR) environments. There has been extensive use of both static and dynamic virtual environments to study perceptual responses (reviewed by HEFT & NASAR 2000) to urban and rural landscapes. However, few papers have specifically linked VR to QOL. The nearest appears to be work of RUBIN & MORRISON (2014) who created virtual versions of four 17th and 19th century utopian cities. These were presented to people using slide shows simulating walks through each city. People were asked about the pleasantness and the environmental quality of the cities. In terms of sub-factors within QOL (Fig. 1) there are many instances of VR use for stated aesthetic responses and also some in relation to public safety. TOET & VAN SCHAIK (2012) explored a number of hypotheses relating to signs of disorder in the environment and perceived personal safety in both real and virtual environments. Their findings did not establish any of the hypotheses. However, their discussion emphasized the importance of sound in the virtual environment, as silence tended to create more trepidation. The potential importance of smells in unpleasant environments was also raised.

Fig. 7: One of the many, perhaps underused, waterways of suburban Shanghai

Fig. 8: The corresponding locations in Melbourne were 'rediscovered' in the 1980s and 90s

While such stated preference perceptual studies could be helpful in understanding subjective relations between EH and some QOL factors, still more potential, and greater ecological validity, is offered by observation and analysis of revealed preference through behaviour in VR. This is an underused option in landscape studies, although the concept has been previously explored in path choice experiments by BISHOP et al. (2001) and ZACHARIAS (2006). In seeking to determine whether QOL and EH are spatially covariant across a city our intended approach is to create a number of virtual versions of a typical modern Shanghai neighbourhood, referred to locally as xiaoqu [小区], and the linking spaces between these largely self contained areas. These virtual environments would have different ecological character and movement opportunities (such as use of stream corridors which are currently neglected – Fig. 7). Local people would then be given the opportunity to score, comment and make movement choices within the different VR environments. These could be compared with crowd-sourced responses to the existing environment. This should clarify

the relationships in question for both a whole neighbourhood and also for individual sites within a neighbourhood.

7 Conclusion

Initial evaluations at city and district scale, using limited sets of available factors, suggest a significant correlation between EH and QOL. This is not necessarily a cause-effect relationship however as wealthy cities tend to score highly on both scales. The various indices used in this preliminary examination are also not ideal but come from sources often developed for linked, but different, purposes. A focus on liveability using quantitative city-wide measures is likely to provide different outcomes than a focus on subjectively evaluated QOL. The work of RUBIN & MORRISON (2014) using virtual imagined cities also demonstrated that individuals may take very different views depending on whether they lean towards individualism or collectivism. This distinction could be interesting to explore further in the light of the preponderance of Asian cities below the line in Fig. 3, with Latin American cities commonly above the line.

Considerable numbers of studies dealing with individual QOL and EH factors have been undertaken around the world in neighbourhood, or smaller, areas. We focused on recent work in Shanghai by way of illustration. The key conclusions drawn from these studies, which frequently include implicit assumptions about the value of EH, are that:

- Assessment using both objective and subjective approaches is essential (perceived noise and thermal comfort can be quite different from levels based on measurement alone)
- Real environments are very complex and may have confounding elements (such as public displays of noise levels); with sounds and smells being very significant in some locations.

This suggests a need for both more efficient means of gathering public attitudes and more effective experimental control. The former can be approached through crowd-sourced data gathering including sensors worn by people, smartphone apps used by people keen to contribute (the Mappiness app referred to above attracted 1,138,481 responses from 21,947 participants in six months), and data mining from social media. The latter can be addressed through development of VR test environments covering a range of conditions while controlling for confounding variables.

To this point we have focused on the aspects of people's living environments, which are commonly measured and fairly well understood – at least in isolation from each other. These might be considered as necessary, but not sufficient conditions, for a high quality of life. We have not paid much attention to what MITCHELL (2000) summarized as 'personal development' and 'community development' (see Fig. 1). At the personal level this surely includes factors such as the availability of diverse experiences, excitement and opportunity for self-expression. Similar terms relating to the joy of living, not merely absence of the unpleasant, could also be applied to communities. At present landscape planners consider these factors in design. The new technologies could be used to test such designs. VR games (BISHOP 2011) could be harnessed to explore design options for their diversity, excitement and expression.

Understanding the intricacies of QOL seems more complex than compiling meaningful measures of EH – especially at the local or neighbourhood level. Certainly EH is the realm of science and objective measures, while QOL will always involve aspects of human character, perception and expectations. If we cannot 'have it all', then there needs to be careful and balanced consideration of the best mix of EH and QOL, with a view also to the needs of future generations.

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