JBU Journal of Biourbanism

ISSN 2240 - 2535

Via Giovanni Giardini, 15B - 00133 Rome, Italy - Tel. +39.393.9426561 Fax +39.06.95190008

www.biourbanism.org jbu@biourbanism.org

INTERNATIONAL SOCIETY OF BIOURBANISM

2013

#01&02

TOPICS Biophilia and urban planning | Biopolitics and design | Human health and design | Epistemology of architecture and urban planning | Peer to peer urbanism | Morphogenetic design | Sustainability | Renewable energy | Urban greening | Ecological networks | Architecture, urban and environmental planning | Landscape ecology and planning | Design learning strategies | Placemaking | Participatory design and planning | Information and communication technology | Multi-criteria analyses for urban planning | Land suitability evaluation | Service Design

Editorial

Eleni Tracada, PhD
University of Derby
Faculty of Arts, Design and Technology
Head of Built Environment Research Group
e.tracada@derby.ac.uk

Once again I should like to thank all authors who contributed to the publication of this current issue of the Journal of Biourbanism. I should like also to express my gratitude to all our colleagues and academics who accepted to review all papers submitted; they also offered guidance and invaluable feedback to all authors. And of course my appreciation to all our colleagues and sub-editors' hard work during the last few months is immense; we continue to support all authors as better as we can and especially we welcome new researchers' efforts, as they offer fresh ideas and topics to the academic world. In fact also in this issue we have accepted research papers, which do not only offer innovative interpretation of theories and practices, but also assess research findings and furthermore recommend new technical methods to improve urban services and infrastructure.

As usual distinguished authors have submitted further research findings from their current projects and I believe that all us together, either established or fresh thinkers are striving to keep our impetus high and honour research accomplishments cherished by Biourbanism principles and practices. And once again I believe that fruitful discussions and debate will emerge and provoke more inquisitions on current issues and problems related to the social and economic growth of communities struggling to recover through the difficult years of turmoil worldwide; urban sprawl often does not seem to respond to what human beings need to see as dwellings and urban facilities. Services and infrastructures often do not follow ordered patterns and decisions are made without consultation with local communities with the result of getting them more and more frustrated and deterred from participatory planning and design of their cities and preservation practices safeguarding the natural resources and environment.

Unquestionably some researchers and authors are still finding vital support to their work by being sustained through Christopher Alexander's theories and practices; these have been further enhanced by Nikos Salingaros' epistemological analysis and elucidation in the last few decades. In fact, in his *Of architecture, music and brains: Do we live in atonal cities?,* Alexandros Lavdas, a Senior Researcher in the Centre for Biomedicine, European Academy in Bolzano, Italy has attempted to argue successfully that the twentieth century has not only reinvented music, but also architectural expression. The author affirms that there are structural parallels between pre-modern and modern music and architecture; he also discusses and offers evidence that neuro-aesthetics depend heavily on tonality and complexity of fractal urban growth. Instead modernism has created tasteless and atonal cities, which often created mental disorders and confusion to the human brain. The author discusses that aesthetics is the result of computation and therefore the existence of this computational function in our brains is biologically so relevant, because "the aesthetic criterion is the result of our ability to detect what is likely to be good for us" and therefore improves and balances our state of mind. The author provides evidence of affinities between music pitches and fractility of the built and unbuilt environments. The author supports the theory that atonal music is not fractal and proves that modern architecture lacks of tone completely; “tonal music, figurative artwork and pre-modern architecture have elements of fractal structure … described by non-Euclidean mathematics”; the sounds carry intelligence which is measured by fractility mainly in harmonious compositions. The author also explains why metaphors about complexity of the city (scientific analogies), which are beloved by designers today, are not the same thing as the actual complexity of cities. The author concludes that neuroscience findings may be equally important to architectural and urban design today; he has also used very relevant sources to be supported throughout this fascinating discourse.

In his *An Adaptive Approach to Domestic Design*, Bruno Postle discusses the need to design ordinary domestic buildings by use of Pattern Language in order to gain design optimisation. Thus, the author attempts to support the idea that, evolution and mutation in domestic design shows that a Form Language through evolution has developed as Free Software; the results obtained by this software are comparable with historical built environment which followed informal and flexible urbanism and not rectangular and very restrictive grids of master planning. Patterns of informally created cities reveal that these were put in place to suit the day-to-day needs of their citizens; an evolution appears as co-evolution between neighbouring buildings. The author discusses with diligence basic pattern language of ideal domestic design and also provides formulas to measure fitness criteria challenged by human needs against cost of life; he also discusses and explains evolution strategies by possible combinations of typologies seen as crossovers. He provides a series of mathematically supported graphs related to typologies/growth of cities and increase of population. Indeed he provides fine examples of graphs related to a fittest single storey house after 640 generations! This proves that patterns play an everlasting role in urban developments and human life as long as life exists on this planet and beyond.

Three authors, Maria Bostenaru Dan, Diana Aldea Mendes and Thomas Panagopoulos discuss the economic efficiency of earthquake risk mitigation in their *Assessing the costs of hazards mitigation in the urban structure.* The authors have looked at the way ICT can contribute to organise the information from the building survey to economic computations in modelling and through games. The authors discuss about economic tools to be adopted for disaster reconstruction by considering Building Information Modelling (BIM) and especially Space Syntax and social games techniques; a disaster involves multiple actors and it may be the basis of a new game. The authors explain carefully how modelling reconstruction after disasters follows game technology and is supported by multimedia and appropriate software capable to provide very precise 3D city models for quick and resourceful reconstruction processes and results.

In their *A Psychological Assessment of Urban Landscaping of Public Agencies Premises in Jos City*, Salaudeen Bayo et al focus on the psychological assessment of urban landscaping practices of public agencies in Jos City, Nigeria. The authors have carried out research by using a specific psychological model of investigation on carefully selected landscape sites of public agencies. The study shows that, in Jos City, there is need for landscape planning policy capable to create awareness of citizens in relation to the appreciation of practices and applications of valuable landscape designs. The adopted methods of landscape design cannot be appreciated by citizens at the moment, because architects do not expand their ideas from the building design to the landscaped surroundings. Thus, psychological reaction may result often very negative towards built and unbuilt spaces in cities, like the case of Jos City.

In a very thought-provoking paper with the title *Urban Spatial Structures and their Economical Sustainability*, Vladimira Šilhánková from the College of Regional Development in Prague analyses six key types of structures and their financial implications in development by considering construction and maintenance. The study also focuses on technical infrastructure and transport costs and gains in suburban areas in Czech Republic; the author compares economic demands of traditional urban forms, especially blocks of flats, and suburban development and also looks at historical urban fabric integration in new planning. The paper show cases in city centres, middle-class villas areas and ex-Socialist developments of blocks of flats as historical urban context and compares with new sprawl of dwellings, industry and recreation areas in green belt new expansion of cities. The author presents with detail economic demands on the implementation of public facilities in all the areas mentioned above from the regeneration of historical fabric to latest developments of expansion; she also explains in detail predictable prices of Building and Transportation Infrastructure and makes clear that there are clear advantages in latest urban residential developments rather than developments in suburban areas.

And we conclude with two very interesting technology papers, which deal with ventilation improvements in buildings and infrastructural details in street networks. Thus, the authors are discussing the latest technologies available to facilitate life and movement in modern cities. Seong Lee, Xuejun Qian and Steven Garcia from Morgan State University present their paper *Analysis of the Integrated Ventilation Systems with Desiccant Wheels for Energy Conservation and IAQ [Indoor Air Quality] improvement in the Commercial Buildings*; they argue that, integration ventilation technologies are now demanding to reduce energy use and ensure that IAQ at the same time. The authors have used a variety of available software to produce annual energy simulation results, which show very interesting information of a considerable amount of savings by using integrated systems and latest technology. Another team of authors from the same University discuss on *Building a Sustainability Index for Highway Infrastructures: Case Study of Flexible pavements.* Stella Obazee-Igbinedion, Manoji Jha and Oludare Owolabi gets us to highway infrastructures which need constant periodical maintenance to retain optimum performance of pavements at times and conditions – several times maintenance has to prevent damages and hazards from freak climate conditions and heavy uses. The authors discuss pavement serviceability by considering sustainability in the processes and especially in their methodology of assessment of the conditions of the pavements.

As it has been explained above, it has been a great pleasure to act as Editor in Chief of this issue as well. I should also like to thank all authors who submitted papers, but did not get the opportunity to be published this time, because of major or minor corrections asked by peer reviewers in the meantime. I am looking forward to receiving these submissions for our next issue and having them published soon as we have in programme to produce two more issues for this year. Our scientific committee and the executive team of the International Society of Biourbanism have published deadlines of submission for the next issues of our Journal of Biourbanism in the official website. Please, keep an eye constantly on this site, in which you will also find more materials published or announcements on the progress of specific important publications relevant to our past, current and future activities. You can also find information about our future events: international workshops, conferences and symposia and also on how you become full member of our thriving community of scholars and academics around the world.

I am always convinced that all issues raised by the papers included in this current issue will continue our fruitful and stimulating discussions, instigating more inquisition and generating new articles and perhaps themes for our Biourbanism conferences and workshops soon. All our members of our committees and, especially our scientific committee, keep encouraging research developments in the discipline and philosophy of Biourbanism worldwide and we shall keep organising events, etc., which constantly enhance international professionalism and relationships in this important discipline. Therefore we wish to encourage all readers and scholars to participate in additional discussions and contribute actively by writing their thoughts and findings in more papers which will populate our next issues of the Journal of Biourbanism and other related publications and especially themed books.

Thank you for considering our continuous peer support efforts. I look forward to receiving your new contributions soon.

My best wishes to all of you.

JBU III (2013) 1

Part A – Peer-reviewed papers

Of architecture, music and brains: do we live in atonal cities?

Alexandros A. Lavdas
Senior Researcher, Center for Biomedicine
European Academy Bozen/Bolzano (EURAC), Italy
alexandros.lavdas@eurac.edu

ABSTRACT

The twentieth century has seen the total reinvention of both music and architectural languages. While radically new music composition systems have known a large popularity by composers – less so by the public – they still occupy only a niche, albeit a large one, in the word of composition. On the other hand, modern architecture sought to dominate the landscape completely, and largely succeeded in it, not only by offering a higher profit margin for developers, but mainly by proclaiming the ideological superiority of its approach, based on criteria that were arbitrary and had no scientific foundation – in other words, on dogma.

We discuss here some structural parallels between pre-modern and modern music and architecture, and propose that Alexander's 15 Properties and Salingaros' 3 Laws of Architecture that derive from them are the equivalent of the basic laws of tonality and harmony in music. We also propose an experimental setting for further investigating the neurological correlates of forms corresponding – or not – to these laws.

Keywords: Architecture, music, brain, neuro-aesthetics, modernism, fractal, complexity, tonality, syntax.

INTRODUCTION

What is wrong with today's cities? Why is it that people view the architecture of the last several decades more as something they just have to live with, rather than as a source of comfort and pleasure? Is it because they are slow to adapt? A long time has already passed since the beginnings of modern architecture, and one would expect that a period of roughly a century should be enough. And, of course, the question why should they adapt also springs to mind. Architecture is supposed to serve the needs of the people, not create environments in which people must try to fit.

A similar question can be asked about some types of modern/contemporary music – we do not mean pop music, but "modern classical" music, as some people call it, for lack of a better generally recognizable term. Certainly, music is a pure art and does not have a utilitarian aspect, like architecture. It does not define the living environment and is not forced upon non-consenting individuals like architecture is (at least this type of music is not). The advent of new material – regardless of whatever disagreements one might have with the rationale behind its creation – is welcome, or at worse indifferent, as it represents an addition to the existing corpus, not a replacement and an imposition as in the case of architecture. But while the importance of the issues is not comparable, in the sense of their impact on society, there are parallels to be drawn between the courses of architecture and music in the twentieth century, and lessons to be learned by the way both modern architecture and modern music are received and perceived by the individual.

From a mathematical point of view, both music and architecture are ways of combining basic materials to form more complex structures. The way that these materials are combined follows certain sets of rules in both cases. These sets of rules have been formed through millennia of technological and artistic evolution (these two are inseparable) and, despite the differences in the forms they resulted in, they all had some common structural features - before the advent of modernism, that is.

Based on observations on architecture from across the globe, and a plethora of theoretical and experimental data from Mathematics and the Natural Sciences, Salingaros (1995, 1998, 2006) has formulated a new Theory of Architecture. This Theory seeks not only to explain the success of pre-modern architecture in connecting with the user, but also to give guidelines for future applications, based on the distilled knowledge of thousands of years. It is assumed that the reader is familiar with this literature, which is the main basis upon which the rationale of the present paper is elaborated. These studies, in conjunction with pioneering work by Christopher Alexander (Alexander et al, 1977), have led Salingaros to codify his "3 laws of architecture":

1. Order in the smaller scale is established by paired contrasting elements, existing in a "balanced visual tension"

2. Large-scale order occurs when every element relates to every other element at a distance in a way that reduces the entropy

3. The small scale is connected to the large scale through a linked hierarchy of intermediate sales with scaling factor of approximately e=2.7.

These laws can be viewed as an algorithm that can describe all pre-modern architecture; accumulating evidence supports the idea that the nature of this algorithm is not arbitrary, but originates in human physiology itself, thus allowing a connection to the human senses – to the human perception mechanisms, to be more precise. Certainly, completely different and intellectually interesting algorithms can – and have – been devised, but their application in an applied art, such as architecture, is of questionable value in meeting actual user needs.

Viewing modern architecture under this prism may explain why contemporary buildings, despite the advertised virtues of their "purity" and "minimalism", usually fail to engage the user/viewer. The relevance of "pure forms" to the user, the idea that these forms should strike a chord within our psyche, is an intellectual construct, which has never been verified at any level, an unfounded claim based on the confusion between reality and mathematical abstraction. The sphere, the plane, the line do not exist; they are mathematical approximations of spherical, planar or linear objects. They are useful for practical reasons, for calculating volumes, surfaces and distances, but they are nothing more than tools for understanding the world. Their idealized nature makes them more irrelevant, not more relevant, to us. There is no doubt that objects in pure forms can be beautiful: their unnaturalness makes them interesting aesthetically because they are not common in nature - but does not give them any preeminent position among other forms. Quite the contrary, it puts them on one end of the "form spectrum", as acceptable as countless other configurations. We can see pure forms in the details of all buildings of all ages. What we had not seen, up until a century ago, was whole buildings made up of pure forms. However, for the best part of the last hundred years, we have been building using only this part of the "form spectrum". What was once attractive because it was rare has become so tyrannically common and omnipresent that suffocates us and alienates us from forms that are truly relevant to our nature. Hundertwasser (1968) wrote "The Austrian Adolf Loos brought this atrocity into the world. In 1908, with his manifesto aptly entitled 'Ornament and Crime'. No doubt he meant well… but (he) was incapable of thinking fifty years ahead. The world will never be rid of the evil he invoked". More recent "decontructivist" architecture has abandoned pure forms, not to return to organized complexity but to turn to disorganized complexity, with results that are usually even less agreeable for the user/viewer.

Here, we aim to discuss findings on organized complexity in the light of data from cognitive neuroscience and to draw parallels between music and architecture in the context of their perception by the individual, proposing to explore these parallels in experimental settings.

NEUROESTHETICS

Neuroesthetics is a term coined by Zeki (1999) and refers to the study of the neural bases of beauty perception in art. The field, as stated by Zeki himself, is not really an approach to studying art: it is an approach to studying the brain through the art that the brain creates. However, inevitably, this comes full circle: knowledge about the source of this art gives us knowledge about the art itself.

For the reader who is not interested in a purely neuroscientific discussion, there is one take-home message to remember before moving on to the next section: in a recent study, Ishizu & Zeki (2011) demonstrated that whenever a visual or musical stimulus was deemed by the viewer or listener as beautiful, this judgment was accompanied by increased activation of a specific brain area (called area A1 of the medial orbitofrontal cortex / mOFC).

This was not a study on art, but on beauty by itself, as not all art is necessarily beautiful, and not everything that is beautiful is art. Many older studies that had addressed the neural correlates of the experience of beauty had also found activity in mOFC (briefly reviewed in Ishizu & Zeki, 2011), and their findings help corroborate the claim of the authors, that the experience of beauty, regardless of the sensory modality through which it is perceived, always correlates with increased activity in this specific area.

Edmund Burke, in his *Philosophical Enquiry into the Origin of Our Ideas of the Sublime and Beautiful*, wrote that, "Beauty is, for the greater part, some quality in bodies acting mechanically upon the human mind by the intervention of the senses" (Burke, 1757). Ishizu & Zeki (2011), based on their experimental data, were able to modify this definition to "Beauty is, for the greater part, some quality in bodies that correlates with activity in the mOFC by the intervention of the senses". Their approach indeed "shifts the definition of beauty very much in favor of the perceiving subject and away from the characteristics of the apprehended object and gives added strength to the Latin proverb that ''De gustibus non est disputandum''", as the authors state. At the same time, they stress that they "do not wish to imply that objects that are classified as beautiful do not have certain characteristics that aid in this classification, although what these characteristics are has been, and continues to be, a subject of debate." At this point it becomes clear that, just as when talking about art, so when talking about beauty, the investigation eventually has to come full circle. For it is inevitable that it becomes an issue of neurobiological importance to investigate what is this "quality in bodies" that correlates with mOFC activity, and how this correlation is effected in practice.

Some components of what constitutes beauty are certainly shaped by cultural factors (Cunningham, Barbee, & Philhower, 2002), but there seems to be a universal neurological underpinning upon which these factors exert their influence. Infants have been shown to look longer at attractive faces within a week of being born, and the effects of facial attractiveness on infants' gaze generalize across race, sex and age by 6 months (Slater et al., 1998; Langlois et al, 1991). This data suggests that there are some common properties in these forms that are recognized as "attractive". Not surprisingly, it has been reported in various studies that attractive faces activate neural circuitry involved in reward systems, including orbitofrontal cortex, the nucleus accumbens, the ventral striatum (Aharon et al., 2001; Ishai, 2007; Kranz & Ishai, 2006; O′Doherty et al., 2003; Kampe, et al, 2001), and the amygdala (Winston et al, 2007) - a function related to mate selection (Ishai, 2007; Kranz & Ishai, 2006). Viewed in the context of architecture, these observations immediately bring to mind one of Alexander's key assumptions: that we can use the human body as a sensing instrument for what is good and bad in architecture (Alexander, 2001). The aesthetic criterion is the result of our ability to detect what is likely to be good for us. "There's a sound reason why the ripe tomato, glistening with dewdrops, looks beautiful to us, and the rotten meat looks ugly and disgusting" (Mehaffy & Salingaros, 2011). Aesthetics is the result of computation, and the existence of this computational function in our brains is biologically relevant and not a "superficial" byproduct of other functions. It can be cultivated, like any other intellectual skill, but the basis for its existence is universal.

RESONANCE

Going back to the mOFC, it is very tempting to consider that there may be cross-modal similarities in the nature of the stimuli that result in its excitation. These similarities would be expected to be of a structural nature – that is, how the shapes or the sounds are organized, a common mathematical underpinning of these diverse stimuli that, through some sort of "resonance", always leads to a common reaction in a specific brain area.

The use of the word "resonance" may not be metaphorical.

There is a growing amount of evidence that sensory stimuli that can be described in specific mathematical terms have a higher impact on our sensory perception system than signals that do not fall into this category.

It has been shown (Zhou et al., 2012) that steady audio pink noise at comfortable levels has a significant effect on reducing brain wave complexity and inducing a more stable sleep, thus improving sleep quality of individuals. What is so special about pink noise is its power distribution over the audible spectrum, its structure, so to speak.

Pink noise, or 1⁄f noise, is a signal (not necessarily an audio signal) or process with a frequency spectrum such that the power spectral density (energy or power per Hz) is inversely proportional to the frequency (Bak et al, 1987). The name arises from the pink appearance of visible light with this power spectrum.

Intriguingly, this 1⁄f distribution seems to be universal and is observed in systems as diverse as resistors, the hourglass, the flow of the river Nile, and the luminosity of stars (Bak et al, 1987). Voss and Clark (1975) showed that the power spectrum for pitch and intensity fluctuations in a recording of Bach's Brandenburg Concerto No. 1 and other recordings of music were approximately 1/f over about 3 decades of frequency. A similar finding was demonstrated for the power spectrum for intensity fluctuations of human voices. Inside the nervous system itself, Musha (1981) showed that the series of fluctuations in the time density (the inverse of transmission speed) of action potentials traveling down the squid giant axon have an approximately 1/f power spectrum below about 10 Hz. Novikov et al. (1997) found that the activity of ensembles of neurons in the brain, recorded from relaxed human subjects by the magnetoencephalogram, shows a 1/f power spectrum. The examples seem endless.

Linked with the 1/f distribution is the ubiquitous phenomenon of self-similarity or fractal structure in nature (Mandelbrot 1967, 1977). Mandelbrot demonstrated that the complexities and apparent irregularities of natural patterns could not be modeled using Euclidean geometry. Many natural objects can only be described by fractal geometry, and are made up of patterns recurring at different scale levels (for example, a tree with its branches). Fractal geometry uses a parameter called "fractal dimension" (D) to describe the fractal scaling relationship between the patterns observed at different scales. A smooth line has D=1, while a filled black area has D=2. For the repeating patterns of a fractal line, D lies between 1 and 2.

Fractal patterns seem to be everywhere in the natural world: coastlines (D=1.05–1.52; Feder, 1988; Mandelbrot, 1982), galaxies (D=1.23; Mandelbrot, 1982), geothermal rock patterns (D=1.25–1.55; Cambel, 1993), plants and trees (D=1.28–1.90; Morse et al., 1985), sea anemone (D= 1.6; Burrough, 1981), snowflakes (D=1.7, Nittmann & Stanley, 1987) etc. Taylor et al (2006, 2011) have shown that exposure to fractal visual patterns, be it in nature, architecture or the visual arts, has positive physiological (stress reduction) and cognitive (better performance at problem solving) effects. Along the same lines, clinical advantages (faster hospital healing and pain relief) of natural environments, as well as artificial environments mimicking geometrical qualities of natural environments, have been demonstrated (Frumkin, 2001). Interestingly, the fractal dimension of the eyes' saccadic trajectory when scanning various images is always mid-range (around 1.5), regardless of the D value of the images themselves (Fairbanks & Taylor, 2011; Taylor et al, 2011)-bringing once again to mind the concept of “resonance”. These and other lines of evidence point to the direction of a hard-wired predisposition of our nervous system to be “tuned” to mid-range fractals, like those to which the organism is exposed in its natural environment. But there is more to the natural geometry than fractal dimension. Our information processing “… system is acutely tuned to the visual complexity of the natural environment, specifically to respond positively to the highest levels of organized complexity. … Fractals are an important component of this effect, but by no means represent the full gamut of connective qualities” (Salingaros, 2013). An extensive analysis of the geometrical properties that exist both in Nature and in all pre-modern architecture – but are absent in in modern buildings – can be found in the work of Nikos Salingaros. The reader can also find a concise overview of the subject in Mehaffy & Salingaros (2012a).

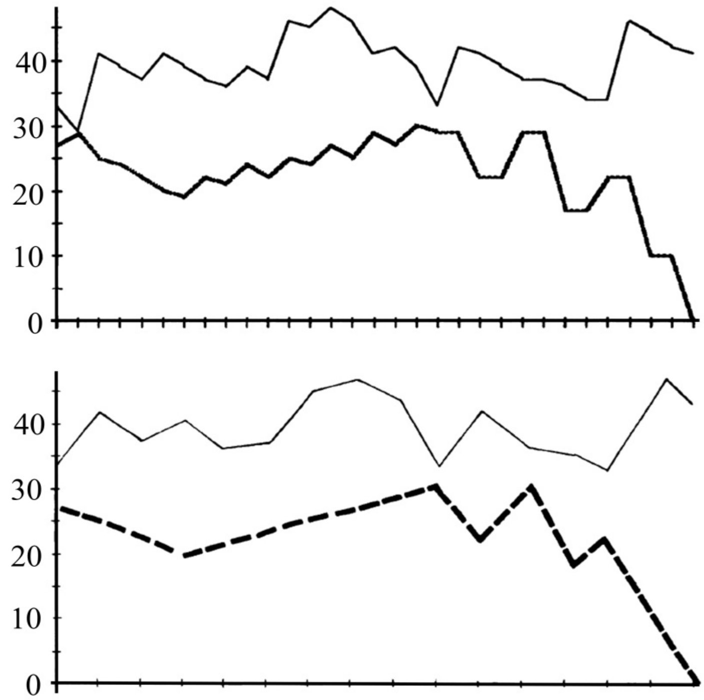


Fig. 1 (from, Hsü & Hsü, 1991). Upper: “silhouette” of Bach's original Invention no. 1 composition. Lower: the half reduction. The ordinate gives the numerical value of I (acoustic frequency), and the abscissa is a parameter of time. The scores for the right hand are shown by the upper lines, while the scores for the left are shown by the lower lines. This is one of many examples of fractal structure revealed in music (© 1991, PNAS).

Keeping all this in mind, let us take a step back and look at music once again. Hsü & Hsü (1990; 1991) published a fractal study of some movements from works of Bach and Mozart, containing a fractal reduction of Bach's Invention no. 1 in C Major, BWV 772, showing the similarity after halving the quantity of notes (see Fig. 1) They reported: “to a novice, the half- or quarter-Bach sounds like Bach, although he gains the impression that the composition has an economy of trills and ornamentations. Further reductions to 1/8, 1/16, and 1/32 tend to eliminate more of the “irregularity of the silhouette”, yet the distinguishing overall line of the music landscape is preserved. The final reduction to 1/64 gives only three notes; they are the three key notes, the foundation upon which the whole composition is built.” As expected, the relative abundance of individual notes of different frequencies is not fractal; it is the abundance of the intervals that is fractal and is demonstrated in these examples. It seems that both loudness and pitch fluctuations are scale-free in all classical, blues, jazz and pop music, as well as traditional music from various parts of the globe. Scale-freeness seems to be associated with our perception of beauty in music (Gardner, 1978; Voss and Clarke, 1975, Hsü and Hsü, 1991).

ATONAL MUSIC – JUST LIKE MODERN ARCHITECTURE – IS NOT FRACTAL

There is an interesting twist to the story: in atonal music, these fractal features are absent, as shown in analyses of works of Schoenberg and Stockhausen (Voss & Clarke, 1975; Hsü & Hsü 1990). Consequently, reduced landscapes like the one demonstrated for Bach earlier would be unrecognizable by the listener when applied in modern atonal music.

So how is this related to architecture? Hopefully it will soon start to become evident. Discussing Mandelbrot's 1977 book, Freeman Dyson wrote in 1978: "Nature has played a joke on the mathematicians. The 19th century mathematicians may have been lacking in imagination, but Nature was not. The same pathological structures that the mathematicians invented to break loose from the 19th century naturalism turn out to be inherent in familiar objects all around us".

In fact, it is tonal music, figurative artwork and pre-modern architecture that have elements of fractal structure-which can be described by non-Euclidean mathematics. And it is the atonal music and modern visual art and architecture that lack such structure. An extra level of irony is added when we think that the application of mathematics to music composition –such as that employed be Xenakis (see below) – result in the production of music of a mathematically simpler form, as far as its fractal values are concerned.

TOWARDS A NEW MUSIC LANGUAGE – OR NOT

Xenakis described his

> …effort to materialize movements of thought through sounds, then to test them in compositions; the effort to understand better the pieces of the past, by searching for an underlying unit which would be identical with that of the scientific thought of our time; the effort to make "art" while" geometrizing," that is, by giving it a reasoned support less perishable than the impulse of the moment, and hence more serious, more worthy of the fierce fight which the human intelligence wages in all the other domains -all these efforts have led to a sort of abstraction and formalization of the musical compositional act... It is not so much the inevitable use of mathematics that characterizes the attitude of these experiments, as the overriding need to consider sound and music as a vast potential reservoir in which a knowledge of the laws of thought and the structured creations of thought may find a completely new medium of materialization, i.e., of communication. (Xenakis, 1971)

He concludes that "for this purpose the qualification" beautiful" or "ugly" makes no sense for sound, nor for the music that derives from it; the quantity of intelligence carried by the sounds must be the true criterion of the validity of a particular music."

What this rationale lacks, is a true appreciation of the function of the human mind. It dismisses all the affective parameters of art – and of art creation – as “impulse of the moment”, hence rendering the aesthetic criterion of “beautiful” and “ugly” as obsolete and unworthy of our intelligence, and tries to impose extrinsic, non-artistic methods in music creation. And therein exactly lies the pitfall. Xenakis – and dozens of others – does not appreciate the fact that the aesthetic criterion, the “beautiful” or “ugly” verdict, is the result of computation – albeit an immensely complicated and subconscious one. The work of Zeki, mentioned earlier, is a clear proof of that, and it equally applies to music, architecture, or any visual art. “The quantity of intelligence carried by the sounds” is indeed the measure of the validity of a particular music – but the instrument by which this intelligence is calculated is embedded in our appreciation of music and is reflected in its affective influence. Gottfried Leibniz had said, “music is a secret exercise in arithmetic of the soul, unaware of its act of counting” (quoted in Sacks, 1987). This concept, evident to Leibnitz centuries ago, is often overlooked today.

Certainly, there is another pitfall here one has to avoid: that is, to believe that this subconscious computation is all there is to music experience. This is certainly not the case; but what is in fact true is that the phonology, the vocabulary and the syntax of the language of music are based on the affective properties of sound intervals and of consonance and dissonance, emerging from the overtone series. The subconscious computation is there to decode the language. Using this language, music can carry all sorts of different meanings.

Transmitting “structured creations of thought” is exactly what music has been doing for millennia, using a language that the brain can understand. By destroying the language, one destroys the code of message transmission. With nothing much to gain:

> These sonic symbols of a mathematical method are not able, except only by chance, to stimulate the thoughts and, even more so, the emotions of the listener. For they cannot convince that they have any reason to exist other than the realization of a self-styled exercise, of a “game” one might say, without any intention to doubt the seriousness of the endeavor in its scientific field. We could …accept… a contribution of mathematical thought in music creation…if the whole process had the opposite direction, if it started based on data on human psychology, if through calculations it sought to discover correlates of affective stimulation... i.e., which combinations of frequencies cause an affect (in the psychological sense of the word) or can cause an affect through habituation. It is, by all means, completely feasible to translate art of any form, not just music, into mathematics – but what kind of contribution to his science would a mathematician see in these sequences of numbers that would arise? The same question can be asked when art is merely a translation of a mathematical process. (Lavdas, 1975).

It seems clear that the fundamental affective properties of musical language (for example, why a minor scale sounds “sad”) have to do with deep innate responses, for reasons that we will not analyze here. “We translate a phonological disturbance into an emotional one – we are affected by it” (Bernstein, 1976). There is recent work that supports the existence of an innate response (Curtis & Bharucha, 2010), as it demonstrates that the minor third interval also occurs in the pitch contour of speech conveying sadness (in non-tonal languages).

Leonard Bernstein supported the idea of a worldwide, inborn musical grammar and that, like languages, all music of every culture, shares certain built-in traits, namely, a connection to the overtone series (the relationship of a fundamental pitch to its harmonic overtones).

That means that harmonic languages for all music rely on the existence of a tonal center. A certain degree of tonal anchoring is inevitable because "the human ear" – i.e. the physiology of our perceptive system – demands it. When we completely deviate from it, we do not enhance creativity – we simply loose the connection to the listener.

The reader may be wondering why we have taken this extensive detour into the world of music. There is a good reason: the idea of a messianic mission to save modern music from the "impulse of the moment", as described by Xenakis, has its exact counterpart in modern architecture. Architects sought to embrace "basic" mathematical forms – lines, cubes – etc., under the dogmatic (and, as such, unproven) principle that going "back" to them would somehow purge architecture of all unnecessary (and unnatural, by their rationale) forms that had dominated it (for a detailed analysis of this, see Salingaros, 2006).

Here are some practical lists of rules given by modernist architects (from Salingaros, 2013):

Naum Gabo and Antoine Pevsner, 1920: "Reject closed mass and volume, and model space from within outwards. Reject color, and use only the natural color of the building materials. Reject all ornament."

Ludwig Mies van der Rohe, 1923: "Open plan for interiors. Materials are limited to concrete, iron, and glass. Use only curtain walls and reinforced concrete – no load-bearing construction."

Le Corbusier, 1927: "Lift the building from sitting with its basement in the earth, to being suspended on posts (pilotis) Only curtain-wall construction is allowed. Roofs have to be flat. Windows can only be horizontal and will extend from one load-bearing pillar to another, which makes them very wide (narrow and long)."

Most remarkably, Le Corbusier (1923) had also proclaimed that "Decoration is of a sensorial and elementary order, as is color, and is suited to simple races, peasants and savages" – which, one has to presume, must include all of the people that created the art of Renaissance and antiquity. Both St Peter's and the Parthenon – originally painted in bright colors – are automatically classified in this category of primitive art for "savages". Loos (1908) was, of course, the first to use such rhetoric, including, for example, the question whether it matters if "are we no longer capable of doing what any Negro can do" (i.e. decoration).

These texts, in their confidence of revealing some unknown truth, resemble more some post-WWII certainties in modern music, such as those described by Xenakis, than their contemporary's Schönberg's writings, as the latter "did not share the scientistic utopianism of those who later took up dodecaphonic composition" (Ashby, 2008) or other modern atonal compositional techniques.

One could argue, at this point, that the paths of architecture and music in fact diverged in the modern era: the abandonment of tonal ground in music can be seen as the end result of an ever-increasing chromaticism (Bernstein, 1976; Webern, 1963), which in fact constitutes an increase in complexity. Is this not the opposite of the simplification that modern architecture brought? On a superficial level, yes. However, the process underneath is common: the abandonment of a well-established system of structured complexity, in favor of another, new, system that lacks this structured complexity.

ON ATONAL BUILDINGS AND DISSONANT ENVIRONMENTS

Are there real parallels between music and architecture?

Drawing parallels between music and architecture has not always been well received. It has been suggested that the temporal dimension of music makes comparisons with architecture difficult, as a building is fixed in time - at least during short periods of time - while music is "flowing" in time. Attempts have been made to parallel this temporal flow of music with the changing view of a building when the observer is moving at constant speed: "A dynamic sense of rhythm and tempo can be created in architecture through a choreographed progression of spaces varied in accentuation, scale, and form. One notable example of this approach in a contemporary context is the pedestrian tunnel at the Chicago United Airlines terminal designed by sculptor Michael Heyden and architect Helmut Jahn. Time in this space is firmly orchestrated. Moving along a conveyor belt, the observer's precepts are sequentially and linearly controlled. Like music, the "piece" has a beginning, variations, a climax of fiber optics and sound, and an end". (Moris, 1996). This is an argument that seems valid for the particular building, provided the desire of the architect was to produce this effect.

However, this is an exceptional case: in almost every other case, the changes in the aspects of a building when viewed by a moving observer –even one moving at constant speed- are extrinsic to the architectural work. They are not really similar to the flow of music in time - they are more similar to the differences in acoustics one will get when moving from the front to the side or the back of an orchestra: changing soundscapes created by the action of the listener, not by changes in the orchestration.

The tempo (or, in fact, the melodic and chord progression within the tempo) is intrinsic to the music – it is not an extrinsically imposed modulator like movement is, in the examples above. So what is the solution to the "time problem"? I would argue that the problem in fact does not exist: the temporal aspects of music are part of a whole. The time domain and the harmonic space in which the composition exists are integral parts of the music space, the same way that the 3 dimensions are an integral part of architecture space. A symphony is a whole unit – from beginning to end- much like a building is a whole unit. A building does not change over time, and neither does a symphony. It is just that their frame of reference is different.

"Syntax" and "tonality" in architecture

The similarities in the way the brain processes both linguistic and musical "syntax" have already been demonstrated. Event related potentials (ERPs) have been recorded off the scalp of volunteers, and analysis has shown that syntactic violations, such as violations of gender, word order or noun/verb agreement, elicit a positive component, peaking around 600 ms (P600). Corresponding experiments showed that violations of harmonic expectancies (by presenting a chord that belongs to a different tonality) are also associated with P600 components with similar scalp distribution. These similarities seem to indicate that the ERPs reflect qualitatively similar functions and that the same cognitive processes are called into play when participants are asked to process the structural aspects of an organized sequence of sounds, be it language or music (see Besson & Schön, 2001, for review).

So, we now know that music and language processing have a similar neurological substrate. They both have a grammar and a syntax –called tonality and harmony in the case of music – and the violation of this grammar and syntax results in specific reactions from the brain.

We also know that all tonal music and pre-modern architecture have some common mathematical features, at least in terms of their fractal structure.

There is an element lacking in this equation: we know the laws of linguistic and musical "grammar and syntax", but what about the laws of "visual grammar and syntax"? Can they be extracted from structures that "connect" affectively with the user/viewer- and then applied to future structures? The argument of this paper is that the answer is "yes" – and these laws have already been described:

The 15 Properties of good design by Christopher Alexander (Alexander, 2001-2005), along with Salingaros' three Laws of Architecture (Salingaros, 1995, 1998) that derive from them, can be considered as the first codification of the laws of visual grammar/tonality and syntax/harmony, in direct parallel with the relevant linguistic and music theory terms. For the past several years, the work of Salingaros has proved not only the existence of laws of "visual grammar and syntax", but also resulted in their decipherment and codification – which was a step of major importance both for the systematization of the study of the phenomena they govern, as well as for practical applications.

It is very intriguing to view these laws and properties in parallel to properties in music. For example, Alexander's property number 8 (Deep interlock and ambiguity: "Ambiguity… comes about when a subsystem belongs simultaneously to two different overlapping larger systems") brings to mind Bernstein's discussion about ambiguity in music – either in the rhythmic structure or harmonic base of a musical phrase – as a source of intellectual and emotional stimulation (Bernstein, 1976).

Maybe then we can paraphrase Leibnitz and say that not only music, but also "appreciation of architecture and visual arts is a secret exercise in arithmetic of the soul, unaware of its act of counting." When Alexander says that we can use the human body as a sensing instrument for what is good and bad in architecture, he does not propose that we abandon an exact science for the sake of obeying arbitrary reactions; instead, he proposes to use the enormous – and yet so often forgotten – computing power of our non-verbal brain.

Let us think again of Bach's "reduced" music (Hsü & Hsü, 1991) – and this time let us consider how the early reduction stages could be paralleled to architectural styles during the transitional period of the 1920s and 1930s: "To a novice, the half- or quarter-Bach sounds like Bach, although he gains the impression that the composition has an economy of trills and ornamentations." This description – if we replace the musical with visual terms when needed – would nicely fit many buildings of the art deco era. The ornamentation is less, but the scaling hierarchy persists. The laws of visual syntax have not been broken yet.

It may be the case that we could find even more basic cross-modal structural parallels between music and architecture, that we may reach a level where we can pin-point not only an architectural consonance or a dissonance, but even affective visual equivalents of a certain interval, a certain melodic line or chord progression. We need to be careful not to get carried away in our effort to draw parallels, of course: we are seeking affective equivalents, not direct ones.

It is a paradigm-shifting perspective to view Alexander's properties and Salingaros' laws as the equivalent of the harmonic laws of music. And it immediately equips us with a new set of arguments. Here is an example: In the famous "1982 Alexander-Eisenman debate", at some point Eisenman says:

> …if I went out in certain places in the US and asked people about the music they would feel comfortable with, a lot of people would come up with Mantovani. And I'm not convinced that that is something I should have to live with all my life, just because the majority of people feel comfortable with it (Alexander & Eisenman, 2004).

We can now see why this argument is wrong. The architecture that Alexander was defending in this discussion was not the equivalent of the music of Mantovani. It was the equivalent of all tonal music ever written. It could be the Mantovani or the Beatles, Bach or even Stravinsky – who, in all his modernism, never abandoned the tonal ground. The architecture that Eisenman was supporting is the built equivalent of a lifetime of listening to Stockhausen and Xenakis. Alexander was not defending a style, he was defending the "tonal" nature of the built environment.

This, of course, is just one example. In this debate alone, there are many other points that can be viewed under a totally different light, if one has the "structured complexity" concept in mind. At another point Eisenman says:

> ...in things like a Mozart symphony or a piece of literature… we can… talk about the innate structure or order… And… this order has little to do with the hierarchical, mechanistic, and deterministic order of the past 300 years. Rather it is based on an alternative to Western values as determined by metaphysics. This order suggests not so much an opposition as an alternative view, which suggests that structures are not dialectical in nature but, rather, that they are made up of differences.

Eisenman seems not to understand it, but the realization that it is the innate structure of the work of art that makes it "work", is in fact in favor of Alexander's view. The innate structure is not based on "an alternative to Western values" – it is based on sets of rules that are so universal that can go unnoticed.

In this whole debate – and in almost any other debate on this issue – this scheme persists: modernists present their arguments as "logical" and their opponent's arguments as "emotional"; at the same time, they use these two words as signifying opposing values, in a simplistic division that equates "emotion" with lack of logic. The fact that the internal mathematical logic present in works of art that elicit emotional responses may be of a higher degree of complexity than their own rules, seems to elude them. Yet, they claim to follow a "scientific" approach to designing. As it has been pointed out by Mehaffy & Salingaros (2012b):

> Today's designers seem to love using new ideas coming from science. They embrace them as analogies, metaphors, and in a few cases, tools to generate startling new designs (computer algorithms and spline shapes are a good recent example of the latter). But metaphors about the complexity of the city and its adaptive structures are not the same thing as the actual complexity of the city. The trouble is, this confusion can produce disastrous results… such confusion pervades the design world today, and spreads from there into the general culture. It plays a key role in the delusional expectation that metaphors will create reality.

An additional, related, issue is that architecture (and the arts in general) seem today to be in need of a verbal narrative, which, by its nature, is extrinsic to the building or artifact. Pre-modern art and architecture had no such need; the artifact "spoke" by itself by – and maybe the expression is not entirely metaphorical: breaking the laws of visual syntax has resulted in buildings that have nothing to say, so their designers speak instead. But, however good the verbal interpretation of their building may be, whatever great ideas may be presented and elaborated in such texts, their intellectual virtues lie outside the object itself. The fact is that things are what they are – a simple yet fundamental concept that is often forgotten these days.

Back to the newly codified laws of architecture, we should remember that their application does not give pre-determined results, no more than using a tonal system and respecting the laws of harmony makes two composers create identical compositions, or respecting grammatical and syntactic laws makes two writers produce identical literature. It just helps avoid errors – the monkey hitting the keys of a computer or a piano. It takes nothing out of creativity – indeed, it helps it, by giving it a ground to stand on, or, more appropriately, to have roots in.

We have a lot to learn from the relevant discussion in music. "The creative mystery", Bernstein wrote, "is inextricably rooted in the rich earth of our innate response, in those deep, unconscious regions where the universals of tonality and language reside" (Bernstein, 1976). There is nothing in this sentence that could not apply to architecture – we should just add "visual" to the tonal and linguistic universals. The same is true for this closing statement of his "Harvard Lectures":

> I believe a great new era of eclecticism is at hand, eclecticism in the highest sense. And I believe it is made possible by the rediscovery, the reacceptance of tonality, that universal Earth out of which such diversity can spring. And no matter how serial or stochastic, or otherwise intellectualized music may be, it can always qualify as poetry as long as it is rooted in Earth. I believe, along with Keats, that the poetry of Earth is never dead, as long as spring succeeds winter and man is there to perceive it. I believe that from that Earth emerges a musical poetry, which is by the nature of its sources tonal. I believe that these sources cause to exist a phonology of music, which evolves from the universal known as the harmonic series, and that there is an equally universal musical syntax, which can be codified and structured, in terms of symmetry and repetition. And that by metaphorical operation there can be devised particular musical languages that have surface structures noticeably remote from their basic origins but which can be strikingly expressive, as long as they retain their roots in Earth. I believe that our deepest affective responses to these languages are innate ones, but do not preclude additional responses which are conditioned or learned. And that all particular languages bear onto one another and combine into always new idioms perceptible to human beings. And that ultimately all these idioms can merge into a speech universal enough to be accessible to all mankind. And that the expressive distinctions among these idioms depend ultimately on the dignity and passion of the individual creative voice (Bernstein, 1976).

Pre-modern architecture is also "rooted in the earth" of the natural forms that surround us and have surrounded us long before we attempted to construct any dwellings, in the geometry of nature that can be found in all levels of the micro- and macrocosm. We argue that the resonance to structured visual complexity lies in the brain "in those deep, unconscious regions where the universals of tonality and language reside".

When those lines above were written by Bernstein four decades ago (the 1976 publication is a documentation of lectures from 1973), the parallels drawn between music and language, influenced by the work of Chomsky (1957), were considered by some to be far-fetched and contrived. However, subsequent research has shown that in principle they were remarkably far-sighted, at least as far as the neuronal substrate behind the comprehension of music and language structure is concerned. We are not really far from taking the next step and incorporating architecture in this equation. The discussion about a visual equivalent to Chomsky's "deep structure" of language has already been started by Ramachandran & Hirstein (1999), where these authors propose the existence of 8 principles which define what we call "art". Remarkably, some of these principles (contrast, symmetry, grouping and binding, perceptual problem solving) either directly coincide or at some level overlap with some of Alexander's properties and Salingaros' laws. Also, there is data correlating the fractal dimension of visual stimuli with human physiological responses (Taylor 2006, 2011 among others; see Salingaros, 2013 for discussion and review), and these results support the idea that structures which correspond to the three laws are neurologically more agreeable. What we now need, at an experimental level, is to directly correlate the presence or absence of a geometry corresponding to Salingaros' laws in visual scenes, to quantifiable physiological brain responses, through studies using eye tracking, Evoked Response Potentials and functional Magnetic Resonance Imaging. Will we be able to correlate exposure to patterns described by these laws to mOFC stimulation? Will we see involvement of reward centers? Are there perhaps systematic correlations between the degree of conformity to these laws and the degree – and perhaps the topology – of response and activation patterns? The simplicity of the three laws, and the ease with which we can apply them to design computerized drawings that are not reminiscent of any particular cultural setting, allows us to use them to produce visual stimuli for such experiments, which are as free as possible from cultural bias, and thus can probe our innate responses to visual structure.

CONCLUDING REMARKS

The answers to the questions posed above would be fascinating from a neuroscientific point of view. At the same time, such investigations may prove to have practical applications that would not only interest neuroscientists, but also architects and urbanists. There are already studies, which correlate perceived scenic beauty to geometrical parameters of landscapes - see, for example, Schirpke et al (2013), where the intended practical application is to use "scenic beauty assessments of mountain regions as a basis for policy making and landscape planning." We will be tapping onto an even deeper source if we manage to associate neurological, objectively quantifiable responses to geometrical patterns relevant to architectural and urban design. We could then eventually be able to test specific designs against batteries of pre-determined neurological responses, and come up with algorithms automatically assessing these designs based on the responses. This, in a way, would give us another level of feedback, in addition to the "on-site design" type of feedback proposed by Alexander.

But we should not forget that the purpose of these tools should, ultimately, be to test the ideas of the existence an innate visual language, perhaps even to facilitate decisions in some cases, but not to replace human intuition and aesthetic judgment. The computing power involved in these processes, as carried out by the human brain, far outweighs anything that any algorithm-driven machine can do.

The ideology of Modernism put emphasis on novelty, following a rationale that considered that all old design was flawed and "irrational", and everything should be designed from scratch. It was perhaps an unavoidable by-product of the social, economic and scientific developments of its age, but today it is becoming more and more obvious that discarding the amassed experience of millions of people over thousands of years was a uniquely mistaken gesture that distanced the built environment from its users. Using solid data from Mathematics and Neuroscience, and having outgrown the adolescent stage of breaking rules without considering why they were there in the first place, Architecture can once again become relevant to its users, its creative process no longer dictated by a restrictive dogma, as it has been for the better part of the last century, but only by "the dignity and passion of the individual creative voice".

REFERENCES

Aharon, I., Etcoff, N., Ariely, D., Chabris, C., O′Connor, E., & Breiter, H. (2001). Beautiful faces have variable reward value: fMRI and behavioral evidence. *Neuron*, 32, 537–551.

Alexander, C., Ishikawa, S, Silverstein, M., Jacobson, M., Fiksdahl King, I. & Angel,S. (1977). *A Pattern Language*. New York: Oxford University Press.

Alexander, C. (2001-2005). *The Nature of Order*. Berkeley, California: Center for Environmental Structure.

Alexander, C. & Eisenman P. (2004). The 1982 Alexander-Eisenman Debate. *Katarxis No. 3*. Retrieved November, 10, 2013, from

http://www.katarxis3.com/Alexander_Eisenman_Debate.htm

Bak, P., Tang, C. & Wiesenfeld, K. (1987). Self-Organized Criticality: An Explanation of 1/*f* Noise. *Physical Review Letters* 59 (4), 381–384.

Besson, M. & Schön, D. (2001). Comparison between language and music. *Ann N Y Acad Sci*. 930, 232-58.

Bernstein, L. (1976). *The Unanswered Question: Six Talks at Harvard (Charles Eliot Norton Lectures)*. Harvard, MA: Harvard University Press

Burke, E. (1757). *A philosophical enquiry into the origin of our ideas of the sublime and beautiful*. London: R. and J. Dodsley.

Chomsky, N. (1957). *Syntactic Structures*. Gravenhage: Mouton.

Crompton, A. (2002). Fractals and Picturesque Composition. *Environment and Planning* B, 29, 451-459.

Cunningham, M., Barbee, A., & Philhower, C. (2002). Dimensions of facial physical attractiveness: The intersection of biology and culture. In G. Rhodes & L. Zebrowitz (Eds.), *Facial attractiveness. Evolutionary, cognitive, and social perspectives* (pp. 193–238). Westport, CT: Ablex.

Curtis, M E. & Bharucha, J J. (2010). The minor third communicates sadness in speech, mirroring its use in music. *Emotion*, 10 (3), 335-348.

Dyson, F. (1978). Characterizing Irregularity. *Science*, 12;200 (4342), 677-8.

Fairbanks, M.S. & Taylor, R.P. (2011). *Scaling Analysis of Spatial and Temporal Patterns: From the Human Eye to the Foraging Albatross. Non-linear Dynamical Analysis for the Behavioral Sciences Using Real Data.* Boca Raton: Taylor and Francis Group.

Frumkin, H. (2001). Beyond toxicity: human health and the natural environment. *Am J Prev Med*, 20 (3), 234-40.

Hsü K. & HSü, A. (1990). Fractal geometry of music (physics of melody). *Proc. Nati. Acad. Sci. USA*,87, 938-941.

Hundertwasser, F. (1968). Los von Loos. Retrieved January, 7, 2014, from http://www.hundertwasser.com/text/1.3.2.2/hl/63%20-%20titleanch#titleanch

Hsü K. & HSü, A. (1991). Self-similarity of the “1/f noise” called music. *Proc. Nat. Acad. Sci. USA,* 88, 3507-3509.

Ishai, A. (2007). Sex, beauty and the orbitofrontal cortex. *International Journal of Psychophysiology,* 63, 181–185.

Ishizu, T., Zeki, S. (2011). Toward A Brain-Based Theory of Beauty. *PLoS ONE* 6(7): e21852. doi:10.1371/journal.pone.0021852.

Kampe, K., Frith, C., Dolan, R., & Frith, U. (2001). Reward value of attractiveness and gaze. *Nature,* 413, 589.

Kranz, F., & Ishai, A. (2006). Face perception is modulated by sexual preference. *Current Biology,* 16, 63–68.

Langlois, J. H., Ritter, J. M., Roggman, L. A., & Vaughn, L. S. (1991). *Facial diversity and infant preferences for attractive faces.* Developmental Psychology, 27, 79–84.

Lavdas, A.K. (1975). The stochastic music of Ianis Xenakis. *E. Kosmos*, 2, 2.

Le Corbusier (1923). *Vers Une Architecture*. Paris: Editions Crès. English translation: *Towards a New Architecture,* London: Architectural Press, 1927. Reprinted, New York: Dover Publications, 1986.

Loos, A. (1908). *Ornament and crime*. Translation, Riverside, CA: Ariadne Press, 1988.

Mandelbrot, B.B (1967). How long is the coast of Britain? *Science,* 156, 636-638.

Mandelbrot,B.B. (1977). *The Fractal Geometry of Nature*. New York: Freeman.

Mandelbrot,B.B. (1982) *The Fractal Geometry of Nature.* New York: Freeman & Co.

Mehaffy, M. & Salingaros, NA (2011) Frontiers of Design Science: Biophilia. November 2011. Retrieved December, 2, 2013, from http://www.metropolismag.com/Point-of-View/November-2011/Frontiers-of-Design-Science-Biophilia/

Mehaffy, M. & Salingaros, NA (2012a) Science for Designers: Scaling and Fractals. 28 May 2012. Retrieved December, 2, 2013, from http://www.metropolismag.com/Point-of-View/May-2012/Science-for-Designers-Scaling-and-Fractals/

Mehaffy, M. & Salingaros, NA (2012b) Science for Designers: The Meaning of Complexity, *Metropolis*, 30 March 2012. Retrieved December, 2, 2013, from http://www.metropolismag.com/Point-of-View/March-2012/Science-for-Designers-The-Meaning-of-Complexity/

Moris E.T. (1996). Musical analogies in architecture. *The Structurist,* 35-36, 66-74.

O′Doherty, J., Winston, J., Critchley, H., Perret, D., Burt, D., & Dolan, R. (2003). Beauty in a smile: The role of orbitofrontal cortex in facial attractiveness. *Neuropsychologia,* 41, 147–155.

Ramachandran, V.S. & Hirstein, W. (1999). The Science of Art. A Neurological Theory of Aesthetic Experience. *Journal of Consciousness Studies,* 6 (6-7), 15–35

Sacks, O. (1987). *The Man Who Mistook His Wife for a Hat and Other Clinical Tales*. New York: Harper & Row.

Salingaros, N.A. (1995). The laws of architecture from a physicist's perspective. *Physics Essays,* 8 (4), 638-643.

Salingaros, N. A. (1998). A Scientific Basis for Creating Architectural Forms. *Journal of Architectural and Planning Research*, 15, 283-293.

Salingaros N. A. & West B. J. (1999). A universal rule for the distribution of sizes. *Environment and Planning B: Planning and Design*, 26 (6), 909 – 923.

Salingaros, N.A. (2000). The structure of pattern languages. Architectural Research Quarterly 4 (2), 149-161.

Salingaros, N.A. (2006). *A Theory of Architecture*. Solingen: Umbau-Verlag.

Salingaros, N.A. (2011). *Logarithmic Sustainable Design*. Solingen: Umbau-Verlag.

Salingaros, N.A. (2013). *Unified architecture theory*. Portland, Oregon: Sustasis Press.

Schirpke,U., Tasserb, E. & Tappeinerc, U. (2013). Predicting scenic beauty of mountain regions. *Landscape and Urban Planning*, 111, 1– 12.

Slater, A., Schulenburg, C. V. D., Brown, E. & Badenoch, M. (1998). Newborn infants prefer attractive faces. *Infant Behavior and Development*, 21, 345–354.

Taylor, R. P., Newell, B., Spehar, B. & Clifford, C. (2005). Fractals: A Resonance Between Art and Nature? In: M. Emmer (Ed.). *Mathematics and Culture II: Visual Perfection* (pp. 53-63). Berlin: Springer- Verlag.

Taylor, R. P. (2006). Reduction of Physiological Stress Using Fractal Art and Architecture. *Leonardo*, 39 (3), 245-251.

Taylor, R.P., Spehar, B., Van Donkelaar, P. & Hagerhall, C.M. (2011). Perceptual and physiological responses to Jackson Pollock's fractals. *Front. Hum. Neurosci*. 5 (60), 1-13.

Voss, R., Clarke, J. (1975). '1/f noise' in music and speech. *Nature*, 258, 317 – 318.

Webern, A. (1963). The Path to the New Music. Bryn Mawr, Pennsylvania: Theodore Presser Co.

Winston, J., O′Doherty, J., Kilner, J., Perrett, D. & Dolan, R. (2007). Brain systems for assessing facial attractiveness. *Neuropsychologia*, 45, 195–206.

Xenakis, I. (1971). *Formalized Music. Thought and Mathematics in composition.* Harmonologia Series No 6, Stuyvesant: Pendragon Press.

Zeki, S. (1999). Art and the brain. *J Conscious Stud: Controvers Sci Humanit*, 6, 76-96.

Zhou, J., Liu, D., Li, X., Mac J., Zhang, J. & Fang, J. (2012). Pink noise: Effect on complexity synchronization of brain activity and sleep consolidation. *Journal of Theoretical Biology*, 306, 68–72.

An adaptive approach to domestic design

Bruno POSTLE
Free Software developer
bruno@postle.net

ABSTRACT

This paper discusses the need for an adaptive and iterative process for the design of ordinary domestic buildings that meet human needs. The approach described here is to use Pattern Languages as fitness criteria to guide an iterative design optimisation. To complement this, a Form Language for domestic buildings is proposed that is physically buildable, sufficiently flexible, and suitable for evolution through mutation and crossover. This evolutionary method has been implemented as Free Software, and the results are comparable with historical informally constructed buildings.

Keywords: housing, adaptive architecture, evolution, genetic programming, informal design, Pattern Languages

INTRODUCTION

Designing a house is a simple matter: we find a 'designer' who can assess the requirements, then mix some knowledge with a bit of creativity, and wait for them to come up with a 'solution'. This is so straightforward and obvious; the same process applies for practically all the 'things' that people make — but why then is our built environment such a relentless disaster, with nothing but suburban sprawl on the one hand and high-rise stacks on the other?

You could argue that these building types bring the highest financial return, and that our cities are just a mirror of our political economy. But just maybe there is also some flaw in the way buildings are designed?

This paper documents an ambitious project to find a new way to design a measured, humane and beautiful environment, and to make this method available as a set of tools that any of us can use.

INFORMAL URBANISM

To start with there is a simple idea — it has long been noted (Jacobs, 1961) that among other things, certain features of historical urbanism, such as narrow streets, short blocks, and high densities, are very well suited to pedestrian movement — when buildings are closer together, there are consequently more destinations within a walkable distance from any one point, and that in turn a pedestrian oriented city has many advantages over a city where a car is necessary for all activities.

However even where this understanding of urbanism is uncontroversial, most approaches to city 'design' favour a rectangular grid of streets and buildings. Rectangular grid urbanism has some big advantages: firstly it is a great administrative convenience, lengths and areas are easy to calculate, counting plots of land, and street lights, and everything else in-between is more practical with a grid; secondly, identical repeating plots of land allow the reuse of generic modular designs.

Contrast with an *informal city* layout that follows the landscape with no overall *master-plan*, this would be spectacularly more complex to design and construct — every building would need to fit a completely different environment, essentially each building would have to be designed independently — a task that is intellectually demanding and time-consuming to say the least.

So, rectangular grids populated with generic modular designs are very scalable and practical to *master-plan* — but how do you impose an 'ideal' rectangular grid on a city when real landscapes have hills and streams, existing buildings and roads, odd property boundaries, interesting views, delightful places, vegetation and wildlife, and any number of other things that can and ought to be preserved or enhanced?

There is some precedent, many historical cities and towns are 'informally planned', or rather they were not apparently 'planned' at all, they look like no effective central authority placed the streets and buildings 'rationally'. The pattern of development in these places appears to be such that each building and street happened ad hoc to suit the day-to-day needs of its citizens, using resources to hand, and responding to just their immediate environment in terms of available water, drainage, light, security and access.

Such historical cities typically have streets in a web-like network that features a larger proportion of 'T' junctions rather than crossroad junctions, multiple alternative routes, irregular shaped plots, and building construction right up to the street edge. Informal street layouts apparently closely follow topography, such as hills and streams, they follow previous structures and property lines, they follow existing vegetation, and they follow the routes that people want to use.

This paper is not going to provide recipes for creating or managing such informal layouts, but it is tackling the other half of the problem — given that we have an informal street, block and plot arrangement as is the case in most cities around the world, and that we are unable to use a modular repetitive design approach — how do we go about populating this layout with buildings?

THE DESIGN PROBLEM

Automating the design of buildings seems an impossible task given that it takes people years to become proficient, and even then many just repeat a small repertoire of successful design strategies.

Repeating previous practice has a real disadvantage; it requires that each new task has to be similar to a previously successful task. The temptation here, when faced with a complex difficult problem, is to attempt to reduce it into a something more familiar. This approach suits large developments where the site can be treated as a blank slate and populated with repeating units of known value — i.e. there is a constant pressure to change the problem to suit the solution, to aggregate small plots so they can be rationally subdivided, to find straight lines to string a series of identical units, or to leave areas of empty space between regular shaped buildings and an irregular boundary.

For a design process that can suit a wide range of sites and produce genuinely responsive solutions to each project, the most obvious and demonstrably successful is to codify the design process into a series of rules. José P. Duarte shows that it is possible to codify the work of the architect Alvaro Siza Vieira using a *decision tree* for the logic and *shape grammars* for the geometrical representation (Duarte, 1999).

Again there is a difficulty with this approach — all possible eventualities need to be considered in these rules, it requires a master architect such as Vieira and a constrained problem-space, such as limitations on the geometry of building plots, and a relatively small number of possible permutations for any one site.

The approach we are taking here is different; the idea is to take clues from the same processes that form buildings in historical cities and towns: i.e. rather than developing the design in a single step, start with a simple building and modify it iteratively using small incremental improvements, i.e. a *generative* process (Mehaffy, 2008).

Such an approach needs two things: a geometric description of the building that is suitable for incremental adaptation, it also needs a method for evaluating models constructed with this description.

Christopher Alexander and his collaborators introduced the concept of Pattern Languages for the built environment in A Pattern Language (Alexander, Ishikawa, & Silverstein, 1977). This *Pattern Language* can be best described as a series of rules for guiding decision making, each

Pattern describes an archetypal situation or problem and is accompanied by a solution. The Pattern Language doesn't necessarily provide a working method for us to use these rules for actual designing, but provides a very effective system for evaluating of any part of the built environment — in machine optimisation terms the Pattern Language provides '*fitness criteria'*.

EVOLUTION

The rest of this paper describes a process that 'designs' buildings in a context of the site, the local topology, street frontage, and the daylight field of the surrounding buildings — ultimately, although *not necessarily*, this process will also 'design' buildings for us as the individuals who will inhabit them.

There are two good reasons why we would 'design' buildings to fit the context of adjacent buildings. One is obvious, we would like better buildings, and the neighbouring buildings determine how we can do this — neighbours block sunlight or overlook for example, and we need to respond to this in the placement of our rooms and windows.

The other not-so-obvious reason is that the relationship between neighbouring buildings can, and should, be deeply intertwined — for this intertwining we need *co-evolution*:

A patch of urban fabric develops over a timescale of centuries with individual buildings being replaced, added or extended one at a time; each building is inevitably formed in the context of the existing neighbouring buildings and responds to them. Over generations, every building is recreated perhaps multiple times, but the incremental change of the urban fabric as a whole is more modest as time goes on. The result, if the number of generations is sufficiently large, approaches a convergence where any two selected buildings can be said to be symbiotic, literally 'living together'.

This is a simplified history of the development of an informally planned settlement; the process takes hundreds of years and, we believe, accounts for the unique evolved character of many historical cities. However it implies a steady-state or slowly changing society; it doesn't help us in a world where cities are growing at an unprecedented pace. With 65 million more city dwellers each year and the total urban population expected to increase by 2.6 billion between 2011 and 2050 (United Nations, 2011), there is no opportunity for modern cities to evolve in the historical manner — unless the lifetime of buildings is reduced such that they are replaced at a much higher rate.

An alternative is simulation: by designing buildings in a virtual environment, repeatedly tearing them down and rebuilding, the process can be freed from the cost constraints of physically having to construct anything. However, there is still a significant design cost — would anyone be prepared to produce the vast number of designs necessary given that only a small percentage would ever be constructed?

What is needed is a machine that can design high-quality buildings that meet human need, in context, consistently, and unattended. With such a machine, we can achieve the ability to extend and create modern towns and cities with all the positive attributes of historical informal urbanism.

As a solution this paper presents the outline of a method for designing individual buildings that is both adaptive to context and fully scalable. This method goes to the heart of the failure of the modern construction industry to match the quality of historical cities as places to live, despite all the obvious failings of these historical cities in terms of inadequate services and crumbling technology.

FORM LANGUAGES

Alexander, and the physicist Nikos Salingaros (Salingaros, 2006) have noted that Pattern Languages need complementary *Form Languages*. A Form Language is a building vernacular, a construction and planning method that is flexible enough to implement a Pattern Language and adaptable enough to allow a building to evolve to suit new requirements in the future.

So Alexander's Pattern Language is ideal as governing fitness criteria in our machine. What we then need is a Form Language that has a geometry that can be described mathematically, but which is also *adaptable* enough for an *adaptive* design method.

What follows is a brief description of a Form Language that is fully adaptive and adaptable, it has some advantages: individual buildings can be summarised mathematically in a compact form; it isn't based on a grid, so sites and buildings are not required to be right-angled; it creates geometries that make some kind of structural sense, so it describes buildings that are buildable — finally, an indication that it is on the right track is that it is possible to use this Form Language to describe the layout of many historical vernacular buildings.

A basic Form Language for domestic design

This Form Language exists at the level of layout planning. Following is a brief description of its fundamental properties:

QUADRILATERAL SPACES The plan form of habitable spaces

The basic unit of the form is the quadrilateral, e.g. triangular and circular spaces are not supported, but L-shaped and T-shaped spaces can be assembled from multiple quadrilaterals. There is no requirement that corners are right-angled, so a rectangle, trapezium, or parallelogram can be used as a space.

An important attribute of a quadrilateral is that it can be hierarchically divided and subdivided into further quadrilaterals.

STRAIGHT WALLS Boundaries between spaces

A quadrilateral implies straight-ish edges. In this adaptive method we need to be able to re-combine two adjacent quadrilaterals to produce a single quadrilateral, so walls that run through a junction implicitly need to be continuous.

Another way of looking at this is, that for a fully adaptable building it should be necessary to demolish and reposition walls; if this results in a kink in the remaining wall then the Form Language is not fully adaptable.

These two 'forms' together are analogous to Alexander's Pattern *191 THE SHAPE OF INDOOR SPACE* (Alexander, Ishikawa, & Silverstein, 1977):

> *With occasional exceptions, make each indoor space or each position of a space, a rough rectangle, with roughly straight walls, near right angles in the corners, and a roughly symmetrical vault over each room.*

(Note that the remainder of this paper refers to many further Patterns from Alexander; these will be indicated in the form '*123 PATTERN NAME*').

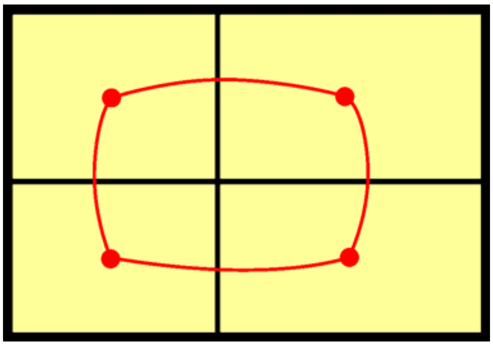


Fig. 1 Graph of four rooms with crossed wall junctions.

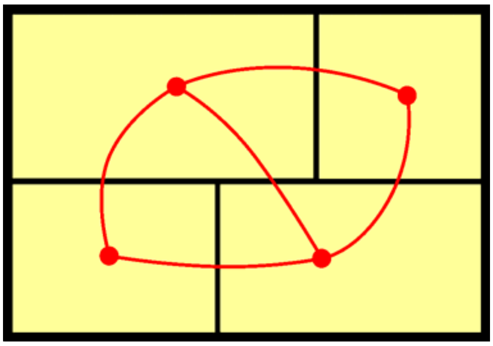


Fig. 2 Graph of four rooms with T-shaped wall junctions.

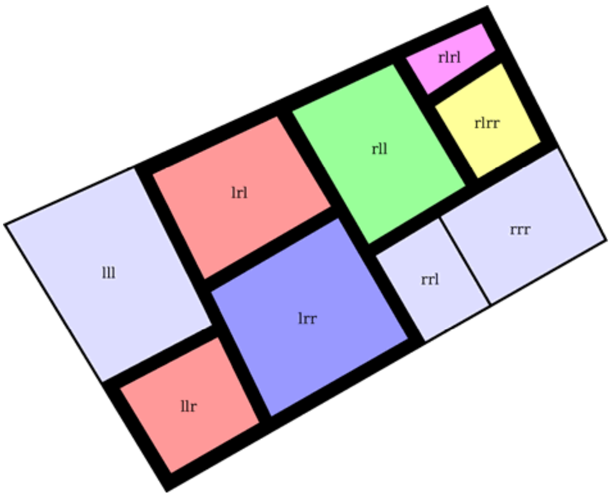


Fig. 3 Schematic plan of Ardéchoise farmhouse showing subdivision.

T-SHAPED WALL JUNCTIONS The arrangement of boundaries

A wall junction that meets with a cross, meaning two walls that intersect and pass through each other, has some real disadvantages. In terms of layout this form is attractive since the regular grid on the plan layout feels 'rational', however:

In terms of an adaptive approach to planning, a crossed junction requires that in order to improve just one room by resizing, at least four rooms need to be resized. This isn't very helpful — it is very unlikely that the incremental value of improving the first room will produce acceptable improvements in the rest of the rooms.

Adaptivity leads to *adaptability*, T-shaped wall junctions provide more circulation options. Imagine four simple spaces connected with crossed walls. The circulation graph has four nodes and four links; whereas four spaces connected with T-shaped wall junctions have a graph with four nodes and five links. Hence *an adaptive form-language has no preference for cross-shaped wall junctions*.

A Binary Tree

The Form Language described above has an implicit hierarchy — quadrilaterals can be further subdivided into smaller quadrilaterals. A process of division like this leads to an '*unbalanced binary tree'* structure, which with appropriate parameterisation can describe all possible layouts of this Form Language.

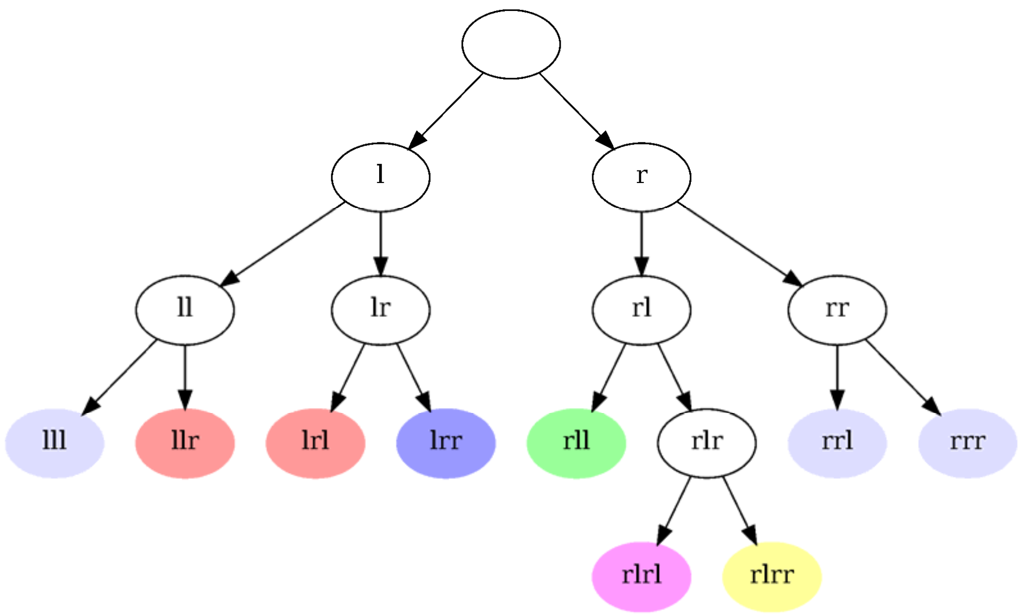


Fig. 4 Binary tree showing subdivision of Ardéchoise farmhouse above, each coloured node represents a habitable space or room

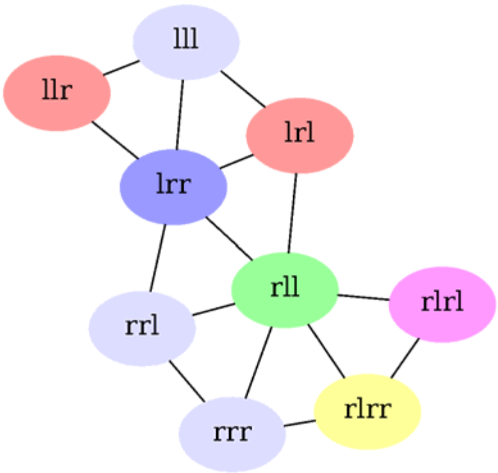


Fig. 5 Undirected graph showing adjacency network of Ardéchoise farmhouse derived from the binary tree above

The immediate advantage is that a binary tree is a data structure suitable for evolution through *mutation* and *crossover*. With a suitable fitness function that consists of the application of Alexandrian Patterns, we can maintain a population of designs and apply a selection process to drive optimisation.

Multiple levels in the building are implemented as stacked binary trees, although each level can have a different layout, the dimensional geometry itself is inherited from the level below — the result is that many walls and spaces will run through from one level to the next where necessary.

Since the Form Language is inherently buildable, the binary tree also describes construction sequence and structural form.

The principle is simple but also very versatile — the Form Language is not just suitable for a machine-driven *adaptive* design method, but the resulting plans are also fundamentally *adaptable* as a consequence. You can look at any of these generated plans and see how the physical building can be further adapted, modified or extended to suit changing needs.

FITNESS CRITERIA USING PATTERN LANGUAGES

So as noted, Alexandrian Patterns are not a design method in themselves, in machine optimisation terms the Patterns can be thought of as *fitness criteria* for evaluation of *human needs met* (as opposed to *monetary value*). However, the optimisation process consists of comparing options, and different options can have wildly varying build *costs* that also effect design fitness — so the fitness function looks like this:

Human Needs Met = on/bathrooms/outdoor space.

WALL LENGTH Placing freestanding wall segments.

Wall segments need to be long enough to place a door, also for future adaptation.
Therefore try to ensure wall segments are longer than 1.25m.

RIGHT ANGLE CORNERS Placing walls.

Corners of rooms need to be approximately right-angle.
Therefore try and make corners 90° ±5.

Future Patterns not yet implemented

The above Patterns are already implemented; the following Patterns are under development (as of November 2013):

SUNNY PLACES Placing indoor and outdoor space for direct sunlight.

Direct sunlight in rooms and outdoor spaces is important *(105 SOUTH FACING OUTDOORS, 138 SLEEPING TO THE EAST).*

Therefore try and place spaces favourably in an orientated variation of the daylight occlusion field.

NICE VIEWS Placing spaces to take advantage of scenery.

Buildings should be arranged to ensure that distant or beautiful views can be seen *(192 WINDOWS OVERLOOKING LIFE)*.

Therefore try and place spaces favourably in a variation of the occlusion field with a ‘views’ overlay.

HALF HIDDEN OUTDOORS Placing outdoor space for privacy.

People need private outdoor space, but not too private *(111 HALF-HIDDEN GARDEN, 163 OUTDOOR ROOM).*

Therefore place outdoor spaces favourably in a new field representing ‘overlooked-ness’.

AVOIDING NUISANCE Placing indoor and outdoor space to avoid external disturbance.

Noise from busy streets is annoying and should be avoided.
Therefore try and place spaces favourably in a scalar nuisance field that varies depending on street.

Notes on ‘Crinkliness’

Above we introduce a new ‘crinkliness’ quantity, this needs some explanation.

Two associated Alexandrian Patterns are *107 WINGS OF LIGHT* and *159 LIGHT ON TWO SIDES OF EVERY ROOM* (Alexander, Ishikawa, & Silverstein, 1977). The utility of the Patterns is not in doubt, but the all-or-nothing finality of the *light on two sides* rule is not well suited to an adaptive design process — it isn’t possible to incrementally change from a room with *light on one side* to a room with *light on two sides*.

What is needed is a Pattern that allows a continuum between a small or shallow room with light on one side, a larger room with light on two sides, or with a higher ceiling, and that dissuades deeper rooms that don’t have enough light even then. What works in an adaptive process is to calculate and assess the measure of *crinkliness*, which can be described as the *potential for light*:

Crinkliness = can share a direct connection in the resulting network graph. A *slide mutation* moves the dividing line (often a wall, although not necessarily) to resize the two child spaces.

A *swap mutation* exchanges the two child quadrilaterals and any of their children.

A *un-divide mutation* removes all children and converts a branch-node into a leaf node, a *type* is then assigned. This is equivalent to demolishing partitions.

Additional mutations *swap*, *add* or *delete* entire floor levels, each represented by a complete binary tree.

Combination

In addition to mutation operations we need to take advantage of another evolutionary process — *crossover* or *combination* performs a 'cut and splice' operation on any pair of buildings, randomly exchanging rooms, a group of rooms, or even entire levels. Two 'child' buildings are then created as a result and added to the population pool.

The following diagrams show some snapshots of the evolution of a small house, it has been limited to a single storey for clarity.

RESULTS AND DISCUSSION

The software is in a proof-of-concept form. Even so it is capable of demonstrating the feasibility of the approach. Below are the results of a more complex example of multiple multi-storey buildings interacting with each other as described in the introduction. The geometry you can see is raw and unaltered, it is visualised in perspective using the Blender ambient occlusion renderer without any manual editing. Hence there are no people, textures or any of the usual things you might see in an 'architectural' visualisation.

One unexpected, but nonetheless interesting, result is that the lower storeys of the generated buildings tend to have higher ceilings compared to upper storeys; this can be seen in the images below where shorter windows have been assigned to upper floors. This is a pattern that is often seen in historical buildings — but there is nothing in the code specifically to make this happen. There are other similar results; for instance there is no code specifically to make a courtyard as seen in the single storey example above. With evolution it can be very difficult to establish cause and effect. Although in this case ceiling height is closely related to the available light in the rooms via the *CRINKLINESS* Pattern; a higher ceiling means a larger external wall, which in turn means bigger windows and more light. So we can presume that since lower floors receive less light from the sky due to surrounding buildings, this leads to some pressure for higher ceilings — although there is another possible chain of causes: the *OUTDOOR SPACE* Pattern tries to ensure there is some outdoor space on every level, and the cost of building-covered space combined with bad daylight characteristics implies a pressure for buildings to become smaller as they go up; this can be seen as a 'ziggurat' effect. So perhaps when we see higher ceilings on lower storeys, this is to counteract the effect of deeper plan layouts. Of course, none of this may be happening, living rooms tend to be concentrated on lower storeys because of the *ACCESS VIA PUBLIC ROOMS* Pattern; they are generally bigger, and it could be that just this process is driving up the height of lower storeys.

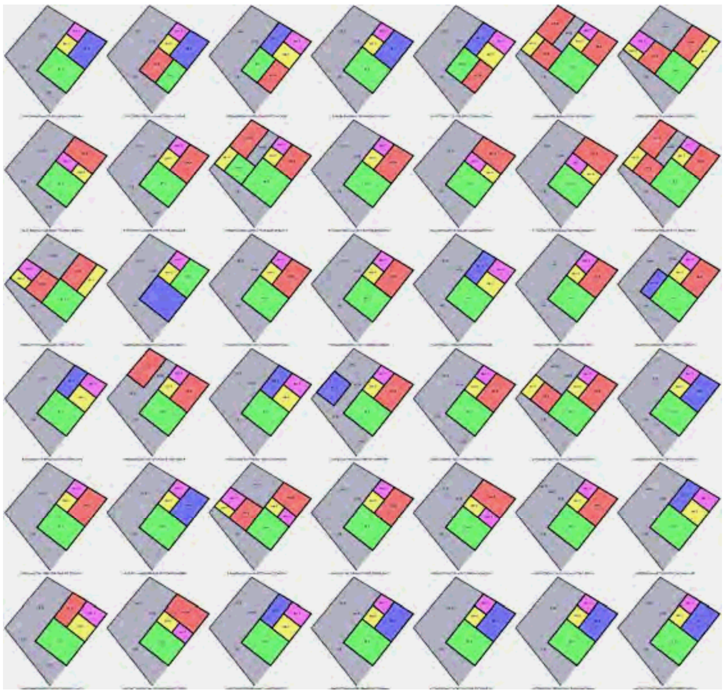


Fig. 6 Population during the evolution of a single storey house, after 48 generations. Note that there is a large amount of variation and the layouts are quite simple.

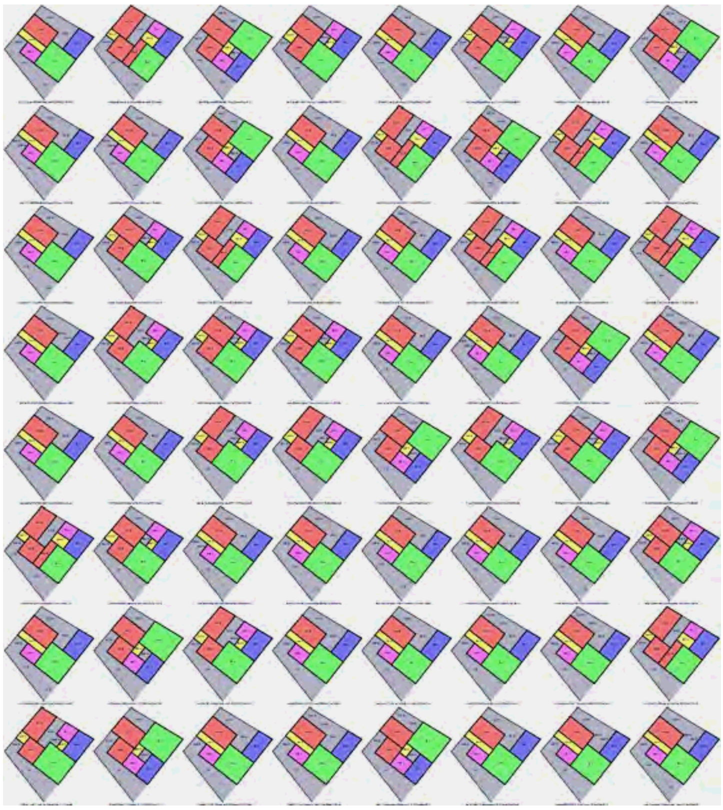


Fig. 7 Population during the evolution of a single storey house, after 640 generations. Note that there is less variation, but the layouts are all more complex.

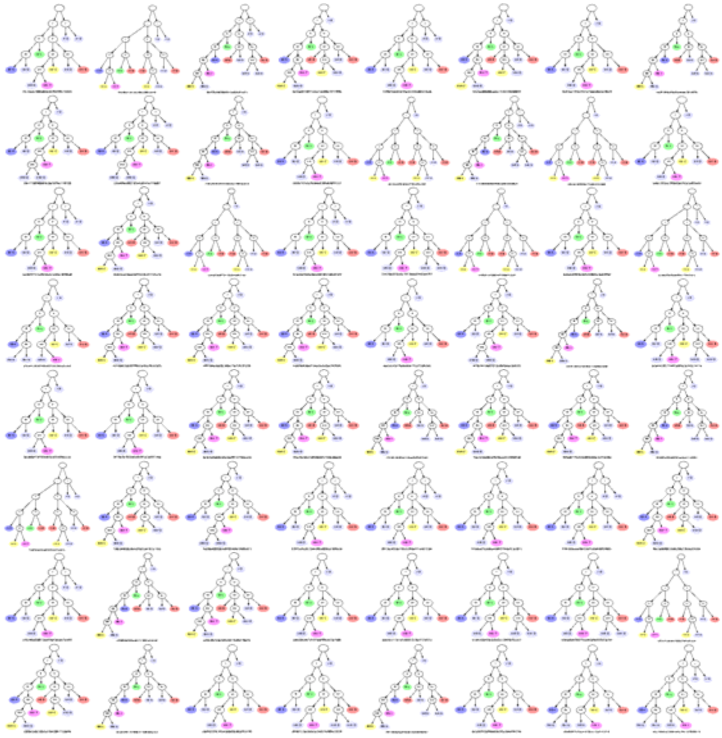


Fig. 8 Binary tree representations of the population shown above, after 640 generations.

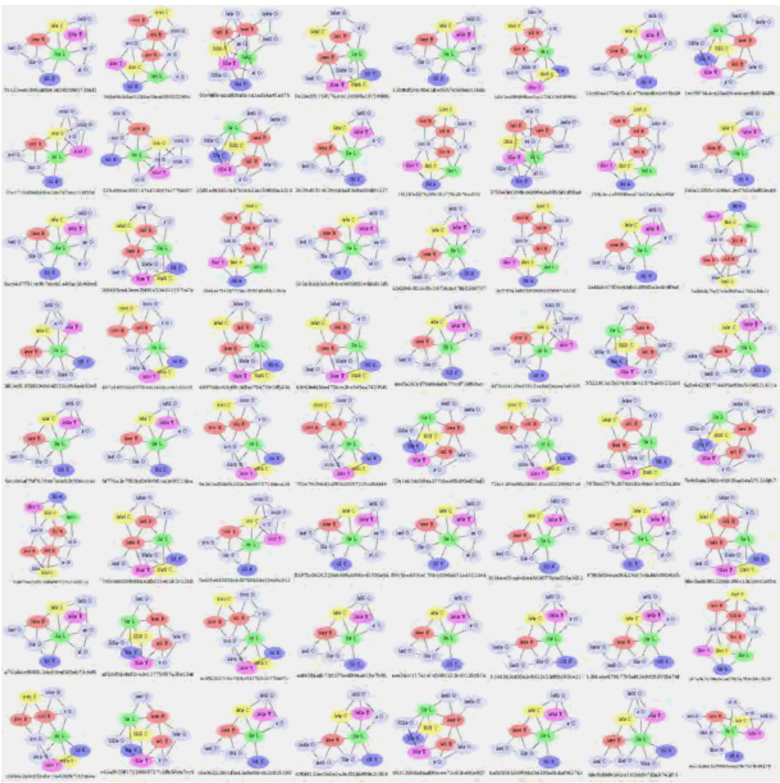


Fig. 9 Undirected adjacency graphs of the population shown above, after 640 generations.

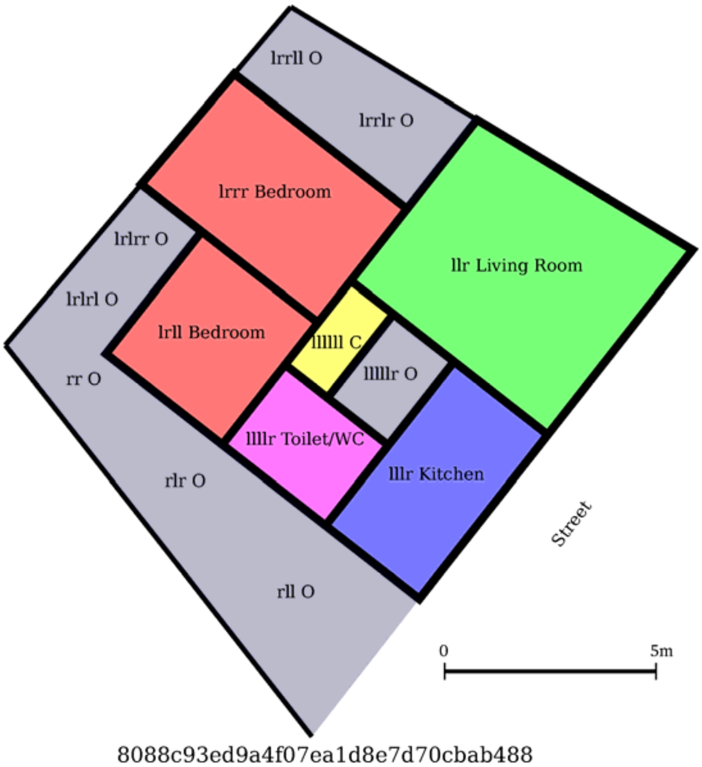


Fig. 10 Plan layout of fittest single storey house after 640 generations. The long number at the bottom is a hash ID that is unique to each possible layout.

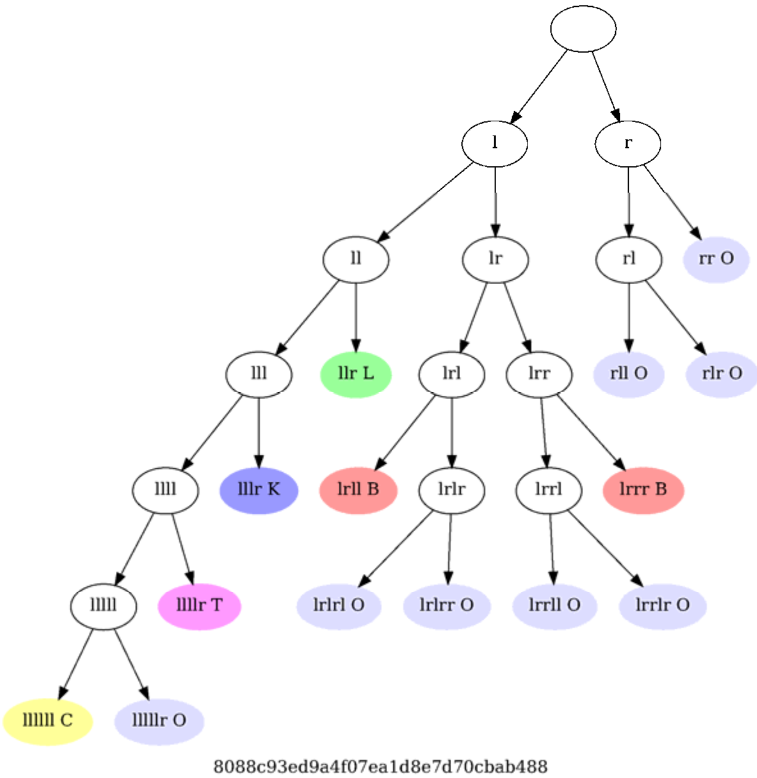


Fig. 11 Binary tree of fittest single storey house after 640 generations.

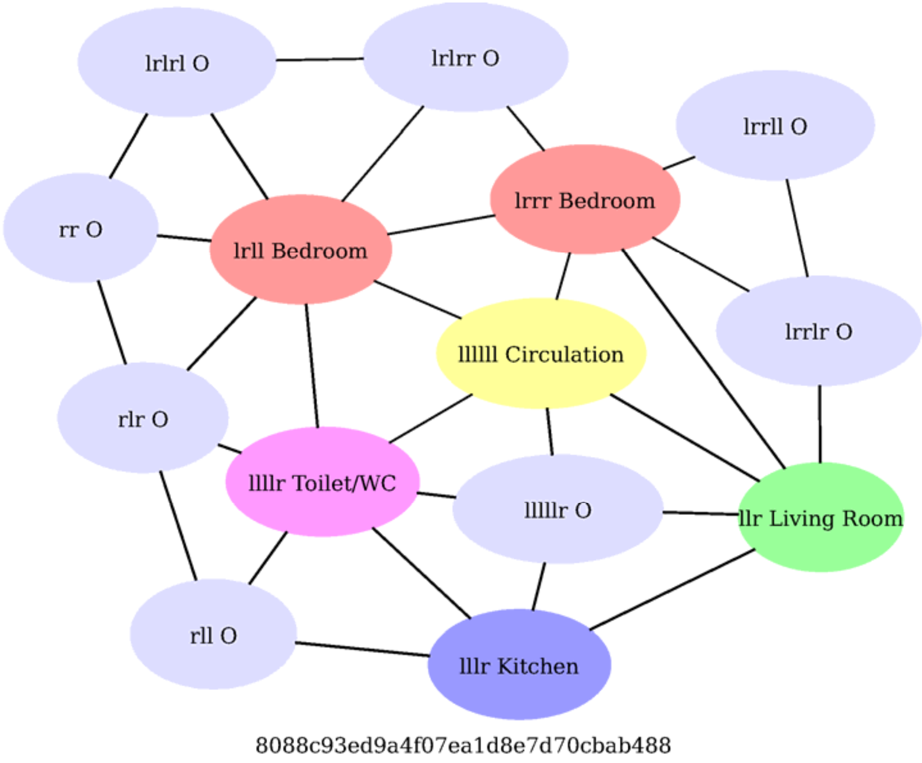


Fig. 12 Undirected adjacency graph of fittest single storey house after 640 generations.

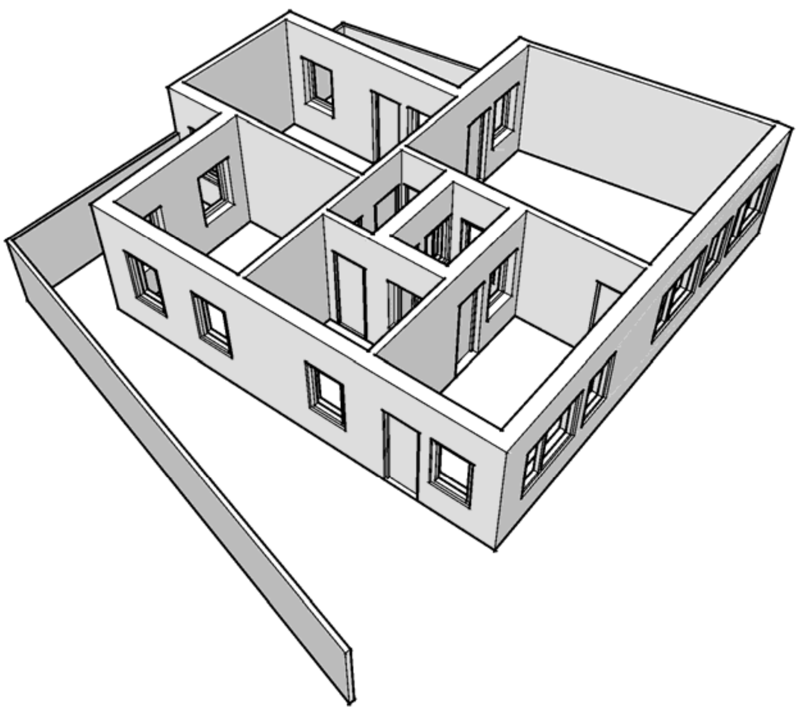


Fig. 13 3D view of fittest single storey house after 640 generations.

An important point that needs to be made is that the evolutionary optimisation process doesn't arrive at equilibrium. There is no intention to try to make something 'perfect' or 'complete'; the end result is simply a snapshot that has the potential for further growth over time using the same process, but in a physical built form.

The images below are of a small group of seven house plots covering a tileable 1/16th hectare patch of land; this layout leaves about 30% of the space for a small square and alleys between the blocks. Houses have been iterated over multiple generations using the daylight occlusion field derived from the previous generation. The result is equivalent to a density of 112 houses per hectare, with an average internal floor area of 130m². This doesn't allow room for much in the way of vehicle traffic, and is at a density where the fitness score for each building has begun to decline, so it isn't really viable for an extensive part of a town. However, each house has a ground floor entrance, and has usable outdoor space on multiple levels, so it compares favourably to an equivalent development of apartment blocks.

This project could be seen as a partial answer to the challenge made to software developers by Christopher Alexander at the end of the 1996 keynote speech to the Institute of Electrical and Electronics Engineers (Alexander, The Origins of Pattern Theory, the Future of the Theory, And The Generation of a Living World, 1996). It isn't a full answer to the problem of creating a living built environment, but the potential is there.

Fig. 14 Rendered view of a generated cluster of seven buildings.

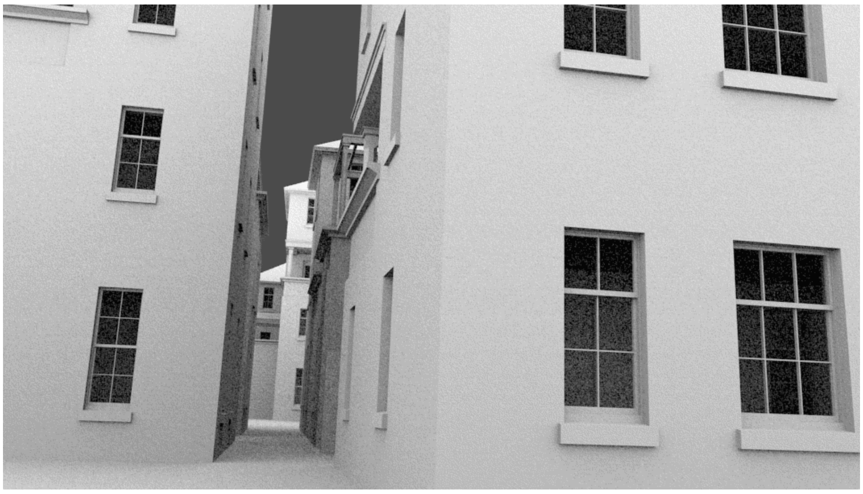


Fig. 15 Rendered view of a generated cluster of seven buildings.

Fig. 16 Rendered view of a generated cluster of seven buildings.

Fig. 17 Rendered view of a generated cluster of seven buildings.

Fig. 18 Rendered view of a generated cluster of seven buildings.

Fig. 19 Rendered view of a generated cluster of seven buildings.

Fig. 20 Rendered view of a generated cluster of seven buildings.

Fig. 21 Rendered view of a generated cluster of seven buildings.

Fig. 22 Rendered view of a generated cluster of seven buildings.

Fig. 23 Rendered view of a generated cluster of seven buildings.

Fig. 24 Rendered view of a generated cluster of seven buildings.

REVIEW OF ALTERNATIVE TECHNIQUES

Our approach is in contrast to existing 'fractal' city generators. One technique uses *split grammars* (Wonka, Wimmer, Sillion, & Ribarsky, 2003) to generate credible building façades. CityEngine (Müller, Wonka, Haegler, Ulmer, & Van Gool, 2006) uses a *shape grammar* approach to create road layout and building façades that look like real historical cities. Our work approaches the problem from the opposite direction; if by creating buildings from the ground up using an adaptive technique, using validated Patterns as fitness criteria, we produce buildings and cities that resemble historical urbanism — this is incidental rather than the intended result.

Other genetic programming approaches are (Jagielski & Gero, 1997) and (Krämer & Kunze, 2005) who also describe the use of *genetic algorithms*, i.e. mutation and crossover to evolve gridded floor plans. (Martin, 2006) describes a method for generating floor plans.

A non-genetic technique (Merrell, Schkufza, & Koltun, 2010) produces generated layouts and buildings, the results are very impressive but concentrate on reproducing the behaviour of architects in the building design process.

FUTURE WORK

More Patterns are needed in the fitness calculations; these new Patterns are typically of a larger and smaller scale than those already implemented. The external environment needs a richer representation, such as allowing for existing trees and other non-building context. The work with the daylight occlusion field can be extended to direct sunlight, in addition to indirect daylight. It can be extended to deal with 'overlooking', and 'views', although how we can define a 'good view' is not entirely obvious.

Smaller scale Patterns will deal with details such as placement of windows and doors which are currently chosen parametrically rather than optimised.

The fitness framework described here assigns quantitative values to each Pattern, this is a very flexible system, but the numbers chosen are based on experience and guesswork. More research is needed to refine these values and the ranges that are used in the Gaussian scoring system.

Currently 3D geometry is created in DXF, RIB and Collada format, but these are more suitable for visualisation than for construction management, future modules will generate more useful IFC (Industry Foundation Classes) data.

The reader will have noticed that all the examples shown here are of small-scale domestic housing. Further work to apply the same methods to small shops and other domestic-scale mixed-use buildings can be foreseen — but the design of a neighbourhood or larger part of a city with routes and public buildings is out of scope of this project.

REFERENCES

Alexander, C. (1996). The Origins of Pattern Theory, the Future of the Theory, And The Generation of a Living World. *The 1996 ACM Conference on Object-Oriented Programs, Systems, Languages and Applications (OOPSLA).* San Jose.

Alexander, C., Ishikawa, S., & Silverstein, M. (1977). *A Pattern Language: Towns, Buildings, Construction.* Oxford University Press.

Duarte, J. P. (1999). Democratized Architecture: Grammars and Computers for Siza's Mass Housing. *Proceedings of the International Conference on Enhancement of Computational Methods in Engineering and Science.* Elsevier Press.

International Commission of Illumination. (1996). Spatial distribution of daylight - CIE standard overcast sky and clear sky. *ISO 15469:1997* . CIE.

Jacobs, J. (1961). *The Death and Life of Great American Cities.*

Jagielski, R., & Gero, J. S. (1997). A Genetic Programming Approach To The Space Layout Planning Problem. *CAAD Futures* , 875-884.

Krämer, J., & Kunze, J.-O. (2005). *Design Code.* Berlin: Technische Universität Berlin.

Krier, L., & Thadani, D. (2009). *The Architecture of Community.* Washington: Island Press.

Martin, J. (2006). Procedural house generation: A method for dynamically generating floor plans. *Symposium on Interactive 3D Graphics and Games.*

Mehaffy, M. W. (2008). Generative methods in urban design: a progress assessment. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability* , 57-75.

Merrell, P., Schkufza, E., & Koltun, V. (2010). Computer-generated residential building layouts. *ACM Trans. Graph.*

Müller, P., Wonka, P., Haegler, S., Ulmer, A., & Van Gool, L. (2006). Procedural modeling of buildings. *ACM SIGGRAPH 2006 Papers.* New York: ACM.

Salingaros, N. A. (2006). *A Theory of Architecture, Two Languages for Architecture.* Umbau-Verlag.

Steadman, P., Evans, S., & Batty, M. (2009). Wall area, volume and plan depth in the building stock. *Building Research Information* , 455-467.

United Nations. (2011). *World Urbanization Prospects, the 2011 Revision.* Retrieved from United Nations, Department of Economic and Social Affairs: http://esa.un.org/unpd/wup/index.htm

Wonka, P., Wimmer, M., Sillion, F., & Ribarsky, W. (2003). Instant architecture. *ACM SIGGRAPH 2003 Papers.* New York: ACM.

Assessing the costs of hazards mitigation in the urban structure

Maria BOSTENARU DAN
Department of Urban and Landscape Design / "Ion Mincu" University of Architecture and Urbanism / Romania
researcher
maria.bostenaru@iaim.ro

Diana ALDEA MENDES
Departamento de Métodos Quantitativos / ISCTE Lisbon University Institute/Portugal
assistant professor and researcher
diana.mendes@iscte.pt

Thomas PANAGOPOULOS
Research Center on Spatial and Organizational Dynamics/University of Algarve / Portugal
professor
tpanago@ualg.pt

ABSTRACT

In this paper we look at an issue rarely approached: the economic efficiency of earthquake risk mitigation. The urban scale at which a natural hazard can impact leads to the importance of urban planning strategy in risk management. However, usually natural, engineering, and social sciences deal with it, and the role of architecture and urban planning is neglected. We look at the way ICT can contribute to organize the information from the building survey to economic computations in direct modelling or through games. Also we take into consideration at a rare element, which is the role of landscape planning, through the inclusion of green elements in reconstruction.

Keywords: Green space; Economic efficiency; Games; Information modeling.

INTRODUCTION

A natural disaster is the most rapid, instantaneous and long-range conflict of the natural environment with the socio-economic system and human society (Mercer, 2009). A natural disaster shapes the human and natural environment and disrupts and affects the operation of the regional an economic and social level depending, of course, on the degree and extent of the disaster (Beckeretal. 2013). The linkage between development and disasters is well known. Unfortunately, despite the modern evolution of technology, natural disasters affect the daily lives of people, disturb the smooth operation of society and constitute a permanent threat (Wisner et al., 2004).

The extreme events can even be devastating for developing countries which have less capacity to adapt (Winkler, 2005), but the effects generally relate to both the developed and the developing regions. There is a global concern that natural disasters are becoming more frequent, deadly and costly; they are also more complex, and the impacts to society and the economy are increasingly more intertwined (Khan, 2012). For that reason, mitigation of disaster management in city planning has become top priority for the local authorities in many countries all over the world (Haimes, 2012; Ye et al., 2012; Alexander, 2013). There are many studies on the possible impact of hazards on cultural heritage (Tarraguel et al., 2012; Daungthima and Kazunori, 2013; Ortiz et al., 2013). One of the major aspects of disaster risk reduction is the economic efficiency of natural hazard risk mitigation through pragmatic disaster risk management planning (Yung and Chan, 2012). Meanwhile, no studies have yet been conducted about the economics of natural hazards mitigation and more specifically of earthquake risk mitigation.

The aim of this paper is to explore an aspect of disaster management to which little research exists, namely on the economic aspects of it. The roles of game theory, agent based modelling and networks and urban public policies in designing decision systems for risk management from earthquakes and climate change are discussed. Climate change can lead to risks related to increased floods, desertification, and sea level rise among others. Reducing the sealed surfaces in cities through green spaces in the crowded centres can mitigate them, and can be foreseen in reconstruction plans in presence or absence of disasters. For this purpose we reviewed the role of green spaces and community centres, such as churches, in games, which consist of the core of reconstruction efforts, as also field and archive studies show.

ECONOMIC STUDIES TOOLS FOR DISASTER RECONSTRUCTION

The economic value of building restoration, particularly the rehabilitation of historic city centres were studied in this paper, by getting evidence from existing studies mentioned from Provins et al. (2008). As earthquake retrofit concerns historic buildings in city centres designed before seismic provisions, it is important to study the economic value of mitigating the effects of natural hazards as earthquakes in those valuable areas of the cities.

Novel approaches such as game theory, drama theory and conflict based software for multi-criteria decision problems of economic efficiency in the field of climate change and natural disasters were performed. City building games are actually construction management games, based on the same rules as devices. SimCity is included in the 2D version simulations of events such as fire after earthquake in San Francisco. In Turin, Luca Caneparo is developing SimTorino (http://www.laq-tip.polito.it/SimTorino/), an adaptation of SimCity to simulate urban development. In this paper we looked at both computer games and hard copy board games, especially at their rules. Drama theory is an alternative way to game theory to look at decision making as the one developed so far by the first author based on utility-value or the one this is compared to in the analytic hierarchy process/balancing method we will approach at decision. Although we look to actors at building scale, the balancing method has been initially developed by Strassert for regional science. So far drama theory has been applied to dealing with climate change (Jason et al, 2009).

This paper translates the balancing principles for earthquake protection into a realistic management environment. In the frame of the drama theory an agreement is looked for, and this can be supported by a software called “confrontation manager” (http://www.ideasciences.com/products/confrontationmanager/), one concurring with other attempts. We had a look at various software applications supporting decision in the context we are looking at. Previously to the involvement in these COST projects, we had accomplished a research grant (PIANO) from which the exploitable foreground results were:

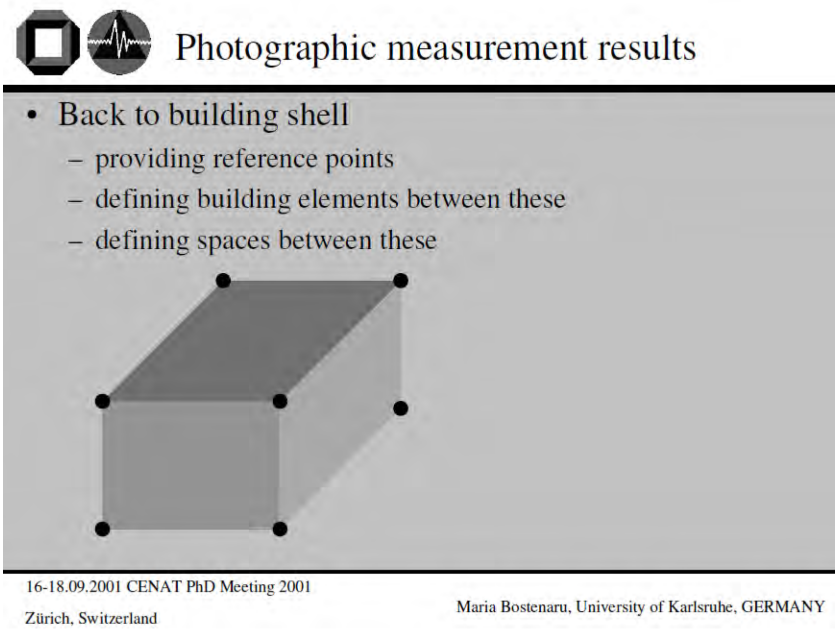
1. The idea of ontology for zoning, which can be used for the development of object oriented software dedicated at project management in construction industry, other than based on spaces or building elements as it is now (Fig. 1). Ontologies are a way of organizing data types for object-oriented programming. Right now the software for facility management is based on project management, so this would be a new approach. Additional work includes the definition of taxonomies and the creation of a database to try out the concept. The two exploitable foregrounds are connected by the sense of ontologies/semantics, but differ in the field of application.
2. Relationship between function and sign (semantics, as seen by Umberto Eco, philosophy) applied to the zonification of this housing, to be connected with the ontology. Umberto Eco used ontology and semantics in its philosophic sense. In order to make it an exploitable foreground, the definitions have to be converted to those used in computer science, especially in semantic web.

Along these lines we looked into how Building Information Modeling (BIM), in our concrete case the ArchiCAD software, can be employed in restoration projects, to which building retrofit is a special case (Fig. 2). Further, the functional relationships identified in zoning in the project PIANO can be further investigated by means of the so-called "space syntax" (Fig. 3), to be investigated with related software (http://www.casa.ucl.ac.uk/ajax/). The computation of prices in the utility-value method is based on this function.

A second step was looking at the application of game theory for urban simulation of the economic environment: review of architecture and urbanism games and their potential, and translation of the resources from the economic computations used at building scale to the urban scale of games using similar rules to existing board and online games.

We reviewed, in view to our decision approach, the contribution of the European project SIREN Social games for conflict REsolution based on natural iNteraction (http://sirenproject.eu/). Games can also serve the participative dimension of risk communication and disaster prevention awareness. For example, loss models by Glaister and Pinho (2003) and Borzi (2008) will be used to translate the costs for post-earthquake repair or preventive retrofit from building scale to regional scale.

The former method is adequate for reinforced concrete buildings. The way city management



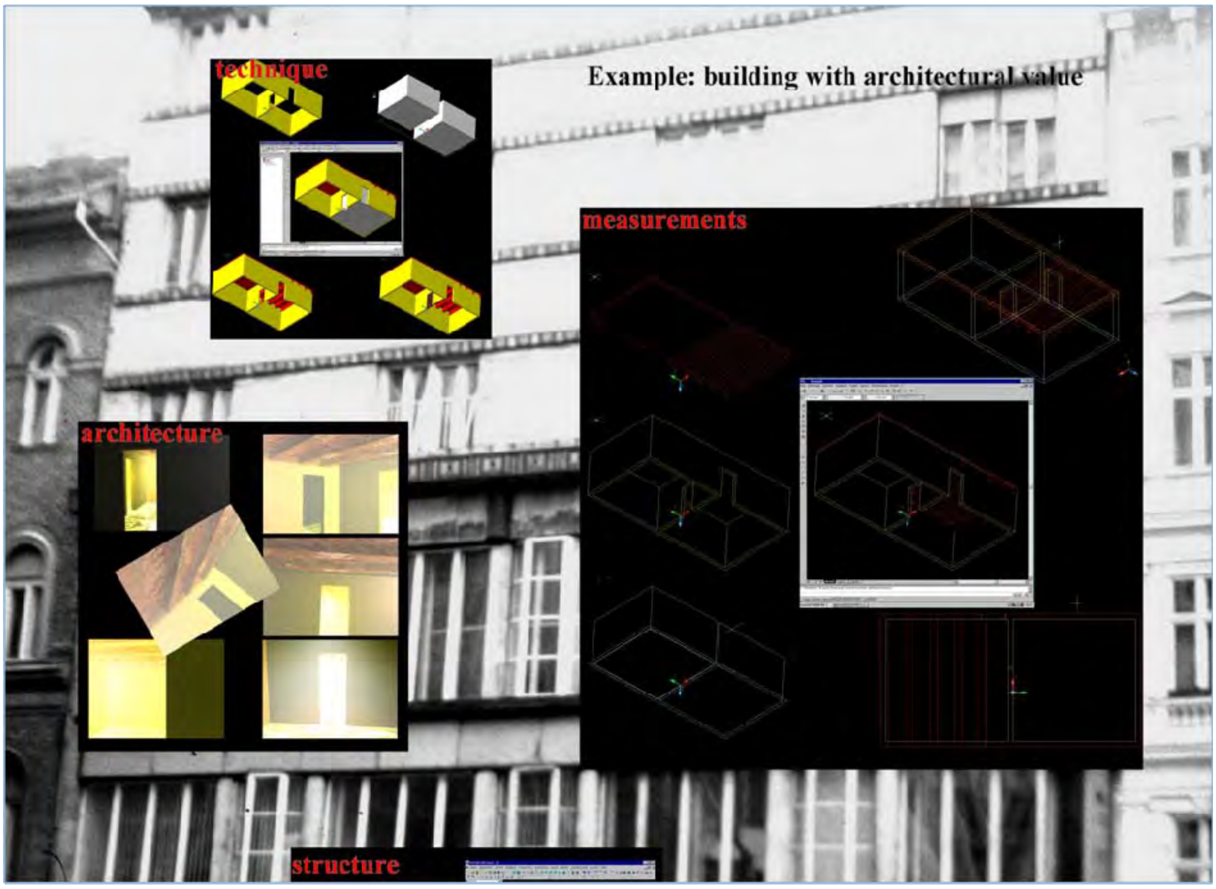


Fig. 1 Building survey system representing the building structure – our approach for a spatial ontology. From building survey to costs – a GIS at building level and an early stage BIM (Building Information Modeling). From a presentation of M. Bostenaru, 2001.

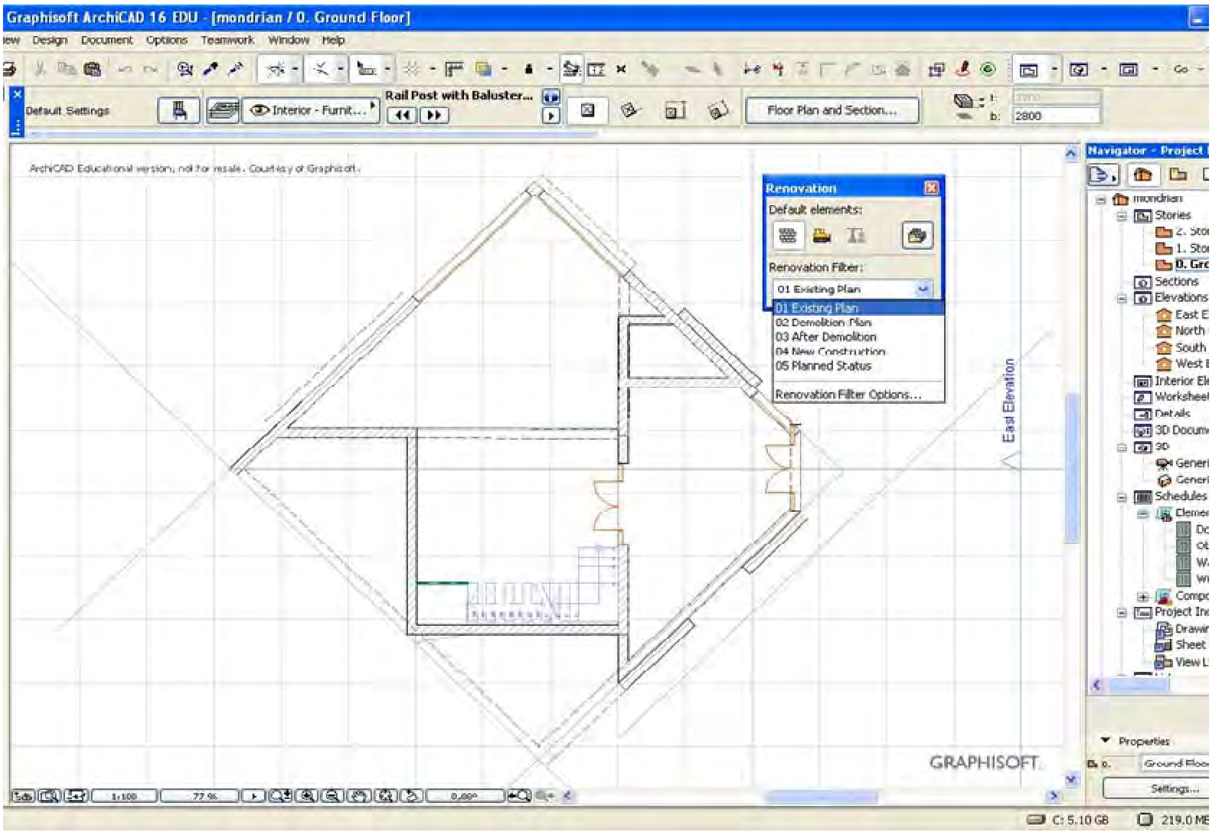


Fig. 2 Today's BIM (Building Information Modeling) – House Mondrian, a house with green walls, designed by M. Bostenaru, 1993, digital modelling 2013. Economic computation in Bursa Constructiilor will follow. http://www.constructiibursa.ro/casa-mondrian-19129&s=proiecte&articol=19129&editie_precedenta=2013-06-28.html

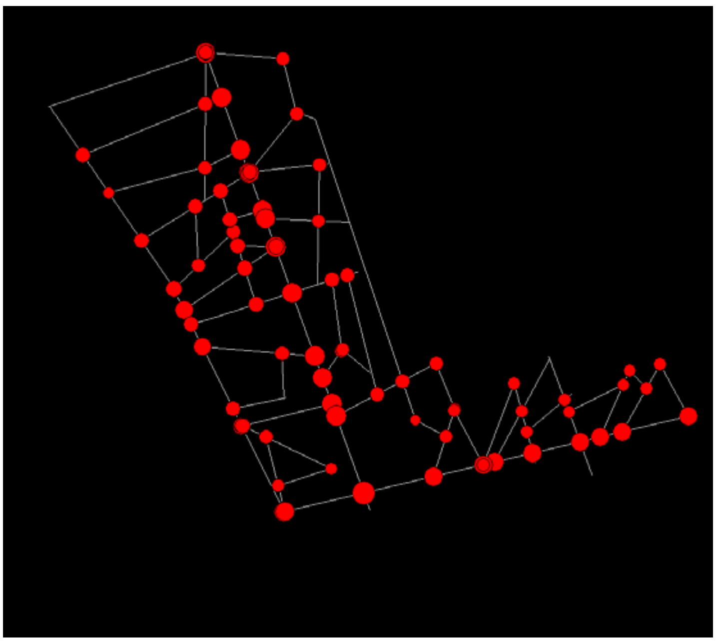


Fig. 3 Space Syntax analysis for the Modernist Boulevard in Bucharest.

games deal with building is strongly related to our computation of preventive retrofit and post-earthquake reparation costs, since it takes into account the resources: materials and people, needed for a certain building element. At the same time it is different from the functional surfaces based computation explained previously. We looked at two kinds of games: cooperative and conflict based games.

The conflict based games put face to face restoration and demolition, an example is the Romanian game "Habitat" (http://www.odaiacreativa.ro/en/habitat-joc-de-tip-board-game-pentru-patrimoniu-si-urbanism-in-bucuresti/), which touches the central area, including that in Figure 3 and presented in Bostenaru et al (2013). Economic aspects play a key role, since demolition and rebuild open the way for speculation and faster wins than in the public participation supported restoration. Cooperative games include such as the ones inspired by the novels of Ken Follett, a different medium to the book and the film we also looked at, and there all players contribute to building the landmarks. The comparison between the digital and non-digital implementation of the game was subject of previous research.

We compare hard paper representation to the digital one in the investigation of the game "Pillars of the Earth". The game is dedicated to the architectural endeavour of the construction of a cathedral using resources such as people and materials, like in construction management. The advantage of the digital method is the better implementation of the rules of the game. Although useful for our general research on project management, it was useful to introduce us to the comparison between "material" and "digital", leading to conclusion on the material model and the 3D model which later led to the developed concept. Also, in games we have to do with the symbolic dimension, and with no issues of scale. We analyzed the way the economics of construction are reflected in the novel, the game and the film derived from it. Below there are images of the digital and the material version (Fig. 4).The church which has to be built in "Pillars of the Earth" follows two different approaches: in the "material" version it is made out of simple volumes which are put one next to the other, like in building a model at an urban scale for architects or in building a model in Google's Building modeler, about which we will talk at results. We will return to what a church means in reconstruction, not just in construction efforts, for the settlement, at the end of the paper.

Jeffrey Head, support grant recipient at the Canadian Centre for Architecture, observed how digital tools such as SketchUp are the toys of today in educating the imagination of architects. In the "digital" version the church is built like with a 3D printer. The game taught us how to deal with construction and in a similar way as in civil engineering. A building consists out of devices for its elements. But, when doing project management in architecture, the spaces are considered at the overall scale and the building elements coming in question at detail scale (the m^3 of built space or the m^2 of floor space for a different function determine the costs and not the resources). In architecture the space is represented, considering the walls monolithic, and this is how they are in archive plans (Fig. 7) or in Nolli's plans (http://nolli.uoregon.edu/). The structural elements appear very rarely.

The way building is performed was explained previously. Intervention in case of a disaster involves multiple actors, and this could be the basis of a new game. The aim is to design which components of the real situation can be brought in the abstract (IT) model of a game to support decision making between the actors involved in decision about preventive retrofit compared to post-earthquake repair, the so-called planned conservation. The difference between the mathematical model in collaborative game theory and the architectural/urban approach of designing participative processes through games was investigated. These aspects relate to urban public policies. The study of Markov populations for example can be related to public policies to relate to disasters (Canbolat, 2013), more suitable however for man-made ones. At the same time, the involvement of these multiple actors in the decision system links to agent based modelling.

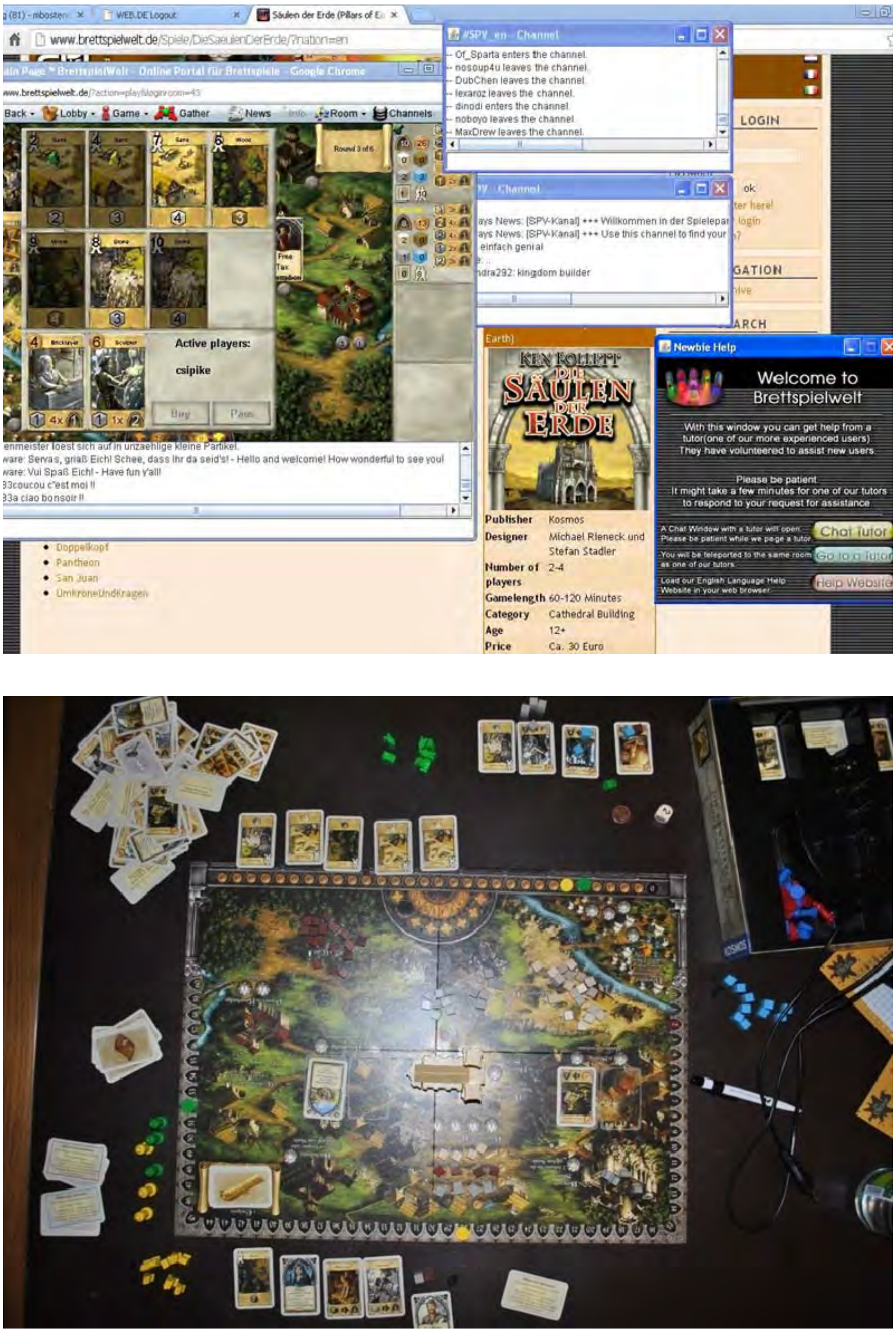


Fig. 4 Dealing with resources in the medieval city in "Pillars of the Earth" – computer game versus hard copy. Photo: M. Bostenaru, 2013.

Going out from a decision tree which we developed between four actors: architect, engineer, investor and user, with the later going over to participative models, a review of similar (the group around Caterino, 2009) and alternative decision systems for earthquake resilient planning, for example, agent based modelling of allocation of resources in post-earthquake intervention (Fiedrich, 2006), including the functioning of the street network was performed. The actors have been selected to incorporate a variety of criteria used historically for decision making, including project implementations, theoretical models, and databases of various associations. Several novel methods will be used in developing decision models. These include:

(i) Traditional quantitative decision trees and qualitative balancing methods (Bostenaru, 2004),

(ii) And newer methods based on adaptive decision trees. The particularities of the newer methods are based on interdependencies between the various criteria (as supporting or aggravating each other), and developing them into a programming environment (as an ontology). For implementing the alternative to utility-value analysis, namely the balancing method of Strassert, confrontation manager can be employed (http://www.ideasciences.com/products/confrontationmanager/screenshots.php a software from IdeaSciences which takes into account the "what if" cybernetic approach of Christopher Alexander (http://www.patternlanguage.com/).

SETTING UP COMPARATIVE ANALYSES OF ECONOMIC STUDIES TOOLS

First a comparison between agent-based modelling (fully computer based choice of resources to be employed in earthquake protection for example) and our approach of decision as well as the drama theory related one was performed. Agent based modelling also involves expert opinion, but not in real time. Instead, plans of reaction in case of a disaster are available for choice after communication between the agents.

Our analysis shows that agent based modelling is more suitable for processes of linear action, such as spread of fire and movement along the street network (thus touching a third element relevant for the action), than for modelling the cooperation in pre-disaster retrofit for example, which is directed to specifically chosen buildings or elements of a building, difficult to model also on GIS, for which reason BIM is more adequate. However, we emphasize the role of agent based modelling for the modelling of resource allocation, the process of retrofit and repair being also one of resource allocation (materials and people).

A further development is the application of a Monte Carlo simulation to numerical simulations at building scale used for the computation of costs using the retrofit elements method developed by the first author; comparison with real examples of earthquake retrofit and their costs (planned conservation: preventive retrofit versus post-earthquake repair).

MODELLING RECONSTRUCTION AFTER DISASTERS

The grid of the planned (re)construction, from case studies to computer games was subject of the modelling. The case study was Lisbon and it was used 3D modelling to model the impact of the 1755 earthquake, but without examining the economic aspects yet. In particular it was related to the development of the Baixa quarter and the timber frame typology used there.

From that case study it could be drawn also conclusions for the city of Bucharest, where several national funded projects on related topics are running (Bostenaru-Dan et al., 2013). We analysed the representation of Lisbon reconstruction in Second Life by a group at CHAIA, University of Evora, a game with rather participative than economic dimension, and at our previous outcome of developing urban traces games. We visited several museums in Lisbon which visualize, interactively in multimedia or not this new urban development, having contact with some of the developers of the software to present GIS content on 3D hard copy model and with researchers reflecting on the post-earthquake development today.

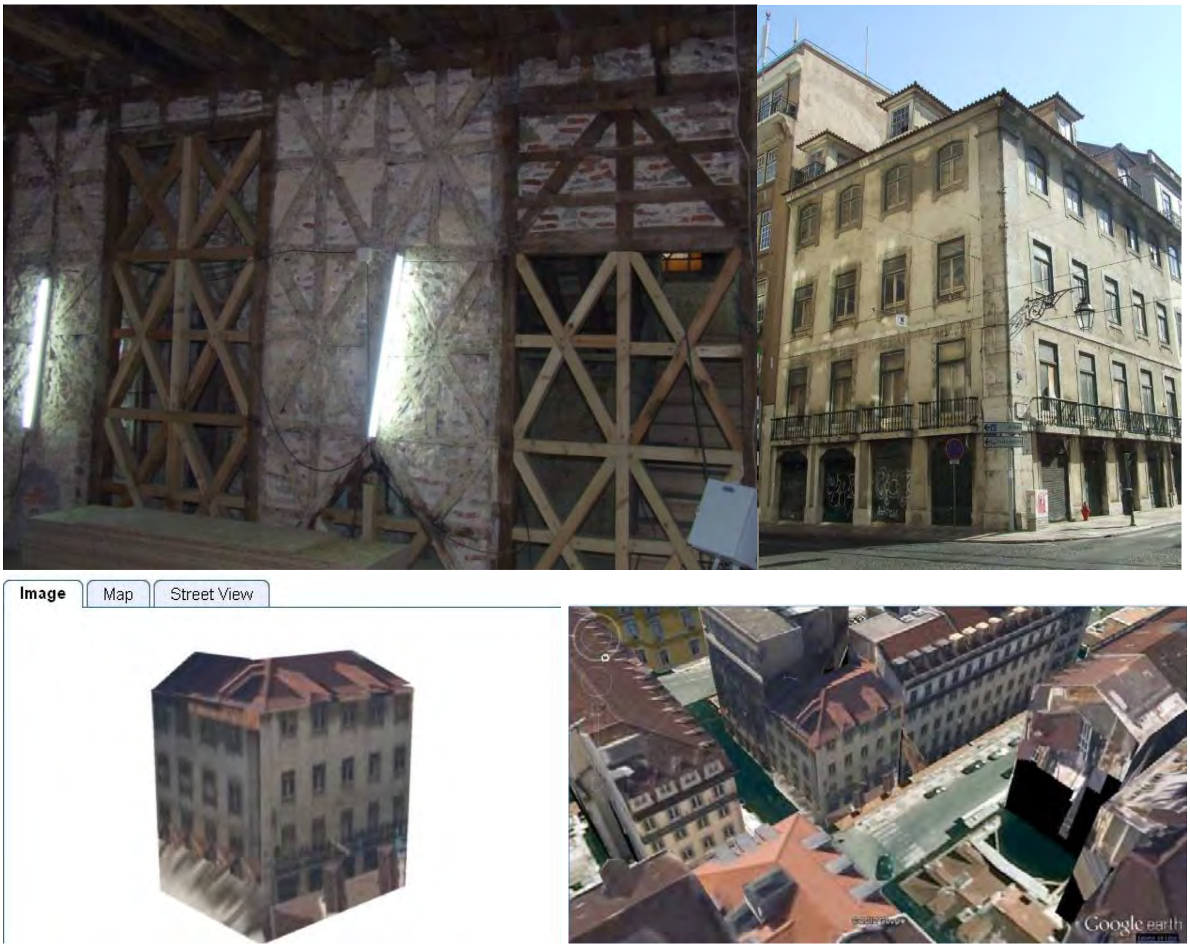


Fig. 5 Modelling on different levels of detail for Baixa, Lisbon: reality and Google Earth model contribution by us with Building Maker. The SketchUp model as alternative can include interior details. Photos: M. Bostenaru, 2008, model M. Bostenaru, 2012.

In continuation of the previous research we identified some of the landmarks presented in the Azulejos depiction of pre-1755 earthquake Lisbon in the city, with the aim of a 3D city model, from eye level and from above, using Lisbon's numerous "miradouros" (points of looking from a hill). Urban traces between landmarks such as those of the Lisbon 1755 earthquake can build the basis of creating a parcour of Pocket Parks in the city (see Bostenaru and Dill, 2014, where we considered the centre of Bucharest as depicted in Fig. 3). Landscape will be the road between the landmarks which are the nodes of the urban trace/route. The

Baixa quarter has a grid structure typical for the geometric development of Baroque cities when reconstruction was done, and is therefore suitable for this research. In Figure 5 can be seen an application of modelling on different levels of detail for Baixa, Lisbon. Here we took into account the concept of monolithic versus modelling of the structure about which we talked at the game analysis and in the early stage BIM design. The SketchUp model can contain the structural modelling in BIM, while the Building Modeler model contains only the textured monolithic common buildings according to Nolli's plan. See Bostenaru and Dill (2014) for more details.

The 3D city model would assure going over from the building size to the city size, thus modelling the region. A special attention was given to Lisbon's green walls, a feature supported by the particular climate (warm and wet), and to the way green spaces contribute to economic development, such a feature being of potential use in earthquake reconstruction, if happening today (Fig. 6).

Fig. 6 Green walls in Lisbon, a possible inspiration for supporting green elements on the timber structure from Baixa in a similar design as that proposed in the Mondrian house, displayed and modeled in BIM through a potted system. Photos: M. Bostenaru, 2012 and portrait.

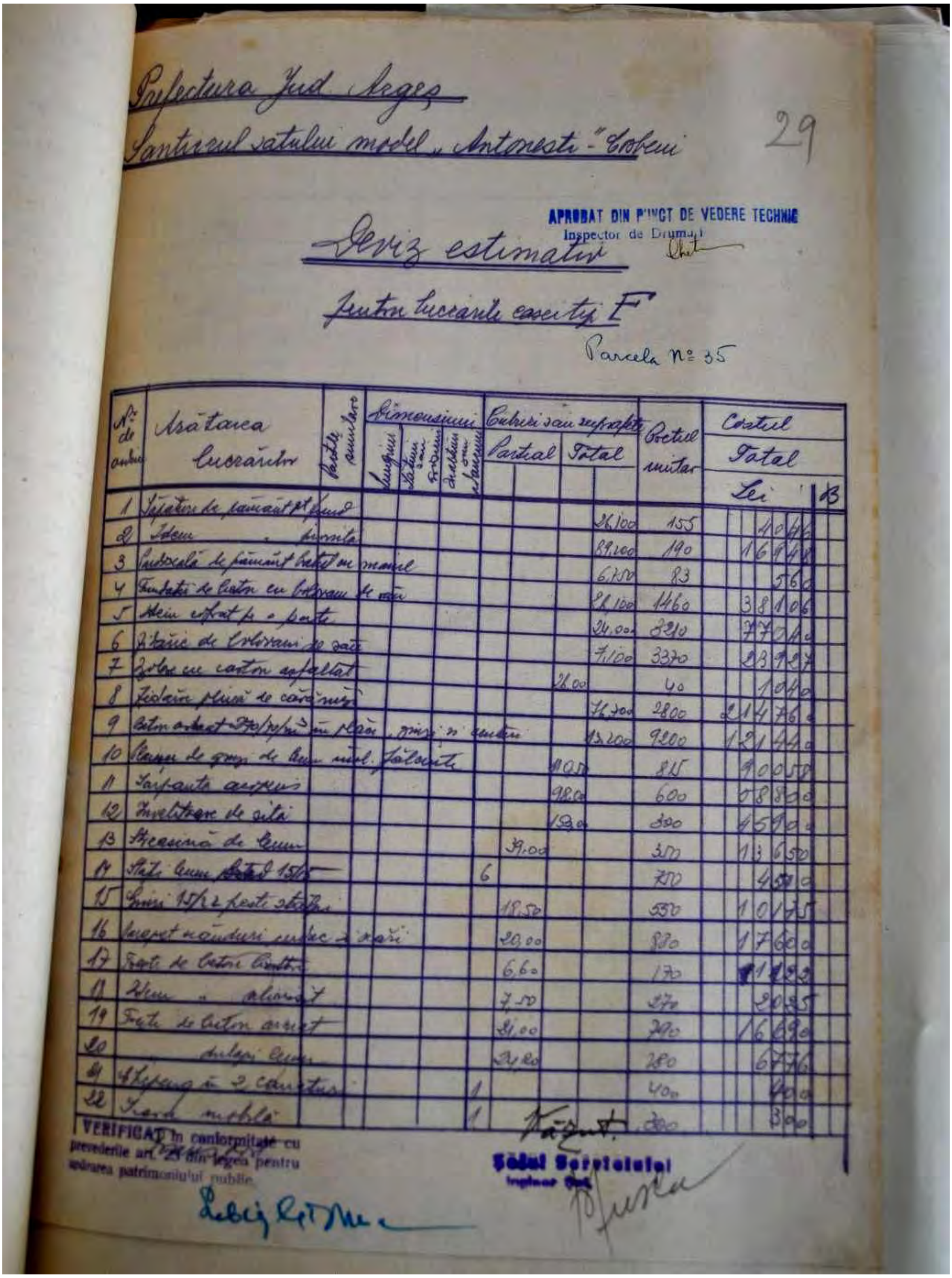
In city centres with crowded construction as here green spaces can appear only in form of pocket parks, or, if even more crowded, on the facades. And they contribute to the improvement of the local climate, against heat islands, and mitigating the raising of temperatures due to climate change. Such a reconstruction is supported by the structural typology of the buildings in central Lisbon as timber supports such a structure (the relationship between timber as support for green walls in reconstruction efforts has been shown in Bostenaru and Mendes, 2013).

The modeling of the costs at the level of resources as from device based computation of costs at the single building included the definition of the interface between structural engineering results and construction economics computation, based on either element costs computation - applicable for the rough structure - or on functional space surface computation - including architectural finishing. In a fore work to ontology we completed several forms on structural taxonomy of buildings, following World Housing Encyclopedia reports (http://www.world-housing.net/related-projects/share-your-knowledge-of-buildings/building-taxonomy-summary-reports), for which we also analyzed to criteria according to the decision tree. It includes employment of the developed ontology for elements and ontology for spaces and how this can react to common architectural design and building management software such as, for example, archiCAD and its new – 2011 – building rehabilitation module.

The resources can be translated in the symbols related to materials or building elements in a game and therefore they build a basis for collaborative decision in bargaining in an earthquake risk management environment. We envisage in developing this with a similar case study in Hungary, which aims to do research in economic bargain games and in landscape planning, connected to our findings resulting the role of green spaces in reconstruction. In Figure 7 the church can be seen as community centre in the middle of a green space in case of reconstruction designed by the architect Richard Bordenache after mountain floods in the 1940s (war time in Romania) and after a chemical disaster in Ajka for Devecser designed by the architect Imre Makovecz. In the first case urban planning played a role in the reconstruction by relocating the settlement to a higher position in the mountains. Such savings of space to provide green spaces can lead to higher rental prices in the neighborhood. Both approaches follow traditional building with timber, as we saw also for Lisbon. For Antoneşti-Corbeni we did a research on the economics of the houses which were sold under a price. Figure 8 presents part of the computation of the costs devices for the house of Antoneşti-Corbeni shown in Figure 7. In designing a game for such issues we can consider the model of construction from Pillars of Earth, focused on the church, and the spread of different items related to it in a later intervention such as in World without End, inspired also from Ken Follett novel, thus having the new construction on the disaster flattened space of the reconstruction in existing tissue to compare. Also, we have the different scales: for the unique object of the church the building scale is considered, while for the urban scale we may consider common buildings such as in World without End. For World without End no electronic form of the game was available.

The ontology of decision (the IT component of the modelling) must adapt again from another more frequent approach to our topic. The IT component of the modelling is that of energy modelling (O'Donnell et al, 2013), also present in the archiCAD module, of structural earthquake retrofit. The results of the modelling will be integrated into a decision system based on regression between the two scales: building object and urban scale of the quarter. An example from this decision support integrated into city planning games (SimCity and CityVille) can be seen in Figure 9, where the vicinity of green spaces increases rental prices

Fig. 7 The church as community centre in the middle of a green space. Reconstruction after floods/mud-floods respectively; the case of traditional housing in Antonești-Corbeni Romania(upper two rows) and of Devecser in Hungary (row at the bottom). Photos: M. Bostenaru 2012/13.



Prefectura Jud. Argeș

Șantierul satului model „Antonești"-Corbeni

29

APROBAT DIN PUNCT DE VEDERE TECHNIC
Inspector de Drumuri

Deviz estimativ

pentru lucrările casei tip F

Parcela Nr. 35

Nr. de ordin	Arătarea lucrărilor	Bucăți	Parțial	Total	Prețul unitar	Costul total Lei
1	Săpătură de pământ pt. fund.			26,100	155	4046
2	Idem [illegible]			89,100	190	169[illegible]
3	Pardoseală de pământ bătut cu maiul			6,750	83	560
4	Fundații de beton cu bolovani de râu			26,100	1460	38106
5	Idem cofrat pe o parte			24,00	3210	77040
6	[illegible] de bolovani [illegible]			7,100	3370	23927
7	Izolare cu carton asfaltat		26,00		40	1040
8	Zidărie plină de cărămidă			76,700	2800	214760
9	Beton armat [illegible] în plăci, grinzi și centuri			13,200	9200	121440
10	Planșeu de grinzi de lemn [illegible]		110,5		815	900575
11	Șarpante [illegible]		98,00		600	58800
12	Învelitoare de țiglă		153,0		300	45900
13	Streașină de lemn		39,00		350	13650
14	Stâlpi lemn [illegible] 15/15	6			750	4500
15	Grinzi 15/12 peste stâlpi		18,50		550	10175
16	[illegible]		20,00		880	17600
17	Trepte de beton [illegible]		6,60		170	1122
18	Idem [illegible]		7,50		270	2025
19	Trepte de beton [illegible]		21,00		790	16[illegible]90
20	[illegible] dulapi lemn		24,20		280	6776
21	[illegible] în 2 canaturi	1			400	400
22	Scară mobilă	1			300	300

VERIFICAT în conformitate cu prevederile art. 25 din legea pentru [illegible] patrimoniului public

Văzut.

Șeful Serviciului
Inginer Șef

Fig. 8 Computation of the costs devices for the house shown in Fig. 7 – archive image from the Romanian national archives, Argeş branch, Piteşti.

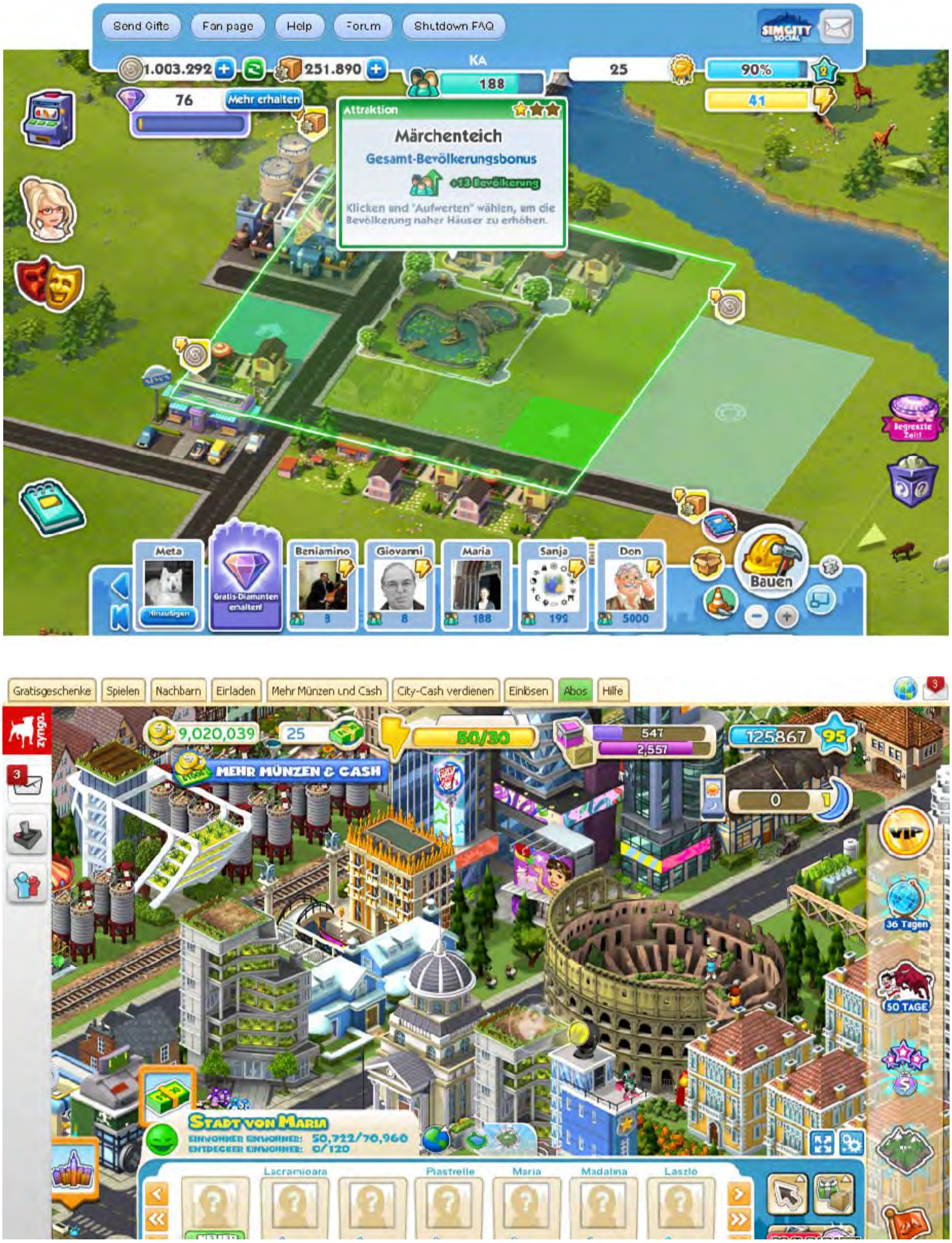


Fig. 9. In SimCity: the vicinity of green spaces increases rental prices (upper image); in CityVille the green houses increased urban agriculture production, as this one is foreseen instead of industry for the economics in this game (lower image). City projects by M. Bostenaru.

through, and green houses increased agricultural production with a limited footprint of the buildings.

For real life situations see papers by Ichichara and Cohen (2011), Conway et al (2010), Mell et al (2013), Saphores and Li (2012), Sander and Height (2012), which evaluate the benefit of green space on land value, while for archive research as ours we recommend Woinaroski (2013). Not only are green spaces contributing to reducing heat islands and thus mitigating climate change effects in city centres, but also are convenient from an economic point of view. Therefore they are to be recommended in reconstruction efforts. The destruction of settlement areas by disasters, such as the chemical catastrophe in Ajka or the floods in Argeş county are an occasion for projects, and for such reconstruction, as earthquakes are. The land is flattened by the disaster and striated by the reconstruction, if we were to follow the philosophy proposed by Gilles Deleuze (1980).Building a new settlement such as these ones requires a community centre, which is foreseen by urban planning rules and included in the rules of city building games (the socio-economic model does not allow adding new residential buildings to raise the number of inhabitants if such buildings are not foreseen). But, as we see, the presence of green spaces also allows certain extensions (Fig. 10), not only rental price increase, since green spaces are a community gathering space as well. We designed ourselves such a new quarter, followed by designing quarters in the computer games. While board games have a pre-designed plan, computer games allow, in frame of a grid (such as the re-building of Lisbon) for urban planning creation. The limited space, as we saw, makes the economic value of green spaces decisive, such as in crowded city centres, as it was the question of re-building in central Lisbon or in central Bucharest.

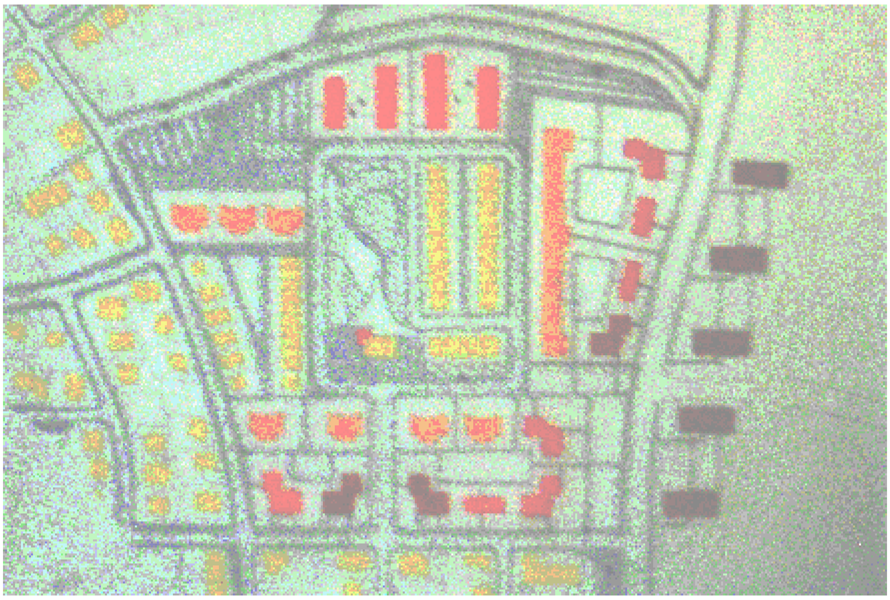


Fig. 10 New quarter in Linkenheim-Hochstetten, Karlsruhe. Note the green space with community centre in the middle. Project by M. Bostenaru, 1997. The surroundings of Karlsruhe feature some more garden city, “Siedlungen”, and a similar approach (with a church) was foreseen also for the Modernist masterpiece Dammerstock.

CONCLUSIONS

The paper has explored the economic aspects of risk mitigation. The roles of game theory, agent based modelling and networks and urban public policies in designing decision systems for risk management were also discussed. The urban scale at which a natural hazard can impact leads to the importance of urban planning strategy in risk management. However, usually environmental engineering and social sciences deal with it, and the role of architecture and urban planning is neglected. ICT can contribute to organize the information from the building survey, for example, through taxonomy and ontology, to economic computations in direct modelling at urban or building scale or through translation of games' rules and thus facilitate decision making. Games rules are at the same time supported by our field and archive studies, as well as research by design. We also take into consideration a rare element, which is the role of landscape planning through the inclusion of green elements in reconstruction after the natural and man-made disasters or in reconstruction efforts to mitigate climate change. Apart from existing old city fabric, also landscape can be endangered by speculation and therefore it is vital to highlight its high economic value, also in this particular case. As ICOMOS highlights for the 2014 congress, heritage and landscape are two sides of the same coin. Landscape may become or can be connected to a community centre, the first being necessary for building a settlement, the second raising its value, or it can build connections between landmarks in urban routes. For this reason, location plays a role not only for mitigating the effects of hazards, but also for increasing the value of land through vicinities. Games are only another way to build a model of the complex system, which is the urban organism in this regard; a model is easier to be analysed than the system while displaying its basic rules. The role of landscape of building roads of memory between landmarks in the reconstruction is yet to be investigated in a future proposed COST action.

ACKNOWLEDGEMENTS

The financial support of the short term scientific missions COST-STSM-ECOST-STSM-IS1104-010413-024718 from Romania to Portugal (first author to second author) with the topic "Economics of the earthquake risk mitigation in the urban and constructive structure" (COST action "The EU in the new complex geography of economic systems: models, tools and policy evaluation") as well as the financial support of the ECOST-STSM-IS1101-101113-037155 from Portugal to Romania (third author to first author) on the topic "Urban adaptation to climate change: the role of the Landscape Architecture" (COST action "Climate Change and Migration: Knowledge, Law and Policy, and Theory") are gratefully acknowledged.

REFERENCES

D. Alexander (2013) An evaluation of medium-term recovery processes after the 6 April 2009 earthquake in Aquila, Central Italy, *Environmental Hazards*, Volume 12, pages 60-73.

J. Becker, D. Paton, D. Jonston, and K. Ronan (2013) Salient beliefs about earthquake hazards and household preparedness. *Risk Analysis*, doi :10.1111/risa.12014.

B. Borzi, H. Crowley, R. Pinho (2008) Simplified Pushover-Based Earthquake Loss Assessment (SPBELA) Method for Masonry Buildings, *International Journal of Architectural Heritage*, Volume 2, Issue 4, pages 353-376 (24).

M. Bostenaru Dan (2004). Multi-criteria decision model for retrofitting existing buildings, *Natural Hazards and Earth System Sciences,* Volume 4, pages 485–499.

M. Bostenaru Dan, A. Dill (2014) Spatial street network and urban traces around the Modernist boulevard in Bucharest. In: Crăciun C, Bostenaru Dan M: Planning and Designing Sustainable and Resilient Landscapes, Springer, Dordrecht.

M. Bostenaru Dan, D. Mendes (2013) Contemporary installations with timber from disaster reconstructions, In: Correia M, Carlos G, Rocha S (eds.): Vernacular Heritage & Earthen Architecture: Contributions for Sustainable Development, CRC Press.

M. Bostenaru Dan, T. Panagopoulos, C.O. Gociman, I. Armas, A. Dill, A. Chiriloae, and T. Florescu (2013) The impact of hazards on the urban tissue – 3-D representation and digital databases. *Advances in Geosciences,* Volume 35, pages 45-53.

P.G. Canbolat (2013) Optimal halting policies in Markov population decision chains with constant risk posture, *Ann Oper Res*, DOI 10.1007/s10479-012-1302-3

N. Caterino, I. Iervolino, G. Manfredi and E. Cosenza (2009) Comparative Analysis of Multi-Criteria Decision-Making Methods for Seismic Structural Retrofitting, *Computer-Aided Civil and Infrastructure Engineering,* Volume 24, pages 432–445.

D. Conway, C.Q. Li, J. Wolch, C. Kahle and M. Jerrett (2010) A Spatial Autocorrelation Approach for Examining the Effects of Urban Greenspace on Residential Property Values *J Real Estate Finan Econ,* Volume 41, pages 150–169

W. Daungthima, H. Kazunori (2013) Assessing the Flood Impacts and the Cultural Properties Vulnerabilities in Ayutthaya, Thailand. *Procedia Environmental Sciences*, Volume 17, pages 739-748.

G. Deleuze (1980) *Mille Plateaux* (Minuit, Paris).

U. Eco (1997) Function and sign: The semiotics of architecture, in Neil Leach (ed.): *Rethinking architecture. A reader in cultural theory,* Routledge, London and New York, p. 182-202

F. Fiedrich (2006) An HLA-Based Multiagent System For Optimized Resource Allocation After Strong Earthquakes, *Proc. of the 2006 Winter Simulation Conference*, L. F. Perrone, F. P. Wieland, J. Liu, B. G. Lawson, D. M. Nicol, and R. M. Fujimoto, eds.

S. Glaister, R. Pinho (2003). Period-height relationship for existing european reinforced concrete buildings, *Journal of Earthquake Engineering*, Volume 7, Issue S1, pages 107–140.

Y.Y. Haimes (2012) Strategic Preparedness for Recovery from Catastrophic Risks to Communities and Infrastructure Systems of Systems, *Risk Analysis*, Volume 32, Issue 11.

K. Ichihara, J.P. Cohen (2011) New York City property values: What is the impact of green roofs on rental pricing? *Letters in Spatial and Resource Sciences,* Volume 4, Issue 1, pages 21-30.

J.K. Jason, W. Keith, K.W. Hipel, N. Howard (2009) Advances in Drama Theory for Managing Global Hazards and Disasters. Part II: Coping with Global Climate Change and Environmental Catastrophe, *Group Decision and Negotiation*, Volume 18, Issue 4, pages 317-334

S. Khan (2012) Disasters contributions of hazardscape and gaps in response practices.*Natural Hazards and Earth System Sciences*, Volume 12, pages 3775-3787.

I.C. Mell, J. Henneberry, S. Hehl-Lange, B. Keskin (2013) Promoting urban greening: Valuing the development of green infrastructure investments in the urban core of Manchester, UK, *Urban Forestry & Urban Greening*, Volume 12, pages 296-306.

J. O'Donnell, E. Corry, S. Hasan, M. Keane, E. Curry (2013) Building performance optimization using cross-domain scenario modeling, linked data, and complex event processing, *Building and Environment*, Volume 62, pages 102-111.

P. Ortiz, V. Antunez, J.M. Martín, R. Ortiz, M.A.E. Vázquez, Galán (2013) Approach to environmental risk analysis for the main monuments in a historical city. *Journal of Cultural Heritage*, In Press, Available online 6 August 2013.

A. Provins, D. Pearce, E. Ozdemiroglu, S.A. Mourato, S. Morse-Jones (2008). Valuation of the historic environment: The scope for using economic valuation evidence in the appraisal of heritage-related projects. *Progress in Planning*, Volume 69, pages 131-175.

J. Mercer, I. Kelman, S. Suchet-Pearson, and K. Lloyd (2009) Integrating indigenous and scientific knowledge bases for disaster risk reduction in Papua New Guinea, *Geogr. Ann. B.*, Volume 91, pages 157-183.

H.A. Sander, R.G. Haight (2012) Estimating the economic value of cultural ecosystem services in an urbanizing area using hedonic pricing. *Journal of Environmental Management*, Volume 113, pages 194-205

J.D. Saphores, W. Li (2012) Estimating the value of urban green areas: A hedonic pricing analysis of the single family housing market in Los Angeles, CA. *Landscape and Urban Planning*, Volume 104, pages 373-387.

A.A. Tarragüel, B. Krol, C. van Westen (2012) Analysing the possible impact of landslides and avalanches on cultural heritage in Upper Svaneti, Georgia. *Journal of Cultural Heritage*, Volume 13, pages 453-461.

B. Wisner, P. Blaikie, T. Cannon, I. Davis (2004) *At risk: natural hazards, peoples vulnerabilities and disasters* (Routledge, New York).

H. Winkler (2005) Climate change and developing countries. *S Afr J Sci*, Volume 101, pages 355–364.

C. Woinaroski (2013) *Istorie urbană. Lotizarea şi Parcul Ioanid din Bucureşti în context european* (in Romanian) (Simetria, Bucharest).

M.W. Ye, J. Wang, J. Huang, S. Xu, Z. Chen (2012) Methodology and its application for community-scale evacuation planning against earthquake disaster. *Natural Hazards*, Volume 61, pages 881-892.

A psychophysical assessment of urban landscaping of public agencies premises in Jos City

Abdulwaheed Bayonle SALAUDEEN
Forestry Research Institute of Nigeria, Jos, Nigeria
Lecturer of landscape planning
bayosalawu@yahoo.com

Co-author: John Yohana DUNG-GWOM
Geography and Planning Department, University of Jos, Nigeria
Professor of urban and regional Planning
jdunggwom@yahoo.com

ABSTRACT

The study focused on the Psychophysical assessment of urban landscaping practices of public agencies in Jos City. The City is experiencing rapid infrastructural development by the state and uncontrolled development alike by the people. As a result of this, the natural vegetal cover has diminished rapidly over the years and the choice of plant materials to complement the new structures is not well chosen. This is not unconnected with the inadequate awareness creation by professionals for developers to appreciate the importance of landscape plan and the value of natural vegetation around most developments. The Psychophysical model was employed to assess seventeen carefully selected landscape sites of public agencies; these were given to seventeen purposely-selected participants from the academia and professionals to sort the landscape photographs according to their own preference. The result revealed that, the four most preferred landscape photographs were from federal agencies, while three out of the four least preferred landscape photographs were from state agencies. This is because most of the federal agencies entail landscape plan prior to landscape establishment, unlike the state agencies that according to the study entail no landscape plan prior construction. The study therefore supports the need for landscape planning policy and awareness creation in the city of Jos.

Keywords: Psychophysical, Landscape, Assessment, Practices, Agencies.

INTRODUCTION

Landscape is transitory. It is merely one stage in the grand cycle of creation that characterizes the surface of the Earth. It is that, which exists as a result of the interaction between internal and external forces operating on the Earth's crust. Landscape is the total surface form of an area. The term 'landscape' is derived from the Dutch word '*landschap*', which simply means the prospects of rural scenery (Falade and Oduwae, 1998). This is considered as a territorial division of rural environment and of visual quality. Harris (2004) has categorized landscape into three types: the natural landscape which exists where human population rarely exists spaced and does not live by working on the land. It is the natural habitat of a region, forest, desert etc., which exist in their own pure forms with no record of interferences by man; the cultural landscape produced by manmade alteration of the natural habitat through various activities of man, such as mining, deforestation activities etc. and that part of the Earth surface, which has experienced a great deal of alteration in professional terms as to create a made-believe natural landscape. This category of landscape type is likened to palimpsests with new landscapes superimposed on the remains of the old. This view implies that, landscapes are mainly composed of what people have created. It is on this premise that this research rests with reference to Jos City, the Capital of Plateau State.

RESEARCH PROBLEMS

Jos City is experiencing rapid infrastructural development by the State and uncontrolled development alike by the people. As a result of this, the natural vegetal cover has diminished rapidly over the years and the choice of plant materials to complement the new structures is not well chosen. This is not unconnected with the inadequate awareness creation by professionals for developers to appreciate the importance of landscape plan and the value of natural vegetation surrounding most developments. This also contributes to the poor perception of the public towards landscaping, hence giving the Cityscape a disjointed and uncoordinated outlook rather than a well-designed and coordinated canvas that can serve functional purpose in a visually satisfactory manner.

OBJECTIVES OF THE STUDY

The aim of this Study is to assess prevailing Urban Landscaping Practises of Public Agencies in Jos City using the psychophysical approach and examine landscape quality of public agencies and perception of the general public in Jos City. The study focus on the nature of landscaping that goes with the developments of public agencies within Jos City.

SIGNIFICANCE OF STUDY

Landscape planning has been kept on the residual list of urban development plans, hence affecting the anatomy and quality of most urban areas/landscapes. Physical features of hard landscapes devoid of nature also have characterized the urban skylines. Therefore, the outcome of the study shall go a long way to upgrade the landscape understanding of developers, planners and policy makers. Besides, the study will serve as reference point for authorities charged with the responsibility of landscape planning and management and landscape practitioners alike. Comprehensive landscape policies and enforcement will enhance a well-organized urban setting full of nature, pleasing to the eye, blending developments with nature and reduce the effects/problems of climate change and global warming.

THE STUDY AREA

Jos City according to the draft copy of the Greater Jos Master Plan (2008) comprises of three local government areas: Jos-North, Jos-South, and Jos-East (Figure 1). Jos City has a population of 821618 inhabitants (National Population Commission, 2007) with a combined population density of 391 persons per km² (1013 persons per square mile) making the areas mentioned above as the most densely populated parts of Plateau State.

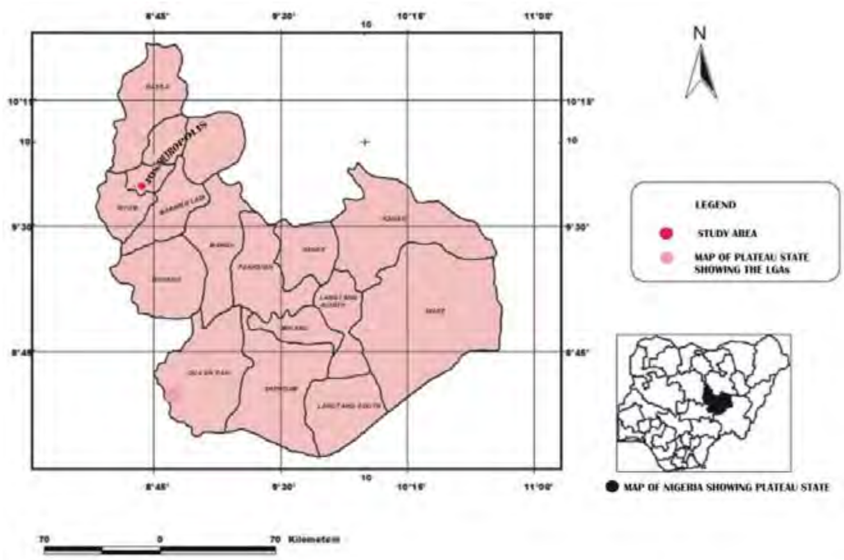


Fig. 1 Map of Nigeria Showing Plateau State and Map of Plateau State Showing the Local Government Areas (Source: Obembe, 2009).

The geology and soil made of 50 million years ago volcanic activity created numerous volcanoes and vast basaltic plateaus created from lava flows. This also produces regions of mainly narrow and deep valleys and pediments (surfaces made smooth by erosion) from the middle of rounded hills with sheer rock faces (Williams and Patterson, 2007). It has a monthly rainfall that varies from 5cm to 30cm with annual rainfall of about 1500mm. About 90% of the rainfall is experienced between April to September and it usually comes in thunderstorms of high intensity. Though situated in the tropical zone, a higher altitude means that Plateau State has a nearly temperate climate with an average temperature between 19° and 25° C. Harmattan winds cause the coldest weather between December and February. The warmest temperatures usually occur in the dry season months of March and April. The mean annual rainfall varies from 131.75 cm in the southern part to 146 cm on the Plateau. The highest rainfall is recorded during the wet season months of July and August (Weatphal, 2003). The vegetation of Jos City has been greatly modified by the traffic congestion within the area as a result of urbanization, which largely contributed to the vegetation of the city. However, the vegetation shows that Savanna woodland modified by relief and climate. Some species of the original vegetation that have survived in specialized locations of an occasional occurrence show in the upland region. The study area is perhaps the best known of the highlands. It is the highest platform in Nigeria with an elevation between 1500 and 1800 meters above sea level. The area is characterized by impressive ridges and inselbergs separated by plains. With an average height of 1400 meters, the sheer hills to the north-east of Jos City provide the peak with an elevation of 1766 meters.

Field Work

Three field surveys of varying intensities and significance are involved in this study. These include the reconnaissance survey, the pilot survey and the main field work of the research. The purpose of the reconnaissance survey was to get acquainted with the landscape sites of all public agencies/organisations in the study area and to determine the sample size for the study. The assignment included making contacts with heads of the various agencies/organisations to solicit for their support and cooperation in the course of the main survey. The pilot survey specifically pre-tested the instrument of data collection. The bulk of the primary data are collected during the main field work.

The study area was drawn from public agencies and organisations in Jos City. These range from Federal (Federal owned), State (State owned) to Local Government Agencies (Council owned) and organisations, and quasi-public institutions. The researcher obtained a list of forty eight public agencies (Federal, State and Local Government Agencies) and organisations from the State Ministry of Information. A total of forty three public agencies were identified in the city. The limit of the sample to forty three is informed by the logistics and the need for indebt study to be conducted from each of the agencies. A total of seventeen of these agencies were taken as sampled size by the researcher based on the availability of landscapes on the sites.

LANDSCAPE ASSESSMENT PROCEDURE

The Q-methodology (i.e. psychophysical model) was implored by developing exemplary photographs of representative landscape sites of seventeen randomly selected agencies out of a total of forty eight public agencies in the city. This is done to widen the base of scenic assessment of the landscape sites, by measuring the aesthetics values of the general public rather than experts. This is based on the assumption that, landscape or elements of landscape act as stimuli to which observers respond. Besides, research involving Q- methodology or perception studies does not necessarily require large population samples (Arriaza *et al.*, 2004). A diverse sample of photographs were taken and presented to seventeen participants selected from the academia and professionals to sort the photographs into a normal distribution. It is a photographic representative technique through ‘Quality Sorting’ (Q-sorting) to assess landscape preference and requires no large sample size. The emphasis on qualitative information for this research was based on the relationship that exists between quality and preference (Harris, 2004). The collection of images (photographs) was done through direct photographs of all the sampled agencies. All photographs were taken using a digital camera with a lens set on 50mm, vertical view and proper angle. The resulting photographs selected were based on criteria, such as background and foreground scenes, layout, vegetation covers, lighting, street furniture, topography etc. The photographs were reproduced at postal card size (5mm x 10mm), laminated for ease of field use and randomly numbered. Having collected photographs of all the seventeen public agencies, all images were assessed and a matrix of 5 x 6 was used to sample the available images based on normal distribution pattern. A total of seventeen participants were selected randomly from the academia and professionals to sort the photographs according to their own preference. Participants were asked to rank the representative images through 'Q-sorting' on a scale from "most preferred" to "least preferred"**.** The images were ranked in a way that limits the number of photographs at the extreme, in order to identify the key preference held by individual participants. The Q-sorting resulted in the photographs being arranged into the shape of a normal distribution curve as presented in figure 2. This placed the majority of images somewhere in the middle of the scale and very few images (only those that participants feel particularly strongly about) at the extremes of "most preferred" and "least preferred". The right hand end of the distribution consists of the 'beautiful' photographs and given positive score. The left hand end consists of the 'ugly' photographs and given a negative score.

No. in column:	1	2	3	4	3	2	1
Score:	-3	-2	-1	0	1	2	3

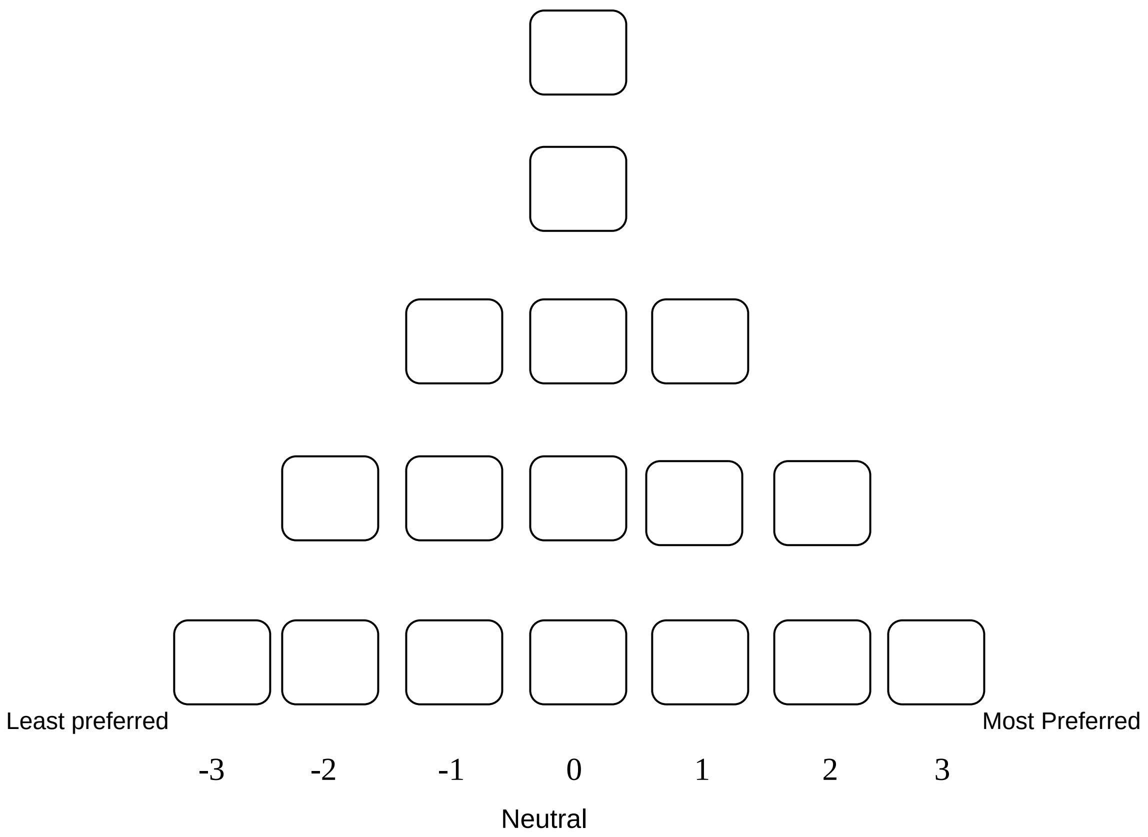


Fig. 2: Normal Distribution Curve of Photographs (Source: Arriaza et al., 2004).

The Q-sorting was used to measure the level of awareness of participants in appreciation of these landscape sites. It assessed individual perception of landscape sites vis-a-vis landscape elements and features of each landscape site. This was analyzed and based on weighting assigned to each of the photographs in order to represent distinct collective preference.

RESULTS AND DISCUSSION

Results

Table 1 shows the summary of the frequency of the Q-Sort exercise as preferred by the seventeen participants.

Agency	R (+3)	A (+2)	N (+1)	K (0)	I (-1)	N (-2)	G (-3)
Federal College of Forestry	**8**	2	4	-	-	2	-
Federal High Court	1	4	4	2	4	-	1
Federal Court of Appeal	3	**8**	1	2	-	-	2
National Library	2	**5**	4	3	2	1	-
State Library	-	2	3	5	4	2	1
Plateau State Polytechnic	-	-	2	8	1	**4**	-
Federal Department of Forestry	-	1	2	5	5	2	1
Federal Road Safety Commission	-	3	1	2	-	2	**3**
Plateau State Agricultural Development Programme	-	-	3	7	5	1	1
Nigerian Security and Civil Defense Corps	3	1	1	5	3	2	-
National Museum and Monuments	-	-	2	9	4	3	-
Plateau Radio Television Corporation	-	2	3	3	3	2	-
Jos North Local Government	-	2	1	3	1	4	**5**
Plateau State Universal Basic Education board	-	1	2	5	3	1	-
National Environmental Standard Regulation Agency	-	-	-	7	4	2	2
Plateau Riders	-	-	1	9	**5**	1	1
Nigerian Television Authority	-	1	2	5	5	3	-

Table 1: Summary of frequency of Q-Sort (Source: Author's field work, 2010).

DISCUSSION

Most preferred landscape photographs as perceived by Participants

The Federal College of Jos City Forestry, (see Plate 1, appendix 2) appeared eight consecutive times as the most preferred with +3 score. The landscape was appreciated for the naturalness of the vegetation and the variation in types of plantings. In particular, the layered effect of the vegetation was noted as giving the bush colour, texture and a sense of place and depth. The street furniture, parking lots and paved driveways provide contrast and spacious feeling within the landscape. It was considered as very attractive. The array of photographs for this is presented in figures 12-13, 15, 17-18, 20-21 and 25 (appendix 1). The Federal Court of Appeal, Yakubu Gowon Way ranked second (see Plate 2, appendix 2), as it appeared eight consecutive times as the most preferred with +2 score. The landscape was considered as very attractive, neat and the most colourful. The site was appreciated for its neat paved driveway with ample parking lots and blending colour combination between the building and the sculpture. It was rated as the most sheared and inviting landscape. The array of photographs for this is presented in figures 13-18, 20 and 25 (appendix 1). The National Library, Yakubu Gowon Way (see Plate 3, appendix 2) appeared five consecutive times as the most preferred with +2 score. The site was appreciated for its well paved and well maintained hedges and shrubs in the landscape. The sculpture gives a real sense of place. The array of photographs for this is presented in figures 11-12, 15, 17 and 19 (appendix 1). The Federal High Court, C-Division (see Plate 4, appendix 2) appeared four consecutive times as the most preferred with +1 score. The landscape was valued for its neat, attractive, well landscaped and well maintained landscape site. It has a wide road shoulder for parking. The array of photographs for this is presented in figures 12-13, 21 and 26 (appendix 1). It is good to note here that all four most preferred landscape photographs are from Federal agencies. This may not be unconnected with the fact that, most Federal agencies in the city adopted the operational landscape policy obtainable from the Federal Capital Territory, where landscaping is given a very high priority (Obembe, 2009).

Least preferred landscape sites as perceived by participants

The Jos North Local Government Headquarters, Gowom Gowon Jos Palace, ranked first amongst the least preferred landscape photographs (see Plate 6, appendix 2), as it appeared five consecutive times with -3 score. The landscape was disliked because of the untidy appearance of a dilapidated interlocking roundabout. It is very unkempt and without any sense of aesthetics and appreciation. The array of photographs for this is presented in figures 17-18, 21, 23 and 25 (appendix 1). The Federal Road Safety Commission Zaria Road ranked second amongst the least preferred landscape photographs (see Plate 7, appendix 2), as it appeared three consecutive times as the least preferred with -3 score. The landscape was unorganised and untidy, though still under construction as at the time of this research. The array of photographs for this is presented in figures 16, 24 and 26 (appendix 1). Plateau State Polytechnic Jos Campus ranked third amongst the least preferred landscape photographs (see Plate 8, appendix 2), as it appeared four consecutive times with -2 score. The landscape was disliked because it was too bushy, unkempt and the entire surrounding untidy and not properly managed. The array of photographs for this is presented in figures 17, 20-21 and 24 (appendix 1). Plateau Riders, Tafawa Balewa Street, ranked last amongst the least preferred landscape photographs (see Plate 10, appendix 2), as it appeared five consecutive times with -1 score. The landscape was disliked due to it bushy nature and being poorly managed and, because of lacking landscape elements of some aesthetic value. The array of photographs for this is presented in figures 12, 15, 17, 22 and 25 (appendix 1). It can be observed also that three out of the four least preferred landscape photographs are from state agencies. This may not be unrelated to the complete lack of landscape policy by the state to guide landscape developments of public developers in the city.

The point above also confirmed the lamentation by Falade and Oduwaye, (1998) that, the neglect of landscape planning consideration in physical planning in Nigeria in the promotion of city development justifies that, landscape degradation has not been valued as much as the problems of unemployment, poverty, housing, income etc. The absence of landscape development plan as well as the lack of landscape design prior development has dovetailed into an aberration of making landscaping an 'after-thought', as being against an integral part of the building design before the commencement of development. From the aforementioned, it can be concluded that, the landscaping practices obtainable in Jos City are a withdrawal from the conventional landscape planning process of research and analysis, designs and implementation as opined by Falade and Oduwaye, (1998). It is only the implementation stage of the process that is considered by the practitioners of landscaping, due to lack of the knowledge and skills of design and even, in some cases, of landscape research and analysis. This has greatly contributed to cosmetic landscaping practices that are fashionable in the city. From this, it can be adjudged that, the landscaping practice of public agencies in Jos City is similar to the norms and values of landscaping practices elsewhere.

RECOMMENDATIONS

- There is need for a landscape planning policy upon which a comprehensive landscape development plan for different land uses and densities in the city. This will serve as a spring board upon which future landscaping practices will rest and it will subsequently bring uniformity and sanity into the city landscape of Jos City. The need for clear cut landscape legislation is also imperative for landscaping practices in the city. This will equip the regulating agencies and guide prospective developers on the types, pattern and form of landscape required for a particular development than what is presently in vogue.
- The Architects and Town Planners in the state should undergo training in landscape architecture or the state should engage the services of professional landscape architects for better coordination and implementation of landscaping in the state at large.
- Landscape Architects should participate in the vetting of building plan approval processes as landscape plan should be a pre-requisite to ensure that minimum requirement of landscape plan is met before approval is given. Once landscape development plan is a pre-requisite, it encourages landscape professionals as well as compels developers to consider landscaping as an integral part of the building plan in the city and against being considered as an afterthought, as currently experienced.
- There is need to improve current landscape planning requirements and specifications in the proposed master plan to give better guidance to both professionals and developers alike.
- There is need for public agencies to support professionals, when it comes to landscaping in order to get the best services that will enhance their environment sustainably and aesthetically.
- Finally, the regulating agencies should evolve an up-to-date and comprehensive landscape checklist to serve as a guide for minimum landscaping by developers for different land uses and densities in the City of Jos.

CONCLUSION

The primary objective of the study has been to investigate the current urban landscaping practices of public agencies in Jos City using a psychophysical model. The main conclusion of the study is that, there is no benchmark upon which landscaping practices are done in the city. So, most of the landscaping practices have been based on self-initiative and afterthought of various types without the full application of basic landscape principles and concepts. There are no laid down landscape requirements that can serve as reference point for other landscape action plans in the city, neither is there any landscape budget to be obtained by federal agencies. It is therefore pertinent that, until a comprehensive landscape development plan is produced for the city and the practices of landscaping are handled by the relevant professionals like Landscape Architects, Town Planners, Architects, Horticulturists, Botanists and other related professionals, operating within the confines of a registered body that can regulate their activities, Jos City will continue to swim in '*abject landscape poverty*'.

REFERENCES

Arriaza, M., Cañas-Ortega, J., Cañas-Madueño, J. & Ruiz-Aviles, P., (2004). Assessing the visual quality of rural landscapes. Landscape and Urban Planning, 69, 115–125

Falade, J. B. and Oduwaye, L. O. (1998). *Essentials of Landscape and Site Planning.* Omega Hi-Tech Information and Planning Systems Ltd. Lagos pp. 259.

Greater Jos Master Plan (2008). Plateau state government of Nigeria.

Harris, R.W. (2004). *Arboriculture Integrated Management of Landscape Trees, Shrubs and Vines*. 4th Edition, Prentice Hall, New Jersey pp. 416.

National Population Commission (2007). Report on the Census 2006 Final Results.

Obembe, T. O. (2009). Landscaping as a Professional Activity in Nigeria: Lagos State as a Case Study. A Project Submitted to the Department of Urban and Regional Planning, Faculty of social Science, University of Ibadan, Nigeria, pp 192.

Westphal, L.M. (2003). Urban Greening and Social Benefits: A Study of Empowerment Outcomes. *Journal of Arboriculture* 29 (3): 137-147.

Williams, D. and Patterson, M., (2007). Snapshots of what, exactly? A Comment on Methodological Experimentation and Conceptual Foundations in place Research. Society and Natural Resources, 20,931–937

APPENDIX 1

Array of photographs

Figure 11: 1st Q- Sort

Figure 12: 2nd Q- Sort

Figure 13:3rd Q-Sort

Figure 14:4th Q-Sort

Figure 15: 5th Q- Sort

Figure 16:6th Q- Sort

Figure 17:7th Q-Sort

Figure 18:8th Q-Sort

Figure 19:9th Q- Sort

Figure 20:13th Q- Sort

Figure 21:14th Q- Sort

Figure 22:15th Q- Sort

Figure 23:16th Q- Sort

Figure 24:17th Q- Sort

Figure 25:18th Q- Sort

Figure 26:19th Q- Sort

Figure 27:20th Q- Sort

APPENDIX 2

Most preferred landscape photographs

Plate 1: Federal College of Forestry

Plate 2: Federal Court of Appeal

Plate 3: National Library

Plate 4: Federal High Court

Least preferred landscape photographs

Plate 5: Jos North Hqtrs

Plate 6: Federal Road Safety Commission

Plate 7: Plateau polytechnic

Plate 8: Plateau Riders

Urban spatial structures and their economical sustainability

Vladimíra ŠILHÁNKOVÁ
College of Regional Development Prague, Czech Republic
vladimira.silhankova@gmail.com

ABSTRACT

The article analyses the spatial structures of a present-day (Central) European town. Based on the research of professional literature it defines nine basic types, which are further characterised and systemised. The six key types of the spatial structures are then studied from the point of view of their economic demands regarding construction and maintenance. The acquired data are subsequently compared taking into account various aspects and, in addition, the demands on construction and maintenance are examined. The article also deals with the analysis of the infrastructure needs of suburban areas and the evaluation of their economic demands. Another analysis focuses on the new transport and technical infrastructure construction requirements in selected suburban areas in the Czech Republic. Subsequently, an analysis of the outlays regarding the building and operation of infrastructure is presented. The closing part is formed by a comparison of the outlays regarding the building and operation of infrastructure in suburban areas and traditional urban structures.

Keywords: spatial structure, sustainability, technical infrastructure, transportation infrastructure, economical analysis, economical sustainability, expenditures.

INTRODUCTION

Each city or town consists of various spatial structures. In such a spatial structure there are various large transport areas, different types of development as well as green areas to be found at a smaller or larger extent and therefore each specific structure has different demands as to maintenance and the financial requirements connected with it. Subsequently, the article will not only focus on the general systematisation of the most frequent spatial urban structures, but predominantly on the comparison of the economic demands of traditional urban forms (blocks of flats) and suburban development.

TYPOLOGY OF SPATIAL STRUCTURES OF A TOWN IN THE MIDDLE OF EUROPE

The structure of a town in general comprises of buildings, technical facilities, a square and non-developed areas of streets and greenery. The characteristic features of the town spatial structure (development structure) are building complexes, groups of buildings as well as individual important constructions (urban castle, medieval stronghold, etc.) and the inner premises of building complexes, main streets and squares and undeveloped areas of parks and greenery. Other characteristic qualities of the urban structure include the development density and method of how the areas are built over, the average height of the constructions as well as the quantity and nature of the dominating buildings (Vágner 1982, Marhold 1991. Navrátilová, Rozmanová 2010).

Having been inspired by our own and foreign authors (Eisner, Gallion, Eisner 1993, Kostof 1991) we have attempted to elaborate the division of urban spatial structures in a way which in our opinion should match the conditions of a present-day (Central) European town. Our division is based on the spatial characteristics of individual urban structures (this way, for example, we differ from social geographers, who proceed in their studies predominately from processes and population migration, or other functions – services and employment – in the territory). Therefore, a town of the early 21st century can be divided into the following spatial structures:

- Medieval City Core;
- City Centre (from 19th and 20th Century);
- Villas Area;
- (Socialist) Blocks of Flats;
- Industrial Area;
- Suburban Residential Area;
- Suburban Commercial Area;
- (Former) Villages Area Integrated into the Town/City;
- Recreational Area.

Medieval City Core

From the point of view of development the town centre is characterised by its density and age of individual buildings located in this part of the town. In the Central European context the town centre is identical to its historic core and its medieval foundation. Typically, there is a dense street network connected to the square; in most cases of existing towns, this is usually of a square or possibly rectangular shape, while in spontaneously growing towns it is of an irregular, usually funnel (triangle) shape. In the instance of spontaneously growing towns, the street network is irregular, following the historic terrain transport ties and links. In existing towns the street network is right-angled. In medieval times the town centre often used to be surrounded with town walls, the remnants of which have survived in some centres up to this day.

The town centre usually has a lower population density, although the opposite might be expected. Moreover, it is essential to distinguish between the so-called "day-time density" and "night-time density". The night-time density covers only the number of individuals who stay overnight in the given area (usually the number of people officially registered in the given place), while the day-time density refers to all people who are present at a certain place at a certain time. The population density term expresses the ratio between the population figures (persons) and area of the territory (in ha), on which these people live. The day-time density fluctuates particularly in the town centres. The value range is around 330 persons/ha (Hnilička 2005).

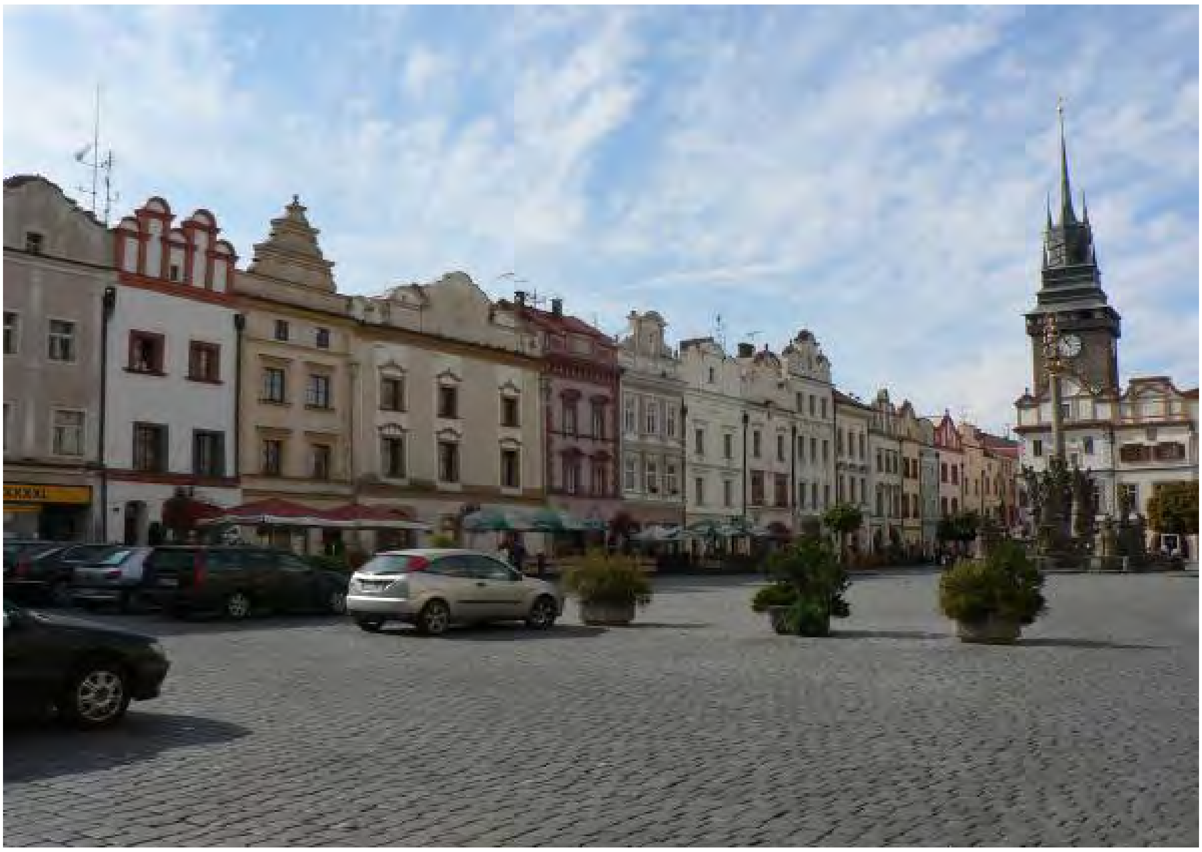


Fig. 1 Structure of a medieval city core – The city of Pardubice (© V. Šilhánková 2008).

City Centre (from 19th and 20th Century)

The nineteenth century is characterised by the development of industry, which started to change towns as well as settlement ties. Industrial areas often sprang up in a disorganised manner and encroached into the system of residential areas. In this very era technical infrastructures began developing in towns, particularly in the residential quarters. The places, where the original town walls used to stand were turned into park areas, usually of a circular shape or saw the onset of new development connecting the town with the suburbs. Later, ring roads started to be built (Šilhánková, Koutný, Čablová 2002).

Population density in the urban block development is higher than in the town centre. The buildings are usually newer and higher. These quarters often contain both administrative buildings and residential premises, along with civic amenities. It represents a multifunctional territory. Consequently, people will not have to commute back and forth to different quarters of the town. Quoting Krier (2001), the usual population density in such an urban district ranges between 250–300 persons/ha.

Fig. 2 Hradec Králové – City Centre from the beginning of the 20th Century (© V. Šilhánková 2008).

Villas Area

The urban villas area represents one of the modern urban concepts, which according to English sociologist Ebenezer Howard can be named as a "Garden City". Howard proposed the construction of the "new town" in such a way that its population density should be at about 80 persons/ha, which corresponds to regular two-storey terraced housing development. Today the term "Garden City" refers to suburban quarters comprising of family houses, which are dependent on the towns and cities that they border with (Hnilička 2005). Urban villas areas were first set up as residential localities for wealthier residents of towns, but in the second half of the 20th century they recorded a boom in the form of partially self-built family houses, which also facilitated development on plots of poorer accessibility.

An urban villas area is characterised by its low population density and is made up of detached family houses amidst greenery, in principal arranged in a block layout. The usual population density comes to approximately 100 persons/ha (Howard gives 80 persons/ha and Unwin 125 persons/ha), which corresponds to usual two-storey terraced development (Hnilička 2005).

Fig. 3 Traditional villas area in Bechyně (© V. Šilhánková 2009).

Socialist Blocks of Flats

The construction of pre-fabricated housing estates in the Czech Republic is a result of the impact of socialism (1950s to 1980s of 20th century), when there was a prevailing idea that the state was the principle entity in ensuring that all people had somewhere to live. Therefore a vast quantity of flats was built in high-rise and large-capacity buildings. Today's estates are parts of towns and cities and frequently from a distance they create a highly visible boundary between the town itself and the landscape. As to their shape they resemble large rectangular-shaped boxes with a flat lid (roof).

Estates are typical for their high population density. The standard population density in housing estates at the time of their construction ranged at around 450 persons/ha., with the maximum density at 600 person/ha. In recent decades the number of residents in housing estates has been dropping and therefore one can estimate that the density will realistically range around the standardised density, i.e. approx. 400–500 persons/ha.

Fig. 4 Krakow – Socialist blocks of flats (© V. Šilhánková 2007).

Industrial Areas

Industrial grounds and production zones started developing during the era of the industrial revolution, in our country particularly in the second half of the 19th century and they experienced their greatest boom after the middle of the 20th century. They were placed on the periphery of towns, which in the first stage was at the edge of the centre (historic core) and later in border locations in suburbia. Because of their nature it was necessary to ensure for the industrial grounds easy transport accessibility and good technical infrastructure. Green vegetation appeared in these grounds on a sporadic basis, predominantly as insulation greenery or for the optical correction of large grounds from the external view.

Fig. 5 Industrial Area – Hradec Králové (© V. Šilhánková 2012).

Suburban Residential Area

These areas are primarily intended for housing. Constructions of new family houses take place in the “green field area” – usually on the peripheries of towns and cities (suburbs), where the population moves to for specific reasons. Civic amenities (schools, shops, services) are hard to find there. The edges of the towns are gradually turned into low-density developments. Rural areas shrink considerably and simultaneously elements of urban architecture start to appear (Šilhánková 2007). By comparing the suburban area with the original rural development, one will arrive at the conclusion that these suburban areas differ not only in their appearance, but also in the domestic facilities. An ideal population density in a residential suburban area should range at around 80-100 pers./ha, which will manifest the fact that this urban settlement type works well from the point of view of housing quality, the establishment of public areas and, last but not least, sufficient greenery (Hnilička 2005). In general, population density in residential suburban areas is usually low; that is to say around 30–40 persons/ha (Šilhánková 2007).

Figure 6. Suburban residential area in Dříteč (© V. Šilhánková 2006).

Suburban Commercial Areas

The second type of suburban development represents areas of commercial nature. Unlike the industrial and production grounds, in this instance storage and sale functions prevail. For this reason they are placed in locations with good traffic access (ideally at motorway crossroads or slip roads). Connection to utility networks does not have high requirements, because the activities carried out in these zones include predominantly re-loading and direct sale of goods. Greenery is to be found in these grounds only very sporadically.

Figure 7 Suburban commercial areas in Jirny (© V. Šilhánková 2012).

(Former) Villages Area Integrated into the Town/City

The (former) villages' area integrated into the town is characterised predominantly by the development of family one or two storeys houses. Most family houses are of a rectangular ground-plan. The area offers basic civic amenities (food stores or cultural facilities). In general, (former) villages have a low building density, but fixed spatial structures (whether these are radial or linear developments). The population density usually ranges from 30 to 80 persons/ha (Hnilička 2005). Inadequate transport services are often quite common and not only inside the actual village areas, but transport connections with neighbouring villages or towns pose additional problems, too. Most of the routes, as we know them today, were completed in the 1970s.

Figure 8 Villages Area in Ptice (© V. Šilhánková 2013).

Recreational Area

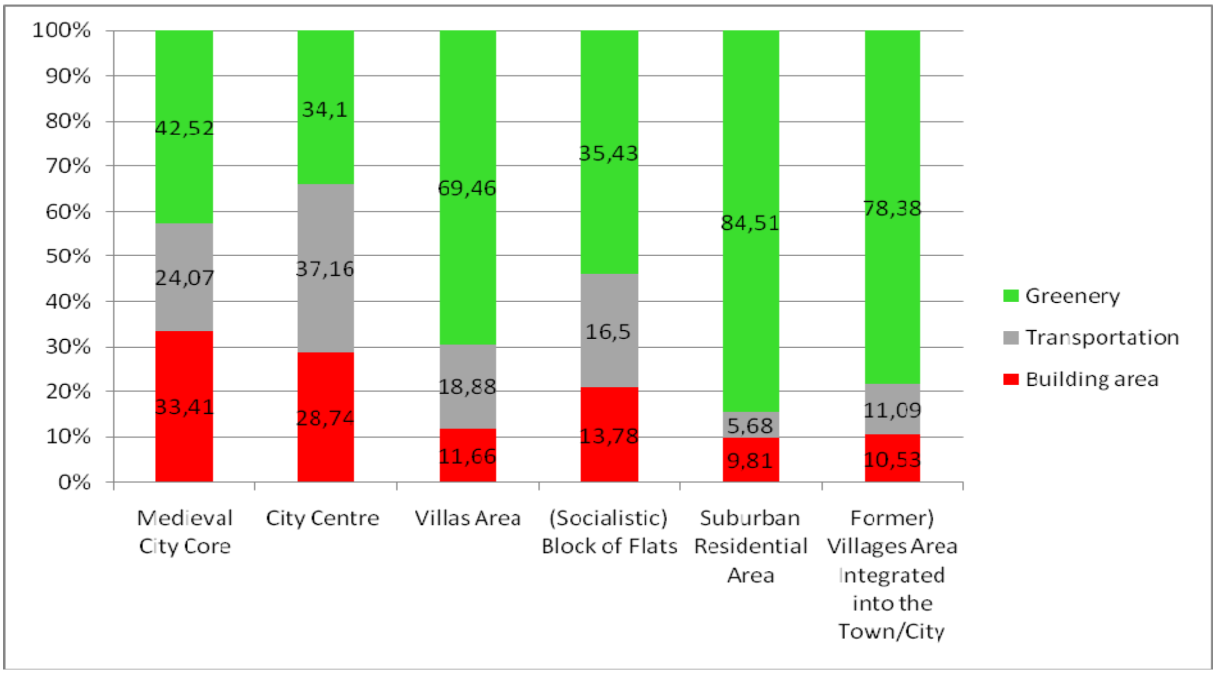
With changing patterns of behaviour and increasing amounts of leisure time the areas of urban and suburban recreation are becoming more and more important. Unlike the parks of the 19th century, today's manner of urban and suburban recreation requires larger areas for various types of sporting and outdoor activities (cycling, in-line skating, barbecues etc.). Recreational functions are thus served by large town parks, wood parks, or possibly suburban woods or the entire landscape adjoining the town. Clearly, an abundance of greenery goes without saying and obviously good traffic accessibility is necessary.

Figure 9 Recreational area – Nové Město nad Metují (© V. Šilhánková 2008).

The enumeration provided here needs to be viewed as an attempt at the systematisation of spatial structures for the purposes of our further study. In view of the more or less private nature of industrial and production zones as well as suburban areas of a commercial character, these will not be the subject of our further work. Similarly, to simplify matters and taking into consideration our objective, we will not involve the recreational zones any longer.

APPRAISAL OF THE SPATIAL ANALYSIS OF INDIVIDUAL TYPES OF SPATIAL STRUCTURES (USING THE CITY OF HRADEC KRÁLOVÉ AS AN EXAMPLE)

In order to appraise individual spatial structures, a detailed analysis was performed, focusing mainly on establishing their total area in ha, and the area of urban (public) green land and motor traffic areas. The analysis findings were put into Graph 1, which provides information about the developed and non-developed areas (the green land in total) in individual spatial structures. The prevalence of non-developed areas, that is to say areas with greenery, is absolutely evident, in some spatial structures stretching over nearly 85% of the area. The green land in total encompasses both private green vegetation and areas of urban (public) greenery. Focusing with greater attention on the residential suburban area, we will arrive at the finding that, in some aspects, it is unique. The built-up area comes to about 15% of the total area of the territory, which is quite low to be considered as urban structure (Kupčíková 2011).



Graph 1 Portion of greenery, transportation and building area in individual types of spatial structures (adapted from Kupčíková 2011).

ECONOMIC DEMANDS ON THE IMPLEMENTATION OF PUBLIC FACILITIES IN THE SELECTED TYPES OF URBAN SPATIAL STRUCTURES (USING THE CITY OF HRADEC KRÁLOVÉ AS AN EXAMPLE)

The below specified cost calculations for the construction of transport infrastructure and greenery planting have been made for typical areas of an average (Central) European town. These calculations represent a theoretical fabrication, used for comparison of the demand of individual spatial structures from the economic aspect. All the prices below are quoted from Polešáková (2011).

Medieval City Core

In the analysed selected structure sample of Hradec Králové centre there are 4.12 ha areas for road traffic. Assuming that 1/3 of this space is made up of pavements, the total area of pavements comes to 1.37 ha. In this part of the town the material used for the surfacing of these will be small cobblestones, which cost CZK 2,280/m^2. The remaining area of 2.74 ha represents roads with a tarmac surface. Moreover, this area comprises of 4.02 ha of public greenery, covering the lawn and plants on the Large Square and the part of the adjoining park. To newly build the park and install greenery on the square, it will be necessary to plant approximately 80 new trees, with each tree costing about CZK 800, plus one will have to add to this sum also the price of the planting work, which is CZK 365 per tree. Furthermore, 4 ha of park-type grass carpet will be laid, amounting to CZK 24/m^2.

Price of the new construction of transport infrastructure and planting greenery in CZK (1 EUR is approx. 25 CZK)			
	Total for the considered area	Recalculated per 1ha	Recalculated per 1 ”recalculated ” resident
Road construction	38,760,170	14,110,000	48,880
Pavement construction	31,304,400	22,800,000	39,480
Caring for the municipal appearance and public greenery	24,320,000	6,049,750	30,670
Total expenses	**94,384,570**	**11,595,160**	**119,020**

Table 1 Price of the New Construction of the Spatial Structure – **“**Medieval City Core” (adapted from Malířová 2012).

Table 1 contains the term recalculated resident. This term is construed as the number of residents in the selected part of the historic core plus the number of establishments, situated in the given location. This recalculation is applied here for the reason of the establishments using the territory in the same way as residents and moreover they contribute to the municipal budget with a certain sum in the same way as residents dwelling in the given locality.

City Centre (from 19th and 20th Century)

The analyzed sample of this urban structure contains 6.8 ha of areas for road traffic. Due to the fact that a busy pedestrian zone is located here, 2/3 of this area represents pavement surfaces. Subsequently, pavements will occupy the area of 4.53 ha and their surface will be made of cobblestones, which cost CZK 2,280/m^2. The area apportioned to roads with tarmac surfaces is 2.26 ha. The public greenery stretches over the area of 2.43 ha. Lawns cover approximately 2.4 ha and 65 deciduous trees of the average cost of CZK 2,000 along with 50 coniferous trees amounting to CZK 800 each will be planted here, plus the planting work at CZK 365 per one tree needs to be added.

Price of the new construction of transport infrastructure and planting greenery in CZK			
	Total for the considered area	Recalculated per 1ha	Recalculated per 1 ”recalculated ” resident
Road construction	31,983,140	14,110,000	10,690
Pavement construction	103,359,240	22,800,000	34,550
Caring for the municipal appearance and public greenery	62,050,000	25,534,980	20,740
Total expenses	**197,968,380**	**21,448,360**	**66,170**

Table 2 Price of the New Construction of the Spatial Structure – “city centre” (adapted from Malířová 2012).

Villas Area

In the selected sample of a part of the villas quarter there are 3.56 ha of areas for road traffic, of which 1/3 represents the pavement areas and the remaining part is apportioned to the tarmac surface of roads. Pavements in this part of the town will not be made up of cobblestones, as was the case in the city centre, but of profile blocks, which will come to CZK 834/m^2; this part of the town is not so frequented, and is not necessary to have such a presentable nature as it is in the central zone of the town. This quarter contains a very low number of public lawns and vegetation areas, i.e. 1.7 ha. The whole area will be covered with new grass carpet, which will cost CZK 24/m^2, and approx. 55 deciduous and 10 coniferous trees will be planted here.

Price of the new construction of transport infrastructure and planting greenery in CZK			
	Total for the considered area	Recalculated per 1ha	Recalculated per 1 ”recalculated ” resident
Road construction	33,487,260	14,110,000	39,540
Pavement construction	9,897,080	8,340,700	11,680
Caring for the municipal appearance and public greenery	76,557,260	45,033,680	90,390
Total expenses	**86,862,340**	**16,513,750**	**102,550**

Table 3 Price of the New Construction of the Spatial Structure – “villas area” (adapted from Malířová 2012).

Socialist Blocks of Flats

The total of 3.58 ha of areas for road traffic is to be found in the analyzed sample, with pavements making up 1.19 ha of that figure. New construction of pavements with profile block surfaces will cost CZK 834/m^2. The area of roads with tarmac surfaces comes to 2.38 ha and its price equals CZK 1,411/m^2. The public greenery areas stretch over 7.69 ha, and 190 deciduous trees, which cost CZK 2,000, and 40 coniferous trees at CZK 800 each will be planted at this location. The price of the actual planting work needs to be added to the price of the trees and it amounts to CZK 365 per tree. The grassed area will take up 7.6 ha with the costs of CZK 24/m^2.

Price of the new construction of transport infrastructure and planting greenery in CZK			
	Total for the considered area	Recalculated per 1ha	Recalculated per 1 ”recalculated ” resident
Road construction	33,676,340	14,110,000	8,600
Pavement construction	9,952,120	8,340,000	2,540
Caring for the municipal appearance and public greenery	152,204,000	19,792,460	38,860
Total expenses	195,832,460	**17,376,440**	**50,000**

Table 4 Price of the New Construction of the Spatial Structure – “(socialist) block of flats”(adapted from Malířová 2012).

Suburban Residential Area

The area of public space in the selected sample of the suburban residential area is very low, the areas destined for road traffic are 0.92 ha, of which 3,067 m^2 is apportioned to pavements; the price of the construction of new pavements using profile blocks amounts to CZK 834/m^2. The area for roads, which will have a tarmac surface, is 0.61 ha, and the price of such a communication amounts to CZK 1,411/m^2. The areas represented by town greenery come to a mere 0.17 ha. This area will be covered with a park-type grass carpet, which costs CZK 24/m^2. Ten deciduous trees that on average amount to CZK 2,000 will be planted here with the costs of the actual planting work being CZK 365 per one tree.

Price of the new construction of transport infrastructure and planting greenery in CZK			
	Total for the considered area	Recalculated per 1ha	Recalculated per 1 ”recalculated” resident
Road construction	8,653,660	14,110,000	26,870
Pavement construction	2,557,880	8,340,000	7,940
Caring for the municipal appearance and public greenery	7,340,800	43,181,180	22,800
Total expenses	**18,552,340**	**17,020,500**	**57,620**

Table 5 Price of the New Construction of the Type Structure –”suburban dwelling area” (adapted from Malířová 2012).

(Former) Villages Area Integrated into the Town/City

The selected sample of the (former) villages’ area contains 2.01 ha of areas for road traffic. One third of this total represents the area of pavements, corresponding to 0.67 ha, and their new construction with profile block surface will cost CZK 834/m^2. The remaining part, that is to say 1.34 health, is made up of tarmac surface roads, whose new construction will come to CZK 1,411/m^2. The town greenery stretches over 0.14 ha. The whole area will be covered with a new park-type grass carpet, which costs CZK 24/m^2, and moreover 10 coniferous trees amounting to CZK 800 each and 10 deciduous trees at the price of CZK 2,000 will be planted here, plus one will have to add to this sum the price of the planting work, which is CZK 365 per one tree.

Price of the new construction of transport infrastructure and planting greenery in CZK			
	Total for the considered area	Recalculated per 1ha	Recalculated per 1 ”recalculated” resident
Road construction	18,907,400	14,110,000	74,440
Pavement construction	5,587,800	8,340,000	22,000
Caring for the municipal appearance and public greenery	68,900	492,140	0,270
Total expenses	**24,564,100**	**11,425,000**	**96,710**

Table 6 Price of the New Construction of the Type Structure – “(former) villages’ area integrated into the town/city” (adapted from Malířová 2012).

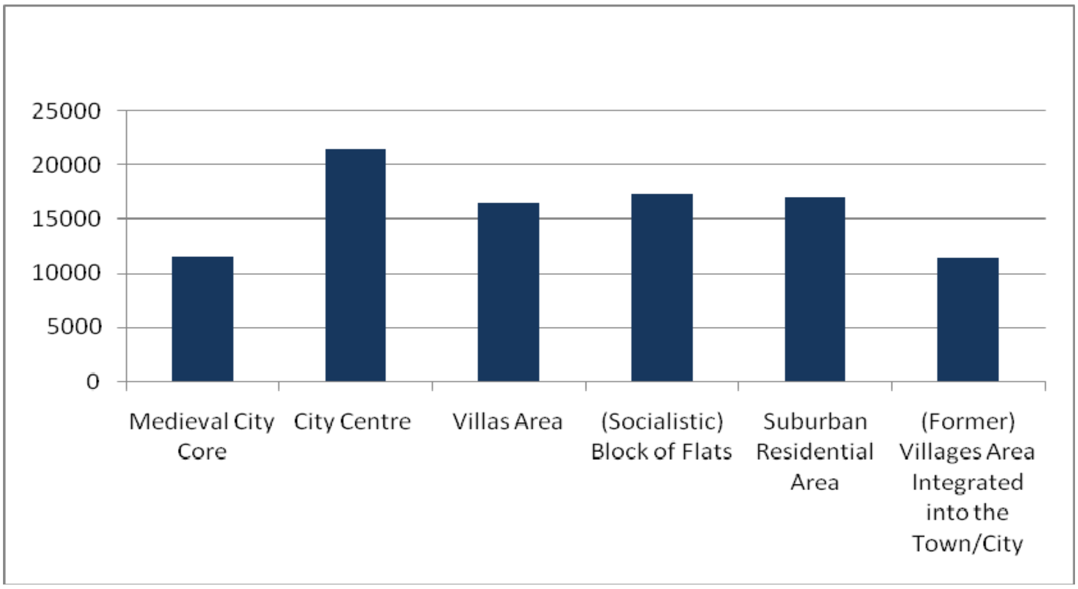
COMPARISON OF THE ECONOMIC DEMANDS OF THE CONSTRUCTION OF INDIVIDUAL TYPES OF URBAN SPATIAL STRUCTURES

A comparison of the economic demands of the construction of individual spatial structures was based on individual expenses, which would theoretically be spent on the construction of public spaces and roads/pavements recalculated per 1 ha of the area of the given spatial structure, if these were to be rebuilt as new.

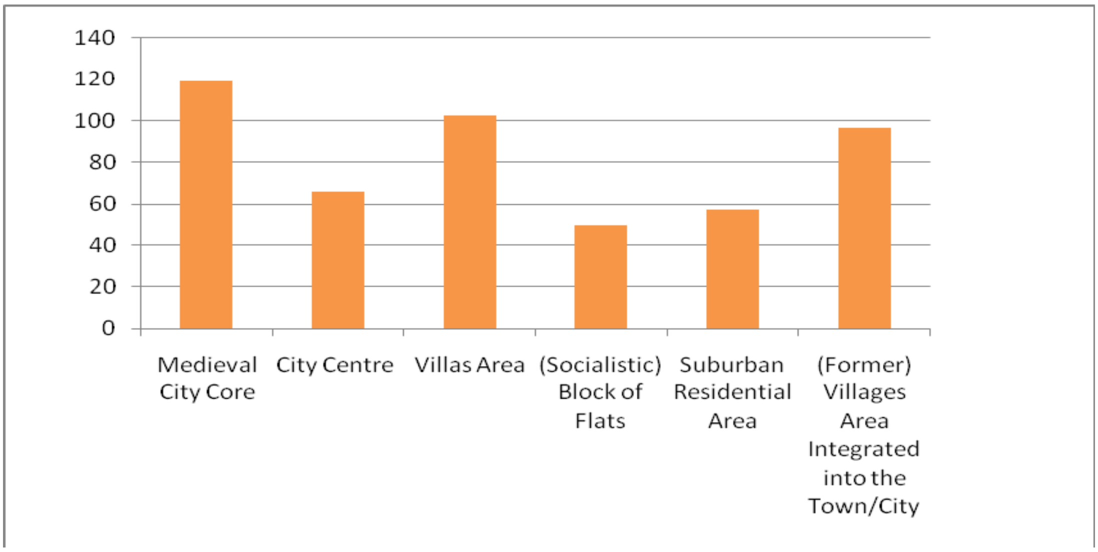
	Costs recalculated per 1 ha	**Order**	**Costs recalculated per 1 resident**	**Order**
Medieval City Core	11,595,160	2	119,020	6
City Centre	21,448,360	6	66,170	3
Villas Area	16,513,750	3	102,550	5
(Socialist) Block of Flats	17,376,440	5	50,000	1
Suburban Residential Area	17,020,500	4	57,620	2
(Former) Villages’ Area Integrated into the Town/City	11,425,000	1	96,710	4

Table 7 Comparison of the Costs of Transport Infrastructure Construction and Planting Greenery according to Individual Types of Spatial Structures (adapted from Malířová 2012).

As seen in the Table, with respect to the construction recalculated per 1 ha the villages area appears to be the most advantageous, with the historic core being second, followed by the urban villas area in third. Nonetheless, if the construction costs are recalculated per 1 resident living in the given locality, the order of advantages is utterly different. In this case it is the housing estate, which arises as the most advantageous, with second place going to be the suburban residential area and third the town centre. For better illustration purposes, these data are depicted in the following graphs.



Graph 2 Comparison of the Costs of Construction of 1 ha according to Individual Types of Spatial Structures (adapted from Malířová 2012).



Graph 3 Comparison of the Costs of Construction Recalculated per 1 Resident according to Individual Types of Spatial Structures (adapted from Malířová 2012).

Proceeding from the data above one may arrive at the conclusion that the economic demands of suburban zone construction are in essence favourable for the municipality, since the simplified analysis shows that when recalculated per 1 ha of the land these structures are comparable with blocks of flats as well as urban villas areas and they are even more advantageous than the traditional urban block development. With respect to the recalculation per one resident they appear to be the second most advantageous spatial structure.

COMPARISON OF THE ECONOMIC DEMANDS OF INDIVIDUAL TYPES OF URBAN SPATIAL STRUCTURES CONCERNING MAINTENANCE

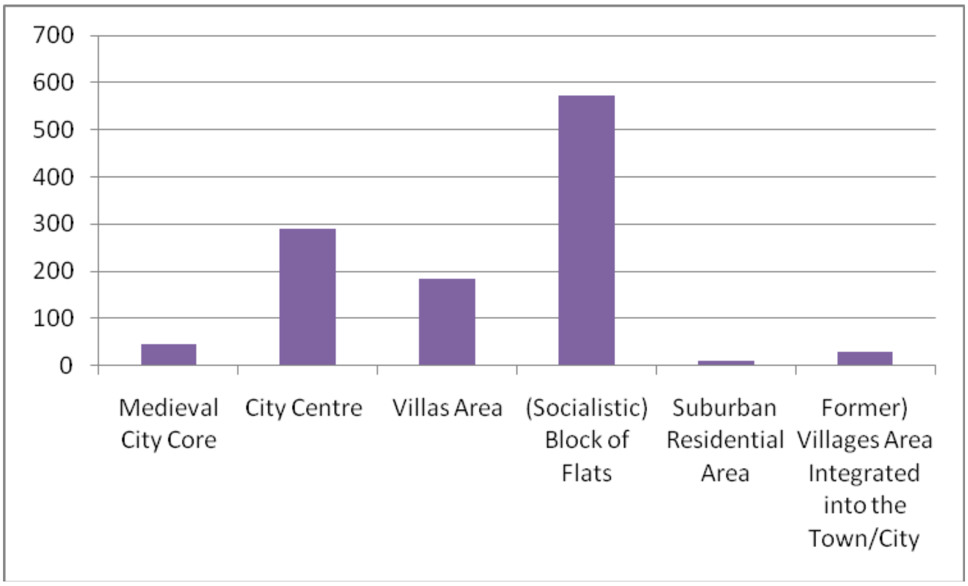
A comparison of the economic advantages concerning the maintenance of individual spatial structures derive from the maintenance costs for 1 ha of the selected area and individual costs per 1 recalculated resident.

	Costs recalculated per 1 ha	**Order**	**Costs recalculated per 1 resident**	**Order**
Medieval City Core	45,750	3	800	4
City Centre	290,510	5	590	1
Villas Area	184,840	4	1,620	3
(Socialist) Block of Flats	571,440	6	610	2
Suburban Residential Area	10,330	1	960	5
Former) Villages Area Integrated into the Town/City	30,010	2	2,500	6

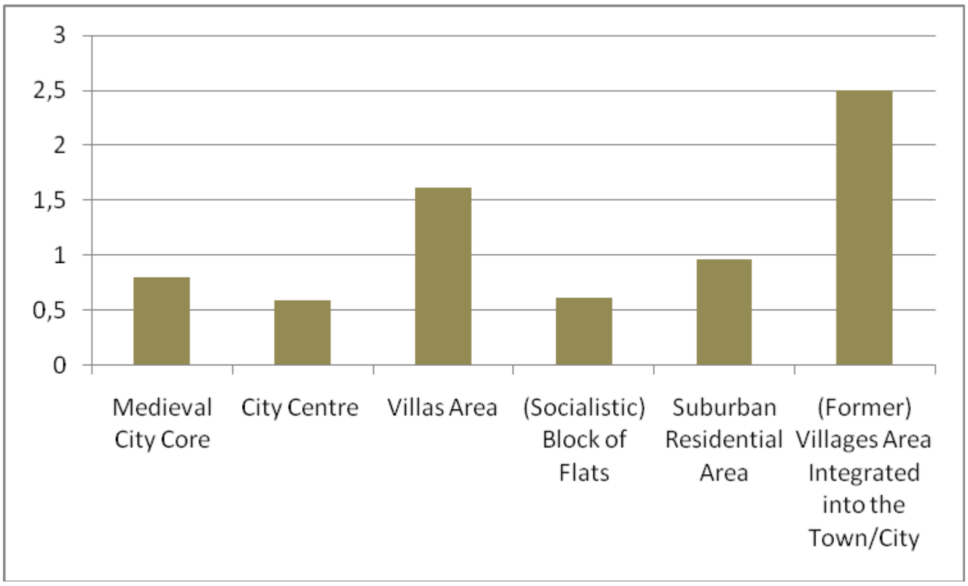
Table 8 Comparison of the Costs of Maintenance of Transport Infrastructure and Greenery Areas according to Individual Types of Spatial Structures per One Year (adapted from Malířová 2012).

This comparison of maintenance costs needed for 1 ha of public space in individual selected urban structures demonstrates that the most costly maintenance of 1 ha of land appears to be on the housing estate, then in the central urban area with the third most costly structures being in this case the historic core. On the other hand the least costly maintenance from this aspect seems to be needed in the suburban residential area together with the former villages' area.

However, on viewing the maintenance costs of the public space recalculated per 1 resident dwelling in the given locality, one will ascertain that the situation is reversed. That is to say the highest costs of maintenance are needed in the former villages' areas together with the suburban development. Instead, the lowest maintenance costs will be consumed by the town in central urban quarters, with a similar outcome also applying to the blocks of flats. For better illustration purposes, the said figures are depicted in the graphs below.



Graph 4 Comparison of the Maintenance Costs per 1 ha according to Individual Types of Spatial Structures in One Year (adapted from Malířová 2012).



Graph 5 Comparison of the Construction Costs Recalculated per 1 Resident a Year according to Individual Types of Spatial Structures (adapted from Malířová 2012).

OVERALL COMPARISON OF THE ECONOMIC DEMANDS OF CONSTRUCTION AND MAINTENANCE ACCORDING TO INDIVIDUAL TYPES OF URBAN SPATIAL STRUCTURES

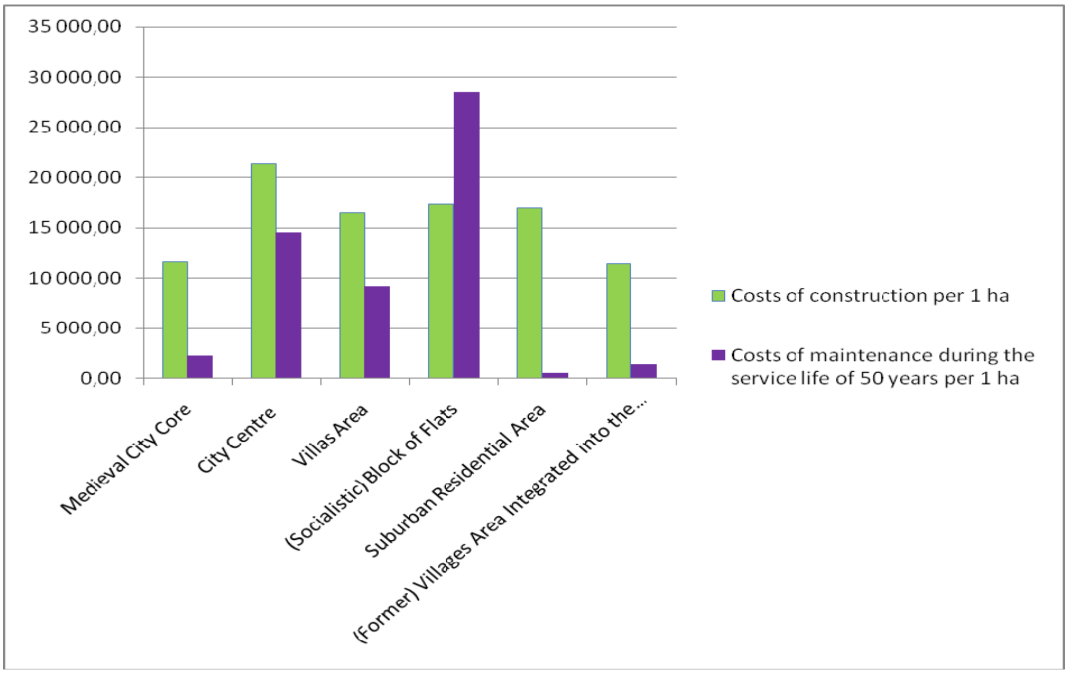
To make it possible to compare the costs of construction of individual spatial structure types, one needs to consider maintenance costs for the entire service life of the individual structure types, this period has been set here as 50 years. For the purposes of the study this value is obtained in a simplified manner by a mere multiplication of the maintenance costs achieved per one year in the previous section.

	Costs of construction per 1 ha	Order	Costs of maintenance during the service life of 50 years per 1 ha	Order	Costs of construction per 1 recalculated resident	Order	Costs of maintenance during the service life of 50 years per 1 recalculated resident	Order
Medieval City Core	11,595,160	2	2 287,500	3	119,020	6	40,000	3
City Centre	21,448,360	6	14 525,500	5	66,170	3	29,500	1
Villas Area	16,513,750	3	9 242,000	4	102,550	5	81,000	5
(Socialist) Block of Flats	17,376,440	5	28 572,000	6	50,000	1	30,500	2
Suburban Residential Area	17,020,500	4	516,500	1	57,620	2	48,000	4
(Former) Villages’ Area Integrated into the Town/City	11,425,000	1	1 500,500	2	96,710	4	125,000	6

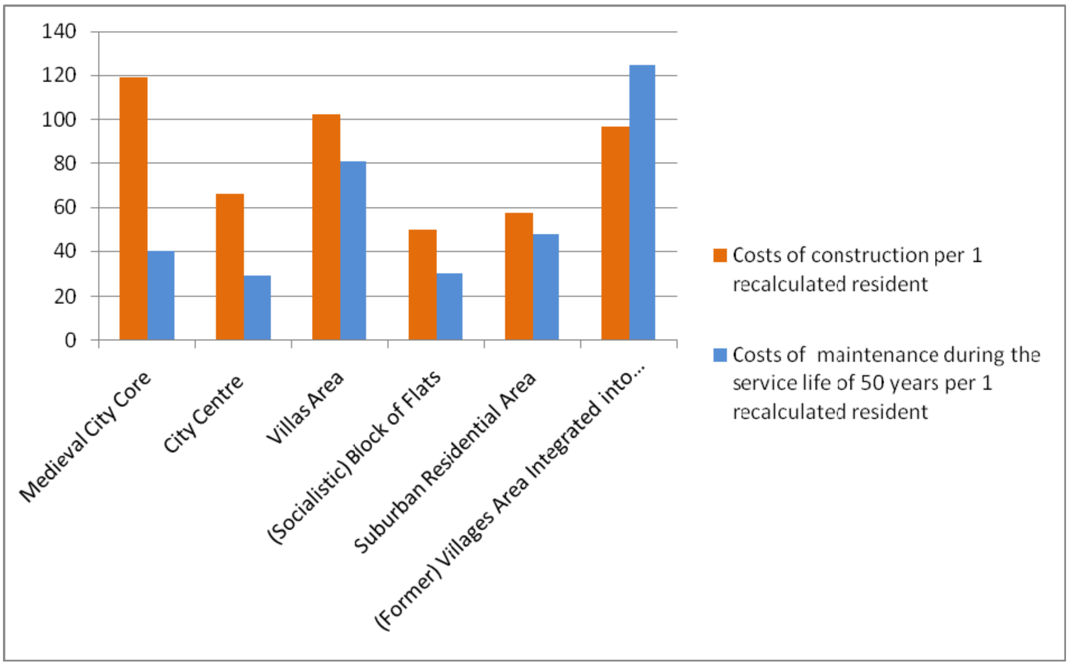
Table 9 Comparison of the Construction and Maintenance Costs of Individual Types of Urban Spatial Structures in CZK (adapted from Malířová 2012).

As demonstrated in the Table, construction costs differ significantly from the maintenance costs for the service life of individual types of spatial structures both when recalculated per 1 ha and per 1 resident. When comparing the construction and maintenance costs recalculated per 1 ha of the area, the largest difference was recorded in the suburban residential area, where the construction costs are nearly the highest, nonetheless the costs of its maintenance are the lowest of all structure types. Moreover, there is an enormous gap between the costs of the construction and maintenance in the historic core, where these two figures differ greatly. Another situation worth mentioning is that of the housing estate area, whose construction is not especially financially demanding, yet the costs of its maintenance significantly exceed the construction price.

Considering the individual costs recalculated per 1 resident the situation appears to be somewhat different. The largest difference between the construction and the maintenance costs have been recorded by the historic core, where maintenance costs are several fold lower than the costs of its construction. Similar figures have been obtained for the central quarter, which has fairly high financial demands on construction, however the maintenance costs recalculated per 1 resident are the lowest of all of the described structures. Relatively balanced costs of construction and maintenance of public spaces can be found in suburban residential areas, blocks of flats and urban villas areas. As to the former villages area one can ascertain that the maintenance costs recalculated per 1 resident for the period of its service life are higher than the construction costs.



Graph 6 Comparison of the Construction and Maintenance Costs per 1 ha according to the Individual Types of Spatial Structures (adapted from Malířová 2012).



Graph 7 Comparison of the Construction Costs according to the Individual Types of Spatial Structures per 1 Recalculated Resident (adapted from Malířová 2012).

The graphs above clearly demonstrate the dissimilarity between the two perspectives on the division of costs recalculated per 1 ha of the land and per 1 resident. Nonetheless, this simple analysis shows that our hypothesis assuming that suburban zones as such are disadvantageous for the city from the point of their financial demands, which they need for their functioning, has not been proven. However, in this connection it is advisable to contemplate about what "town" and "town-creating" functions the individual type of spatial structures offer and whether this is not the case of some quarters of the town getting a "free ride" to the detriment of the others.

FINANCIAL DEMANDS OF THE TRANSPORTATION AND TECHNICAL INFRASTRUCTURE – COMPARISON BETWEEN SUBURBAN AREAS AND URBAN (BLOCKS) DWELLING AREA

To simplify matters the following text will concentrate only on the comparison of the requirements for the transportation and technical infrastructures between traditional urban development (blocks of flats) and residential suburban development.

Economic Demands of the Transportation and Technical Infrastructures in Suburban Areas

Predictable Price of Building the Transportation Infrastructure

Under Czech technical regulations (ČSN 736110, 2006) the most common width of one traffic lane for type C - local frontage roads is 2.75 m. The width of the road must therefore be 5.5 m. On the outer side of each traffic lane, there must be at least a 0.25 m marginal strip serving for drainage purposes. There must also be a safety zone between vehicles and pedestrians on each side measuring 0.25 m. The final part is the footpath which must be at minimum 1.5 m wide. The entire road must be 8 m in width. By using formula (1) we are able to calculate the area utilized by the transportation infrastructure in the analyzed municipalities.

$$R_{DI} = (ZU \times 10^4) \times DI \ [m^2] \qquad (1)$$

where R_{DI} = Transportation infrastructure area [m²]

ZU = Urbanizing area [ha]

DI = Portion of transportation infrastructure area [%]

It is impossible to know the exact financial requirements of the planned transportation infrastructure in urbanizing residential areas. We can however make use of the data showing average financial requirements which are available from the state Urban Research Institute (Polešáková 2011).

Roads of type C - local frontage roads have most frequently non-solid surfaces, i.e. asphalt layers. The cost of 1 m^2 of road is between CZK 1,176.00 and 1,411.00 per 1m^2 depending on the thickness of separate layers and their type. In our work we calculated an average of CZK

1,300.00 per $1m^2$. The footpaths were calculated as being a pavement of concrete construction which is most frequently used. The average price of $1m^2$ of pavement is between CZK 775 and 916 per $1m^2$ depending on the thickness of separate layers and their type. The average price of $1m^2$ of footpath is CZK 850. Bicycle lanes and parking spots were not calculated for reasons of simplification (Rybová 2012).

Predictable Price of Building the Technical Infrastructure

The price of the technical infrastructure depends on several factors. It does not only depend on the length of the cables and pipes used. The position of the urban structures and the technical parameters of these structures are also important. It is important to understand the differences between the technical infrastructure in the city centre, in the main city streets, in residential areas or in the areas outside the urban structures.

The first set of information, which was necessary to calculate, was the proposed length of the technical infrastructure network in urbanizing areas. The calculation is based on the assumption that the technical infrastructure will be implemented beneath the surface of the transportation infrastructure (e.g. under new roads or footpaths). By using previous data it was possible to calculate the length of the transportation infrastructure and also the length of the technical infrastructure which was the same.

$$d=\left(\frac{ZU x DI}{Š}\right) x 10^4 \text{ [m]} \qquad (2)$$

where
d = Length of TI pipes [m]
ZU = Urbanizing area [ha]
DI = Proportion of transportation infrastructure area [%]
Š = Road width [m]

Using this formula we are able to count estimated price of individual items of technical infrastructure. From this, it is clear how many meters of technical infrastructure must be built in each municipality. The following task was connected with establishing the average price of a running meter (rm) of separate types of technical infrastructure.

The water supply for one residential house is usually implemented by using PVC pipes (PN 10) of 100 mm gauge. The price of these pipes is CZK 6,120 per rm. Plastic pipes with a 400 mm gauge are used for the sewage system (information from master plans). The price of these pipes is CZK 15,000 per rm. The cost of the connection of a house for sewage and rain water, if we use plastic pipes for the calculation, will be on average CZK 3,600 each. The cable line for houses in a residential area uses low voltage of the 4 x 16 to 35 type. It is necessary to count on using two cables in an urbanized area. The average price is CZK 960 per rm. Today the gas pipes used are also plastic, so we calculated the cost of plastic pipes with a 110 mm gauge, which amounts to CZK 3,110 per rm. The connection of the house is also necessary to calculate. In our case a connection on the lowest level is adequate, which means a DN 32 connection to the DN 110 pipe line as mentioned above. The gas connection of a house is on average 5 m long and will cost CZK 14,870. One very important part of the technical infrastructure in a residential area is public lighting. There is only one possible solution for this which is metal street lamps of 8 m in height. These lamps including the cabling cost CZK 44,800 each. The lamps must be placed at a distance of 30 m apart (Polešáková 2011, ČSN 73 6005, 1994).

Due to the fact that in some cases the calculation is based on house connections with prices per piece, it was necessary to calculate how many residential houses could be built in the newly planned urbanizing area. For our calculation we used as an average a building plot with the area of 1,000 m^2 for one house.

In the average prices of technical infrastructure the cost of the new technical infrastructure network for 1 ha in a residential area is CZK 2,231,000 which represents approx. CZK 223,500 per one new family house, or more precisely CZK 89,400 per one new resident (Rybová 2012).

Economic Demands of the Transportation and Technical Infrastructures in Urban (Blocks) Dwelling Area

Estimated Price of the Transportation Infrastructure Construction

In calculating the estimated price of the transportation infrastructure construction, this is processed similarly, as in the case of the calculation for the suburban zone. However, the proportion of transportation areas in this type of development will be counted with the width of the traffic belt of 12 m (compared with 8 m in suburban development), which represents two traffic lanes of the overall width of 6.5 m, hard shoulder of 1.5 m in width and two 2 m wide pavements. Subsequently, that means that the main traffic area with tarmac surface will take up 8 m and the adjoining block-paved traffic area 4 m of the width of the street section.

The calculated estimated price of the transportation infrastructure construction in CZK thousands for individual localities of urban type housing in apartment buildings is such: installation of the transportation infrastructure on 1 ha of a new area for residential purposes costs approx. CZK 2,132,800 (Rybová 2012).

Estimated Price of Technical Infrastructure Construction

For the calculation of the length of the technical infrastructure the formula (2) will be used and further it will be preceded in the cost calculation of individual types of technical infrastructure in various localities. Since it is necessary to include in the calculation individual service lines, we will count one service line on average for 12 flats (3 flats per floor in a four-storey building).

With the average prices the price of new technical infrastructure per 1 ha of new area for residential purposes costs CZK 6,172,900, which represents approximately CZK 85,900 per one new flat or more precisely CZK 34,400 per one new resident (Rybová 2012).

CONCLUSION

In conclusion the estimated costs of the transportation and technical infrastructure in suburban and urban (town) residential zones have been compared. As it arose from the previous discussion above, the installation of the transportation infrastructure on 1 ha of new land for residential purposes in the suburban area costs almost CZK 730,000, the same sized development area with the urban type of development represents approx. CZK 2,130,000, which is about 3 times higher. With average prices, the price of new technical infrastructure on 1 ha of a residential development area comes to CZK 2,231,000 in suburbia, and with respect to the urban development type represented by apartment buildings the price climbs to CZK 6,173,000, which is still almost three times as much. Therefore, it could seem that the construction of the urban type housing is economically less expedient.

However, these data will look somewhat different if we recalculate the costs per one new family house or more precisely new flat. Here the economic advantage completely turns around, since in the suburban zone the price of the technical and transportation infrastructure is approximately 296,300 per one family house and in the urban development it is CZK 115,600 per one new flat. Recalculated per resident (proceeding from the same average number of dwellers in the family house/flat of 2.5 residents per one residential unit) we arrive at the prices of CZK 118,500 per one new resident in suburbia vs. CZK 46,200 per one new resident in urban housing, which is more than a 2.5 times advantage in favour of urban residential development compared with a suburban area.

At this stage of knowledge one may say that the emerging suburban development is considerably disadvantageous from an economic point of view. If the costs connected with its construction are assumed by investors or possibly developers, it could seem that the economic impact of this type of construction does not burden municipal budgets. In fact the opposite is true. Almost all of the infrastructure built in this way becomes municipal property after its approval by building authorities or it is handed over to infrastructure companies founded by municipalities (e.g. Water-piping and Sewage), whereby the public sector assumes the obligation to maintain and repair this infrastructure and after the end of its service life to renew it. In this a problem emerges, because the ratio of economic disadvantage between the suburban development and urban development remains the same, i.e. administration and maintenance of suburban areas will cost municipalities 2.5 times more than the administration of urban type areas.

Obviously, one has to point out that the performed comparative analysis proceeds from average calculated prices and does not include other aspects of construction and particularly the functioning of urban and suburban structures (it will be necessary to include public greenery land, the public transport service in the area and include the costs connected with infrastructure maintenance etc.). An analysis of specific construction including a real price calculation for both types of spatial structures will be the next step in this work.

REFERENCES

ČSN 73 6005 *Prostorová úprava vedení technického vybavení*, Český normalizační institut: Praha 1994

ČSN 73 6110 *Projektování místních komunikací*, Český normalizační institut: Praha 2006

S. Eisner, A. Gallion, & S. Eisner *The Urban Pattern*, John Willey & Sons: London 2003

Google Maps (2012) Retrieved July 15, 2013 from http://www.maps.google.cz

S. Kostof, *The City Shaped, Urban Patterns and Meanings through History*, Thames & Hudson Ltd.: London 1991

L. Krier, *Architektura - volba nebo osud*, Academia: Praha 2001

Z. Kupčíková, (*Charakter (hustoty) zástavby a její vliv na místní ekonomiku (investiční i provozní náklady) ve městě Hradec Králové*. Unpublished master's thesis, Supervisor Vladimíra Šilhánková, Univerzita Pardubice:Pardubice 2011

T. Malířová, *Prostorové struktury měst a jejich ekonomická náročnost* in Regionální rozvoj mezi teorií a praxí, mimořádné číslo 2012, Retrieved June 25, 2012 from: http://www.regionalnirozvoj.eu/2012mimoradne-cislo/prostorove-struktury-mest-jejich-ekonomicka-narocnost

K. Marhold, *Sídla. Urbanistická typologie II.*, České vysoké učení technické: Praha 1991

A. Navrátilová, N. Rozmanová et al., *Principy a pravidla územního plánování*, Ústav územního rozvoje: Brno. 2010 Retrieved February 18, 2011, from http://www.uur.cz/default.asp?ID=2571

M. Polešáková et al., *Průměrné ceny dopravní a technické infrastruktury – aktualizace 2011*, Ústav územního rozvoje: Brno 2011 Retrieved June 25, 2012 from: http://www.uur.cz/default.asp?ID=899>

J. Rybová, *Vyhodnocení infrastrukturních potřeb pro lokality suburbánní zástavby na příkladu zázemí města Pardubic*, Unpublished master's thesis, Supervisor Vladimíra Šilhánková, Univerzita Pardubice: Pardubice 2012

V. Šilhánková et al. *Suburbanizace - hrozba fungování malých měst*, Civitas per Populi: Hradec Králové 2007

V. Šilhánková, J. Koutný & M. Čablová, *Urbanismus a územní plánování*, Univerzita Pardubice: Pardubice 2002

S. Vágner, *Sídelní struktury*, Vysoké učení technické, Fakulta architektury: Brno 1982

An analysis of integrated ventilation systems with desiccant wheels for energy conservation and IAQ improvement in commercial buildings

Seong W. Lee[1], Xuejun Qian, Steven Garcia
Industrial and Systems Engineering Department
School of Engineering
Morgan State University, Baltimore, Maryland 21251, U. S. A.
[1]*seong.lee@morgan.edu*

ABSTRACT

Ventilation systems are critical to heating or cooling spaces in commercial buildings. 2% of one fifth of all the energy produced in the U.S. is consumed by the commercial buildings' ventilation systems. However, the existing ventilation systems are needed to improve the energy efficiency and indoor air quality (IAQ) strategy. The integrated ventilation technologies are demanding to reduce energy use and ensure IAQ and dissemination to market. The Schaefer Engineering Library at Morgan State University was selected as a demonstration site with integrated ventilation strategies. Different Software (Design Builder, Trace 700, etc.) and Design of Experiment (DOE) were used to model and analyse the UFAD and overhead variable air volume (VAV) ventilation systems. The annual energy simulation results indicated that integrated systems along with different source technologies could save more than 20% of energy and improve significant amount of IAQ.

Keywords: Ventilation; Overhead Variable Air Volume (OHVAV); Under Floor Air Distribution (UFAD); Desiccant Wheel; Energy Efficient; Indoor Air Quality (IAQ).

INTRODUCTION

According to the Department of Energy 2012 Annual Energy Review, commercial buildings consume 19% of all the energy produced in the U.S. Ventilation is the method to deliver air to the individual space. Ventilation systems in commercial buildings consumed 12% of that energy. At a price of $28.92/million Btu, these systems cost $12.6 billion dollars to operate (U.S. Energy Information Administration, 2012). Therefore the design and implementation of the integrated ventilation systems are critical to commercial buildings.

There are various types of conventional ventilation systems used in commercial buildings; of which the most common are conventional air distribution (CAD) systems – for example, an overhead variable air volume (OHVAV) system. An overhead VAV ventilation system typically consists of an air handler unit (AHU) to provide the conditioned air, duct work to move the conditioned air, VAV box which modulates the conditioned air, and a ceiling diffuser which introduces the conditioned air into the space. Another new approach is the under floor air distribution (UFAD) system, which consists of an AHU, VAV box, floor diffusers, duct work, and raised floor panel. UFAD systems, in which raised access floors serve as plenums for distributing cooled air through buildings, offer the potential to reduce energy use under certain conditions (Lee et al, 2013). Cool air with low velocity in this ventilation system is introduced at the lower part of the space and spreads out above the floor. Compared to the traditional mixing ventilation, this under floor air distribution system has the possibility of creating both high temperature effectiveness and high-ventilation effectiveness (Wang et al, 2011).

HVAC systems with a desiccant wheel (DW) system are more energy efficient, with a low ambient impact, and can be profitable if compared to the traditional system; it also allows better indoor air quality (Prakash et al, 2012). It will be used in refrigerated warehouses, schools, hospitals, supermarkets etc. It is believed that thermal comfort and IAQ can be critical for energy efficiency, driving market acceptance and improvement in life cycle economics.

The objective of this study is to analyze the potential of a specific integrated ventilation system to energy conservation and improving indoor air quality in commercial buildings. Analysis and simulation results have demonstrated that the integrated ventilation system could significantly improve energy efficiency and IAQ.

BASIC CONCEPTS AND PROBLEM FORMULATION

Air Flow Model

Ventilation systems depend on the air distribution in rooms that are ventilated. Air distribution has various elements; according to (Aiulfi et al, 1998) "air distribution in ventilated rooms is a flow process that can be divided into different elements, such as, supply air jets, exhaust flows, thermal plumes, boundary layer flows, infiltration and gravity currents". Figure 1 shows the flow element model with its various jets, flow, etc.

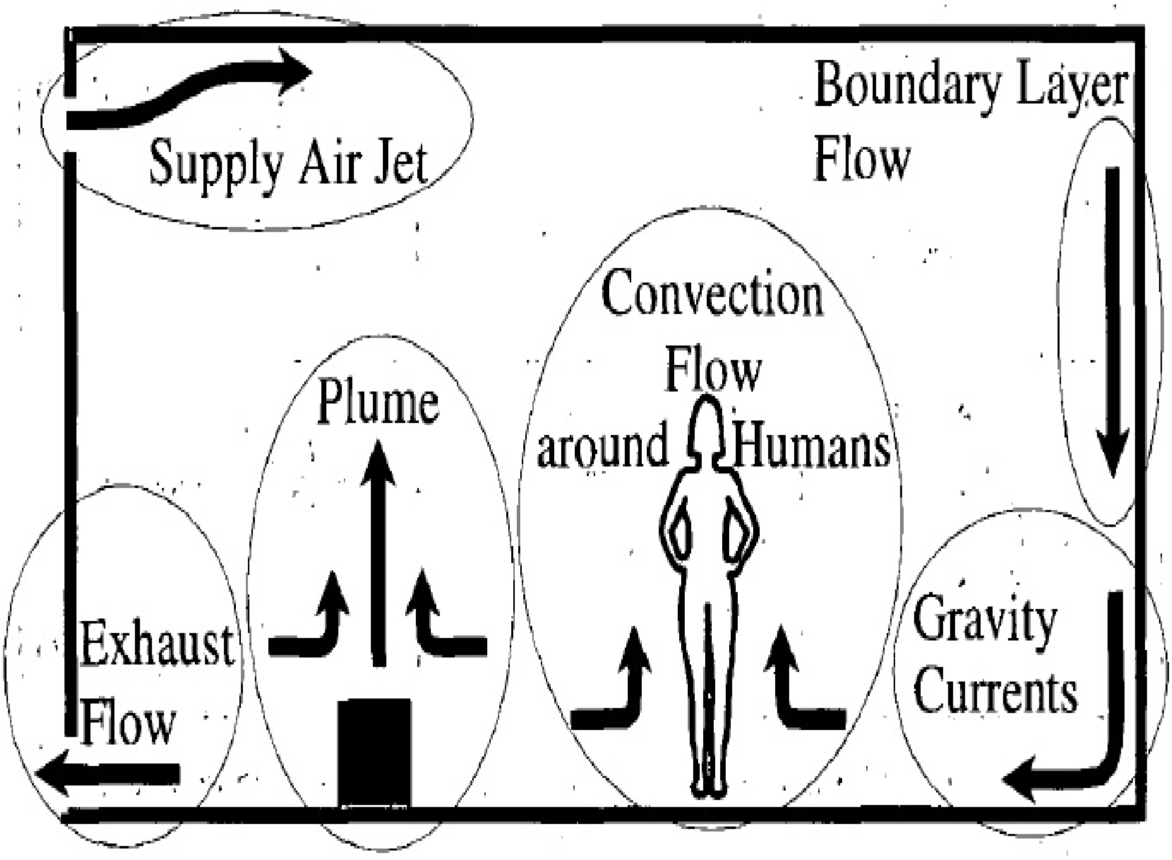


Figure 1. Flow Element Model

UFAD and OHVAV Air Distribution Systems

Air distribution systems can be designed using the flow element model. However, this model is appropriate when there is only one flow element in the room or the flow elements that do not interact with one another. In the case of displacement ventilation, such as under floor air distribution (UFAD) systems, "the supply air from a low level device and the thermal plume from heat sources above the floor are good examples of different flow elements that do not influence each other, and where the design of the air distribution system can be based on the models of these two flow elements" (Aiulfi et al, 1998).

Daly describes the system as one that "…supplies conditioned air through ducts at the ceiling and typically takes return air back through a plenum above the ceiling. The diffuser or air outlets to the supply duct system are designed to throw air around the room in such a manner to induce full mixing of the air in the occupied space. For this reason, these systems are called "mixing" systems" (Daly, 2006). The "mixing" system is ideal ventilation system which combines the conventional ventilation systems. There are two different air distribution scenarios as shown on the Figure 2 and Figure 3. Figure 2 shows the overhead air distribution scenario. Figure 3 shows the UFAD ventilation scenario.

The OHVAV air distribution is a method of bringing the conditioned air into a space using the duct- located on the top of the ceiling. The outside unconditioned air and return air coming to the AHU and mixing in the AHU becomes the conditioned air. Then, the conditioned air goes

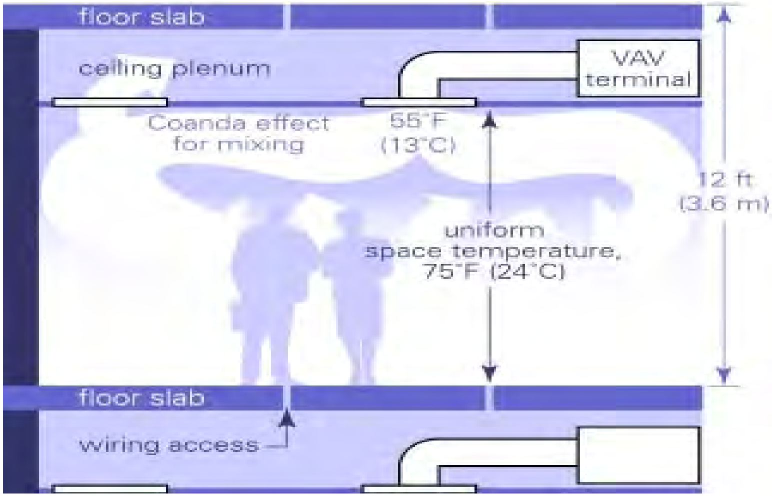


Figure 2. Overhead Ventilation Scenario

through the supply duct into the VAV box and finally the VAV box sends it through the ceiling diffuser into the space. The Overhead VAV systems use the inlet guide vanes for duct static pressure control. And the supply duct pressure is controlled by modulating dampers on the inlet of the fan, open and closed. Nowadays, variable frequency drives (VFDs) offer superior fan speed control and quieter energy efficient operation. In the overhead ventilation systems, the temperature in the room is uniform; supply and return plenum are located on the top of the ceiling with no under floor plenum.

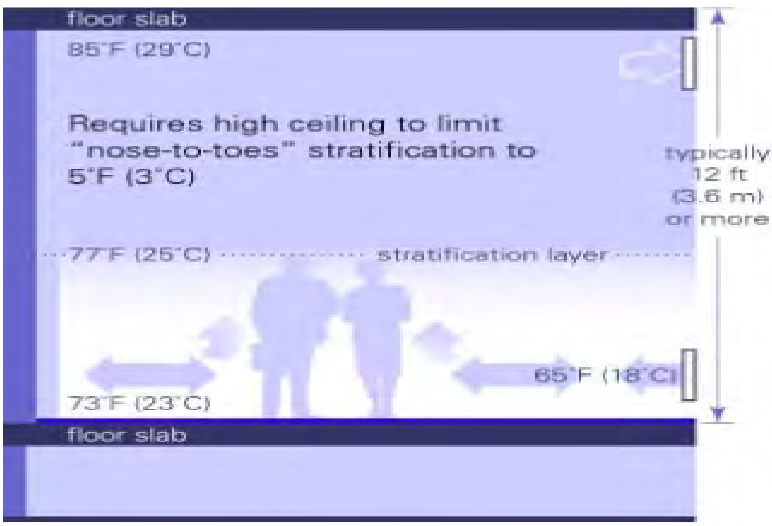


Figure 3. UFAD Ventilation Scenario

The under floor air distribution is a method of bringing the conditioned air into a space through an under floor plenum that is below the raised floor system. The operation of a

UFAD system is the opposite of an overhead ventilation system. Stanke's description of the UFAD system operation is the following:

- Floor-mounted diffusers release cool 63°F-to-68°F (17°C-to-20°C) air, which induces local circulation and causes partial mixing and relatively uniform temperatures from the floor to a height of 3 to 6 ft (1 to 2 m). Above that point, the air temperatures stratify.

- At the return openings near the ceiling, the air temperature ranges from 80°F to 85°F (27°C to 29°C), depending on heat sources, airflow, and ceiling height. (http://www.trane.com/commercial/library/vol30_4/ April 22, 2013.)

According to York International, UFAD systems offer "20% - 30% total energy savings vs. overhead HVAC system". This is due to many reasons. For example, the UFAD system operates by using low differential static pressure, "0.05" vs. "1.5 – 2.0" which is typically used for overhead supply plenums" (http://www.seco.cpa.state.tx.us/TEP_Production/g/TEPMtgsb5-york_09082004_14.pdf, 4-20-2013).

As a result, the "fan horse power" is reduced, and consequently energy consumption. Using EnergyPlus V6., Webster et al was able to create simulations comparing the UFAD vs. the overhead air distribution systems (Webster, T. et al, 2012). For example, Figure 4 shows the results of the simulation. Figure 4 shows that UFAD systems produced total heating savings of about ~45 KBtu per square feet per year. Furthermore, the total HVAC savings is between 5% and 25% (Webster et al, 2012). Other research has yielded a tool for "cooling airflow design for Displacement Ventilation (DV)". Researchers at the Center for the Built Environment (CBE) have created a program that allows the user to calculate cooling airflow based on input parameters such as the heating load of a space (Schiavon et al, 2009).

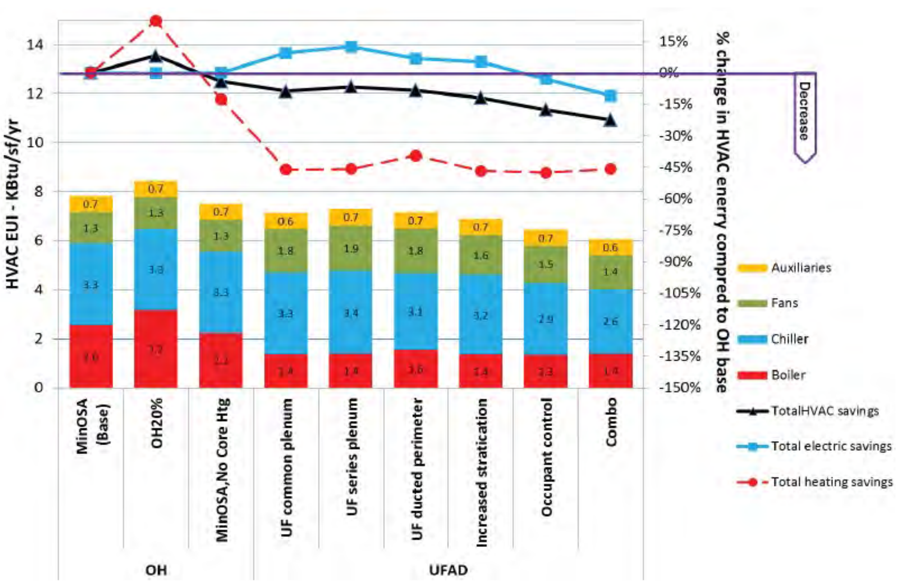


Figure 4. EnergyPlus Simulation Results

Desiccant Wheel Systems

A Desiccant wheel is a type of heat recovery system which is a honeycomb circular matrix for the moisture absorption to remove humidity from the air. Thus, the desiccant wheel has a high potential to saving energy and improve the indoor air quality (Lee et al, 2013). Desiccant wheel is rotated slowly within a system by a small electric motor and spins the desiccant coating on the wheel which absorbs the humidity in the airstream. The desiccant cooling is a technology that, based on an open psychrometric cycle, is able to provide cooling using heat as the main energy carrier. This technology uses a considerably smaller amount of electricity than refrigerators based on the vapor-compression cycle, which is an electricity driven cycle (Urrutia, 2010). Electricity is often more expensive than other types of energy and has CO_2 emissions associated with its generation, so desiccant cooling has the potential of achieving both economic and envrionmental benifits (Beccali et al, 2004).

The heating, ventilation, and air conditioning (HVAC) industry faced several challenges in the 1990s, including a decrease of energy souces, an increase in energy demand due to the population growth, and new regulatory policies. To respond to these challenges, more energy efficient heating, cooling ventilation and dehumidification technologies are needed. The higher ventilation rates for the buildings are needed because of concerns regarding IAQ and occupant health. However, the higher ventilation rates translate into greater cooling loads - in particular, greater latent loads - during cooling seasons when the relative humidity within a building must be kept sufficiently low to inhibit the growth of micro-organisms that cause health problems and also may damage building materials. Air dehumidification has become a very important part of HVAC function (Tang, 2010). Desiccant dehumidification and cooling technology can provide energy-efficient solutions for the industry. (Ahmad, 1993) Facing an increase in energy demand and the IAQ problems of the humidity which comes out from the conventional system, we need the integrated system along with the desiccant wheel to respond to the problem of the humidity and provide high energy efficient systems.

METHODOLOGY

As a fifth of all the energy produced in the U.S., 12% of that energy is being consumed by the commercial buildings' ventilation system; this means that the existing conventional ventilation systems need to improve the energy efficiency and indoor air quality (IAQ) strategy. The integrated ventilation technologies demand the reduction of energy use and ensure IAQ and distribution to the market. The Department of Energy has funded an energy innovation hub known as the EEB hub to solve this problem. Morgan State University is among the participating institutions in the hub. The staff at the Center for Advanced Energy Systems and Environmental Control Technologies (CAESECT) has applied integrated ventilation systems which include the under floor air distribution (UFAD) system and overhead variable volume (OHVAV) air distribution along with the desiccant wheel systems to reduce energy consumption and improve indoor air quality in the buildings.

Design Builder Software (version 3.0.0.105) is used for creating 3D models of buildings and is also used to perform energy simulations. Minitab 15 is used for collected baseline data and also used for analyzing and displaying data. Desiccant simulation software is used to choose the size and type of the desiccant wheel. Trace 700 software is used to design integrated systems (UFAD and OHVAV systems) along with the desiccant wheel system, and perform the heating and cooling load calculation and energy consumption simulations.

Baseline information of the schematics for the Schaefer engineering library of Morgan State University was obtained from the Department of Design and Construction Management located in the Montebello complex. The schematics included 1st floor plan view, building sections, wall sections, etc. Figure 5 is the 1st floor plan view of the Schaefer engineering library.

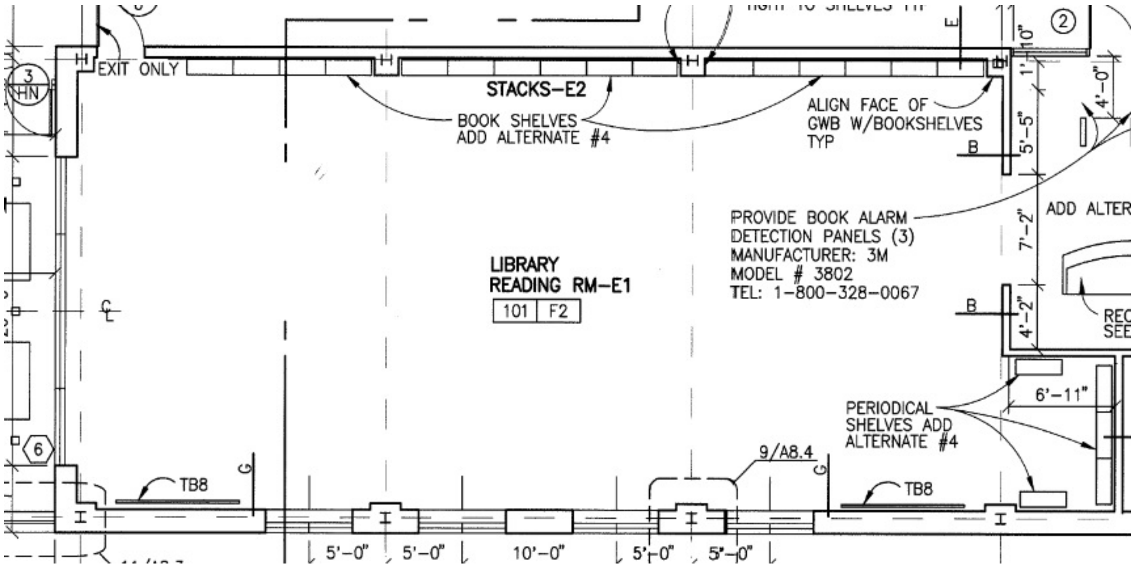


Figure 5. 1st Floor Plan View of Schaefer Engineering Library

Table 1 shows the baseline information of Schaefer Engineering Library which shows the schematics and measurement. It includes the area of the library, the dimensions of the windows, door, door opening and curtain wall. We also observed the direction of the wall and the direction and configuration of the roofs in Library. Additionally, the library has three hot water radiators to heat along the perimeter by the windows. It also has eight ceiling diffusers and three ceiling returns. There are 27 2 ft. x 4 ft. recessed fluorescent light fixtures and 15 down lights.

Type	Dimensions
Square Footage	1,839 ft.
Windows (4)	5 ft. 5 in. x 6 ft. 7 in.
Door	3 ft. x 7 ft.
Door opening	7 ft. x 8 ft.
Curtain Wall	19 ft. x 9 ft. 3 in.

Table 1. Schaefer Engineering Library Data

Based on the schematics and the all dimensions of different components in the Schaefer Engineering Library, we have designed the Overhead VAV 3D model Schaefer Engineering Library by using the Design Builder software which is shown in the Figure 6. And for the UFAD 3D model, we have just added the under floor plenum; we have also designed the return plenum height. And we are now using different construction materials to design the individual walls, door, door opening and current wall with several layers.

Then, we have defined a different ventilation system in Schaefer Engineering Library at Morgan State University, which serves the building, so that the program knows how to size the fans and coils. After having performed cooling and heating load calculations for the buildings, the program calculates the room airflows, coil loads, fan sizes, and other design system information. Defining the system tells the program how to calculate design information and what components (coils, fan, etc.) make up the system itself.

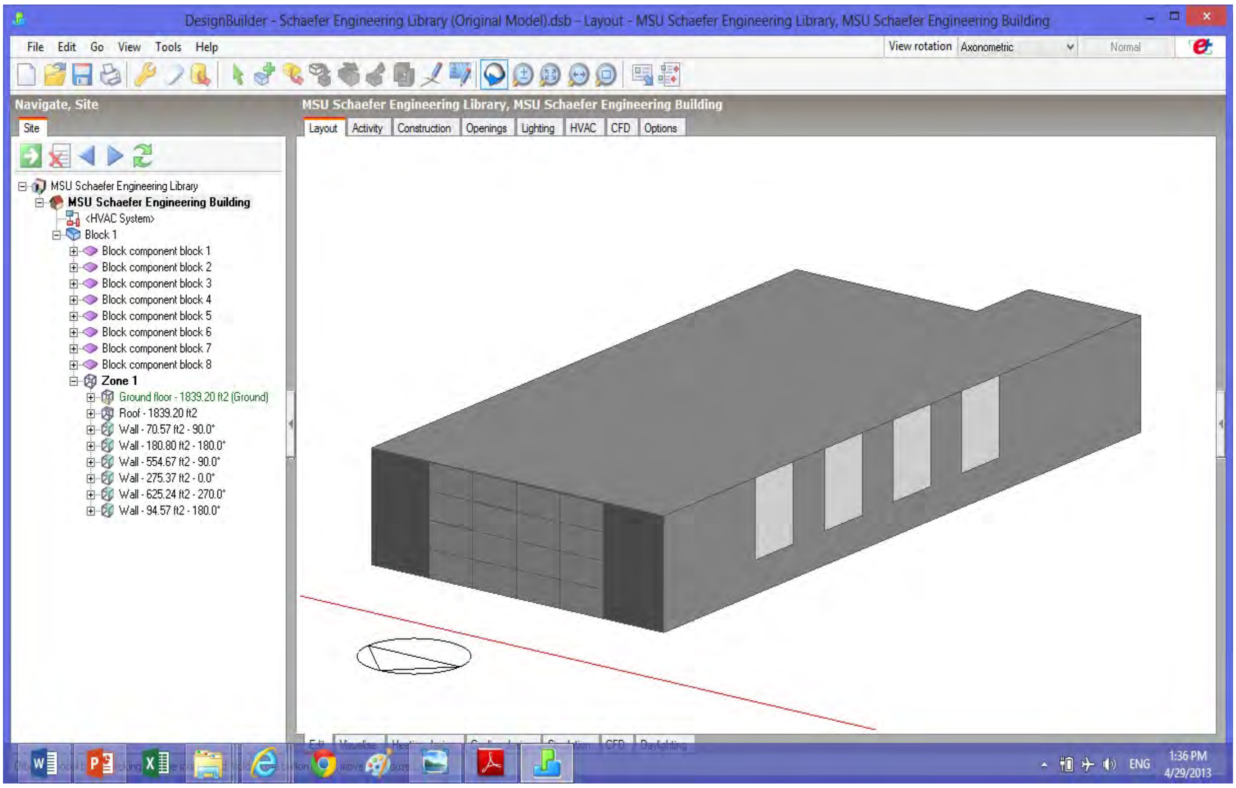


Figure 6. Schaefer Engineering Library Overhead VAV 3D Model

The HVAC system is designed to resemble the HVAC system conditioning Schaefer Engineering Library. It has a boiler, which supplies hot water to the heating coils, a chiller which supplies cold water to the cooling coils, a condenser which condenses the refrigerant back to liquid, an AHU which supplies the conditioned air to the library zone, and a VAV with reheat to control the dry-bulb temperature in the library zone. All of these components are either connected by the hot and cold water supply; return and/or duct plenum objects in the model aid the function of actual plenums for supply and return air. HVAC system is shown on the Figure 7. Data for various parameters obtained from the Morgan State Plant personnel were entered for each component. Schaefer Engineering Library UFAD 3D Model is the same as the previous model. The only differences are that the model has an under floor plenum, its function is defined in the HVAC model, and the VAV reheat is replaced with a VAV reheat variable speed fan.

In order to simulate the annual energy consumption, you need to model the plant and equipment configuration using the pieces of the equipment, create the plant by including the configuration of the heating and cooling plant, cooling equipment, heating equipment and base utility and miscellaneous equipment. For Schaefer Engineering Building at Morgan State University, the cooling equipment is water cooled chiller and the heating equipment is a boiler. The chilled water plant provides the cold water for the cooling coils in the AHU and VAV; the boiler supplies the hot water to heating coils in the VAV box for heating in the winter.

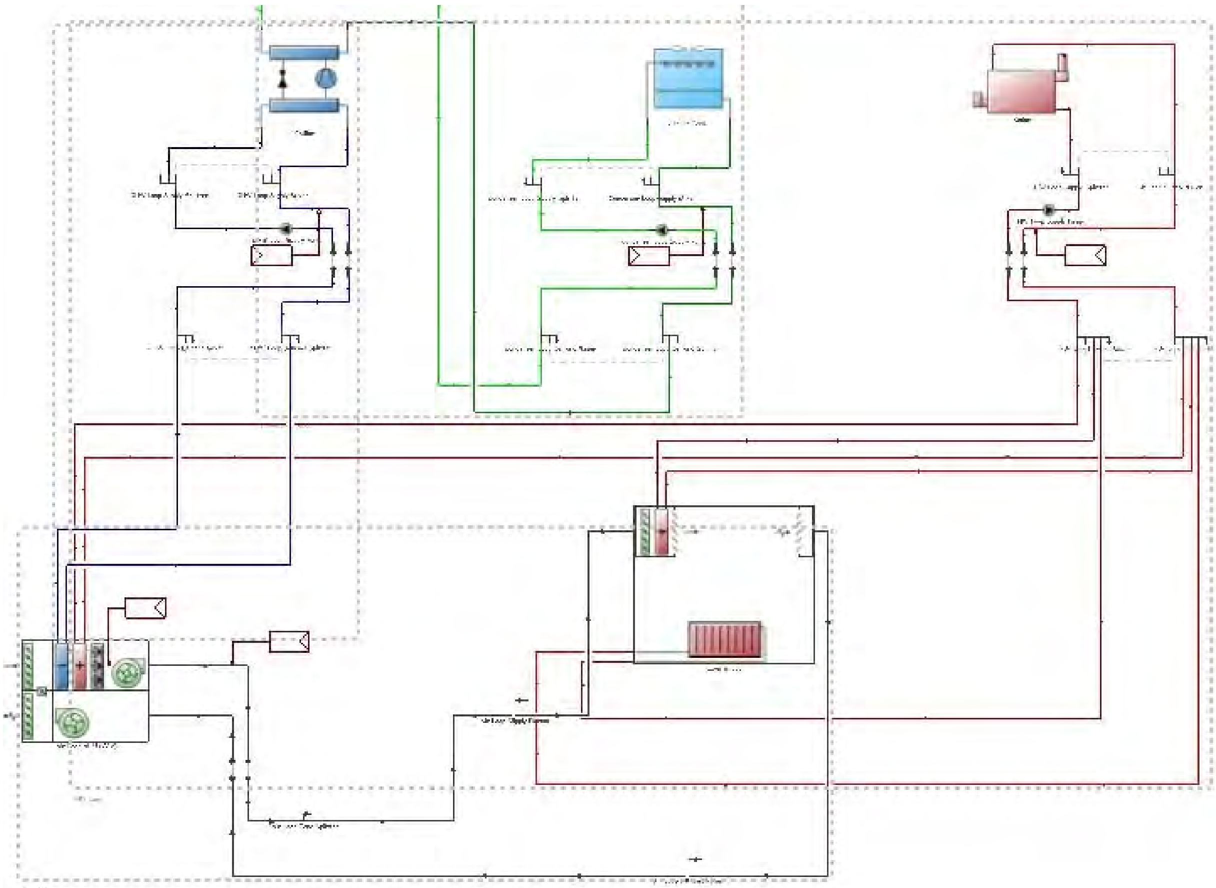


Figure 7. HVAC System for Overhead VAV 3D model

The chilled water plant provides the cold water for the cooling coils in the AHU and VAV. When the conditioned air in the AHU goes through the cooling coils, it becomes cooled; it sent into to the space for cooling in summer. Figure 8 is the scheme for AHU #8 that provides the conditioned air to the Schaefer Engineering Library. In Figure 8, we could find the exhaust fan, supply fans, heating coils, cooling coils, filters and adjustable inlet guide vanes; we could see that part of the return air is used again.

Figure 9 is the scheme for the VAV that delivers the conditioned air into the library. The VAV box includes the supply fan, pressure sensor, heating coils and ceiling diffuser. When the conditioned air is going through the inlet of the VAV box, the pressure sensor is measuring the static pressure and the inlet guide vanes will control the static pressure. If it does not satisfy the set point, inlet guide vanes will be either closed or opened, and fan speed will be increased or decreased to control the amount of stock air. The conditioned air goes through the heating coils to become hot, and it is sent through the ceiling diffuser into the space.

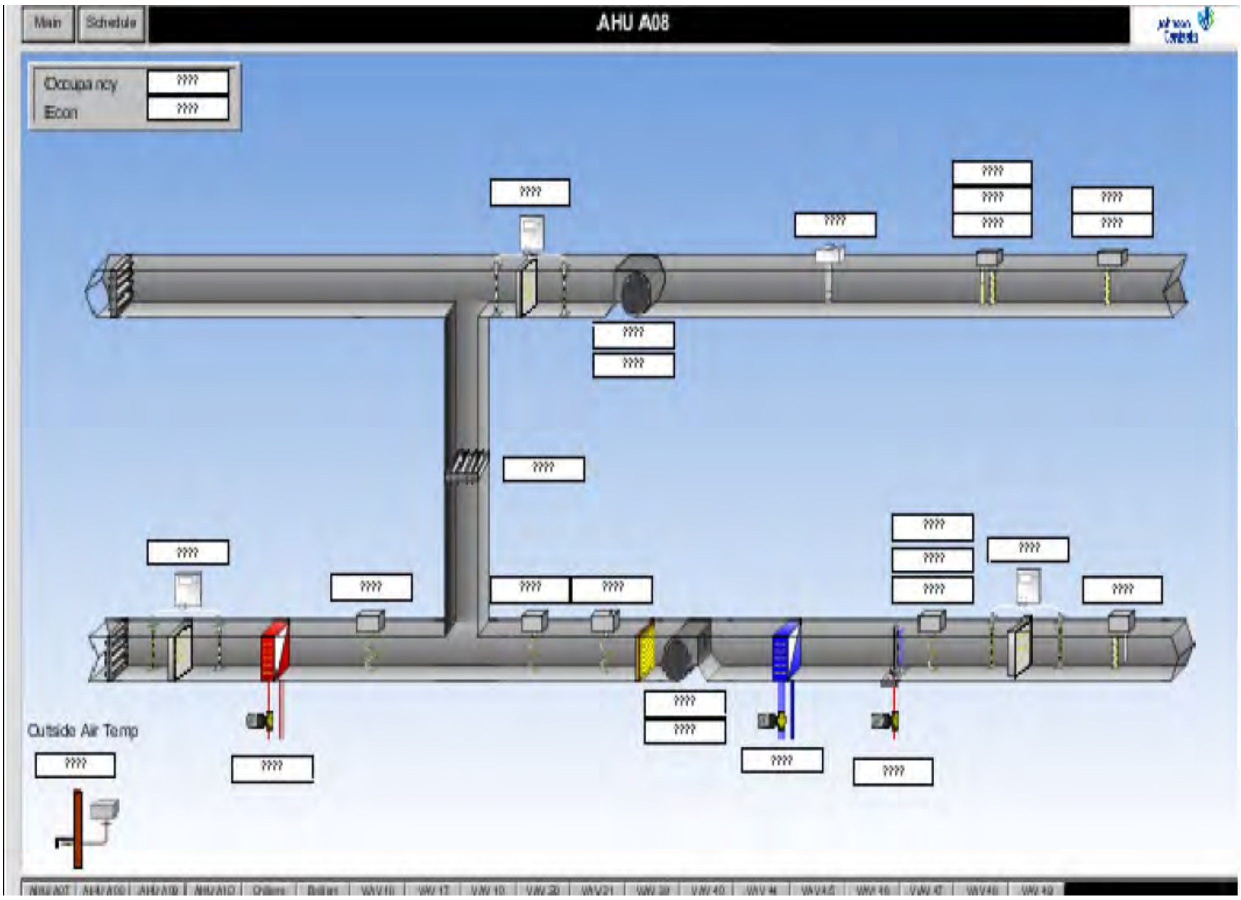


Figure 8. Schematic Diagram of Air Handling Unit (AHU)

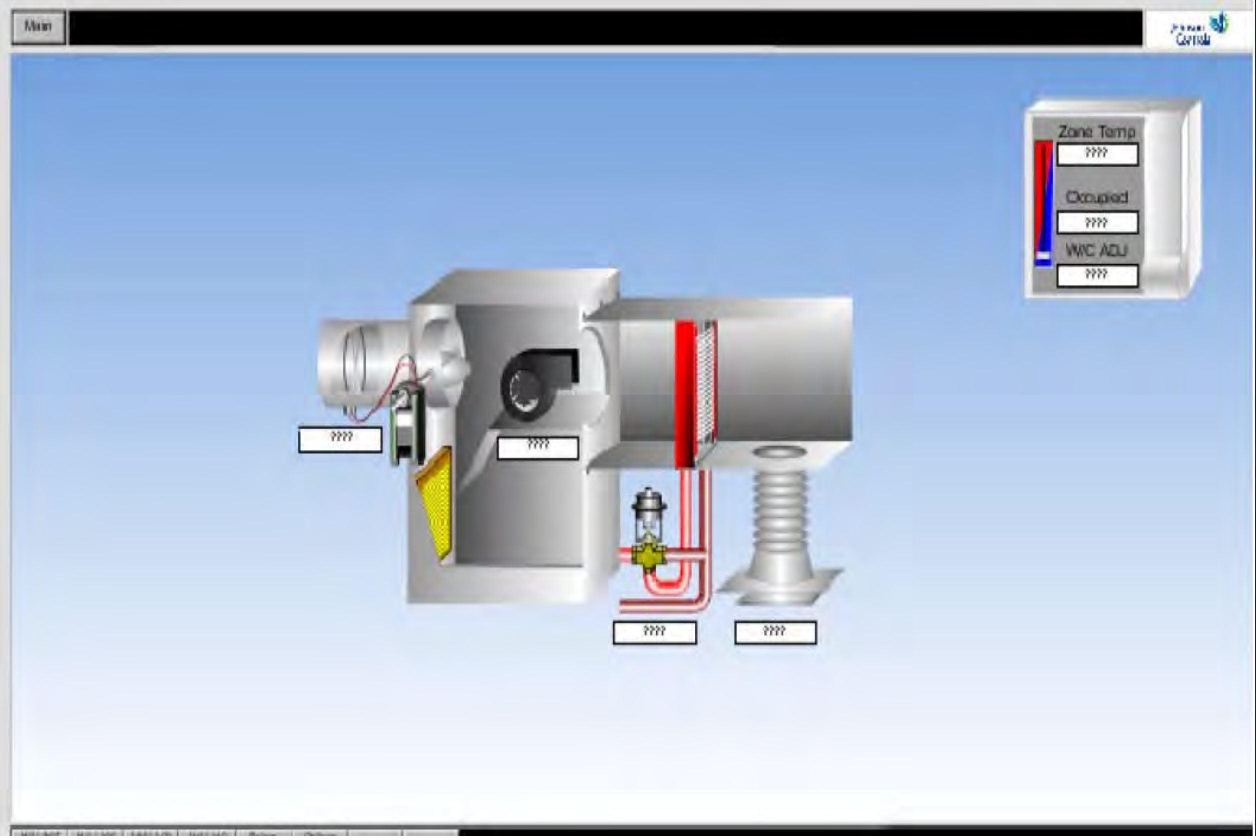


Figure 9. Schematic Diagram of VAV

For the energy consumption simulation, we need to know the internal load of the buildings. It includes the people, lights and the miscellaneous equipment. Both of them are very important factors for the energy consumption. We need to know how many people are in the room at different periods, how many lights are on and off, how many workstations are in the library, etc. The most important thing is control strategies on these system and internal loads. We should make the specified schedules for the internal loads (people, lights, etc.), ventilation systems and equipment (chiller, boiler, etc.). And also the temperature setpoint, humidity setpoint, ventilation requirements should be designed. We need to monitor the Library between week and weekend days in order to make a schedule.

Then, we need to select a weather profile to use to calculate building design cooling and heating loads, system load profiles, and equipment energy consumption. From the location of our library, we could select the location of Baltimore, MD into the location fields in the program. This will ensure that when energy simulations are run, that weather data for Baltimore, MD will be used.

After creating the buildings' ventilation systems and plants, we could perform the heating and cooling load and monitor energy consumpion. Additionally, some levels of the indoor air pollutants which related to the indoor air quality could be obtainted.
From the results on the annual energy consumption based upon UFAD and OHVAV systems, we set the 2-sapmle T-test to compare the main annual energy consumption and analyze the results. Parameters of interest are as follows,

$\mu_1 = mean\ energy\ consumption\ for\ OHAV$ (1)

$\mu_2 = mean\ energy\ consumption\ of\ UFAD$ (2)

Null hypothesis, H_0 is

$\mu_1 = \mu_2$ (3)

Alternative hypothesis, H_1 is

$\mu_1 > \mu_2$ (4)

which is based on the comparison of the mean energy consumption. The 2-sample t-test is used to determine which ventilation system is more energy efficient.
Test statistic equation is as follows,

$$t_0 = \frac{(\overline{X} - \overline{Y}) - \Delta_0}{s_p\sqrt{\frac{1}{n_x} + \frac{1}{n_y}}}, \quad (5)$$

Where $\overline{X}$ and $\overline{Y}$ are the sample means, and n_x and n_y are the sample size; the root of the estimated common variance is computed as s_p from

$$s_p = \sqrt{\frac{(n_X - 1)s_X^2 + (n_Y - 1)s_Y^2}{n_X + n_Y - 2}}, \quad (6)$$

$$\text{Degrees of freedom} = n_X + n_Y - 2 \quad (7)$$

ANOVA (Analysis of Variance) Method is the appropriate procedure for testing the equality of several means. The name analysis of variance is derived from a partitioning of total variability into its component test. ANOVA is used to determine which factors may significantly affect energy consumption.

A factorial design means that, in each complete trial or replicate of the experiment, all possible combinations of the levels of the factors are investigated. The main effect refers to the primary factors of interest in the experiment. An interaction occurs when the difference in response between the levels of one factor is not the same at all levels with the other factors (Montgomery, Douglas C., 2012).

For the energy simulation experiments, a 2^5 factorial design will be used. It means five factors and two levels of each factor. The five factors will be: fan efficiency, motor efficiency, set point temperature, dehumidification set point, and humidification set point. Each factor will have two levels, a "high level" and a "low level." For fan efficiency, the high level is 70% and the low level is 50%. For motor efficiency the high level is 90% and the low level is 70%. For set point temperature, the high level is 72 °F and the low level is 68 °F. For the dehumidification set point, the high level is 65% and the low level is 55%. For the humidification set point the high level is 30% and the low level is 20%. The following Table 2 shows the different combinations of the factors on the 2^5 factorial designs.

Run	Fan Efficiency (%)	Motor Efficiency (%)	Set Point Temperature (°F)	Dehumidification Set point (%)	Humidification Set Point (%)
1	50	70	68	55	20
2	70	70	68	55	20
3	50	90	68	55	20
4	70	90	68	55	20
5	50	70	72	55	20
6	70	70	72	55	20
7	50	90	72	55	20
8	70	90	72	55	20
9	50	70	68	65	20
10	70	70	68	65	20
11	50	90	68	65	20
12	70	90	68	65	20
13	50	70	72	65	20
14	70	70	72	65	20
15	50	90	72	65	20
16	70	90	72	65	20
17	50	70	68	55	30
18	70	70	68	55	30
19	50	90	68	55	30
20	70	90	68	55	30
21	50	70	72	55	30
22	70	70	72	55	30
23	50	90	72	55	30
24	70	90	72	55	30
25	50	70	68	65	30
26	70	70	68	65	30
27	50	90	68	65	30
28	70	90	68	65	30
29	50	70	72	65	30
30	70	70	72	65	30
31	50	90	72	65	30
32	70	90	72	65	30

Table 2. 2^5 Factorial Design

After having set up the experiments, following the procedures of data collection is completed. At first, we look at the combination of factors, i.e. fan efficiency level. Secondly, we adjust the parameters for the components in the HVAC model according to the combination of factors. Thirdly, we click on the simulation tab and set it for an annual run. As a fourth action, we perform the annual simulation and as a fifth action, we look at and collect the results. Finally, we repeat steps one to fifth, until all experiments are completed.

Then, the simulation of the desiccant wheel is performed. Before doing the simulation of desiccant wheel in the Schaefer Engineering Library at Morgan State University, the first step is selecting the type of the desiccant wheel. The type of the desiccant wheel depends on relative humidity of the outside air or inlet air. Based upon the average relative humidity in Baltimore area for the summer (June, July, and August), which is around 65.5% and higher than 60%, the High Performance Silica Gel type is determined. Then, the size of the desiccant wheel is designed by the desiccant wheel simulation software. The Schaefer Engineering Library at Morgan State University has two VAV boxes and 8 diffusers which provide near 2163 cfm, and the return air is around 2000 cfm with half of them supposed to be used to regenerate the desiccant wheel. Average temperature and relative humidity for summer is as shown in Table 3.

Outside Average Air Temperature	74.8°F
Outside Average Air Relative Humidity	65.5%
Supply Air Flow Rate	2163cfm
Return Average Air Temperature	72°F
Return Average Air Relative Humidity	60%
Return Air Flow Rate	1022cfm

Table 3. Summary of DW Input Data for simulation

The computer software (Trace 700) is used to the modelling and simulation of the desiccant wheel along with the UFAD system and OHVAV systems to perform the heating and cooling load calculation and energy consumption simulations. The simulation procedures included: a selection of input of weather information; data on the construction of the building structure (dimensions, direction, materials, etc.); creating a ventilation system and assigning the system to individual rooms; creating the heating and cooling plant and assigning the plant to the systems (chiller and boiler, etc.). Finally, the annual energy consumption could be calculated.

SIMULATION RESULT AND DISCUSSION

Tables 4 and 5 are shown the summary of heating and cooling design calculations for overhead VAV and UFAD systems respectively.

Design Calculations	Btu/h
Heating	50.820
Cooling	49.40

Table 4. Heating and Cooling Design Calculations for Overhead VAV System

Design Calculations	Btu/h
Heating	51.85
Cooling	58.80

Table 5. Heating and Cooling Design Calculations for UFAD System

Run	Fan Efficiency	Motor Efficiency	Set Point Temperature	Dehumid. Set Point	Humid. Set Point	OHVAV Total	UFAD Total
1	50	70	68	55	20	165637.99	137973.70
2	70	70	68	55	20	147813.69	118201.67
3	50	90	68	55	20	165637.99	130973.70
4	70	90	68	55	20	147813.69	118201.67
5	50	70	72	55	20	135572.58	110584.83
6	70	70	72	55	20	124260.89	102953.39
7	50	90	72	55	20	135572.58	110584.83
8	70	90	72	55	20	124260.89	102953.39
9	50	70	68	65	20	166236.22	130973.70
10	70	70	68	65	20	148394.98	118201.67
11	50	90	68	65	20	166236.22	130973.70
12	70	90	68	65	20	148394.98	118201.67
13	50	70	72	65	20	135883.32	110584.83
14	70	70	72	65	20	124530.76	102953.39
15	50	90	72	65	20	135883.32	110584.83
16	70	90	72	65	20	124530.76	102953.39
17	50	70	68	55	30	177945.30	137353.95
18	70	70	68	55	30	159864.64	124806.22
19	50	90	68	55	30	177945.30	137353.95
20	70	90	68	55	30	159864.64	124806.22
21	50	70	72	55	30	147647.15	116907.01
22	70	70	72	55	30	136205.95	109294.26
23	50	90	72	55	30	147647.15	116907.01
24	70	90	72	55	30	136205.95	109294.26
25	50	70	68	65	30	178548.85	137353.95
26	70	70	68	65	30	160490.06	124806.22
27	50	90	68	65	30	178548.85	137353.95
28	70	90	68	65	30	160490.06	124806.22
29	50	70	72	65	30	147946.21	116907.01
30	70	70	72	65	30	136441.37	109294.26
31	50	90	72	65	30	147946.21	116907.01
32	70	90	72	65	30	136441.37	109294.26

Table 6. Annual Energy Simulation Data for Overhead VAV vs. UFAD

Table 6 shows the annual energy consumption on the different combinations of fan efficiency, motor efficiency, set point temperature, dehumidification set point, humidification set point.

From the Table 6, the mean annual energy consumption for the overhead VAV system is 149,588.75 KBtu. The mean annual energy consumption for the UFAD system is 118,884.38 KBtu. The UFAD system could save more than 20% of energy than that of the overhead VAV system. The statistical results of two-sample T-Test for OHVAV and UFAD systems are summarized in Table 7.

	N	Mean	StDev	SE Mean
OHVAV	32	149589	16884	2985
UFAD	32	118884	11021	1948

Table 7. 2-Sample T-Test for mean annual energy consumption

Where,

Difference = mu (OHVAV) - mu (UFAD).
Estimate for difference: 30704. 95%.
CI for difference: (23579, 37829).
T-Test of difference = 0 (vs not =)
T-Value = 8.61. P-Value = 0.000.
Degree of Freedom=62.
Both use Pooled StDev = 14257.270.

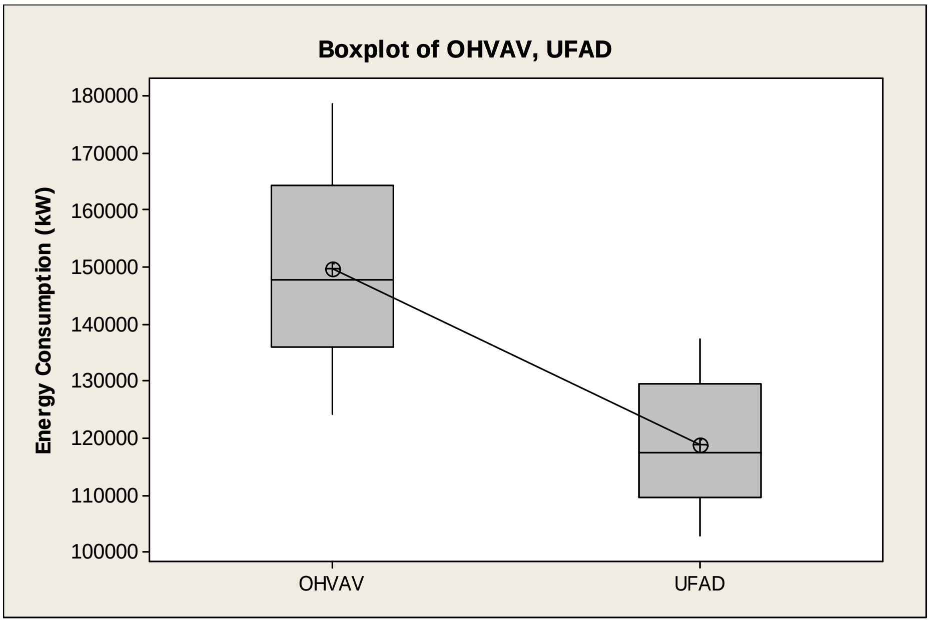


Figure 10. Box-plot for Energy Consumption

From the results of 2-sampe t-test in Table 7, there is a significant difference in the mean energy consumption and therefore the null hypothesis is rejected since $p < 0.05$. The alternative hypothesis is therefore true.

The mean energy consumption of the UFAD system is much lower than that of the Overhead VAV system as shown by the Box-plot for energy consumption in Figure 10.

Table 8 shows different types of ANOVA sources for C10 (code units). According to the ANOVA results in Table 8, p is less than 0.005 for the main effects. Therefore, one or more individual factors might have a significant effect on energy consumption. In addition, the 2-way interaction indicates that interaction of two factors has a significant effect on energy consumption.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	5	3714620312	3714620312	742924962	562349.01	0
2-way Interactions	10	50839839	50893839	50839839	38.27	0
Residual Error	16	21138	21138	1321		
Total	31	3765481289				

Table 8. Source of Analysis of Variance (ANOVA) for C10 (coded units)

The letters A, C, and E as shown in Table 9 indicate the fan efficiency, set point temperature, humidification set points respectively. These are the individual factors that significantly affect energy consumption. In addition, the interaction AC is the interaction of fan efficiency and set point temperature, which has a significant effect on energy consumption.

sTerm	Coefficient
Constant	704867
A	**-4930.30 (Fan efficiency)**
B	-0.0000
C	**-8152.55 (Set point temperature)**
D	-0.0000
E	**886.279 (Humidification setpoint)**
A*B	0.0000000
A*C	**62.9723(Fan efficiency*set point temperature)**
A*D	0.000000
A*E	0.607475
B*C	0.000000
B*D	0.000000

B*E	0.000000
C*D	-0.000000
C*E	-4.02187
D*E	-0.000000

Table 9. Summary of ANOVA Table

Figure 11 shows the simulation result for the Schaefer Engineering Library at Morgan State University. The results provide optimal dimensions (wheel diameter and depth) and types of desiccant wheel required for the demonstration site.

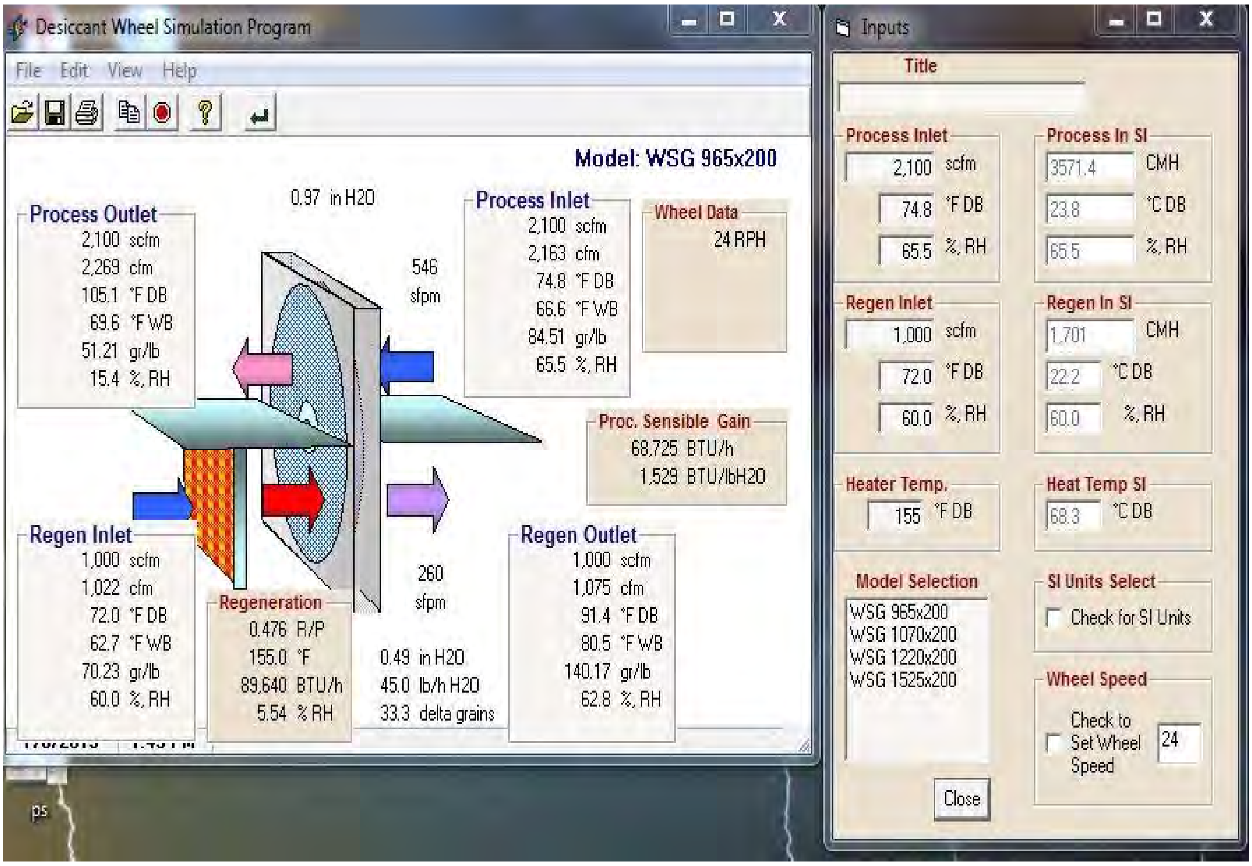


Figure 11. Simulation Result

Table 10 shows the annual energy comsuption results. The annual energy consumption for the OHVAV system is around 107,749 KBtu. When added the materials (eg. insulation materials) and schedules (eg. seasonal, time) of the OHVAV system, the annual energy consumption decreases to 94,329 KBtu (energy savings over 13%). For the OHVAV system along with the desiccant wheel and energy recovery wheel, the annual energy consumption decreases to 78,471 KBtu(energy savings over 26%).

	Without adding materials	With adding materials	With adding schedules
VAV	107,749 KBtu (or 59.86 KBtu/ft^2)	123,069 KBtu (or 68.37 KBtu/ft^2)	94,329 KBtu (or 52.40 KBtu/ft^2) **Saving:** over 13%
DW and ERW with VAV	101,739 KBtu (or 56.52 KBtu/ft^2)	107,024 KBtu (or 59.46 KBtu/ft^2)	78,471 KBtu (or 43.60 KBtu/ft^2) **Saving:** over 26%

Table 10. Summary of Annual Energy Consumption Results

CONCLUSION

1. The energy consumption by using the UFAD system could save over 20% energy than that of the overhead air distribution system.

2. An ANOVA results test indicated that individual factors, such as fan efficiency as well as 2-way factor interactions had a significant effect on the energy consumption in the UFAD system.

3. The desiccant wheel could remove the humidity for over 50%, which could contribute to IAQ improvement.

4. OHVAV system along with the desiccant and energy recovery wheels could save over 26% of energy consumption.

5. Integrated Ventilation System along with the desiccant and energy recovery wheels could save energy effectively and improve the indoor air quality in the commercial buildings.

Acknowledgements: This work is partially supported by the U.S. Department of Energy.

REFERENCES

Wang, X., C. Huang, W. Cao, X. Gao, W. Liu (2011). Experimental Study on Indoor Thermal Stratification in Large Space by under Floor Air Distribution System (UFAD) in summer. *Engineering, 2011, 3,* 384-388.

U.S. Energy Information Administration (2012). *Annual Energy Review 2011*, U. S. Department of Energy

Lee, S. , S. Garcia, X. Qian (2013). Modeling and Simulation of the Mixed Mode Ventilation Strategies with Heat Recovery and Energy Recovery Wheels for Energy Conservation and

IAQ Improvement in the Commercial Buildings. *World Scientific and Engineering Academy and Society (WSEAS) Series of International Conference*. Baltimore, MD.

Prakash M., S. Arora, S.N. Mishra. (2012). Quality Improvement Of Indoor Air by Using Heat Recovery Wheel. *IJRET, (1)4*, 526-531.

Aiulfi, D. D., Blay, D. D., Clancy, E., Collineau, D. S., Fracastoro, D. G., Heiselberg, D. P., & Hibi, D. K. (1998), Energy Conservation in Buildings and Community Systems Annex 26: Energy Efficient Ventilation of Large Enclosures, *Ventilation of large spaces in buildings.*

Lee, S. , R. Shehan (2013). Feasibility Study of Desiccant Wheel System For Energy Savings and Increased Indoor Air Quality in the Buildings. *Proceedings of WBHR-LSAMP Summer Research Symposium*, Bowie, MD.

Urrutia, J. A. (2010). Desiccant Cooling Anaslysis Simulation software, energy, cost and environmental analysis of desiccant cooling system. Master's Thesis in Energy systems. University of Gavle.

Beccali, M., Adhikari, R. S., Butera, F (2004). Update on Desiccant Wheel Model. *International Jornal of Energy Research*, 28: 1043-1049.

Stanke, D. (2001). Underfloor Air Distribution: Turning Air Distribution Upside Down. *Engineers Newsletter, volume 30-4.* Retrieved from April 22, 2013. http://www.trane.com/commercial/library/vol30_4/

Harriman, L. , G. Brundrett, R. Kittler (2001). *Humidity Control Design Guide for Commercial and Institutional Buildings.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. Atlanta, GA.

"Underfloor Air Distribution System." *Underfloor Air Distribution System*. Retrieved April 20, 2013, Retrieved from http://www.seco.cpa.state.tx.us/TEP_Production/g/TEPMtgsb5-york_09082004_14.pdf

Webster, T., Hoyt, T., Lee, E., Daly, A., Feng, D., Bauman, F., Schiavon, S., Lee, K. H., Pasut, W., and Fisher, D. (2012). "Influence of Design and Operating Conditions on Underfloor Air Distribution (UFAD) System Performance." *Proceedings of Simbuild 2012,* Madison, WI.

Schiavon, Stefano; & Bauman, Fred. (2009). Cooling airflow design tool for displacement ventilation. UC Berkeley: Center for the Built Environment.

Montgomery, Douglas C. (2012). *Design and Analysis of Experiments.* (pp. 183-184). Wiley.

Tang, F. (2010). HVAC System Modeling and Optimization: A Data-mining Approach. *Iowa Research Online.* University of Iowa.

Pesaran, Ahmad A. (1993). A Review of the Desiccant Dehumidification Technology. Prepared for *Proceedings of the Electric Dehumidification: Energy Efficient Humidity Control for Commercial and Institutional Buildings Conference,* Electric Power Research Institute, Louisiana.

Building a sustainability index for highway infrastructures: case study of flexible pavements

Stella O. OBAZEE-IGBINEDION, Manoj K. JHA, Oludare OWOLABI
Center for Advanced Transportation and Infrastructure Engineering Research
Department of Civil Engineering
Morgan State University, USA
stellato@mail.com, manoj.jha@morgan.edu, oludare.owolabi@morgan.edu

ABSTRACT

The road network system consists of highway infrastructures which need to be maintained periodically – due to deterioration – in order to increase the life span of the system and provide riding comfort to the travelling public. Factors that cause pavements to deteriorate are accumulated traffic axle loads, environmental conditions, climate, etc. Deterioration creates conditions that undermine the performance of pavements. A literature review indicates that analytical methods have been developed to design different components of pavement performances due to pavement conditions and sustainability. These models were mostly based on definitions, operation, structural and functional research oriented analysis and they have contributed substantially to the society. However, the integration or correlations of sustainability indices with pavement condition indices were not fully explored. To fully understand and develop the proposed model, the triple sustainability dimensions (environmental, economic and social) which plays a major role in planning for both construction and maintenance of pavements is discussed. A multi-linear regression analysis (MLRA) is proposed to calculate the sustainability index. The following four possible characteristics of pavement performance indices for flexible pavements are considered (as independent variables) and analyzed for each section of pavement under consideration: (1) roughness, (2) surface distress, (3) skid resistance index, and (4) structural deflection. A numerical example using field investigation data is performed to illustrate the developed approach.

Keywords: Flexible Pavements; Sustainability Index; Pavement Condition indices; Multi-Linear Regression Analysis (MLRA) Model; Pavement Performance Evaluation.

INTRODUCTION

This paper explores the problem with building a sustainability index for highway infrastructures by using flexible pavements as a case study. For the past couple of decades, there have been global concerns regarding climate change, energy usage, environmental impacts, and the financial limitation as they affect highway transportation infrastructures, both in developed and developing countries. Engineers and policy makers have been looking into different ways to plan, design, construct, operate, and maintain pavements so to sustain these highway infrastructures. Pavement infrastructures are considered vital and important in safely transporting people and goods from one point to another, which makes it one of the fundamental components of any transportation system both in the United States of America and the world in general.

Although many researchers have undertaken various aspects of pavement research, such as pavement evaluation, maintenance, pavement management systems, to name a few, very little research has been carried out on pavement serviceability and sustainability. The aim of this paper is to illustrate some major transportation sustainability indicators (such as, environmental, social and economic impacts) and correlate them to pavement performance/evaluation indices (such as serviceability, structural capacity, skid resistance and pavement surface distress). The paper addresses the problem of sustainability in the context of pavement performance (pavement conditions) in a statistical multi-linear regression analysis framework. The facility is divided into shorter manageable sections and each section is analyzed and correlated in order to obtain a correlation index. The motivation behind this paper therefore is to develop a comprehensive model that determines the relationship between pavement conditions (indices) and sustainability indices - known as the universally accepted "triple bottom line" or ("Three Pillars") of sustainability (WCED, 1987).

Prior to maintaining any highway infrastructure, such as pavements and bridges, the preferred mode of maintenance is selected based on the need and availability of funds for the project. The next deciding issue is whether to maintain or fix the problem of the highway infrastructure or do-nothing. The planning and maintenance strategies depend largely on the type of highway infrastructure to be maintained or rehabilitated. Another important issue to be considered is to carefully assess the environmental, economic, and social impacts – such as: types of material used (not within the scope of this paper), environmental pollution, and traffic congestions.

In the past two decades transportation industry has shown increasing interest in the concept of sustainability due to the phenomena of climate change, accidents, resource depletion, increased degradation of quality of the life of pavements and bridges; and inequity of access. This paper intends to develop a statistical multi-linear regression analysis model (MLRA) that would determine these indices and help support pavement managers/engineers to make rational decisions to enhance pavement performance and sustain the infrastructure. The goal here is to provide a mathematical tool that would enable agencies meet the basic needs and improve the quality of life of pavements; while the natural resources they depend on are maintained and enhanced for their benefits and the future generations without compromising safety, health and efficiency.

LITERATURE REVIEW

The literature review discusses past related research works pertaining to pavement conditions, transportation sustainability, maintenance strategies, and pavement maintenance optimization models. It also provides detailed perception on past researches that relate to pavement conditions and sustainability models. The purpose of literature review is to establish the originality of this paper in order to obtain useful background information concerning the research topic. Although there have been a lot of research works on pavement facility maintenance optimization and pavement sustainability, very few researches have been done on maintenance optimization in the context of pavement (condition) performance indices and sustainability indices; i.e., determining how sustainability indices depend on pavement conditions. The literature search provides several reports as reference materials on this research work. These reports, relevant to the research topic were reviewed to determine how pavement conditions correlate with the "three-pillar" sustainability dimensions (environmental, social, and economic) (see Figure 1), such as environmental pollutions, congestion, travel time, noise, water pollution, to mention a few. Also, research articles were reviewed to understand how rapid axle loads on pavements can quickly reduce the life span of a pavement (pavement distresses), which ultimately affects the user's comfort when pavements become distressed. Pavement conditions directly influence the cost of operating the vehicles, such as fuel consumption, accidents – termed as "user and social costs". Accident is outside the scope of this research.

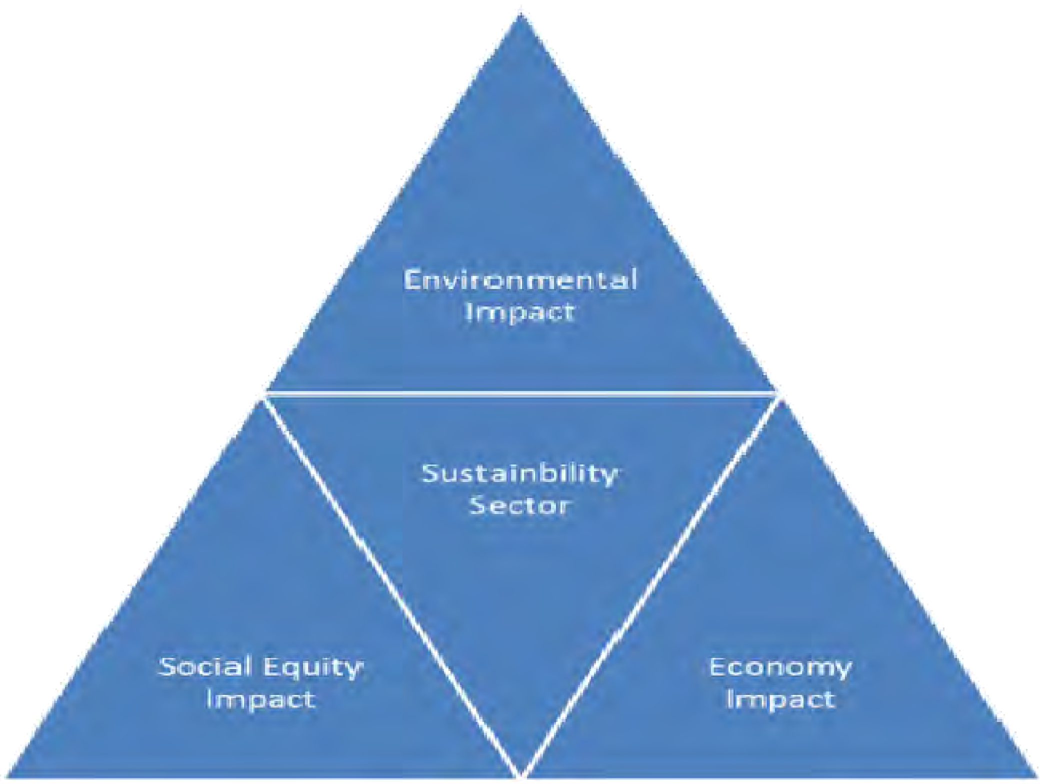


Figure 1. Modified "Three Pillars" of Sustainability Model

Definition and history of sustainability

The word "sustainability" is often used in terms of public policy. In this paper, the definition is directed towards transportation infrastructures, such as pavement management. Sustainability is defined as the process to continuously maintain and meet the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). According to Federal Highway Administration (FHWA), sustainability in transportation perspective is defined as "providing exceptional mobility and access in a manner that meets development needs without compromising the quality of life of future generations. A sustainable transportation system should be safe, affordable, and renewable, operates at a fair level, emits emissions at reduced level, is healthy to the society, and uses new and non-renewable resources" (FWHA, 2008).

The development of sustainability started about twenty years ago between 1972 and 1992 during various international conferences. The first meeting was held during one of the UN conferences on Human Environment in Stockholm in 1972. Sustainability on a world scale was the major issue of discussion, which generated a momentum that created series of recommendations.

Highway infrastructure deteriorates over time, primarily due to traffic demand (axle loads), environmental conditions, and other factors. Transportation infrastructure system needs to be maintained periodically in order to increase the life span of the facility. Pavement is one of the most valuable components in transportation infrastructure system, and it is therefore very important to keep these facilities in good condition by carrying out periodic maintenance. In order to effectively meet this obligation, an efficient pavement management system (PMS) is considered. PMS is a tool that provides a technical and economic approach to assessing problems associated with pavement conditions. Various components of a road network system are analyzed and quantified in order to achieve total or partial optimization of pavement performance over certain period of time.

(Mayer, 2007) developed a framework that determines the strengths and weaknesses of common sustainability indices for multidimensional systems. The author emphasized the importance of sustainability indices in a system and grouped them by an aggregation method. (Barrera-Roldan et. al, 2003) designed a methodology for obtaining Industrial Sustainability Index (ISI) in the context of the sustainable development philosophy and to identify the issues that have to be addressed in order to bring the industry closer to a sustainable performance. The authors used the multi-attribute decision theory to develop their methodology as the ISI main structure which could be used with variances in other industries. Another paper authored by Ortiz-Gallarza et. al, (2003) discussed the selection of environmental parameters to estimate an industrial sustainability index. The paper included a methodological proposal to select and validate statistically, natural system or environmental parameters with other economic and social values in order to construct an interdisciplinary sustainability index in the petroleum refinery industry. Moretti et. al (2012) developed an economic sustainability of concrete pavements using a computer program to analyze structural, functional, and financial characteristics of joint plain concrete pavements (JPCP).

Pavement performance evaluation

This section discusses the concept of serviceability and its importance. There are four major characteristics of evaluating pavement conditions: (1) roughness, i.e., the comfort of ride-ability; (2) pavement distress, i.e., surface condition; (3) pavement deflection, i.e., structural failure; and (4) skid resistance, i.e., safety. Each of these characteristics is imbedded in the triple bottom-line factors of sustainability, examined and explained briefly in subsequent sections.

Pavement roughness is the irregularities of the pavement surface which makes the smoothness of the surface to be either comfortable or uncomfortable to the rider. Present Serviceability Rating (PSR) and Present Serviceability Index (PSI) were first introduced in the AASHTO Road Test to qualitatively and quantitatively rate the quality of ride-ability of pavements. The PSR is a grade number in a pavement section to rate the ability of the section to serve the designed traffic loads. Its rating scale is from 0-5; where 0 signifies very poor and the number 5 signifies "very good" (Papagiannakis, A. T. and Masad, E.A., 2007).

The PSI is a surrogate of PSR which is based on physical measurements and not based on panel ratings. Another closely related performance indicator is Pavement Condition Index (PCI) which was developed by U.S. Army Corp of Engineers to rate pavement condition. The PCI can be obtained through pavement serviceability evaluation panels (group of evaluators) which provide information concerning pavement conditions. PCI rates and evaluates the condition of a road network on annual basis; it provides numerical rating of a road segment within the network or project level. Its numerical rating is between 0-100; where 0 is the worst condition and 100 is the best condition as illustrated in Figure 3. The PCI is normally conducted annually in order to evaluate changes that occur in a road network system. It is a subjective method of evaluation based on inspection and observation. The PCI is also an informative tool that shows the current condition of the road network and its deterioration over time as illustrated in Figure 2.

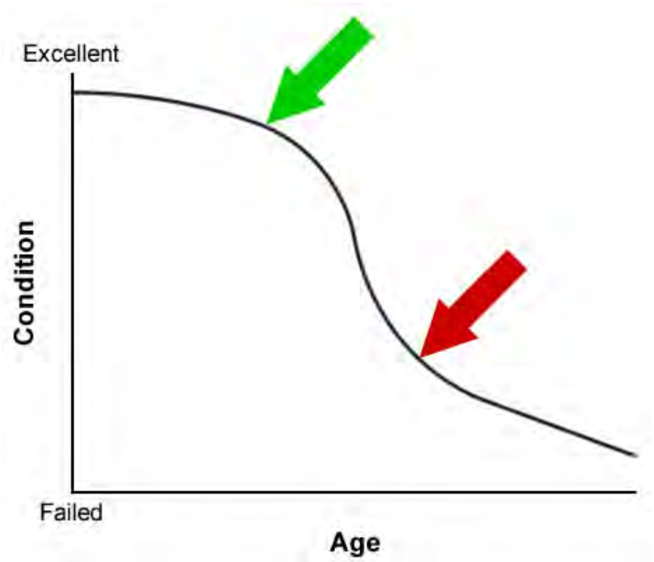


Figure 2. Pavement condition vs. Age (source: Pavement Interactive (2013) http://www.pavementinteractive.org (accessed October 25, 2013).

Some uses and benefits of PCI include, identifying the need for immediate maintenance and rehabilitation (M & R) (Galehouse et. Al. 2003) of roads; developing a road network preventive maintenance strategies and budgets; and for evaluating pavement materials and designs (see Figure 3).

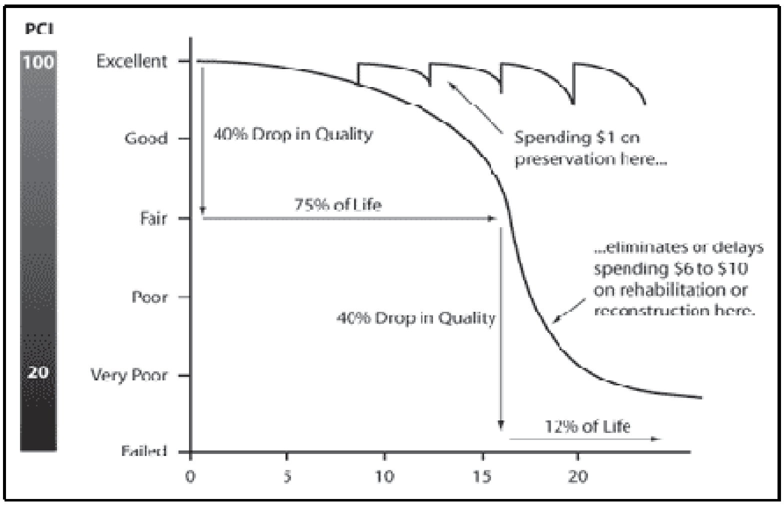


Figure 3. Benefits of M & R as a function of pavement condition (PCI) (source: Galehouse et. al. 2003).

In order to develop an effective PCI, the road network should be divided into manageable segments or sections; sections with relatively uniform pavement structures, design and traffic volumes will have similar performance characteristics. For instance, a road network in urban settings should be kept in manageable length (shorter lengths for roads with severe deteriorated conditions) due to high volume of traffic activities. Whilst in the case of rural settings, the road network can be kept in manageable longer lengths due to lighter volume of traffic.

The road section under consideration will be identified (using field survey data) based on the following basic history:

- Road class (freeway or arterial);
- Length, width, and geometry of the roadway;
- Type and volume of traffic along the roadway;
- Initial construction date;
- Maintenance history;
- Current PCI conditions and their relationship to past PCI conditions.

The condition of a pavement provides information through the PMS, when it has some defects, such as: (1) surface defects: ravelling, flushing; (2) surface deformation: rippling & shoving, wheel track rutting, distortion; (3) cracking: longitudinal, centerline, pavement edge, and transverse defects.

Pavement condition states are used to measure pavement performance in terms of discrete condition levels as stated above. These condition states help to provide information as to how the pavement would perform under each category in order to develop pavement serviceability indices, such as International Roughness Index (IRI), Present Serviceability Index (PSI), Pavement Serviceability Rating (PSR), Structural Capacity Index (SCI), Functional Index (FI), Ride-ability Index (RI), etc. Pavement Serviceability (PS) was initiated by American Association of State Highway Official (AASHO) Road Test. In the proposed research, some of the relevant pavement indices (e.g., IRI, PSR, SRI (skid resistance index), SDI (surface distress index), and DI (deflection index)) will be discussed including Life-cycle cost analysis (LCCA) (FHWA 1998).

Pavement serviceability

This section discusses individual Present Serviceability Rating, Present Serviceability Rating (PSR), Present Serviceability Index (PSI), and the Performance Index (PI). These terms are defined to correlate the subjective rating of pavement performance with objective measurements. Pavement serviceability is defined as the ability of the pavement to carry the accumulated traffic axle load it is designed to serve under the existing pavement condition. There are two major methods for determining pavement serviceability; the Present Serviceability Index (PSI) and the International Roughness Index (IRI).

Present Serviceability Index (PSI) is the ability for a particular pavement section to serve the traffic (with different traffic mix, high volume of traffic, and high speed) under current pavement condition. PSI method was developed by AASHO Road Test (Carey and Irick, 1960). The PSI is mostly based on both pavement distress condition and roughness, such as patching, cracking and rutting (in flexible pavements). IRI is the ability of a road section to serve vehicular traffic due to axle loads imposed on that particular section of the road under its current condition. PSR is defined as the rating of a pavement under its current conditions as illustrated in Figure 4.

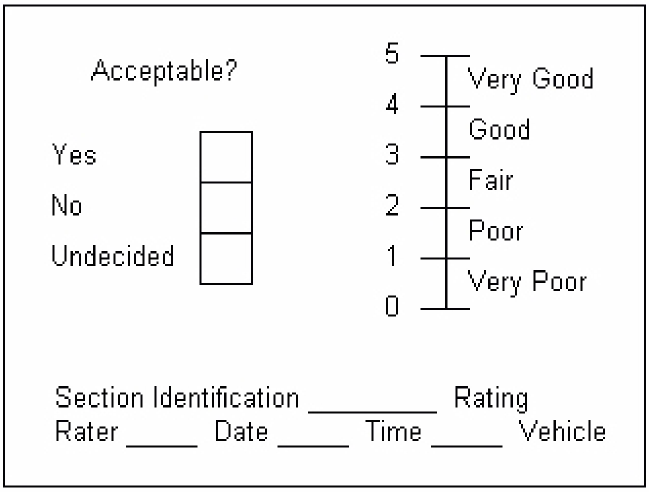


Figure 4. Pavement Serviceability Evaluation Form (Papagiannakis and Masad, 2007).

The PSI is a combination of mathematical formulation that is obtained from measuring pavement sections used to predict the PSR. The PSI for both flexible and rigid pavements was developed based on an AASHO Road Test (Jayawickrama et al, 1998). For the purpose of this paper, the PSR, PSI and IRI are estimated using the FHWA guidelines, respectively (see Figures 4, 5, and Table 1); while the PCI data was obtained from field survey inspection.

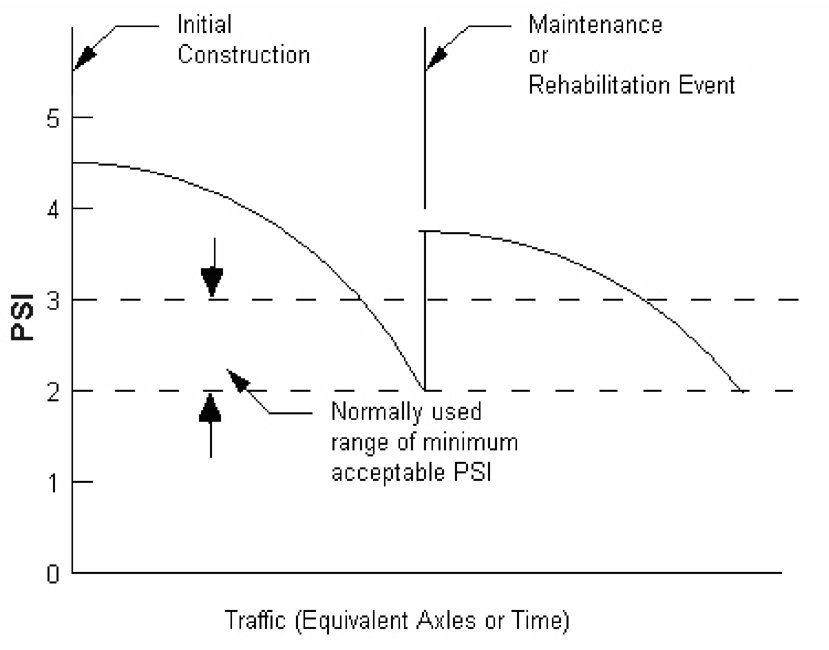


Figure 5. Concept of Pavement Performance using PSI (Source: Hveem and Carmany, 1948).

Condition Category	IRI Threshold (in/mile)
Good	<95
Fair	$95 \leq IRI \leq 170$
Poor	>170

Table 1: IRI Thresholds (FHWA, 2008).

The following equations are also used to determine the PSI for flexible and rigid pavements, respectively:

$$PSI = 5.03 – 1.9 \text{ Log } (1+SV) – 0.01\sqrt{C+P} - 1.38RD^2 \quad \textbf{(1)}$$

$$PSI = 5.41–1.80 \log (1+SV) – 0.09\sqrt{C+P} \quad \textbf{(2)}$$

where:

SV = Slope variance (rad²),
P = bitumen patching in ft²/1000ft²
RD = average rut depth in inches,
C+P = the relative extent of cracking and patching in the wheel-path (ft²/1000ft²)

Correlations between PSR and IRI

Two important correlations were reported by Paterson (1986) and Al-Omari and Darter (1992), which are expressed as:

$$PSR = 5.0e^{-0.18(IRI)} \quad \textbf{(3)}$$

$$PSR = 5.0e^{-0.26(IRI)} \quad \textbf{(4)}$$

where:

PSR = present serviceability rating
IRI = international roughness index

The smoother the riding pavement surface, the higher the value of PSR. The PSR is a subjective measure of ride quality based on individual observation of pavement conditions; while the IRI is based on the Average Rectified Slope (ARS) – a filtered ratio of a standard vehicle's accumulated suspension motion (measured in millimeters, inches, etc.) divided by the distance travelled by the vehicle (Papagiannakis and Masad, 2007). For the purpose of this paper, IRI data are estimated based on field survey performed on a 3.5 mile arterial roadway pavement condition. These data are estimated using the FHWA IRI thresholds (see, Table 1). IRI can also be calculated using Equation (5) below:

IRI = ARS*1000 (5)

Skid Resistance (SR)

Skid resistance is a vital part or component of pavement performance evaluation. It is the force that develops when the tires are prevented from rotating on pavement surfaces (Hveem, 1948). It can cause skid related incidents or accidents if inadequately designed. Pavement skid resistance depends on four factors: the texture of the pavement surface, the tread of a tire, the presence of water at the interface between the two, and the amount of slippage between them (Papagiannakis and Masad, 2007). It is the responsibility of the agency to provide road users reasonably safe pavement surface for good ride quality depending on the materials and construction quality, such as microtexture (small-scale texture of pavement aggregate that is in contact between the rubber tires and the pavement surface) and macrotexture (the large-scale texture of the pavement aggregate that controls the escape of water from the rubber tires which may cause loss of SR if the speed is increased) (Corley-Lay, 1998). SR of a pavement increases in the first 2-3 years of the initial construction and decreases over the remaining years of the pavement due to wear of the pavement surface either by traffic or loose aggregate. Seasonal variation does affect SR – such as higher in the fall and winter and lower in the spring and summer seasons (Awoke, 2011). SR on dry pavements is higher than that of wet pavements, i.e., the higher the Skid Number the better the pavement quality as illustrated in Table 2 (Jayawickrama et. al, 1996).

There are different techniques of measuring SR; the most common are the surface texture measurement, the locked wheel tester, and the spin up tester. Details of the various techniques are not within the scope of this research and so will not be discussed in this paper. The measurement of SR can be quantified using either Skid Number (SN) or friction factor; expressed mathematically:

Skid Number	**Remark**
If SN < 30	Take measurements to correct
If SN ≥ 30	Acceptable for low volume roadways
If SN 31 - 34	Frequent monitoring of pavements
If SN ≥ 35	Acceptable for high volume and heavily traveled roadways.

Table 2. Skid Resistance Threshold and treatment actions (Source: Jayawickrama et al, 1996).

Friction factor f = F/L (6)

Skid number SN = 100(f) (7)

where:

F = frictional resistance to motion in plane of interface
L = load perpendicular to interface

Structural Capacity (Pavement Deflection)

Structural deflection is one of the four components for evaluating and measuring pavement performance. It also plays an important role in evaluating pavement structures because the size and shape of pavement deflection is a function of factors that cause pavements to deteriorate. Such factors include, but not limited to the following: axle loads due to traffic volumes, temperature, and moisture due to expansion and contraction of the pavements; and pavement structural section. There are various methods and techniques for measuring pavement structural deflection; such as back calculation, impact load deflection (Falling Weight Deflectometer – FWD), the static deflection, and steady state deflection. Detailed description of these techniques is not within the scope of this research. Figures 6-8 illustrate how deflection is measured in flexible pavements when a force is applied. For instance, when a truck drives along a pavement section on a roadway, the set of tires are the weights (i.e., empty) applied to the pavement surface and the load is transferred to the subgrade; which causes the pavement structure to deflect. This deflection is known as deflection basin as illustrated in Figures. 7 and 8. But, in the case of static or stationary load, the force is applied repeatedly using a cyclic load and the deflection basin is measured in a number of locations as either single or multiple quick impacts.

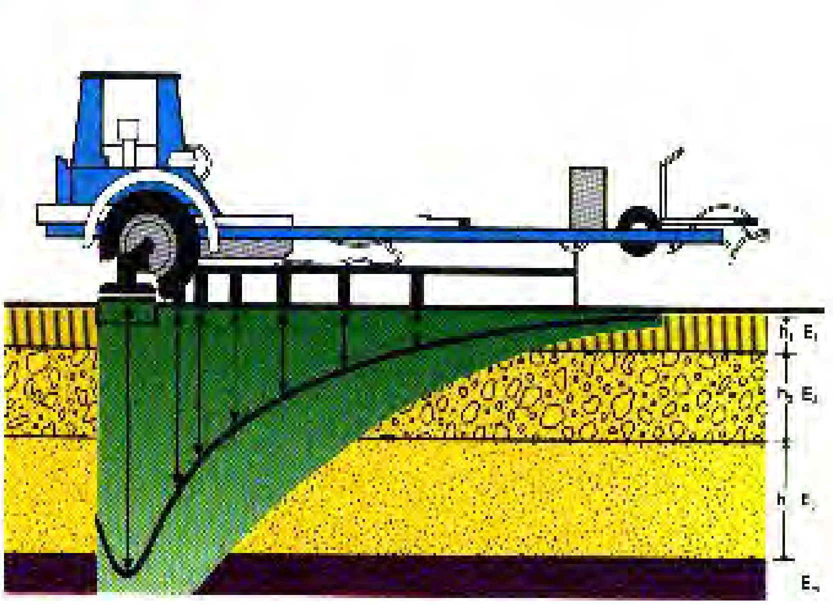


Figure 6: Deflection Basin collected with falling weight deflectometer (National Association of County Engineers, 1992).

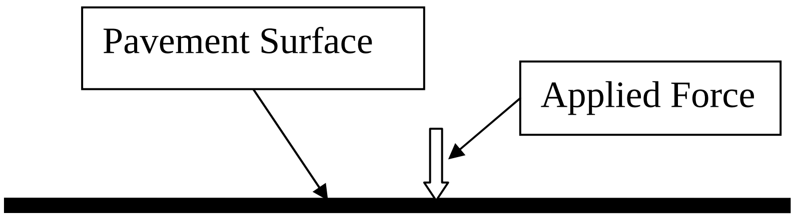


Figure 7. Force applied to pavement surface

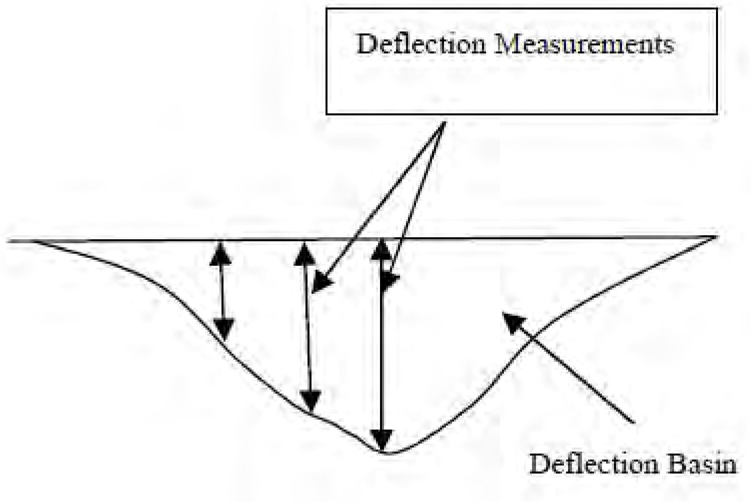


Figure 8. Deflection basin

Surface distress

This category of pavement evaluation is the collection of pavement condition data. It is the presence of different types of distresses due to either construction defects, traffic loads, and environmental or climate interaction, such as cracks and surface distortions. Data can be collected manually or by an auto collection processes. Data collected through manual process are recorded on special forms as severity and extent. Three common types of flexible pavements distress are patching, cracking, and rutting (SHRP, 1993).

EFFECTS OF PAVEMENT CONDITIONS

Pavement condition impacts vehicle speed, safety, and travel time. It can also have various indirect impacts, such as environmental, social, and economic impacts. These indirect impacts are the basis of sustainability in this paper. Majority of these impacts are due to the roughness of the pavement surfaces. Roughness is the irregularities that occur on pavement surfaces due to age, environmental effects, climate, and traffic usage. These irregularities cause discomfort, delay, and increase the likelihood of accidents; as a result it becomes costly for a highway agency to maintain or rehabilitate the road segment with increased pavement roughness. The World Bank classified roughness as one of the main factors in the analysis and trade-offs involving road quality vs. user cost. Roughness is quantified using IRI and PSR; with IRI being the most important index to determine performance.

Past models

Past models provide insight to different areas of pavement management system, such as predicting future condition of pavements and estimating the timing of maintenance. It helps provide feedback to the design process, and life-cycle cost analysis (Haas, et. al, 1994). The purpose of developing a modeling framework for pavement management is to identify optimal timing of undertaking maintenance activities in order to maximize the pavement life-cycle. According to Darter (1980), there are four basic measures for developing reliable pavement models. These measures include database from existing pavements, adequate functionality of the model, models that meet the statistical criteria for prediction error, and measures that include all parameters that have relevant effects on pavement performance. There are several existing methods used for assessing and predicting pavement conditions; some of which include: Markov processes, regression analysis, neural networks, fuzzy logic, expert systems, etc. These methods are used for creating index for pavement condition evaluation and future prediction of pavement conditions.

REVIEW OF RELEVANT STATISTICAL MODELS

In order to understand the data and develop the statistical model, the following factors shall be considered: the method of data collection, determination of sample size "n", type of regression analysis, analysis of variance, mean square of error (MS_E), confidence level, *F-tests* & *t-tests*, etc. The factors to be considered for designing a statistical model are mathematically expressed below:

1. Sample size (n) =

$$\boldsymbol{n} = \frac{X^2 * N * P * (1-P)}{(ME^2 * (N-1)) + (X^2 * P * (1-P))} \quad \textbf{(8)}$$

where:

n = sample size
X^2 = Chi-square for the specified confidence level
N = Population size
P = Population proportion
ME = desired margin of error

2. Confidence Intervals (CI) =

$$\textbf{CI} = \overline{Mean} \pm \left(Z * \frac{\sigma}{\sqrt{n}} \right) \quad \textbf{(9)}$$

where:

CI = confidence interval
z = standard normal variants
σ = assumed standard deviation
n = sample size

3. Standard Error (S_e) =

$$S_e = \sqrt{\frac{MS_E}{n}} \quad \textbf{(10)}$$

where,

MS_E = mean square error
n = sample size

4. The z-score:

$$Z_i = \frac{X_i - \overline{X}}{S} \quad \textbf{(11)}$$

where:

X_i = value of data *i*
$\overline{X}$ = sample mean
S = sample standard deviation

METHODOLOGY

A multi-linear regression analysis (MLRA) is employed to calculate the sustainability index of a given pavement segment (see flow chart in Figure 9).

The categories for pavement performance evaluation considered in the analysis are:

1. Serviceability:
   - IRI
   - PSI
   - PSR
2. Skid resistance – safety
3. Structural capacity (deflection) index,
4. Surface distress index:
   - Patching,
   - Cracking, and
   - Rutting.

Data collected under this study are classified as ratings (i.e., subjective measures based on opinions of a survey crew consisting of 5 people). The study site is a 3.5 miles section of Muncaster Road in Montgomery County, Maryland divided into 36 sections (500 feet apart) on both eastbound and westbound directions. The subjective judgment of each rating is converted into numerical values on a scale of 0 to 1 (0, being very poor and 1, being very good). It is divided into five subjective categories as illustrated in Table 3.

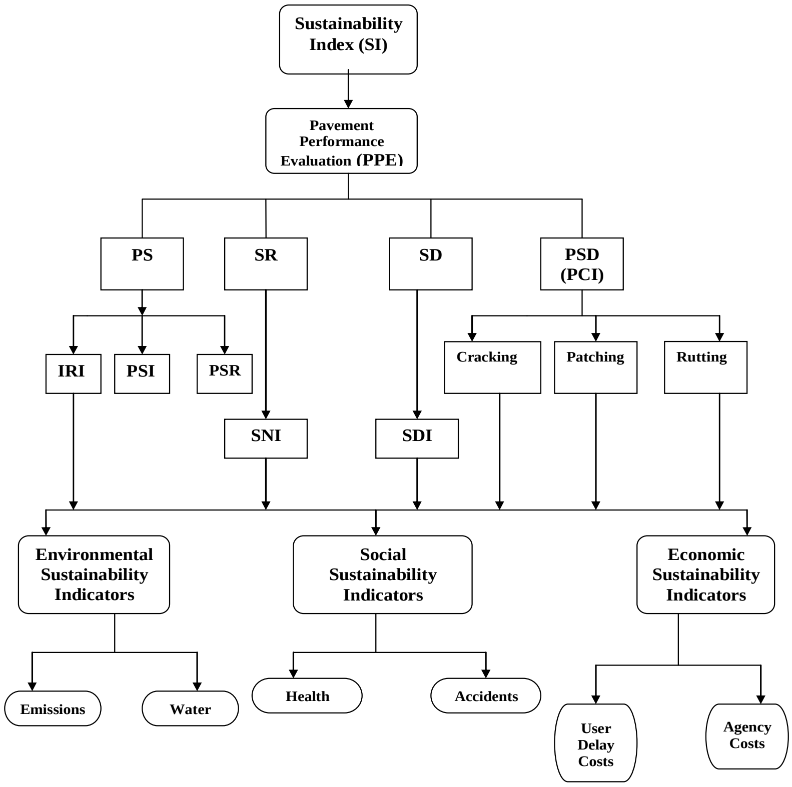


Figure 9: Flow Chart of the Proposed Model

Subjective Category	**Numerical Value (Sustainability Index- SI)**	**Pavement Condition Index (PCI)**
Very poor	0 – 0.2	0 - 40
Poor	0.2 – 0.4	40 - 55
Fair	0.4 – 0.6	55 - 70
Good	0.6 – 0.8	70 - 85
Very good	0.8 – 1.0	85 - 100

Table 3: Subjective Rating of Muncaster Road.

In the MLRA, Sustainability Index (SI) is treated as the dependent variable which is a function of PSI, PSR, and IRI as illustrated in Table 4. The pavement condition survey is conducted on a scale of 0 – 1 for SI; and the MLRA is used to model the relationships between the independent variables (IRI, PSR and PSI) and SI. In general, SI depends on a number of additional factors shown in Eq. (12) and its actual value is calculated using the AASHTO (2001) procedure (see, Table 4).

Subjective Category	**Numerical Value (SI)**	**PCI**	**PSR**	**PSI**
Very poor	0.0-2	0-40	0-0.9	0
Poor	0.2-0.4	40-55	1-1.9	1
Fair	0.4-0.6	55-70	2-2.9	2
Good	0.6-0.8	70-85	3-3.9	3
Very good	0.8-1.0	85-100	4-5	4-5

Table 4: Using FHWA Guidelines for rating PCI, PSR, and PSI.

SI = f(IRI, PSI, PSR, SDI, SRI, CI, RI, PI) (12)

assuming:

SI = y (dependent variable)

PCI = $x_{1,} x_2, x_3, ...x_n$ (independent variables)

expressed as a function,

$Y = f(X)$ **(13)**

therefore,

$Y = f(x_1, x_2, x_3, ...x_n)$ **(14)**

$Y = \beta_0 + \beta_1 * X_1 + \beta_2 * X_2 + \beta_3 * X_3 ..... + \beta_{p-1} * X_{p-1} + e,.$ **(15)**

where:

Y= dependent variable,
$X_{1,2,..p-1}$ = independent variables
β_0 = regression constant (linear regression intercept)
$\beta_{1,2,..p-1}$ = variable constants (slope for linear regression); and
e = random error

There are three objectives to consider when developing the MLRA model:

- Estimate the unknown parameters (β),
- hypothesize the proposed linear model, and
- Check if the model is good for predicting the dependent variable Y .

Model Accuracy

Once the developed model is checked for fitness, it is important to determine if the designed model is good for predicting the dependent variable. In order to perform this, a hypothesis test is carried out on all the regression (β - parameters) constants (excluding β_0), using Eq. (16); F-test based on the null (H_0); and alternative (H_a) hypothesis:

H_0 **:** $\beta_1 = \beta_2 = ...\beta_k = 0$ **(16)**
H_a : one of the parameters should differ from zero

therefore,

F = model mean square/error mean square,

$$F = \left(\frac{R^2}{1-R^2}\right)\left[\frac{n-(k+1)}{k}\right] \quad \textbf{(17)}$$

rejection region F>F $_a$

where:

n = number of observations,
k = number of parameters in the model (except β_0),
R^2 = multiple coefficient of determination, and
a = significance level

NUMERICA EXAMPLE

We analyze a 3.5 miles two-lane roadway pavement along Muncaster Road in Montgomery County, Maryland, which is divided into 36 sections of 500 feet in a residential community setting. The input data is shown in Table 5. The roadway connects two State maintained roadways used by drivers as cut through to their destinations (see, Figures 10 & 11). The roadway has a configuration of two-lane with pavement markings of double yellow center line and white edge marking. A Geographic Information System (GIS) is used to map out the roadway as shown in Figure 10.

Data Point	Pavement Distress Category	Subjective Category	(PCI)	(PSI)	(PSR)	IRI	Sustainability Index (SI)
1	cracks	Fair	55	2.5	2	100	0.5
2	Cracks	Fair	55	2.5	2	100	0.5
3	Cracks	Good	70	3.5	3	95	0.7
4	Cracks	Good	70	3.5	3	95	0.7
5	Patchy	Good	70	3.5	3	95	0.7
6	Cracks	Good	70	3.5	3	95	0.7
7	Good	Very good	85	4.5	4	90	0.9
8	Cracks	Very good	85	4.5	4	90	0.9
9	Cracks/Patchy	Good	70	3.5	3	95	0.7
10	Cracks	Very good	85	4.5	4	90	0.9
11	Cracks	Very good	85	4.5	4	90	0.9
12	Cracks	Very good	85	4.5	4	90	0.9
13	Cracks	Fair (unacceptable)	50	2	1.5	150	0.4
14	Patchy	Fair (unacceptable)	50	2	1.5	150	0.4
15	Patchy	Fair	55	2.5	2	100	0.5
16	Patchy	Fair	55	2.5	2	100	0.5
17	Cracks	Fair	55	2.5	2	100	0.5
18	Cracks	Good	70	3.5	3	95	0.7
19	Cracks	Good	70	3.5	3	95	0.7
20	Cracks	Fair	55	2.5	2	100	0.5
21	Cracks	Fair	55	2.5	2	100	0.5
22	Patchy	Fair	55	2.5	2	100	0.5
23	Cracks	Good	70	3.5	3	95	0.7
24	Cracks	Good	70	3.5	3	95	0.7
25	Cracks	Very good	85	4.5	4	90	0.9
26	Cracks	Good	70	3.5	3	100	0.7
27	Cracks	Very good	85	4.5	4	90	0.9
28	Patchy	Good	70	3.5	3	100	0.7
29	Cracks	Very good	85	4.5	4	90	0.9
30	Cracks	Good	70	3.5	3	95	0.7
31	Patchy	Fair	55	2.5	2	100	0.5
32	Patchy	Fair	55	2.5	2	100	0.5
33	Cracks	Fair	55	2.5	2	100	0.5
34	Cracks/Patchy	Poor	45	1.5	1	170	0.3
35	Cracks/Patchy	Poor	45	1.5	1	170	0.3
36	Some cracks	Good/fair	65	2.5	2	110	0.6

Table 5: Average Parameters obtained from a 5-man panel field Survey.

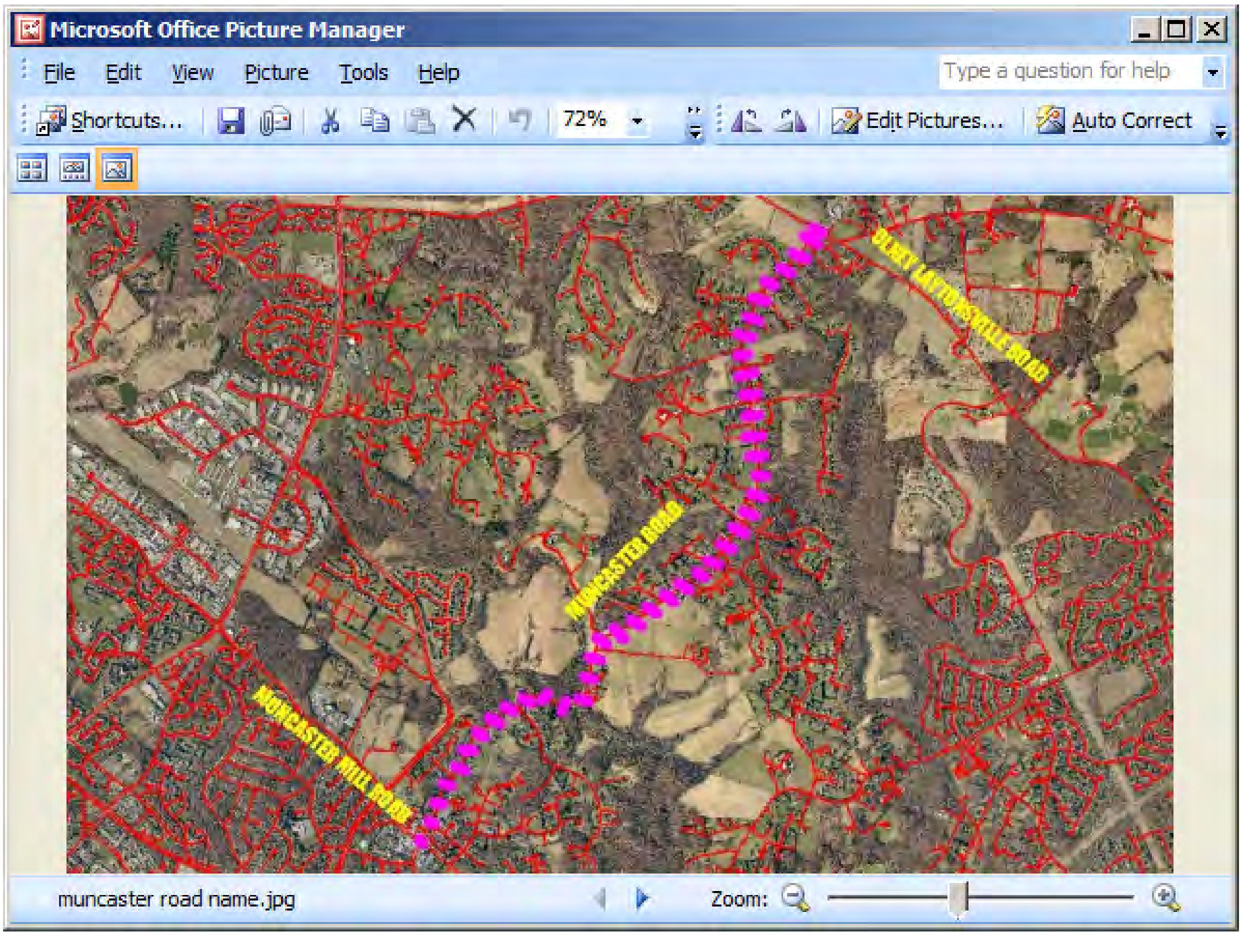


Figure 10: GIS map of Muncaster Road (in 36 sections of 500 feet apart).

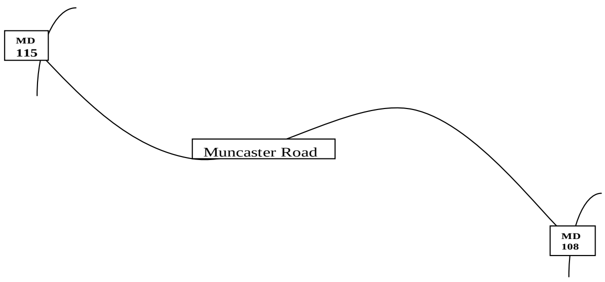


Figure 11: Line Drawing of Muncaster Road

The volume of traffic on this link is assumed to be moderate with Annual Average Daily Traffic (AADT) of more than or equal to 10,000 veh/day/lane in each direction. Assuming each lane is 12 feet wide without shoulders in both directions. The proposed analysis is performed in Microsoft Excel. The input data used for this model are listed in Tables 5; in this application *y* (SI) = dependent variable; and *x*1, *x*2, *x*3, and *x*4 = independent variables. The paper assumes parameters *k* = 4 (*x*1, *x*2, *x*3, and *x*4) to represent PCI, PSI, PSR, and IRI, respectively.

Where:

PCI (*x*1) = Pavement Condition Index,
PSI (*x*2) = Present Serviceability Rating,
PSR (*x*3) = Present Serviceability Index, and
IRI (*x*4) = International Roughness Index.

RESULTS AND CONCLUSIONS

Field data used for the PCI in the numerical example, for the most part exhibit characteristics of real-world pavement conditions. FHWA threshold guidelines were used in estimating the IRI, PSI, and PSR; while SI data were weighed on a scale of 0-1 (1, being very good condition and 0, being very poor condition). IRI is usually measured in meters/km or millimeter/meter; a higher value usually represents a deteriorating pavement.

The analysis of the numerical example was performed using Microsoft excel software. The graphs of coefficient of determination R^2 for the different independent variables (PCI, PSI, PSR, and IRI) indicate perfect fits for PCI, PSI, and PSR respectively; compared to the R^2 of IRI. This indicates that the regression line perfectly fits the line of data and is strongly correlated to the first three independent variables (see, Figures 12, 13 & 14). IRI R^2 is also moderately correlated because the regression line does weakly fit the line of data (see Figure 15).

Analyzing the graphs for the different variables, we observe that the first three independent variables are strongly correlated; with the independent variable x_1 (PCI) R^2 = 0.993, x_2 (PSI) R^2 = 0.9917, x_3 (PSR) R^2 = 0.9917, and x_4 (IRI) R^2 = 0.5165. It can be concluded from the above analysis that the first three variables are highly correlated; which means there is a strong linear relationship between sustainability index and the first three indices (i.e. PCI, PSI, & PSR); compared to R^2 of IRI, which is moderately correlated. This makes the model to be a useful one in determining the relationships between the independent variables and the sustainable index (dependent variable).

In conclusion, it is observed that the coefficients of determination R^2 are very good fits between the proposed model and data for the numerical example as demonstrated in the graphs shown in Figures. 12-15.

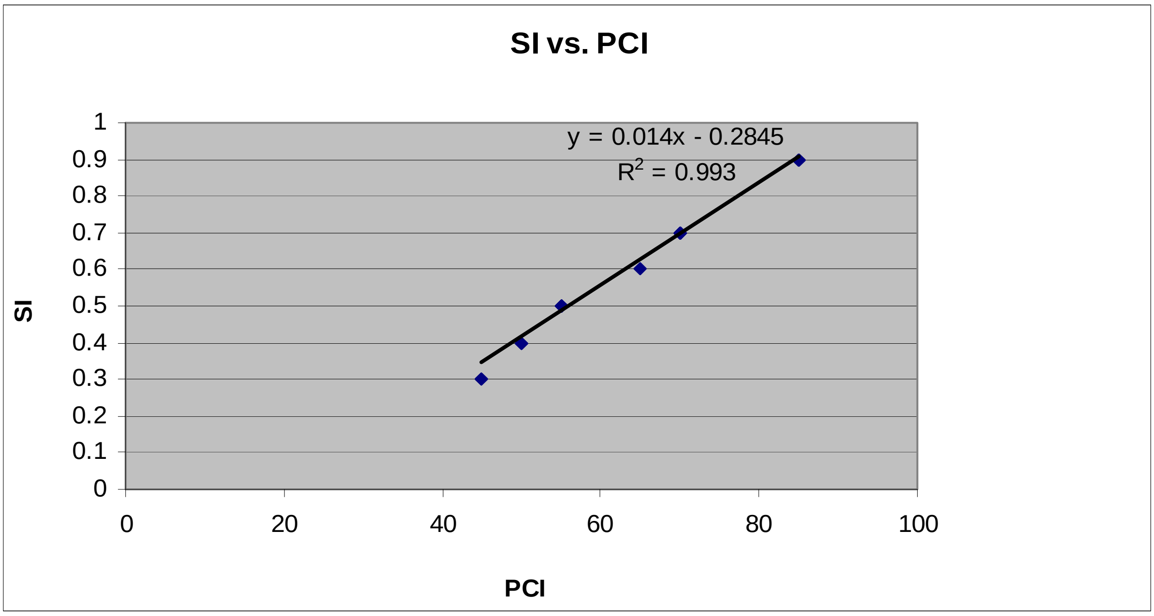


Figure 12: Graph of SI vs. PCI

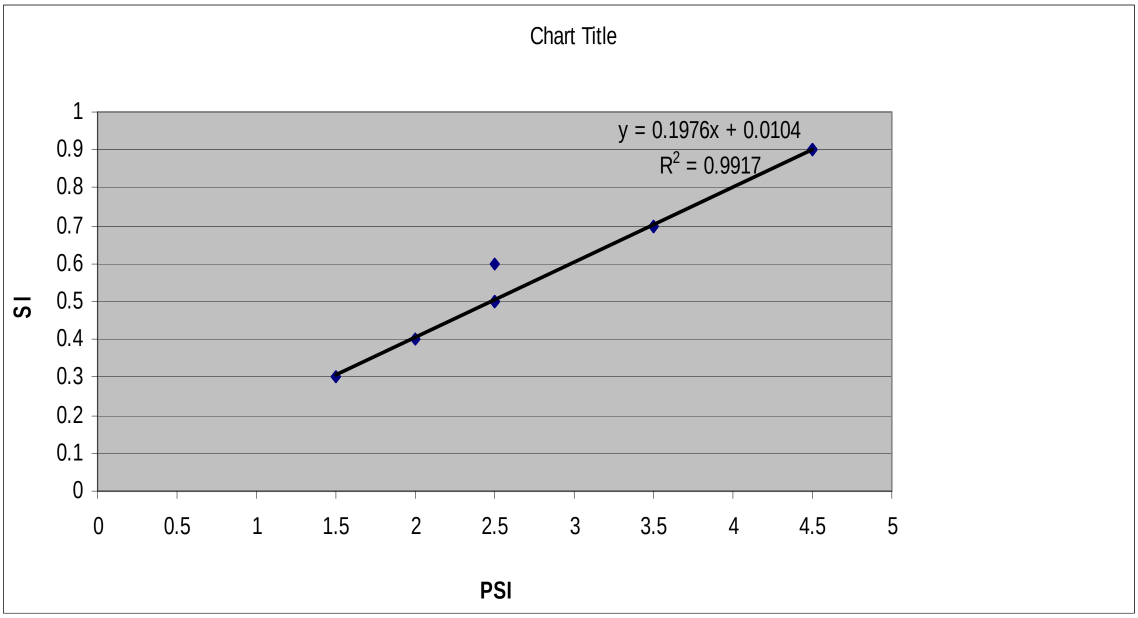


Figure 13: Graph of SI vs. PSI

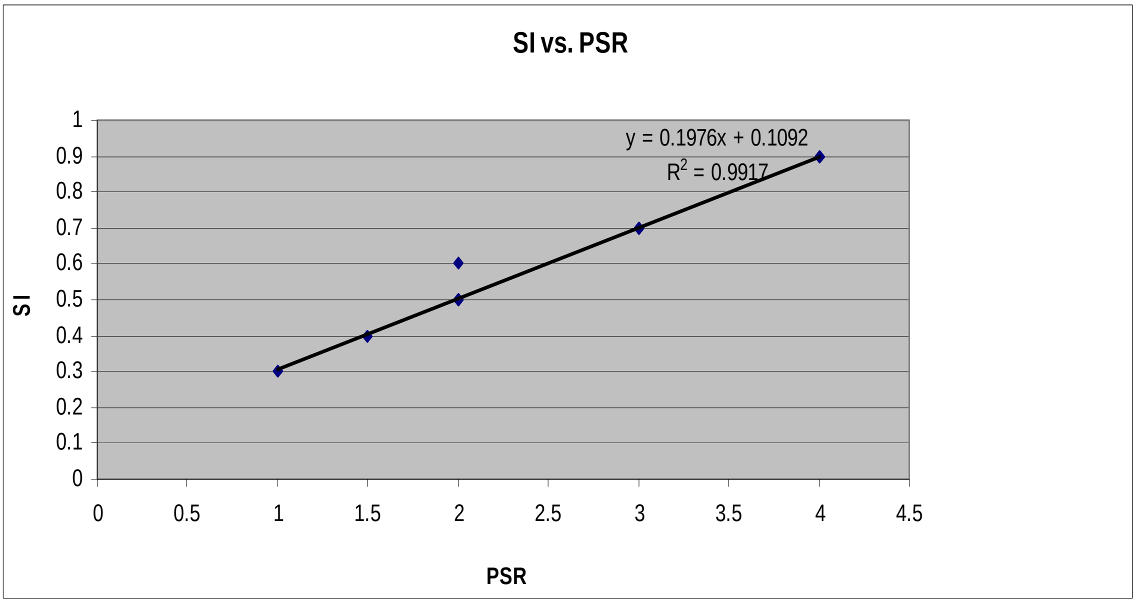


Figure 14: Graph of SI vs. PSR

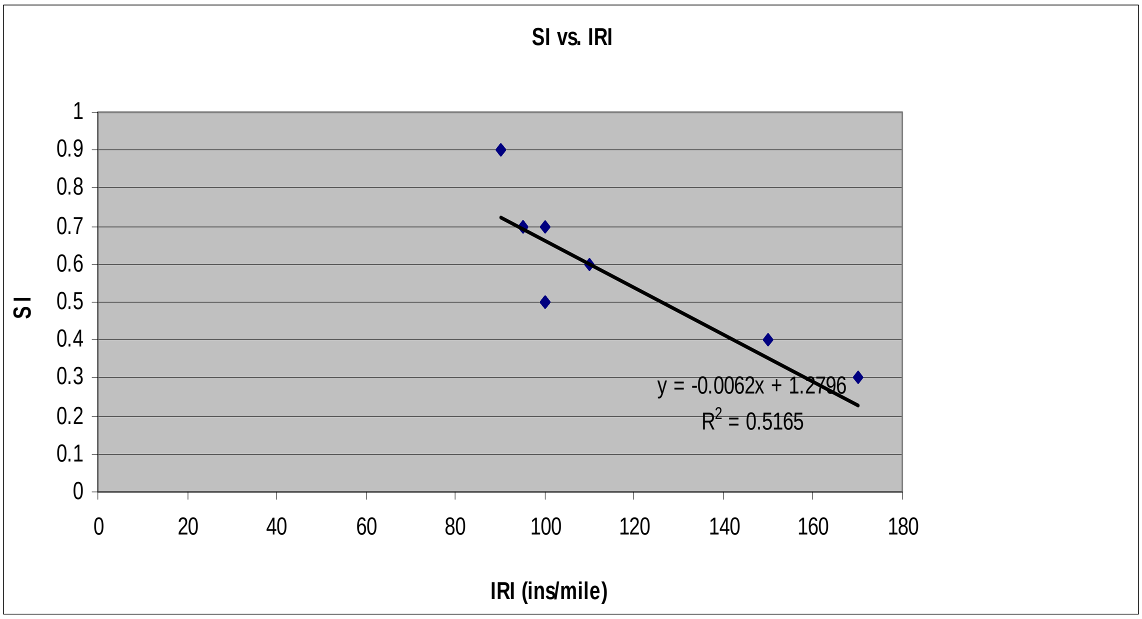


Figure 15: Graph of SI vs. IRI

Future Work

Additional work is to be carried out in the future to further analyze more data regarding the "Three Pillar sustainability dimensions (environmental. Social, and economic values) and using a Life-Cycle Cost Analysis (LCCA) to minimize both user and agency costs and maximize pavement serviceability and life-cycle. A maintenance scheduling optimization model can also be developed in the future (see, Jha 2010).

REFERENCES

Al-Omari, B. and M.I. Darter (1992): Relationships between IRI and PSR. Report Number UILU-ENG-92-2013. Springfield, IL: Illinois Department of Transportation

Awoke, G.S. (2011): Estimating the Friction Performance of Hot Mix Asphalt Pavements based on Aggregate Properties and Route Characteristics: Analysis, Modeling and Validation

Bester, C.J. (2002); "The Effect of Road Roughness on Safety"; Transportation Research Board TRB (2003) Annual Meeting

Bonneson, J., Zimmerman, K. and Fitzpatrick, k. (2006) Interim Roadway Safety Design Workbook – Project Report, Texas Transportation Institute, Texas A&M University System, April 2006

Bruntdland Commission on World Commission on Environment and Development (WCED)(1987): Our Common Future, Oxford University Press, Oxford, England, 1987

Barrera-Roldan A., Saldivar, A., Ortiz, S., Rosales, P., Nava, M., Auilar, S., Rodriguez, L., Villasenor, E., and Angeles, A. (2003). Industrial Sustainability Index Transaction on Ecology and the Environment vol. 63, (2003) WIT Press, www.witpress.com, ISSN 1743-3541

Carey, W. N., Jr. and Irick, P.E. (1960), The Pavement Serviceability Concept. Highway Research Board Bulletin 250. National Research Council, Washington D.C., pp. 40-58

Corley-Lay, Judith B. (1998).Friction and Surface Texture Characterization of 14 Pavement Test Sections in Greenville, North Carolina.Transportation Research Record, No. 1639 (1998): pp. 155-161

Darter, M.I. (1980). Requirements for Reliable Predictive Pavement Models", Transportation Research Record 766, Transportation Research Board, Washington, D.C., 1980

Deakin, E. (2001). Sustainability Development and Sustainable Transportation: Strategies for Economic Prosperity, Environmental Quality, and Equity. (IURD Working Paper Series; Institute of Urban and Regional Development, University of California Berkeley). http://escholarship.org/uc/item/0m1047xc

Durango-Cohen, P. and P. Sarutipand (2009). Maintenance optimization for transportation systems with demand Responsiveness, Transportation Research, Part C, 17(4), pp.337-348

Federal Highway Administration (FHWA, 2002): Status of the Nation's Highways, Bridges, and Transits: Conditions and Performance. www.fhwa.dot.gov/policy/2002cpr/pdfs.htm (Assessed on February 24, 2013)

Federal Highway Administration (FHWA, 2008): Status of the Nation's Highways, Bridges, and Transits: Conditions and Performance. www.fhwa.dot.gov/policy/2008cpr/pdfs.htm (Assessed on July 2, 2013)

FHWA Life-cycle cost Analysis, FHWA report FHWA-SA-98-079: (1998) Life-Cycle Cost Analysis in Pavement Design. http://www.fhwa.dot.gov.infrastructure/asstmgmt/lcca.htm (accessedJuly, 2013)

FHWA (2011): Sustainability Evaluation and Planning Guidance for Transportation Systems. Transportation Planning Cooperative Research Board Agency Announcement DTFH61-08-R-00011

Gillespie, T. D.; Sayers, M.W.; & Sepel, L.; NCHRP Report 228 (1980). Calibration of Response-Type Road Roughness Measuring System TRB, National Research Council, Washington D.C., 1980

Galehouse, L., Moulthrop, J.S. and Hicks, R.G.(2003) Principles for Pavement Preservation: Definitions, Benefits, Issues and Barriers. TR News 228, Sep./Oct. 2003, pp. 4-9 (via NCHRP Synthesis 343)

Graham, J, (2005), Internal Traffic Control Plan; Midwest Research Institute

Haas, R., Hudson, W.R., and Zaniewski, J. (1994). Modern Pavement Management, Krieger Publishing Company, Malabar, FL

Hveem, F.N. and Carmany, R. M. (1948) Factors Underlying the Rational Design of Pavements. Proceedings, Highway Research Board, Washington D.C., December 7-10, 1948

Hicks, R. G. (1991), NCHRP Synthesis of Highway Practice 175: Moisture Damage in Asphalt Concrete. Transportation Research Board. National Research Council, Washington D.C.

Jayawickrama, P.W., Prasanna, R. and Senadheera, S.P. (1996). Survey of State Practices to Control Skid Resistance on Hot-Mix Asphalt Concrete Pavements. Transportation Research Record, No. 1536 (1996): pp. 52-58

Jeon, C. and Amekudzi. A. (2005). Addressing Sustainability in Transportation Systems: Definitions, Indicators, and Metrics – The Journal of Infrastructure Systems, ASCE, March 2005

Jha, M.K. (2010). Optimal Highway Infrastructure Maintenance Scheduling Considering Deterministic and Stochastic Aspects of Deterioration, in Sustainable and Resilient Critical Infrastructure Systems, K. Gopalakrishnan and S. Peeta (eds.), pp. 231-248, Springer

Lou, Z. (2007). Flexible Pavement Condition Model Using Clusterwise Regression and Mechanistic-Empirical Procedure for Fatigue Cracking Modeling.

McManus, K. J., Mann, A., and Evans, R. P., (1998). The Analysis of Road Roughness and Perception of Road Roughness. International Symposium on Heavy Vehicle Weights and Dimensions, 5th 1998, Maroochydore , Queensland, Australia, Part 4

Mayer, A. (2007). Strengths and Weaknesses of Common Sustainability Indices for Multidimensional Systems. ScienceDirect Environmental International 34 (2008) 277-291. www.sciencedirect.com

Moretti, L., Di Mascio, P., and Panunzi, F. (2012). Economic Sustainability of Concrete Pavements. Procedia – Social and Behavioral Sciences 53 (2012) 125-133.

NCHRP Synthesis 334; (2001); Automated Pavement Distress Collection Techniques – A Synthesis of Highway Practice

National Association of County Engineers, US (NACE) (1992). Action Guide, Volume III-1 "Road Surface Management", National Association of County Engineers, 1992

Nick J. B. and Janoff, M. S. (1983). Evaluation of Panel Rating Methods for Assessing Pavement Ride Quality. Transportation Research Board (TRB) 946, National Research Council Washington D.C., 1983

Ortiz-Gallarza, S. M., Nava, M., Rodriguez, L., Barrera, A., and Villasenor, E. (2003). Selection of Environmental Parameters to Estimate an Industrial Sustainability Index. Transaction on Ecology and the Environment vol. 67, (2003) WIT Press, www.witpress.com

Papagiannakis, A. T. and Masad, E.A. (2007): Pavement Design and Materials. John Wiley & Sons, New Jersey

Paterson, W. D. O. (1986). International Roughness Index: Relationship to other Measures of Roughness and Riding Quality. Transportation Research Record 1084, Transportation Research Board, 1986, pp. 49-59

http://www.pavement interactive.org; Pavement Interactive (2007): Life-Cycle Cost Analysis; published on August 15, 2007. Accessed on March 16, 2013

http://www.pavement interactive.org "Pavement - Preventive or Repair?" (May 2013) and accessed on October 25, 2013

Ramani, T., Zietsman, J., Eisele, W., Roas, D., Spillane, D., and Bochner, B. (2009): Developing Sustainable Transportation Performance Measures for TXDOT's Strategic Plan. Technical Report No. SWUTC/09/0-5541-1

Rodrigue, Jean-Paul, (2013) – New York: Pollutants Emitted by Transport System (Air, Water and Noise), ISBN978-0-415-82254-1

Salami, O., CPC,. El-Assaly A., and AbouRizk S.,(2003).; Performance Prediction Models of Pavement Highway Network in Alberta. TRB, 2003 Meeting CD – ROM.

Strategic Highway Research Program (SHRP) (1993), National Research Council-P338; Distress Identification Manual for the Long-Term Pavement Performance Project

Transportation Research Circular Number E-C118, (2007); Pavement Lessons Learned from the AASHO Road Test and Performance of the Interstate Highway System.

Virginia State of Transportation (2009). Pavement Evaluation and Design, Chapter VI.

Pavement Interactive. (2013). http://www.pavementinteractive.org (accessed October 25, 2013)

Vogt A. and Bared, J. G. (1998) – Accident Models for Two-Lane Rural Roads: Segments and Intersections, Publication No. FHWA-RD-98-133, October 1998.

Washington State Department of Transportation (2005).Pavement Policy. Vol. 1. May 2005. www.wsdot.wa.gov/biz/mats/pavement/WSDOT_Volume1-Pavement Policy.pdf

JBU III (2013) 1&2

Part B – 2013 ISB Summer School in Neuroergonomics and Urban Placemaking Students' notes

2013 ISB Summer School in Neuroergonomics and Urban Placemaking Students' notes

Antonio Caperna, Stefano Serafini

antonio.caperna@biourbanism.org
stefano.serafini@biourbanism.org

The ISB summer school in Neuropergonomics and Urban Placemaking has been held in Artena from July 21st-28th 2013. Almost 40 people from several Countries attended. The theoretical part focused on a multidisciplinary mix of neurophysiology, complexity, biology, urban sociology and service design so to encourage people thinking out of the box about urban design, and considering the relevance of body, senses, locality, and real people needs.

The practical workshop was directed by professor Marco Casagrande, who encouraged students to get in touch with the local environment in order to "become by doing" and act accordingly to what they had learned.

Here's the list of the teaching staff and of the participants:

• Philosopher and psychologist Stefano Serafini (I.S.B., Italy) introduced the use of environmental psychology and post-darwinian biological theories to re-orient the approach to design.

• Artist and architect prof. Marco Casagrande (Ruin Academy, Finland/Taiwan) led hand-building experiences after listening to the city's organism (biourban acupuncture).

• Design thinker and architect Yulia Kryazheva (Yulia Ink., The Netherlands) introduced the use of sketching & drawing as a tool to get in touch with the complexity of a place.

• Professor Antonio Caperna (I.S.B.,Italy),architect,and professor Eleni Tracada (University of Derby, UK), architect, introduced and showed practical examples of Biourbanism and algorithmic sustainable design.

• Architect Angelica Fortuzzi (I.S.B., Italy) contrasted the American experience of Placemaking with the European context and with Biourbanism.

• Katie Donaghy, BA in Sociology and Anthropology and MA in Town and Regional Planning, and Menno Cramer, BSc in Neuroscience and Medicine explained how city, society, and neurology interact, and how we can change design to influence behavioural outcomes.

• Psychologist Silvia Micocci offered an experimental workshop on bodily self-perception in an open space through an original projective tool such as clay modeling.

• Professor Mariano Bizzarri, Oncologist, Biochemist, President of the scientific council of the Italian Space Agency, Head of the Systems Biology Laboratory, Medicine Dept, Sapienza University of Rome, gave a lecture about his professional and scientific experience about complexity.

Participants: Emily Lorance Rall (UK), Nissa Shahid (UK), Pavel Farkas (Czech Repubblic), Catherine Ryan (USA), Francesca Rogers (UK), Inge de Boer (The Netherlands), Jiang Liu (China), Dilara Akülke (Turkey), Leandros Koutakos (UK), Davide Damiano Pio (Italy), Eleni Ploumidi (Greece), Tatjana Capuder Vidmar (Slovenia), Ottavia Molatore (Italy), Jing Wen Lin (Taiwan), Maria Valese (Italy), Sherryl Muriente (USA), Kyle Perry (USA), Sira Savoldi (Italy), Francesca Troiano (Italy), Aggeliki Lymperopoulou (Greece), Esra Demirel (Turkey), George Surovov (USA), Francesco Letteriello (Italy), Guglielmo Minervino (Italy), Angelo Gentili (Italy), Clemente Brunetti (Italy), Vishank Kapoor (India).

Students presented the results of their work to the people of Artena at the end of the school, whilst the whole experience was shot by the company “Peleo Film”, who released the documentary movie *Regeneration Town* on June 2014.

Down here we have collected some short papers written by the participants after they had returned home. We hope these writings may transmit part of the exciting feeling that we shared during the school, while experimenting, creating, discovering, learning, and enjoying.

Next school will be held in Artena from July 13th to the 20th 2014, and it will be devoted to Neuroergonomics and sociogenesis. Urban design affects social relationships, health and justice of a community. We whant then investigate how biourbanism and biophila can contribute for designing a city able to generate social relations, instead of breaking them.

The relationship between design and the so called “economic crisis” that is hitting the European Countries will be the main subjects of another workshop to be held in Heraklion, Greece, August 1st-9th, and that will be partly founded on the Artenese experience.

Uncovering social needs and values in Artena, Rome A community values mapping approach

Emily Lolance Rall

e.rall@tum.de

Sira Savoldi

sira@renatosavoldi.191.it

ABSTRACT

The following paper describes a community values mapping approach designed to explore social needs and values as well as hotspots of activity in the small village of Artena, Italy. The research was conducted during the course of the 2013 Biourbanism Summer School, and designed to form the socio-cultural context for small intervention projects conceived as part of a revitalization strategy for the town. Short semi-structured interviews were carried out with a random sample of 26 residents of the town using paper-based maps to locate important meeting areas and walking routes, places of meaning, and places of opportunity. The research indicated that the most activity-rich and meaningful areas of town lie on its outer edges, whereas areas most needing improvement are concentrated in the middle of town, particularly in bombed out vacant lots. The community values mapping approach used proved to be a useful tool for highlighting important elements of the social context of a community as well as for providing a voice to community residents who are frustrated at the lack of municipal attention to town concerns. The potential application of the tool as an aspect of biourbanism research and design are highlighted.

Key words: community values mapping; participatory planning; biophilic design, urban revitalization, biourbanism, urban planning, human well-being, mental mapping

INTRODUCTION

Artena is a small town at the base of the Lepine mountains situated 30 km east of Rome. It was built between the 5th and 6th century BCE, carved out from the limestone mountain on which it rests. Its ancient name "Montefortino" still reflects the current character of the place – a difficult to reach, densely built mountain village perched high above with still visible stone fortifications, lending it an equally imposing and charming air. The entire village is composed of stone, from its attached houses to its winding streets to the few mansions which dot the town and hint at the town's history as the residence of noble families such as the Borghese. The town's narrow, cobblestone streets are characterized by steep slopes improvised with continuous steps and are passable only by foot or by donkey, the latter of which is used for heavy goods transport. A few stores in town provide the most basic of necessities and the couple public areas in town are largely undefined, providing few amenities other than a possible bench and overlook. Cars can only access the town at three points on the outer edge. Green spaces in town are meager and concentrated in the central part of town, the result of bombing during World War II. These spaces have since remained unresolved, indicated by their sparsely vegetated, neglected, trash-strewn character.

Taken together, these features do not make living in Artena easy, which is why development spread from the foot of the historic village into the plain below. Most of Artena's population of 14,000 live in the new part of town, "Artena nuova," where a series of new neighborhoods catering especially to young families are better suited to contemporary needs. Old Artena's dwindling population numbers at a couple hundred, and there is a growing urgency to develop a vision for the town.

In connection with the newly founded Progetto Artena and the International Society of Biourbanism, the 2013 Biourbanism Summer School in Artena aimed to create new visions and design impulses in the village by integrating theory on complexity, neuropsychology, architecture and biophysics with action-oriented "bioacupunture projects" across town. The bioacupuncture projects were conceived as test beds for instituting biophilic design, whereby patterns in nature are carefully reinterpreted in the built environment to support social and cognitive functioning while strengthening the "genetic code" and resiliency of a place (Caperna, 2013). According to Caperna (Ibid.), one of the tenants of biophilic design is understanding the "*wholeness of the site*" as a context for different planning actions. Thus, before implementing place-based bioacupuncture projects, it was first necessary to explore the social landscape of Artena, to talk with inhabitants to better understand their own needs, difficulties, values and desires in relation to the physical environment.

MAPPING ARTENA'S SOCIAL LANDSCAPE

In an effort to better understand how Artenese conceive of and interact with their environment, we decided to institute community values mapping (Raymond et al., 2009), whereby community members are asked to identify areas of value and threat on a map, and these answers are compiled to produce a community-level picture of the intensity and distribution of these values and threats. This style of mapping has been alternatively called landscape values mapping (Carver et al., 2009), participatory mapping (Fagerholm & Käyhkö, 2009), place attachment mapping (Brown & Raymond, 2007), and social values mapping (Sherrouse, Clement, & Semmens, 2011). Though these approaches often have slightly different methods, they all draw greatly from theory and research in behavioural geography and environmental psychology (McLain et al., 2013), whereby place is differentiated from space as mental constructions of areas embodied with experience, whether real or imagined, and meaning (Tuan, 2001). The academic use of maps to represent place was most influenced by American urban planner Kevin Lynch, whose most famous work *The Image of the City* (1960), showed that people perceive urban environments in consistent ways through the use of a mental mapping exercise. Most notably, Lynch found that people tend to define the environment in terms of five elements: paths, edges, districts, nodes and landmarks.

Figure 1 Base map of Artena used for interviews

The project described here used place-based nodes and paths, or focal points and channels of mobility, respectively, to uncover places of meaning and opportunity in Artena as part of the 2013 Biourbanism Summer School. The aim of the project was to use these nodes and paths of meaning and opportunity to map Artena's social landscape as a context for the "bioacupunture" projects undertaken during the summer school. While social landscapes are multifaceted, including attitudes, values, perceptions, activities, sense of place and social capital (Ryan, 2011), each of which may be connected with place, for our project, we chose to concentrate on perceptions, attitudes and activities of and within Artena.

The research was carried out through the use of semi-structured interviews with a random sample of 26 residents of Artena. The interviews each lasted approximately five minutes and consisted of an introduction to the study and five sections. In the first section, participants were asked where people congregate in town, when, and if this is the same in the winter as in the summer. The second section asked each participant for places most meaningful to them personally in terms of social interaction, beauty and spirituality and why (in a few words). The third section asked for public places in town that could use improvement and why (in a few words). The next section asked participants to identify routes they often use, and the last asked whether or not the participant was a native Artenese. Each of the interviews involved use of a hand drawn map of Old Artena (Fig. 1), transparent paper, and different colored markers. After an introduction and inquiry about the participants' first name and age, participants were given a brief orientation to the map and asked to mark each of the places asked for (places of congregation, meaning, opportunity or improvement, and commonly used routes) directly on the transparent paper atop the map. Different colored markers were provided for mapping places of meaning, whether social, spiritual, or aesthetic.

A pilot conducted with two residents uncovered substantial language difficulties with a purely paper based, translated version of the interview. Thus, a native Italian speaker was recruited to lead the interviews while another researcher assisted with the mapping and equipment. This decision not only made interviews flow more smoothly, they also allowed the capture of a much greater level of sensitivity regarding attitudes and survey feedback.

All maps were superimposed to reveal concentrations of perceived social activity and places of personal meaning and opportunity, in terms of their distribution and intensity. These concentrations were summarized in two thematic maps (places of value and improvement) for presentation to the community at a final workshop on the last day of the summer school.

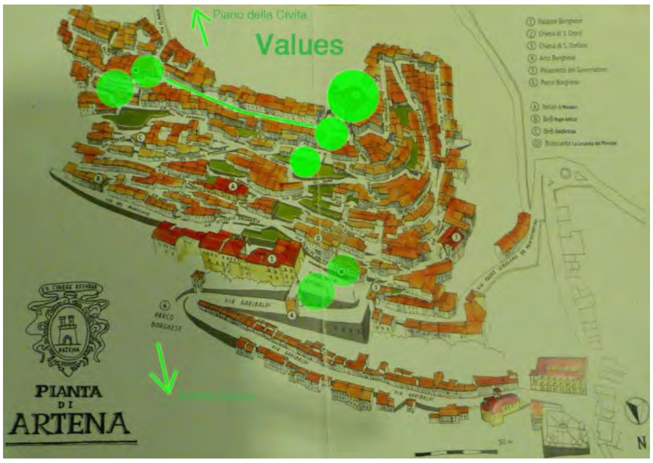


Figure 2 Composite map of the most valued places in Artena

Figure 3 Composite map of places perceived to need the most improvement

Places and paths identified as the most valued sites (Fig. 2) corresponded in most cases with their role as a social meeting space, but in some cases also related to their historical, cultural and religious significance. Identified places of value included the churchyard and the church of S. Croce, Piazza Vittoria, Via Maggiore, the Piazza della Resistenza, the Palazzo Borghese park called "the Villa", the archaeological site called "Piana Civita," and Piazza Don Amedeo Vitelli. The largest vacant lot in town, called "Case spallate," the result of bombing during the Second World War, was also mentioned by a few residents, particularly adolescents. Many of the places identified were discussed in terms of cherished memories.

Places for improvement (Fig. 3) corresponded mostly to the many trash-filled and neglected vacant lots in the heart of town caused by World War II bombing, but also to old Artenese palaces such as the Palazzo Borghese and the small Palace of the Governo, which are in dire need of restoration. The Borghese park called "la Villa", which is remembered as a very nice place but now difficult to access, was also mentioned. These "places for improvement" were concentrated within the inner part of town as opposed to the more valued sites, which were found on the outer edges of Artena.

Though the values mapping research described herein was intended to inform the other bioacupuncture projects, time constraints made their concurrent execution necessary. Nevertheless, the Biourbanism Summer School participants were intuitively drawn to the many vacant lots in the heart of town. These decisions were likely made as much because of the low risk associated with the spots on account of their obvious neglect, as of a perceived intervention need.

In conducting the values mapping interviews, many of the residents, when asked to participate, were initially reluctant or hesitant. After explaining the reasons why we were looking for information on Artena – in order to understand their needs and their difficulties, ambitions and desires – we found people very willing share. Often our interest in them was rewarded with gratitude for our work and our attention to them. Thus, aside from uncovering places of social and personal meaning and opportunity, we discovered that one of the pressing needs of the community is that of "being heard," especially by the municipality, which was often referenced during the interviews.

Figure 4 Churchyard of St. Croce during the "Live Artena" Festival

In response to the perceived lack of municipal assistance in community development, many Artenese have taken it upon themselves to initiate activity. One group of young Artenese have recently organized a blog and a website which serves as an intermediary between people and institutions in Artena towards community development. Village residents also organize several activities throughout the year, from folk festivals to religious events. Particularly important as a center for these festivals is the churchyard of St. Croce, which was identified in the interviews to be as important for social meaning as for religious meaning (Fig. 4). "Live Artena" is one of the largest such events of the year (Fig. 5), in which old cellars and warehouses are revived as art galleries and mini-bars. The expansion of this event is seen as an opportunity which could become an important vehicle to boost the local economy and to revive the historic village. In particular, many residents would like to see Via Maggiore be redeveloped to become a place in which typical food products and crafts of the area are displayed in order to attract tourists and people from outside to move to Old Artena.

Figure 5 Photographs of the galleries of "Live Artena"

VALUES MAPPING AS A TOOL FOR BIOURBANISM RESEARCH AND DESIGN

One of the major problems in modern architecture is that projects are often designed and built without sensitivity to the place in which they are situated and the social and natural systems which operate there, seeking instead to create a universal artistic statement. Biourbanism seeks to counter this issue by treating the urban environment as a complex system within which interactions between human and physical elements can be deepened in a way that provides environmental enhancement, psychological restoration, and a higher quality of life (Caperna et al., 2010). By conducting community values mapping, subjective and objective elements of the landscape are combined in a way that can deepen understanding of physical and social interactions within an urban environment.

Kevin Lynch's *The Image of the City* (1960) and subsequent work demonstrated that uncovering human perceptions of the urban environment through mental mapping can be used as the conceptual basis for sound urban design. The research described herein utilized paper-based maps to uncover Artena residents' mental maps of their community and demonstrated a consistent picture of meaningful and activity-rich areas on the one hand, and negatively perceived areas on the other hand. While paper maps allow a certain degree of flexibility in capturing multifaceted, place-based relationships and values, they are also time-consuming in data analysis. Though this method worked well for the small population of Old Artena, GIS (Geographic Information Systems) and other digital cartographic tools may be more appropriate in other urban settings with higher populations and more complex built areas to uncover place meanings and how they connect with physical form.

Combining place-based perceptions with geographic information on the built and natural environment has multifaceted, powerful planning capabilities. Though this area of research is relatively new, it has already shown great promise for exploring aesthetic preferences, psychological well-being, restoration, social interaction and place attachment (Brown & Raymond, 2007; Fuller, Irvine, Devine-Wright, Warren, & Gaston, 2007; Matsuoka & Kaplan, 2008). Values mapping also facilitates participatory planning by providing a communication tool and a means to more deeply think about the way one relates to and interacts with one's environment, as well as offering a powerful visualization of community values and threats. The latter point is particularly important considering participatory planning has been the subject of increasing emphasis in both research and planning practice over the last 20 years (King, Renó, & Novo, 2013). Future biourbanist research could incorporate community values mapping to explore how biophilic designs affect various dimensions of human well-being and quality of life in urban environments.

CONCLUSION

The community values mapping approach described demonstrated to be a useful method of charting important elements of the social system in Artena, notably important meeting areas and walking routes, places of meaning, and places of opportunity. The research indicated that the most activity-rich and meaningful areas of town lie on its outer edges, whereas areas most needing improvement are concentrated in the middle of town, particularly in bombed out vacant lots. Though a sense of intuition directed the location of most of the bioacupuncture projects completed during the course of the 2013 Biourbanism Summer School, which correlated with the values mapping results, intuition and artistic inspiration in architecture do not always lead to well-placed and well-received results. A values mapping approach such as the one described herein has the potential to pinpoint areas of activity, meaning and opportunity so that natural social flows and values are respected while areas in need of urban revitalization can be pinpointed. It also proved to be a useful tool for community members to voice their hopes and frustrations regarding planning in the city. Though the approach described here only used basic paper-based maps means and no digital analytical tools, more sophisticated community values mapping approaches have been shown to have vast potential for underlining interactions between social and natural systems at a myriad of scales, from the individual to the neighborhood and city-level. Community values mapping is thus recommended as a powerful tool for future research in biourbanism.

REFERENCES

Brown, G., & Raymond, C. (2007). The relationship between place attachment and landscape values: Toward mapping place attachment. Applied Geography, 27(2), 89–111.

Caperna, A. (2013). Introduction to Biophilic Design. International Society of Biourbanism. Retrieved September 20, 2013 from http://www.biourbanism.org/introduction-to-biophilic-design/

Caperna, A., Cerqua, A., Giuliani, A., Salingaros, N. Serafini, S., (2010). "Biourbanistica". Retrieved from: www.biourbanism.org

Carver, S., Watson, A., Waters, T., Matt, R., Gunderson, K., & Davis, B. (2009). Developing computer-based participatory approaches to mapping landscape values for landscape and resource management. Planning Support Systems Best Practice and New Methods, 431–448.

Fagerholm, N., & Käyhkö, N. (2009). Participatory mapping and geographical patterns of the social landscape values of rural communities in Zanzibar, Tanzania. Fennia-International Journal of Geography, 187(1), 43–60.

Fuller, R. A., Irvine, K. N., Devine-Wright, P., Warren, P. H., & Gaston, K. J. (2007). Psychological Benefits of Greenspace Increase with Biodiversity. Biology Letters, 3(4), 390–394. doi:10.1098/rsbl.2007.0149

King, M. F., Renó, V. F., & Novo, E. M. L. M. (2013). The Concept, Dimensions and Methods of Assessment of Human Well-Being within a Socioecological Context: A Literature Review. Social Indicators Research, 1–18. doi:10.1007/s11205-013-0320-0

Lynch, K. (1960). The image of the city. MIT Press: Boston.

Matsuoka, R., & Kaplan, R. (2008). People needs in the urban landscape: Analysis of Landscape And Urban Planning contributions. Landscape and Urban Planning, 84(1), 7–19. doi:10.1016/j.landurbplan.2007.09.009

McLain, R., Poe, M., Biedenweg, K., Cerveny, L., Besser, D., & Blahna, D. (2013). Making Sense of Human Ecology Mapping: An Overview of Approaches to Integrating Socio-Spatial Data into Environmental Planning. Human Ecology, 1–15. doi:10.1007/s10745-013-9573-0

Raymond, C. M., Bryan, B. A., MacDonald, D. H., Cast, A., Strathearn, S., Grandgirard, A., & Kalivas, T. (2009). Mapping community values for natural capital and ecosystem services. Ecological Economics, 68(5), 1301–1315. doi:10.1016/j.ecolecon.2008.12.006

Ryan, R. L. (2011). The social landscape of planning: Integrating social and perceptual research with spatial planning information. Landscape and Urban Planning, 100(4), 361–363. doi:10.1016/j.landurbplan.2011.01.015

Sherrouse, B. C., Clement, J. M., & Semmens, D. J. (2011). A GIS application for assessing, mapping, and quantifying the social values of ecosystem services. Applied Geography, 31(2), 748–760. doi:10.1016/j.apgeog.2010.08.002

Rethinking "Case Spallate"

Sira Savoldi

sira@renatosavoldi.191.it

ABSTRACT

During the Summer School in Artena, one of the proposed exercises was about resetting the so-called "*Case spallate*" – an area below the small Piazza Don Amedeo Vitelli, consisting of two terraces without access from the street. This empty urban space is the result of war bombing, and it is underutilized and neglected until now.

Several proposals were made, in order of summarizing wishes and demands of the population, but they have been gradually dropped during the construction. Trying to overcome the difficulties of the place and to emphasize its potentialities was one thing on paper. On the other hand, going on the field revealed the "essence of the place", who prevailed over the will of designers. For example, benches for admiring the view were added, which were not previously thought of before our survey. Upon project completion some structures were created: an access path, a "waterway" to collect meteoric waters, a space which can work as a water pool or an entertainment area, according to the time of year.

In the final phase of the work, which lasted a couple of days, the population began to take interest in the re-qualified space, and to reclaim it.

Key words: redevelopment, re-evaluation, meeting place, belvedere, events, participation of the population, biourban acupuncture.

INTRODUCTION

The historic village of Artena spreads over a hill of the Lepine mountains in the province of Rome. Its urban density makes the connecting roads and open spaces to seem part of the houses themselves. The steeply sloping connections are resolved with stone steps, along which mules only can carry heavy materials and supplies. The spaces that open up unexpectedly here and there, are the results of bombing during the last world war. The so-called “Case spallate” are gaps left by the destruction of some houses, and never re-sewed. For decades, these spaces kept being small landfills between the houses.

One of the proposed exercises during the Summer School was the redevelopment of one of these areas. More precisely, we identified the terracing below Piazza Don Amedeo Vitelli, as a particularly significant point on which to intervene.

Having to “rethink” a place so special and complex, we tried to better understand how the Artenese lived and conceived these spaces.

Figure 1 Festival in piazza Don Amedeo Vitelli

Some people were interviewed, from the youngest to the most elderly, and asked what they wanted for Artena, what was missing and what they needed. As a result we found out that one of the most significant points for them is Piazza Don Amedeo Vitelli. Upon request of the population, the municipality recently paved it to make it available for community gatherings and events (Fig. 1). Nonetheless the square remains an unfinished space, with stones still stacked by the existing benches, which makes it difficult to use the space fully (Fig. 2). Further below, looking out over the parapet, one can see the abandoned terraces.

FROM CONCEPT TO CONSTRUCTION PROJECT

The space below Piazza Don Amedeo Vitelli on which action was taken, is structured around a couple of terraces on a steep slope. These terraces do not have any direct access, one has to climb over some rocks to enter. The usability is also difficult due to the presence of debris and materials of varied nature, which were accumulated and abandoned in this place during decades of neglect and abandonment.

Trying to plan a redevelopment project area, we thought back to the interviews. People had expressed the need for meeting spaces, public gardens, playgrounds for children, and places for recreation, where they could organize events able to attract people from the outside.
The team working at "Case spallate" was big and heterogeneous in both nationality and background, and produced several threads (Fig. 3) and project proposals (Fig. 4).

A further analysis through the site let the group focus on physical space, morphology, problems, potentialities, and it brought up some common themes, which would be included in the final design (Fig. 5).

Figure 2. Piazza Don Amedeo Vitelli with cobblestones no longer repositioned

Figure 3. Exchange of ideas and arguments in the working group

Figure 4. Some project proposals

Figure 5. Proposal for final project

First of all, we realized that the two areas were needing "connection". As a consequence it felt natural to design a path that would link them to each other. Additionally, we tried to create a meeting area surrounded by greenery, and a leisure centre for concerts, shows, and more. Somebody found relevant the realization of a "water space" in which people could find refreshment during summer. A hard task to achieve indeed, due to the dryness of the climate. We thus decided to perform this space as a "flow basin", which would convey the "waterway" naturally self-forming during the rains, but that could be used as a small theatre during the dry season.

Figure 6. Situation of the terraces before the intervention

Figure 7. Cleanup work

In the initial phase we started to clean up the place (Fig. 12.6 and 12.7), both on the surface and in depth. Cleaning was continued in depth, until we were able to find the level where the land could be usable. We considered all the terrace wall and street pavement stones, poles and wooden beams from demolitions, and various ferrous pieces that we found on the ground (Fig. 12.8) as useful material to be reused for realizing some of the structures of the project.

Figure .8. Installation of benches to enjoy the view below

Figure 9. Final layout with seats, the waterway, the access path, and the basin at the bottom

During the construction phase, such material started to be utilized. Initially an access path in clay was created, following the contours of the existing ground. As we proceeded with the work, the "essence of the place" took over the project. Looking at the panorama of the valley below, it seemed natural to build a "lookout", creating relax spots which weren't initially planned (Fig. 8). Beside it the waterway with a cascade of stones to mark the path, and the water collection basin below were created (Fig. 9).

Figure 10 A forecast of complete work

ESTIMATION OF THE COSTS

If the work could had been carried on, this is its possible maximum cost, according to the official 2012 public works rate list of Lazio Region.

Work carried out during the Summer school (about 18 people who have alternated three days of work):

1. Cleaning of the surface layers: manual digging of the soil, raking, collection and sorting of waste and found materials	€ 4.000,00

Works estimated to complete the project area:

2. Realization of the soil layer useful for further work: carrying cultivation soil, forming levels of land, bagging and carrying materials on man's shoulder, landfills transportation	€ 15.300,00
3. Creation of access stairs from the side streets: opening access for demolition, construction of stairs with concrete, stone cladding of the space, retaining wall, arrangement of rock existing access	€ 6.500,00

4. Creation of fences on the outer wall of the border:	€ 3.000,00
5. Creation of internal pedestrian access path paved with site stones	€ 3.500,00
6. Creation of retaining walls by using the stones found on site, terracing the area, flower bedding	€ 5.000,00
7. Creation of three levels with recycled materials found on site	€ 1.500,00
Creation of gutter stone for the "waterway", of a containment tank for water made by semi-circular tiers, to be used as an entertainment space	€ 7.500,00
8. Irrigation system	€ 4.000,00
9. Supply and installation of urban furniture: benches, litter bins, children's games.	€ 9.000,00
10. Turfing about half of the area	€ 1.500,00
11. Supply and installation of trees	€ 4.500,00
Total	**€ 69.300,00**

CONCLUSION

After the realization, the attraction and curiosity of the Artenese towards the job we were doing increased, especially towards the change that had taken place in just a few days. The inhabitants began to make proposals on how to continue the work or embellish the different spaces with flowers, plants and other things.

This area seemed to have finally been "unlocked" and they were starting reclaiming it.

One of the aims of the intervention was the participation of the population, which unfortunately hadn't been established in the early phase, but was then increasing.

Following the theory of "biourban acupuncture", our small intervention managed to create a greater repercussion of our intentions, which we hope will continue in the future.

REFERENCES

Casagrande M. (2013), Biourban Acupuncture, International Society of Biourbanism Summer school (2013), Artena (Roma).

Brown, G., & Raymond, C. (2007). The relationship between place attachment and landscape values: Toward mapping place attachment. Applied Geography, 27(2), 89–111.

Caperna, A. (2013). Introduction to Biophilic Design. International Society of Biourbanism. Retrieved September 20, 2013 from http://www.biourbanism.org/introduction-to-biophilic-design/

Caperna, A., Cerqua, A., Giuliani, A., Salingaros, N. Serafini, S., (2010). "Biourbanistica". Retrieved from: www.biourbanism.org

Fagerholm, N., & Käyhkö, N. (2009). Participatory mapping and geographical patterns of the social landscape values of rural communities in Zanzibar, Tanzania. Fennia-International Journal of Geography, 187(1), 43–60.

Fuller, R. A., Irvine, K. N., Devine-Wright, P., Warren, P. H., & Gaston, K. J. (2007). Psychological Benefits of Greenspace Increase with Biodiversity. Biology Letters, 3(4), 390–394. doi:10.1098/rsbl.2007.0149

King, M. F., Renó, V. F., & Novo, E. M. L. M. (2013). The Concept, Dimensions and Methods of Assessment of Human Well-Being within a Socioecological Context: A Literature Review. Social Indicators Research, 1–18. doi:10.1007/s11205-013-0320-0

Lynch, K. (1960). The image of the city. MIT Press: Boston.

McLain, R., Poe, M., Biedenweg, K., Cerveny, L., Besser, D., & Blahna, D. (2013). Making Sense of Human Ecology Mapping: An Overview of Approaches to Integrating Socio-Spatial Data into Environmental Planning. Human Ecology, 1–15. doi:10.1007/s10745-013-9573-0

Ryan, R. L. (2011). The social landscape of planning: Integrating social and perceptual research with spatial planning information. Landscape and Urban Planning, 100(4), 361–363. doi:10.1016/j.landurbplan.2011.01.015

Sherrouse, B. C., Clement, J. M., & Semmens, D. J. (2011). A GIS application for assessing, mapping, and quantifying the social values of ecosystem services. Applied Geography, 31(2), 748–760. doi:10.1016/j.apgeog.2010.08.002

The Artena's "Case Spallate"

Dilara Akülke

dilaraakulke@gmail.com

Esra Demirel

esrademirel3@hotmail.com

Christian Kyle Jordan Perry

PerryKJ@alfredstate.edu

ABSTRACT

The historical identity of Artena has strong texture and natural spaces that give the town a strong potentiality for social life. Nevertheless the town lacks an effective, recreation area. We identified an unlinked free space used as a weak green garbage area. Our aim is returning that potential area into life, by linking it to a green recreational function, i.e. by making it a meeting and vista point.

Key words: potential, strong texture, stone, link, meeting point, unique, turn into alive place, vista point

NEEDED SOUL

When we decided the area for our project, we knew that our space had a potential, despite it looked like a garbage dump. All we needed to bring that dead space back to life was just a little bit of spark and nature touch.

The area has a very sloped topography that allow us to find more creative, dynamic and surprising usages.

Figure 1 An expected view from vertical garden and waterfall

WHAT UNDERLIES THE DESIGN

The constraint of using onsite recovered material only (stones, wood, etc.) brought the unique biophilic character of Artena to our design. The goal was a multi useable area, that can attract both old and young visitors. In undertaking that function it should link the whole green spaces and also make connection between people and nature. The project area has a very good and huge vista point over the valley (Fig. 4). It also can be seen from the valley widely. Using the wall as a vertical garden with waterfall can make the town even more attractive to everybody, so that not only Artena people, but also neighbourhoods can come visiting and using it as a recreation area.

Figure 2 Water cascade

Generally a slope represents a design problem because it makes costs and work time grow; but we can turn that difficulty into a function, by making it a privileged point of observation over the valley. We thus created little terraces with wood benches, where people can relax and contemplate the panorama where all the beauty of the valley lies on underfoot (Fig. 3).

Considering our desire of making the place as ecological and compatible with the environment as possible, we focused on the big wall behind it. We realised that we can use rain water, let it flow, and collect it in a pool at the lowest level of the place (Figures 1 and 2). Thus youth of Artena could use that pool… and maybe even older people could!

We hope that our idea brings in a new landmark and more connectedness into the urban space, because disconnected, soulless spaces make people to become more unsocial and more alone.

Figure 3 Benches for rest and relax, vista points

Figure 4 A different view of the site

Green reminiscence

Aggeliki Lymperopoulou

gellaki@hotmail.com

ABSTRACT

The theory of Biourbanism considers the urban body as a complex living organism, since it represents humans' living environment. Thus, combined with the designing tool of Urban Acupuncture that pinpoints areas in need of repair (Casagrande, 2013), it is able to relieve stress through the living space, in the human species. Using these theories, the "green reminiscence" project held in an historical area of Artena's location, brings in a symbol in order to stimulate the habitants. Using local materials and local patterns, it creates everlasting fractals that make the dwellers familiar with the Gaia Hypothesis, the humans' subconscious connection with Earth, which exists under each and every man-made action.

Key words: Biourbanism, Urban Acupuncture, Gaia Hypothesis, local pattern, fractal, self-similarity

"Read Nature with an open heart, listen to Nature with a ready mind"

(Barbiero, 2013)

INTRODUCTION

The projects of Biourbanism Summer School 2013 focus on the impact of man-made urban actions on the surrounding environment and therefore, on the humans' short-term and long-term physicality and psychology. What happens if you dig and find a root, or plant a small tree in an area where people only used to see concrete and rocks? How and why do dwellers choose an alternative use of that area afterwards and the most important, how do they by themselves preserve or alter this use only for their benefit? The greater impact is not only for scientific teams, but basically for inhabitants to realize that cities or villages are not only the space where we live, but in fact a *locus*, since locus is when space is imbibed with the man-made actions (Philippakis, 2010). According to Biourbanism, this living hypercomplex system is composed of several interconnected layers of dynamic structure, all influencing each other in a non-linear manner (Caperna, 2011). Thus, in a world ruled by the laws of complexity, it seems extremely difficult for any scientist to predict, when pulling a string with brutal and large scale interventions on an urban layer, which Pandora's Box is opened in another.

Here comes (Bio) Urban Acupuncture, a theory which studies not only the layers of the environment, but basically the links between them. It is based on the combination of urban design with traditional Chinese medical theory of acupuncture (Casagrande, 2013) and teaches us that, as in the human body, urban space needs needles in strategic points where "stress" is held and can't be relieved. These urban needles are small-scale interventions that seem to heal many linked layers and eventually the larger urban context (Casagrande, 2013).

This theory is strictly connected with environmentalism, as many actions attempt to balance relations between humans and the various natural systems (Lincoln, 2009), such as the big tree in the alley of Ruin Academy (Artena, Italy) that has spread its roots over a wide surface on the wall and it has penetrated through the wall in order to lock itself into the primary structures of the building. This tree has chosen a man-made structure as its living environment (Casagrande, 2013; p. 6) and constitutes one of the greatest small-scale verifications of human's and nature's co-existence. This kind of actions helps us after all to re-discover little by little our ecological selves, being part of our deepest self (Barbiero, 2013), which lead us to the Gaia Hypothesis, the human's deeper connection to Nature (to Earth, from its core to its surroundings), as being part of it. Even in this evolved, artificial society, where our naturalistic intelligence is progressively fading out, we still have the need to interact with natural elements, to feel the Ground under our feet, to drink water directly from the fountain, to discover the roots under the floor. The rocks, the minerals, the water, the air, the earth and its visible inhabitants, each creature, living or not, can speak to us, can help us feel at ease within our common home, the Habitable Earth (Barbiero, 2013).

"Green reminiscence" project, held in Artena village (Italy), is the symbolic outcome of that theory; it's the archetypal reminiscence of the lost balanced relation with what's around us, what's inside us, what surrounds the boundaries of our bodies. Its purpose is a gesture of revival of our naturalistic instinct, a gesture to re-discover our connection with life, which gives us the key, after all, to open the door of sustainability.

THE PROJECT

Artena is an Italian village that, according to a civil settlement excavated recently, is dating back to the fifth and forth century BC. Destroyed by the Romans it was revived and developed in the Middle Ages as a fortified castle. By then, due to its strategic structure, it became one of the most important targets in many wars, so in the World War II it was bombed, leaving ruins instead of houses. Artena is a living organism, with its free spaces being organized in the most effective way and fully adaptable to dwellers' needs. So these holes, created brutally by the war, became dead spaces with no use. Until now one of these areas is covered by concrete and has become an intolerable place unable to be used during the daylight because of the heat and the lack of shadow provided. It contrasts significantly with the picturesque landscape.

Actions for covering the reminiscence of the war like the concrete put over this area sound in opposition to the naturalistic instinct. Nature lies under the cement and tries to find cracks in order to rise again and co-exist with its physical landscape and the inhabitants. And it could, in the end. Roots started cracking the concrete seeking for sun and water, giving a tremendous hint of what's lying above.

Clearly, what this area needed was to get re-attached with its actual ground, to get rid of the impression of abandonment that was the war heritage. The ground needed to be alive; its power was emerging through the concrete towards the whole space. The evidence was in the corner where some roots had started cracking the material, next to a useless bench. Getting rid of the concrete along the whole area was the first impulse, but of course it was unrealizable. Thus, the corner became the strategic point of what this project symbolizes.

Several rocks and stones left after some road repair were lying over the roots, making impossible for the inhabitants to observe the extraordinary effort of nature for re-gaining its space. At the beginning I thought to make a new plant grow in that specific corner in order to achieve this symbolic re-connection, until I realized that nature have had this idea first. A climbing plant could also have a functional role, providing the existing bench with shadow.

So I started re-arranging and organizing the existing stones in order to create a proper place for the plant to grow, small rocks that seemed to match with each other, like a puzzle. For their re-arrangement, existing patterns of the village were used: rocks that pop out of the walls and floors of Artena, their cracks, even the staircase that occupies most of the village's free space, qualities observed in every corner, constituting its most representative characteristics.

These elements and motifs with an underlying mathematical structure that repeat themselves (Stewart, 2001 p. 6), have a significant importance in this project, while their use in a smaller scale is the result of the observation of the wider space. Its characteristic geometric shapes create a fractal. Fractality or the presence of self-similar patterns where self-similar means they are the same from near as from far (Gouyet, 1996), is one of the most important structural laws of the world, the way every complex element of nature is formed. We usually begin noticing such a structure on a large scale. The power of self-similarity begins at much greater levels of complexity, it is a matter of looking at the whole (Gleick, 1987 p.115). Thus, the significant importance lies in the fact that, by obtaining and using these local patterns, we actually use the primitive law of self-similarity that describes the whole concept of the world – while theoretically, fractals are not limited to geometric patterns, but can also describe processes in time (Vicsek, 1992 p. 31), images, structures and sounds (Brothers, 2007) – in order to achieve our re-connection with it through one of its smaller-scale living hyper-complex systems: our society.

CONCLUSION

Reading the urban layers, acknowledging their links, choosing strategic points in need to be pinpointed and making small-scale interventions to relieve stress; that is the procedure of biourbanism combined with urban acupuncture, for everlasting balanced societies to be created. Regarding the environmental layer, actions trying to accomplish re-connection of humans with other living organisms should be taken into great consideration, since this connection constitutes one of the most significant issues of our society. If the ecology is the science of the relationships between living organisms and their environment, the relationships between human beings and the rest of the living world should receive particular attention (Barbiero, 2013). Nevertheless, for the majority of people, an exclusively rational and cognitive approach to the environment issues is often insufficient to motivate them to take preventative or remedial action (Barbiero, 2013). Nevertheless, sometimes, even observing a slight difference in our intimate environment is all we need to re-discover the balance needed for continual evolution. Thus, the impact of these actions would be the response by the locus, by the living organisms that compose the society. My symbolic gesture wants to open such a dialogue between them. After all, actions without an impact don't exist; every action, even the urban one, indicates movement, but without the social impact it remains static and eventually dies.

REFERENCES

Barbiero G. (2011). Biophilia and Gaia: Two Hypotheses for an Affective Ecology. *Journal of Biourbanism,* I(1), 11-27.

Brothers, H. (2009). Intervallic scaling in the Bach cello suites. *Fractals,* 17(4), 537-545.

Caperna A. (2011). *Biourbanism: Towards a human oriented design.* International Design Workshops on Tourism and Architecture, Aycalik/Turkey.

Casagrande, M. (2013). *Biourban Acupuncture – Treasure Hill of Taipei to Artena*. Rome/Italy, International Society of Biourbanism & Ruin Acsdemy.

Casagrande, M. (2013). Biourban Acupuncture. ISB Summer School 2013: «Neuroergonomics and Urban Placemaking».

Gleick, J. (1987). *Chaos – Making a new science*. New York/USA: Penguin Books.

Gouyet, J. (1996). *Physics and fractal structures*. Paris/France, New York: Masson Springer.

Lincoln C. (2009). *Light, Dark and Bright Green Environmentalism*. Green Daily. Retrieved 2009-11-02, from http://www.greendaily.com/2009/04/23/light-dark-and-bright-green-environmentalism/.

Philippakis, C. (2010). «Ο Μεγάλος Περίπατος – μια κριτική παρουσίαση» (Tech Rep.: Πολεοδομία – Χωροταξία, Προσεγγίσεις σχεδιασμού στην Ελλάδα), Athens/Greece, National Technical University of Athens, Department of Architecture.

Stewart, I. (2001). *What Shape is a Snowflake? Magical Numbers in Nature.* London/UK: Weidenfeld & Nicolson.

Vicsek, T. (1992). *Fractal growth phenomena*. Singapore/New Jersey: World Scientific.

Life bearing rocks

Eleni Ploumidi
eleniploum@hotmail.com
Ottavia Molatore
otty88@msn.com

ABSTRACT

Landed in the city of Artena for the International Society of Bioburanism's summer school, we were immediately challenged to understand its environment at a level that would permit us to recognize not only its individual parts, but more importantly, how these parts are organized into a pattern (Lynch, 1960) which forms Artena's unique identity. Following the Biourbanism approach, we aimed to decipher and point out the existing patterns and their interrelations. The project 'Life Bearing Rocks', focuses on the sequence of patterns that are manifested in the city's rock cracks, bringing life in through the complexity of emerging buildings, movement flows, vegetation, and people. Using the tool of biourban acupuncture (Casagrande, 2013) we tried to give prominence to the wholeness that nature creates in the body of Artena through its discreet presence in the rocks' cracks, by planting and cleaning the soil of small nodal points.

Key words: Biourbanism, biourban acupuncture, patterns, rock cracks.

INTRODUCTION

The choice of developing a project beside the city's rocks lies in the fact that these tiny spatial nodes are an eloquent narration of Artena's nature and human beings cohabitation. They embody the whole system of inhabitants spatial practices, through which they recognize themselves and both enjoy and modify their space by slowly producing it whilst appropriating it (Lefebvre, 1991).

The rocky landscape of Artena demands a constant movement in a vertical axis which is pleasantly interrupted by small horizontal surfaces, through the diffusion of the rocks' cracks. This geometry creates a spatial system of small surfaces, which through their direct connection generates the city of Artena and organizes its social life in a multi core web of life. Hence, in some cases, the rock cracks form the street network of the city; in others the foundation of houses; or, in our case, the locus of children's daily activity and the place of their gradual maturation.

PROJECT IMPLEMENTATION

From the first moments of our presence at this special spot of Artena, we felt an invisible bond with it. Fascinated by the outstanding, almost dramatic, morphology of the rock, we felt invited to explore its cracks and enjoy the sun like little lizards in their natural environment. Only a few minutes later, we realized that it was not feeling like home only to the two of us. We were standing exactly at the afterschool playground area of Artena, the place of the children's daily afternoon appointment for playing, talking and living: their favourite spot in Artena as they all spontaneously confessed. The boys were playing with the rocky vertical landscape by climbing and practicing impressive jumps, performing a daily silent ritual of maturation. The higher they conquered the rock, the more they grew up. The girls, more quiet, always united, were observing the boys and at the same time claiming the space for their needs, a sanctuary away from the eyes of the 'grannies', a clean space with flowers where they can sit, talk, play volleyball, and hide and seek.

As soon as the children saw us with gloves and plastic bags, they started working with us. Soon, we became their helpers. They could reach every spot of the rock, no matter how steep it was. The rock cracks were their home and they knew every single part of it. After two days of constant work, their rock was a white canvas, ready to be enriched with their desires.

During the following days, our team became larger. The local construction workers taught us how to rebuild some small ruined stone supporting walls. They gave us the materials and lent us their tools. With them, we also created some sitting places, using the slabs we found during the cleaning process. We also cleaned some parts from some stones that the heavy winter rain had made slide down.

Through the cleaning process, by removing the alienating human traces that fouled the spatial experience of the place, we had the opportunity to highlight the readability of nature's design. The small supporting constructions aimed to enhance the cooperation of nature and humans in the process of the production of the space. Thereafter, our acupuncture points were revealed, calling for the existing small soil patches along the rock cracks network to become flowerbeds. Together with the children, we planted the small colourful flowers and created the garden that was already there, hidden among the rocks.

CONCLUSION

Thanks to the project ‘Life bearing rocks’, we had the opportunity to understand to a satisfying level the complexity of Artena’s urban structure. Studying the behavioral patterns of its dwellers in a small scale, such as the everyday random and exploratory movement of the children along the rocks, we were able to recognize the interrelations between the people and the space they inhabit (Whyte, 1980). The geometry of the rock cracks, being itself a micrograph of Artena’s urban fabric, reveals the spatial practices of people and the flows of multiple movements, be them human, informational, or energetic.

Working with the children as a united team, Roberta, Lorena, Valentina and Tiffany, we aimed to nurture people’s interest for their living environment and unfold its existing qualities.

Figure 1 Moment 1: Cleaning

Figure 2 Moment 2: Small restorations and constructions

Figure 3 Moment 3: Planting

Figure 4 The life bearing rocks project

REFERENCES

Casagrande, M. (2013). *Biourban Acupuncture*. Treasure Hill of Taipei to Artena. Italy. Rome: International Society of Biourbanism

Lefebvre, H. (1991). *The production of space*. USA, Maiden:Blackwell Publishing

Lynch, K. (1960). *The image of the city*. USA, Massachusetts: The MIT Press

Whyte, W. H. (1980). *The Social Life of Small Urban Spaces*. USA, New York: Project for Public Spaces

Sound as an acupuncture needle of placemaking Soundscape design in Artena, Rome

Jang Liu

jiang.liu@uni-rostock.de

Nissa Shahid

nissa.shahid@outlook.com

ABSTRACT

The paper presents a project based on the theories of Urban acupuncture and Placemaking, incorporated with the concept of Soundscape. The intention of this project was to move away from traditional placemaking strategies that usually result in visible improvement of the space. The aural environment, i.e., the soundscape in Artena was designed by introducing a specific sound into the local soundscape, the bell rings along with the mules' movement. The bell ring was recognized as not only a pleasant sound that could change the atmosphere in the village, but also as an information source, a local seniors' social care media. The bell ring also has the potential to become a soundmark of Artena, which could become incorporated in the cultural identity. A design concept for the bell of Artena was also proposed.

Keywords: Placemaking, urban acupuncture, sound, soundscape, soundmark, bell ring, mule, Artena.

INTRODUCTION

This paper presents a project developed during the summer school 2013 "Neuroergonomics and Urban Placemaking" in Artena, Rome, organized by the International Society of Biourbanism. Based on the theories of "Urban acupuncture" and of "Placemaking", this project was done in combination with the concept of "Soundscape", and showed how sound could change a place with multiple significance.

Acupuncture is a traditional Chinese medical theory, which stimulates specific acupuncture points on the body with needles to correct imbalance (disease) in the flow of *Chi* through channels known as meridians. "Urban acupuncture" is an urban environmentalism theory which combines urban design with this traditional Chinese medical theory, and uses small-scale interventions to transform the larger urban context, thus to relieve stress in the environment (Casagrande, 2013). As stated by the champion of the concept, Marco Casagrande, Finnish architect and social theorist, "urban acupuncture means focusing on small, subtle, bottom-up interventions that harness and direct community energy in positive ways to heal urban blight and improve the cityscape" (Casagrande, 2013). The principles of urban acupuncture theory are in many aspects in consistence with those of "Placemaking" which is a multi-faceted, community-driven, bottom-up approach to planning, design and management of public spaces. Placemaking is also recognized as both a process and a philosophy, and an hands-on tool for improving a neighbourhood, city or region (Metropolitan Planning Council of Chicago) (Fortuzzi, 2013).

The concept of "Soundscape" was first introduced by Schafer (1969, 1977) who was concerned about noise pollution and people's awareness of acoustic environments. It is treated as the "auditory properties of a landscape", and defined as the totality of the sounds that reaches the human ear from a particular environment. The soundscape concept focuses not only on the negative aspects of the sonic environment, i.e. noise, but also on the positive aspects. It deals with the physical, social, and psychological factors in the human perception of the acoustic environment. A pioneering soundscape research was also carried out by Southworth (1969) who was concerned about soundscape in terms of the identity and the delightfulness of the sounds, as well as about the correlation between visual and auditory perception. Several guidelines about the sound elements of a preferred soundscape could be extracted from the findings of his research in soundscape design, including that sounds should be novel, informative, responsive to personal action, and culturally approved; sounds should fit into the context; and sounds should have low to middle frequency and intensity. Recent soundscape researches also provided rich knowledge for designing purpose (Liu et al., 2013a, 2013b; Yang and Kang, 2005), and a soundscape oriented design approach has been already adopted in urban planning (De Coensel et al., 2010), and in urban park design (Gaetano et al., 2010). The soundscape approach has the potential to inspire and provoke new thoughts, and to challenge the visual dominance in design and planning of spaces. As stated at the beginning, this project was done exactly on this purpose.

LOCATION AND CONTEXT OF THE PROJECT

Artena is a village in the province of Rome, Italy. It is situated in the northwest of Monti Lepini, in the upper valley of the Sacco River. It is approximately 40 km southeast by rail, and 30 km direct from Rome. Economy is based on agriculture, animal husbandry and tourism. The project is conducted in the historical part of the village built on the north side of the mountain and overlooking the valley. Though there are traffic roads reaching to both north and south sides of the village, the road system inside the village is not approachable for modern transportation, as most of the roads are narrow steps built with stones. Thus, mules are used until now in the village for delivery of necessities, rubbish and construction materials, etc. (Fig. 1). The image of mule is used already for external propaganda of Artena, as one of the local characteristics (Fig. 2).

Since the beginning of our research we had in mind the idea of combining the soundscape approach with placemaking. The soundscapes in the village are formed mainly by human sounds (talking, activities), regular sounds from the church bell, weak traffic sounds from the valley, and natural sounds (wind, birdsong). Generally speaking, this is a quiet village, but the soundscape here has no typical characteristic. Thus, we recognized that there was a chance to change the soundscape here, and to improve its quality, and to enhance the soundscape characteristic of Artena.

Figures 1 and 2 Mules in Artena

SOUNDSCAPE DESIGN PROCESS

Although the project used a soundscape concept, the process of soundscape design closely followed the three steps of placemaking (Fortuzzi, 2013).

1) Discover. The first step of placemaking requires the designers to discover the needs and aspirations of the people who use this space through communication with them, to view the place as an entirety, and to pay attention to issues on the small scales.

The inspiration came out when the mules were passing by. Yet it is worldwide common to put bells on livestock such as cows, donkeys, mules and goats, who inform their owners about the animals' location, most of the mules in Artena are normally not wearing bells. The bell worn by only 1 out of 15 mules rings only at night, not during the delivery, as stated by the owner. The ring produced by bells along with the mules' movement is a kind of low to middle frequency and intensity sound in its physical characteristic, and could be a pleasant sound if introduced into the soundscape. The bell ring could be more significant in terms of giving information. As the road inside the village are usually narrow, when the mules pass by, the others from the opposite direction may have to wait. The bell ring could give a signal to the villagers about mules' approaching, thus they could have an earlier response. Also because of the road condition in Artena, it is difficult for seniors to walk out of their houses even to the nearby shops to get their necessities, especially in winter time. As the mules are already used for delivery of these necessities to the local shops, with the bell ring along with them, it is possible for the seniors to get their necessities directly in front of the door of their houses. When they hear the bell ring, they know that the mules carrying their necessities are coming. Here the bell ring could function as a specific social care of the seniors. Thus, bell ringing along with the mules' movement is recognized as a placemaking acupuncture needle.

2) Create a common vision. The second step of placemaking is to create a common vision about that place, by the use of the gathered information.

Routes where the mules are usually passing by were surveyed with the help of the delivery man, and shown later on the map of Artena (Fig. 2). It was found that the routes cover almost the whole village. It means that, by just putting bells on the mules, they could bring the pleasant sound to the whole village as they are passing by different routes. Thus the action could change the whole image of the soundscape in Artena.

Figure 2 The routes where mule pass by in Artena

3) Implement. This is the last step of placemaking, in which the common vision should be evolved into an implementation strategy, beginning with small-scale and feasible

improvements that can immediately bring benefits to public spaces and to the people who use them.

With the help of a villager, we found one old bell that gives a pleasant sound. We walked with the bell across the mules' routes in the village to observe their reactions. Most villagers were curious and showed interested in the bell ring. When we asked their opinion about the belling ring, most of villagers said that it was a pleasant sound, and that they would like to hear it in the village regularly. The bell ringing with the mules' movement could be culturally approved by the local villagers.

We considered necessary to design a specific bell for Artena, in order to bring its connection to a deeper cultural level. Thus, we developed a design concept based on the information gathered from the local villagers.

Our bell's shape follows the traditional type used in Artena, which is very similar to the famous Treicheln style Swiss cow bell. Then the most important symbol of Artena (Arco Borghese) along with its motto "EX CINERE RESURGO" which means "We Rise from the Ashes" is put on the bell, as shown in Fig. 3. The villagers were consulted about the design of the bell.

Figure 3 Bell designed with the symbol of Artena

Because of time reason, although we could not make the designed bell or find enough bells to be put on the mules, with the support of the delivery man, we shot a video of our walk through the village routes with the mule carrying a bell, in order to clearly explain the project idea.

CONCLUSION

The initial purpose of soundscape concept was to arouse people's awareness of their surrounding acoustic environment. In this project, instead of using traditional placemaking strategies that usually result in visible improvement of the space, the aural environment or soundscape of Artena was designed by introducing a specific sound into the local soundscape: the ring of a bell carried on by mules. The bell ring is not only a pleasant sound able to change the atmosphere in the village, but it also works as a helpful information source and a resource of social care for local elders. Soundscapes have been recognised as vital for the sense of a place (Schafer, 1994). Schafer coined the term soundmark out of the word landmark, to describe the sound unique to a specific location. Soundmarks can give specific information about places, and help people to form the sense of their living environment. If the project idea would be adopted by the village, the ringing mule's bell has the potential to become a soundmark of Artena, thus part of the local culture in future.

The project idea was developed by closely examining the life style and the requirement of the villagers. Putting a bell on the mule is this kind of pinpointed and quickly accomplished interventions that release energy and create a positive ripple effect, as proposed by the urban acupuncture theory (Hinchberger, 2006). The soundscape design process followed also the placemaking steps. We believe that the bell ring will improve the spiritual qualities of the village. The mules will play music on the way whilst carrying history and life in this mountain village.

REFERENCES

Casagrande M. (2013). Biourban Acupuncture. International Society of Biourbanism. Retrieved August 13, 2013 from http://www.biourbanism.org/biourban-acupuncture/

De Coensel, B., Bockstael, A., Dekoninck, L., Botteldooren, D., Schulte-Fortkamp, B., Kang, J., & Nilsson, M. E. (2010). The soundscape approach for early stage urban planning: a case study, *Proceding of Internoise, (Lisbon, Portugal).*

Fortuzzi A. (2013). Introduction to the American experience of Placemaking. International Society of Biourbanism. Retrieved August 13, 2013 from http://www.biourbanism.org/introduction-to-the-american-experience-of-placemaking

Gaetano, L., Lorenzo, B., & Mattia, C. (2010). Italian Sonic Gardens: An Artificial Soundscape Approach for New Action Plans, in: *Designing Soundscape for Sustainable Urban Development* (Ö. Axelsson, ed.), Stockholm, pp. 21-25.

Hinchberger B. (2006). Curitiba: Jaime Lerner's Urban Acupuncture. Retrieved August 13, 2013 from http://www.brazilmax.com/news.cfm/tborigem/pl_south/id/10

Community youth engagement as an acupuncture needle for placemaking Open space revitalization in Artena, Rome

Inge De Boer
deboeringe@gmail.com

Francesca Rogers
frarogers@gmail.com

Catherine Ryan
catie@terrapinbg.com

ABSTRACT

Open space revitalization in Artena had the aim of introducing a design element that would serve as a catalyst for future interventions by the local community. As ISB students of Neuroergonomics and Urban Placemaking, we planned to achieve this through two tools and an acupuncture 'needle'. The intent was in establishing a space that would appeal to the greater community and encourage interaction, followed by conceiving of an event, a small intervention that would awaken the potential of the space to the people of Artena; and perpetuated by the presence of a mobile kiosk that could be used for supporting any number of community activities.

The well-intended project was limited by time, materials and terrain, unexpectedly leading to a more powerful intervention than what was originally envisioned. Girls of fourteen, and of their own accord, took ownership of the revitalization effort to make the open space into a place for social interaction and activity.

Key words: Artena, urban acupuncture, placemaking, open space revitalization, youth engagement.

INTRODUCTION – ARTENA IN CONTEXT

Artena is by some counts a rustic, medieval, and enchanting old town. But by many contemporary standards, Artena is not an easy place to live. Situated on a steep hillside, all goods and services brought in and out must be carried by foot or by mule. Over the millennia, this practice has only changed in terms of frequency – goods and services are now provided less often and in smaller quantities.

As lifestyle expectations have changed, so too has the population. As new commodities became more accessible, younger generations began to move out of old Artena to the new town in the valley below, where there are new houses with modern amenities and reliable services. The more people leave the hillside, the more services disappear, inducing more people to leave – and thus the cycle continues. Currently, somewhere between 50-75% of the homes of Artena are vacant, and the approximately 400 people who remain are serviced by three grocery shops, two restaurants and two bars, all located on the periphery of the historic town and intermittently open for operation.

The densely woven network of resources and relationships that had kept Artena together for hundreds of years has slowly deteriorated, leaving large gaps in both the town's social and physical infrastructure. Talking to people of all ages, there is a sense of being the few survivors, a strong nostalgia for the past and a feeling of abandonment by funding institutions. As new waves of immigrants benefit from these gaps – attracted by the availability of low-cost housing – new challenges to rebuilding the social and physical infrastructure arise. Whether the result of ethnic prejudice, cultural and linguistic differences, or the potential impermanence of their residency in Artena, newer populations are spoken of by native inhabitants as a separate community. Yet evolution of this disparity is also evident, whereby the youngest generation now share the same language, attend the same schools and, perhaps most importantly, play together.

Artena's untapped potential was striking, but with deteriorating infrastructure and services, a diminishing population base, and no distinct ownership over most open spaces – one begins to understand how it must be difficult for locals to envision that potential. Confronting these issues head-on was a focus of our week-long academic sojourn to Artena. The theories of Biourbanism during our lectures explained to us why we are so fascinated by places such as these, and why Artena is a model candidate for biourban acupuncture. The task at hand, then, would be for us to devise a strategy to call attention to this potential for the people of Artena.

OPEN SPACE REVITALIZATION

With five days to assess potential biourban acupuncture opportunities, identify resources, and implement our plan, we aimed to introduce an idea that would serve as a catalyst for conceiving future interventions by the Artenese themselves. We planned to do so through two tools:

1. *Establishing a Space:* an open space that would be safe and clean and possess some qualities of biophilia – a view outward from the space to both the streets and the valley (prospect), shade and seating (refuge), and more vegetation (visual connection with

nature) – that would have broad community interest and be a magnet for use by and interaction among natives and newcomers, youth and adults, men and women, and Artenese and tourists.

2. *Staging an Event:* a small-scale, publically accessible recreational event – an activity, pastime, entertainment event, or other busyness – that would draw attention to the revitalized space, and shed light on its transformative potential for the town.

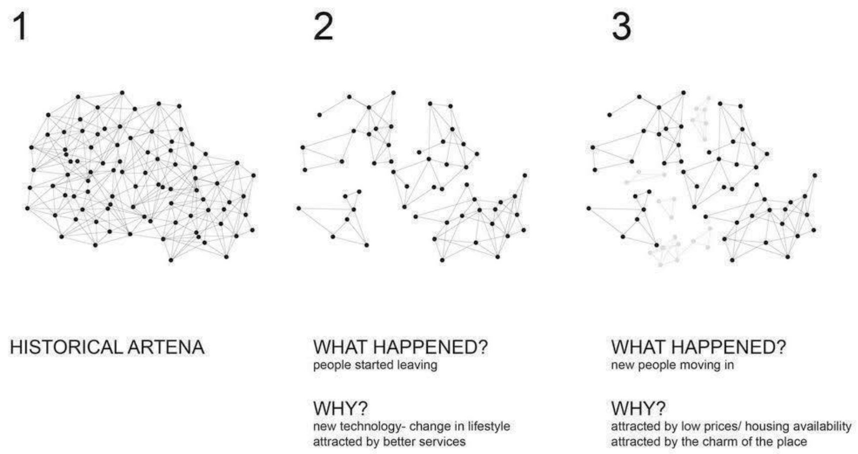


Figure 1 Artena from then to now

We began by selecting a space with the potential to meet our criteria for a space in which to stage an event, including proximity to pedestrian flows, presence of shade trees and potable fountain water, and visual access to and from the space. We settled on a designed hardscape that was evidently not well cared for; the next step was to gather and dispose of the rubbish.

THE NEEDLE: COMMUNITY YOUTH ENGAGEMENT. THE NEEDLE WE SOUGHT TO CREATE

Once the revitalization space, intent and tactic were established, we set out to identify the design intervention that would serve as the 'acupuncture needle'. We began with the idea of a portable and multifunctional kiosk that would provide the very basic elements for any variety of activities:

1. *Shade:* under which to find refuge from the solar heat – Artena currently had few, if any, public outdoor spaces offering shade.

2. *Surface:* on which to place objects (e.g., goods for selling, games for playing) – The few flat surfaces that existed in the whole of the town were hardscaped and/or littered with debris.

3. *Seating:* from which to observe, participate or rest – Artena currently had no semi-permanent group seating options available to the public.

A simple kiosk could be used as a weekly market stall for local or traveling shopkeepers to sell groceries in the heart of the town; as a gaming space for children or seniors to play cards or board games; a seating area for watching a neighborhood soccer game; or an evening hang-

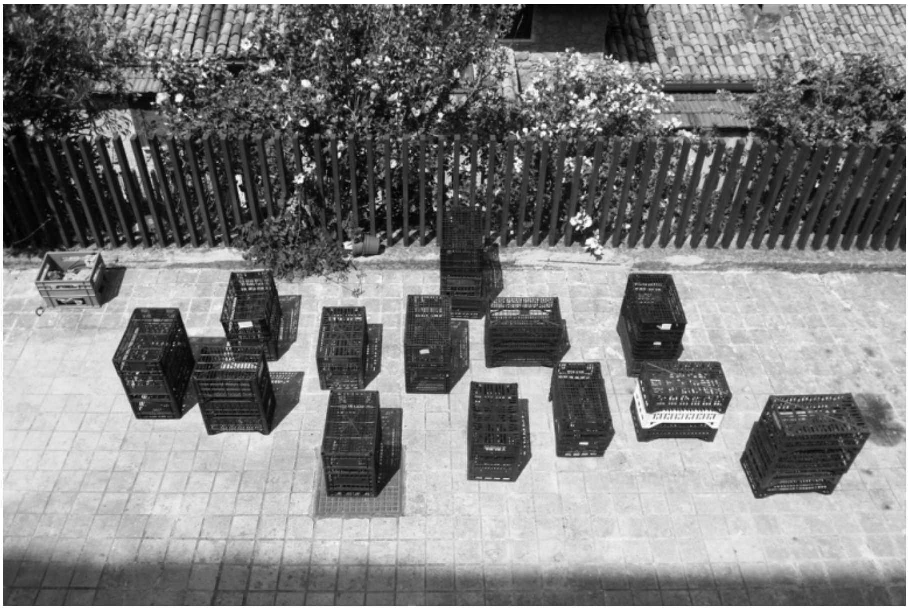


Figure 2 The chosen location

out space for young adults when the local bars close down. In the center of the town – midpoint on the hill – no open space was currently able to serve these activities, and through dialogue with community members, it was clear that such services were desired.

As we began with a search for potential second-hand materials to build the kiosk, we realized that material availability, transportability, and implementation time were more constraining than we had expected. We were now on day two of a five-day project. A growing familiarity with the topography and street design, which were defining attributes of the town, was giving us a greater appreciation for the complexities of goods and services delivery and waste disposal. However, this was also a constant reminder of how project implementation may be impacted. This realization encouraged us to reassess what was feasible with the resources available primarily on the project site (the open space), and secondarily within Artena. Consequently, options for constructing the kiosk had become dire. Near the end of the day, we had collected nothing but a few wood posts and plastic crates each of questionable durability. Aesthetics and safety became a concern – if the kiosk was perceived by the public as being made of waste and was potentially unsafe to utilize, its capacity to function as a representational kiosk and inspire positive change would fail.

Around the same time, a trio of fourteen year-old girls – interviewed during our initial opportunities assessment on the previous day – began helping to clean up, along the way explaining to us the history of the space and its relationship to the community. We departed the project site that afternoon leaving in place a salvaged table and the plastic crates serving as representational seating, reluctantly convinced of the efficacy of our 'needle'.

THE NEEDLE THE COMMUNITY GAVE US

Upon returning to the site some 36 hours later, we noticed two things had happened in our absence that would redefine our understanding of what a 'needle' could be. During our absence on day three, the girls had progressed the project and transitioned the focus of the intervention to a larger space one street above – they had selected a more flexible space with greater visual and physical accessibility. They had also put up a temporary barrier, which, as they told us later, was to prevent the boys from messing it up; this indicated to us a sense of ownership in the project and pride in their efforts. In response, the boys later placed flowers on the makeshift kiosk as a gesture of peace.

This transition shifted our team's role from leader to participant: the girls had taken ownership of the space, and had developed their own vision for how the space could be utilized, as well as its potential relationship to adjacent spaces. There was a de-emphasis on designing a kiosk due to limited access to appropriate and safe materials, and our project was now to follow them: the girls had become the 'needle'.

This latter concept of an open-air cinema had high visibility potential, could be enjoyed by the whole town population and, from what we gathered, was unique and unpracticed in Artena.

On days four and five, we helped the girls remove rubbish and debris, relocate earth and stones to build flower beds, and plant flowers, until the space resembled somewhere one would want to spend time, somewhere that looked cared for. The new space was better situated to serve a wider variety of activities: a playground, urban farm or garden, open-air market, small sports field, or an open-air cinema. This latter concept of an open-air cinema had high visibility potential, could be enjoyed by the whole town population and, from what we gathered, was unique and unpracticed in Artena.

To help envision what this cinema might look like, we repositioned the plastic crates in rows for sitting. White-washing the windowless wall of the adjacent building could serve as the screen, and the town had a projector that could be plugged in to a neighboring building. Located at the centre of the town and visible from one of the town squares at higher elevations on the hill, the movie screen would easily attract attention, serving as a low-cost activity that could be regularly provided to the public.

On days four and five, we helped the girls remove rubbish and debris, relocate earth and stones to build flower beds, and plant flowers, until the space resembled somewhere one would want to spend time, somewhere that looked cared for. The new space was better situated to serve a wider variety of activities: a playground, urban farm or garden, open-air market, small sports field, or an open-air cinema.

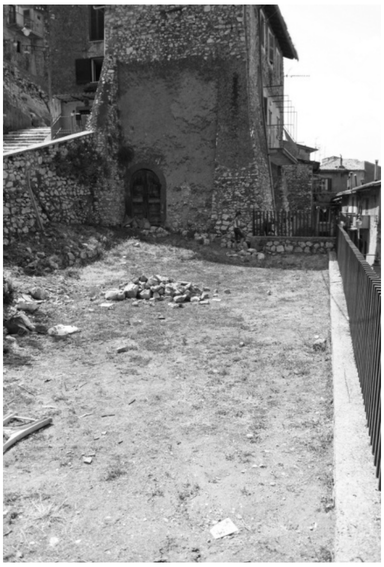


Figure 3 The given location

Figure 4 The work

Figure 5 Rubbish

Figure 6 CineArtena

CONCLUSION – LESSONS LEARNED

For our team, we perceived Artena as a precious but neglected island. However, we also recognized that there are an infinite number of layers of information behind what we observed at the surface. This point was made ever so clear when our intended event was derailed by a community-wide annual event a youth group had organized for the same day – their own urban acupuncture needle. By the end of the five-day project period we had staged no event, but were able to reflect upon a few lessons learned:

- Engaging the whole town is not necessary to have an impact – The event we were seeking to stage could have been as simple as an impromptu soccer game, a picnic with the girls, or a brief movie clip.

- Responding more directly to the needs of the population's various sub-groups requires more time for research and surveying – When time is of the essence, it is easier to grow a small-scale idea than to restrict one that starts at a big-scale.

- Implementing neuroergonomic design requires a greater understanding of the people, their needs and usage patterns of a space, as well as how such information can be aligned with design strategies to enhance human psychophysiological and cognitive experiences.

- Being flexible allowed the project outcome to be more impactful than it might have been had we insisted on following through with the plan as it had originally been envisioned – As a group, we were largely unconvinced any one plan was the most appropriate and were consequently open-minded to change, such as when we moved locations midway through the project.

- Engaging with the community youth was the most valuable experience of the revitalization project, both for the perspective it provided us and for the potential to have a lasting impact on the community.

As an exercise in neuroergonomics and urban placemaking, we found that our comprehension of biourban acupuncture – though it changed over the course of the project – came naturally to us, and to the student group at large; it was a deliberate effort. Whereas, the human science – and the degree to which it was valued by each group member – was largely skirted, and was thus hardly incorporated. This is likely due to challenges in drawing familiar connections between the neurosciences and the built environment.

While this aspect of biourbanism was meant to have a more prominent role in the ISB student program, ultimately, what is important is that the capacity to make change in Artena was realized, even if only by a few. At the very least, the trio of teenaged girls shared an experience that will live on with them and, hopefully, for the long-term benefit of Artena.

REFERENCES

Alexander, Christopher, Sara Ishikawa, Murry Silverstein et al., 1977. *A Pattern Language: towns, buildings, construction*. Oxford University Press: New York.

Beatley, Timothy. 2011. *Biophilic Cities: Integrating nature into urban design and planning*. Island Press: Washington.

Casagrande, Marco. 2013. *Biourban Acupuncture*. International Society of Biourbanism, Summer School in Neuroergnomics and Urban Placemaking. Artena (Rome), Italy, July 2013. http://www.biourbanism.org/biourban-acupuncture/

Fortuzzi, Angelica. 2013. *Introduction to the American experience of Placemaking*. International Society of Biourbanism, Summer School in Neuroergnomics and Urban Placemaking. Artena (Rome), Italy, July 2013. Retrieved from: http://www.biourbanism.org/introduction-to-the-american-experience-of-placemaking/

Jacobs, Jane. 1961. *The death and life of great American cities*. Modern Library.

Manzini, Ezio. "*Enabling platforms for creative communities*". (draft) Indaco, Politecnico di Milano, 18 March 2005. Retrieved from: http://doors8delhi.doorsofperception.com/presentationspdf/manzini.html

Salingaros, Nikos A. *Fractals in the New Architecture*. First published in Archimagazine (2001). Retrieved from: http://www.biourbanism.org/fractals-in-the-new-architecture/

Serafini, Stefano. 2013. *Neuroergonomics and urban placemaking*. International Society of Biourbanism, Summer School in Neuroergnomics and Urban Placemaking. Artena (Rome), Italy, July 2013.

Serafini, Stefano. 2013. Sign, cognition, body: Test, Operate, Test, Exit. International Society of Biourbanism, Summer School in Neuroergnomics and Urban Placemaking. Artena (Rome), Italy, July 2013.

Terrapin Bright Green, 2012. "*The Economics of Biophilia: why designing with nature in mind makes financial sense*." Retrieved from: http://terrapinbrightgreen.com/downloads/The%20Economics%20of%20Biophilia_Terrapin%20Bright%20Green%202012e.pdf

Terrapin Bright Green. Whitepaper on biophilic design patterns and implementation, publication expected 2014.

JBU

Journal of Biourbanism

Biannual review edited in Rome, Italy

ISSN 2240-2535

Publisher: Società Internazionale di Biourbanistica / International Society of Biourbanism

Via Giovanni Giardini, 15B 00133 Roma – ITALY

Tel. +393939426561 | fax +39069597399 | e-mail jbu@biourbanism.org