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Abstract: The early years of the journal Landscape and Urban Planning, then called Landscape Planning, coincided with the start of the era of digital landscape visualizations. This paper examines this journal's articles on landscape visualization published over its 99 volume history (1974-2010). This work has contributed to representation, assessment, and decision-making in landscape planning and design. Technological advances are noted, as are case studies and research topics and questions considered to be important at the time. This work is then looked at in the context of subsequent developments in the field of landscape visualization in terms of distinct research areas, directions, and topics reflected in the publications. From this analysis, the paper presents an outlook on future challenges for research and practice that includes themes such as the diffusion of 3D visualization in our everyday environment, linking visualizations with underlying models, going beyond highly-realistic but simply descriptive visualizations, using visualizations in an assessment and decision-making context, and incorporating multi-sensory experiences. It also considers the prospects for further technological advancements such as augmented reality for making decisions in planning and design of our future environments.

# 1. Introduction

"Landscape and urban planning" are words selected as the name of this journal but also refer to activities concerned with natural and urban environments of the past, present, and most importantly, the creation of future environments. As an interdisciplinary focus of concern, both the journal and activity of landscape and urban planning deal with the study, analysis, planning, and design of biophysical and social environments that express a range of sensory qualities. Humans in turn possess a suite of perceptual systems that allow them to sense these qualities: an auditory system (the sense of hearing), a tactile system (the sense of touch), a kinaesthetic system (the ability to sense and coordinate movement), a vestibular system (the sense of balance), an olfactory system (the sense of smell), a gustatory system (the sense of taste) and a visual system (the visual sense). Of all the senses, the visual sense is by far the dominant component of human sensory perception (Bruce et al. 1996). Fortunately, for landscape and urban planners and designers, the visual environment with its range of visual stimuli can be represented via a palette of analogue and digital media as an essential means for communicating to experts and the public in planning and design.

This paper examines this journal's articles on landscape visualization published over its 99 volume history (1974-2010), and the contribution to representation, assessment, and decision-making in landscape planning and design, also in the wider context.

# 2. Technological advances

Within only a few decades, contemporary Western society has evolved from being dominated by digital immigrants hesitant to embark on a digital landscape journey to a society and professional world now dominated by digital natives. In this short timespan, tools and techniques for

24    representing our world in three dimensions using 3D visualization have diffused throughout our

25    everyday environment. Unborn babies can be seen in 3D ultrasound. Children only a few years

26    old are already playing with 3D computer games, as are young adults, parents, and even some

27    grandparents. These multiple generations can watch the weather forecast together in 3D, possibly

28    on a new 3D TV screen; enjoy a multi-sensory 4D cinema and other futuristic movie

29    experiences; travel to remote areas using a satellite navigation system that shows the

30    environment in perspective view; and use Google Earth to explore remote environments through

31    data streamed over the Internet (cf. Sheppard and Cizek 2009), showing 3D representations of

32    the whole globe enhanced with information-tagged imagery. As landscape and urban planners

33    and designers, how will we cope with the raised expectations of this new cohort of visual

34    sophisticates?

35    While in previous decades visual representation techniques were only very sporadically utilised,

36    they have now become a standard in landscape research and practice. The array of techniques at

37    our disposal is broad, and their evolution from physical models, drawings or paintings,

38    perspective views, and analogue photomontages to digital photomontages, virtual reality,

39    Internet-based visualizations and augmented reality is impressive. 3D landscape visualization has

40    developed from an extremely costly and therefore restricted technology requiring specialized

41    equipment and labs into an essential tool for landscape design, planning and management that

42    can be accessed in the field on small tablet computers and mobile phones. Sophisticated 2D and

43    3D software is even available for free.

44    Also within the last few decades, digital landscape representations have developed from very

45    abstract and static representations to highly realistic visual representations capable of being

46     explored through dynamic spatial movement, possibly providing an immersive experience in

47     multiple spatial and temporal scales.

48     Digital 3D visualizations have now become a common feature in landscape and urban planning,

49     in reference to both this journal as well as the actual activity. The use of visual representations

50     based on digital or virtual environments is well established in planning statements, as part of

51     Environmental Impact Assessments, design competitions, and site development (just think of all

52     those large display boards one sees these days showing a design proposal posted next to the

53     actual construction site). In each of these cases, the purpose of the visualizations is to

54     communicate with the public or with potential clients. To a certain degree, and not studied by the

55     research community so far, visualizations also serve an internal communication function among

56     experts of different (or the same) disciplines working on a joint project. Typically, in terms of

57     their content, landscape visualizations still focus on the outcome or final product of a planning

58     and design process.

59

60     **3. Case studies and areas of research: A timeline of published articles**

61     In the early 1970s, the US Forest Service was a major driver in developing new methodologies

62     for landscape assessment as well as new techniques of landscape representation. The first

63     published paper in this journal that introduced 3D computer graphics was thematically focused

64     on the visual management of forested landscapes over time (Myklestad and Wagar, 1977).

65     However, most parts of the paper concentrated on the technology itself. Rather abstract tree and

66     ground cover symbols were used to communicate landscape changes caused by timber

67     harvesting. It was published only two years before the highly influential 1979 Lake Tahoe

68   conference 'Our National Landscape' (Elsner and Smardon 1979), which at that time included

69   the state-of-the-art on methods of digital landscape representation and landscape assessment.

70   In the early 1980s, in Berkeley, Syracuse, and Lund, "modelscopes" comprising a miniature lens

71   and camera hung from overhead gantries enabled researchers to explore alternative planning

72   scenarios within analogue, physical models and to study urban landscape perceptions from a

73   visual as well as dynamic perspective (Smardon 1988).

74   In 1990, digital photomontages and photo editing, nowadays standard tools of landscape

75   architectural education and practice as well as landscape research, were for the first time

76   introduced in *Landscape and Urban Planning* to explore vista management options in Acadia

77   National Park in response to anticipated landscape change (Lange 1990).

78   Since 1990 there have been three major Special Issues of *Landscape and Urban Planning*

79   published that have helped spur increased interest in landscape visualization and modelling in the

80   research community for assessing, planning and designing landscapes. The first focused on

81   "Data Visualization Techniques in Environmental Management" (Orland 1992) and addressed

82   visualization linked to the modelling of environmental systems including air pollution, fire

83   history, ozone concentration, ocean currents, and forest pest impacts. While the modelling-

84   visualization linkage is still a major area for research with unresolved issues, especially

85   considering real-time interactive approaches, since then many of the basic technical difficulties

86   that were pointed out in terms of software, hardware and data have now largely been resolved.

87   A second Special Issue appeared shortly thereafter and focussed on "Landscape Planning:

88   Expanding the Tool Kit" (Bishop 1994). It covered new approaches to GIS-based landscape

89   visualization and modelling and introduced the new concepts of cellular automata and

90   autonomous agents. Cellular automata act based on rules affecting neighbouring cells of a grid,

91   while autonomous agents are able to pursue programmed goals (such as finding a route on a

92   mountain top), which can also include learning or communicating with other agents.

93   The third and so far last Special Issue dedicated to this topic was from the 1999 Ascona

94   conference "Our Visual Landscape: Analysis, Modelling, Visualization and Protection" (Lange

95   and Bishop 2001). It addressed landscape assessment, GIS-modelling, visual representation, and

96   also perceptual issues in relation to digital landscape representation, including questions of

97   realism and perception of simulated landscapes as well as representational validity and criteria

98   (Bishop et al. 2001, Danahy 2001, Lange 2001, Sheppard 2001) that were cited as important

99   topics for research by several authors in the earlier special issues.

100  The relative ease of use of digital photomontages (Lange 1990) led to a revolution in landscape

101  preference research, allowing for investigators to digitally create images of alternative

102  landscapes, instead of having to rely on photographs of existing landscapes, and systematically

103  vary features, e.g. including all possible combinations of them in rigorous factorial designs. This

104  has the advantage of being highly controllable in terms of the independent and dependent

105  variables studied. The applications to landscape design and planning are numerous, as evidenced

106  by a large number of research publications in this area (recently e.g. Lindemann-Matthies et al.

107  2010, Zheng et al. 2011). In landscape preference research this has now also extended to using

108  virtual landscape models.

109

110  **4. Outlook and further questions for research**

111  There are a number of neglected or unresolved research areas that need further exploration.

112  These include issues about the complexity and dynamics of the real world, human perception of

113     landscapes, simulated sensory environments, new and emerging technologies, as well as

114     landscape visualization for improved communication, public participation, and decision-making.

115     Nowadays, the virtual environments that we create can be highly realistic representations of the

116     real landscape including terrain, vegetation and built structures. Does it matter that

117     representations of animals and humans and their movement as well as the dynamics of water,

118     atmosphere, and light are less convincingly done? Perhaps. But it also depends on the questions

119     that one would like to answer.

120     Regarding people's perception of landscapes, both real and virtual, there is a tendency to assume

121     that an image is worth a thousand words and that images speak for themselves. However, we

122     must also consider the nature of the perceiver and how landscape stimuli are perceived and

123     interpreted. While different people may have different views and values associated with the real

124     landscape that surrounds us, they might also have different views and values associated with

125     virtual representations of existing or proposed landscapes that do not yet exist. Therefore, even

126     the most realistic virtual representations that we create might not be perceived as we think they

127     are perceived. Landscape visualizations are illusions, illusions of the past, present and future. We

128     can judge the realism of landscape visualizations that portray existing conditions by comparing

129     them with real places and in many cases the results will be surprising. A plan or design may look

130     entirely plausible when visualized on paper or a computer screen but may feel and function quite

131     differently when viewed as a real-world space. This challenge of realism is heightened when

132     dealing with the re-creation of past landscapes and creation of future ones.

133     Issues that need to be considered in developing realistic visualizations include data availability,

134     data precision, and the level of uncertainty in a proposed plan or design. In 3D visualizations

135     uncertainty is typically not addressed. For example, the software and hardware available

136 nowadays makes it possible to represent a development proposal as a 3D visualization in a

137 highly realistic fashion. Often, in practice exactly this is done. However, at the early stages of

138 planning and design many details are not necessarily confirmed or fixed. In such cases,

139 "realistic" visualizations do not reflect this fuzziness, and therefore a more abstract visualization

140 would be more appropriate. This still needs more systematic experimental research regarding the

141 validity and the perception of such representations.

142 Clearly, in the last few decades we have witnessed major advances (seminal work e.g. by

143 Appleyard 1977, Zube et al. 1987) in how we represent the visual landscape, how we assess it,

144 and how we use visual simulations and virtual landscape representations in environmental

145 decision-making. Although the visual sense is by far the most important human sense, focussing

146 only the visual provides us with a sectoral 'view', literally, of our environment.

147 What we are lacking is an integrative multi-sensory approach. Beyond the dominance of the

148 visual sense, we know very little about the role other senses play in landscape perception and

149 experience or of the interrelation and interplay among our senses. We know even less about how

150 to represent a multi-sensory environment, how such representations might influence landscape

151 assessments and how they could influence decision-making in planning and designing our

152 environment. For example, the view of a very beautiful existing or proposed landscape can be

153 adequately represented in visual terms--as printed in reports or online via the Internet--and

154 assessing such a representation solely on visual quality will likely generate uniformly high

155 scores. But what if next to this viewpoint is a highway or an airport generating a high level of

156 ambient noise? A waste dump site or a farmer spreading manure? This poses a range of

157 technological problems in terms of sensory representation, but it also raises serious planning and

158 policy issues on how to deal with multiple and conflicting landscape values. Is a beautiful view

159    of a landscape located next to a smelly waste dump site better or worse than a mediocre

160    landscape view without any odorous impact? And what if some noise is added as well? In our

161    multisensory world, decisions can quickly become complex.

162    While such considerations may be important to landscape and urban planning research and

163    practice, there are high technological hurdles that need to be overcome for an entire artificial

164    representation of our sensory experiences in a laboratory environment. But perhaps such a

165    strategy is unnecessary. Considering the ubiquitous access that people have to mobile phones

166    that are able to display 3D graphics, and given increasing access to high-capacity mobile phone

167    networks, it is likely that in the future we will not just be able to represent, assess, and make

168    decisions about our environment in a remote office or lab. Newly emerging technology such as

169    mobile phone augmented reality (figs. 1 and 2) expands the currently available planning and

170    design toolkit, allowing us to provide people with an augmented view of the real world on-site,

171    where proposed changes can be seen in the context of a fuller ambient array of sensory

172    experiences. While such technology may take time before it becomes a standard approach in

173    planning and design, augmented reality holds significant promise in expanding our ability to

174    more fully represent the multisensory characteristics of landscapes.

175    Further developments in landscape visualization will have an impact towards improved and more

176    informed public participation as supported by visualization technology for communication

177    between policy makers and non-experts (e.g. mobile phone augmented reality allowing the

178    streaming of data of planning proposals while one is on-site), improved integration of the visual

179    landscape quality in decision-making in planning and design, and a forward-looking, pro-active

180    approach to making decisions about our future environments. This involves further work

181    regarding the use of 3D visualizations in terms of relevant phases of planning and design,

182    audience, the level of engagement, as well as questioning the still existing focus on the

183    representation of the final product of planning and design ('the icing on the cake', cf. Orland

184    1992). Instead, what we need is a more 'playful' and experimental approach to planning and

185    design with an emphasis on the process, involving relevant stakeholders early-on, and thereby

186    possibly improving the outcome.

187    Also, recently the general public is increasingly gaining importance in landscape visualization as

188    suppliers of freely accessible 3D models and visualization materials, e.g. through Google Earth

189    and SketchUp warehouse which can be seen as a major shift in the field and which will need

190    further research exploration.

191    Finally, landscape visualization needs to move beyond focussing on the physically perceivable

192    environment and towards linking 3D visualizations with climate change models, flood models,

193    ecologic models (e.g. Hehl-Lange 2001), economic models, and other tools pertinent to

194    landscape and urban planning research and practice as well as potentially being a powerful tool

195    to project future consequences for many disciplines and sectors.

196    In a different but equally important direction, it might be worth investigating the connection of

197    virtual or augmented reality with social reality including new approaches to communication such

198    as blogs, forums, and social networks. These interesting possibilities leave us with a large

199    uncharted research territory to be explored for both the field and the journal of *Landscape and*

200    *Urban Planning*, expanding the scope and significance of our work and providing new

201    opportunities for collaboration with a broad range of disciplines and professions.

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Figure 2: Mobile phone augmented reality. The real scene is captured by the camera of the mobile phone. A proposed new park is aligned to the real world scene, also while moving the mobile phone and changing the viewpoint.

**Figure 1**



Figure 1 Mobile phone augmented reality. For spatial reference, notice the railing in the visualization and in the real world. In the future, will we all be using our mobile phones to look at planning proposals on site?

**Figure 2**



Figure 2. Mobile phone augmented reality. The real scene is captured by the camera of the mobile phone. A proposed new park is aligned to the real world scene, also while moving the mobile phone and changing the viewpoint.

**Graphical Abstract**



Mobile phone augmented reality. For spatial reference, notice the railing in the visualization and in the real world. In the future, will we all be using our mobile phones to look at planning proposals on site?

## Acknowledgments

**\*Short Author Biographies**

Dr. Eckart Lange is Professor and Head of the Department of Landscape at the University of Sheffield. He is a Member of the Scientific Committee of the European Environment Agency (EEA), Copenhagen, Denmark, in the area of Spatial Planning and Management of Natural Resources and an elected Academic Member of the Landscape Institute (Royal Chartered Body for Landscape Architects in the United Kingdom). His research focuses on how landscape and environmental planning can influence and direct anthropogenic landscape change, while developing innovative methodologies of how advanced virtual landscape visualizations and modeling can be used to explore human reaction to these changes.