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THE ROLE OF VISUALIZATIONS IN URBAN FORESTRY.

CONCLUSIONS FROM MANAGERS' PERSPECTIVES

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To my son, Lucas

Resumen

La presente tesis examina el uso potencial y actual de las técnicas de simulación visual aplicadas al campo de la gestión y la planificación del arbolado urbano. El estudio incluye las aplicaciones potenciales de las visualizaciones por ordenador, así como los beneficios que esto acarrearía. También se analizan las posibles barreras que surgirían de la implementación de esta nueva herramienta y se ofrece una lista de recomendaciones para superarlas.

La investigación tiene un carácter exploratorio que utiliza una combinación de técnicas de investigación cuantitativas y cualitativas, dónde se emplean cuestionarios y entrevistas personales semi-estructuradas para estudiar y analizar las opiniones y reacciones de los gestores de arbolado urbano de los distritos de la ciudad de Londres (Reino Unido), denominados Tree Officers (LTOs). Para el desarrollo de la tesis se recopilaron y analizaron las respuestas al cuestionario del 41 por ciento de los LTOs pertenecientes al 88 por ciento de los distritos de Londres y se realizaron un total de 17 entrevistas personales.

Los resultados del análisis estadístico de las respuestas del cuestionario y los análisis cruzados de las distintas variables se complementaron con las conclusiones obtenidas del análisis temático de los datos cualitativos recopilados durante las entrevistas. Los usos potenciales de las técnicas de simulación visual aplicadas a la gestión y planificación del arbolado urbano sugeridos fueron obtenidos combinando las conclusiones de, primero, la comparación de las cuestiones que los LTOs consideraron que más tiempo y recursos necesitaban y que actualmente no era posible resolverlas satisfactoriamente con las herramientas y los procesos disponibles, con la información acerca de cómo se habían empleado las visualizaciones en situaciones similares en otros campos tales como planificación urbano, el paisajismo o la gestión forestal. Segundo, se analizaron las reacciones y opiniones de los LTOs ante un conjunto de visualizaciones presentadas durante las entrevistas, desarrolladas ad hoc para mostrar un abanico representativo de ejemplos de utilización de las técnicas de simulación visual, que, a su vez se complementaron con los usos adicionales que los propios LTOs sugirieron tras ver las visualizaciones presentadas.

Los resultados muestran que el uso actual de simulaciones visuales por parte de los LTOs es muy limitado pero si que reciben un gran número de visualizaciones de otros departamentos y como parte de la documentación presentada en las solicitudes de permisos para edificación o desarrollo urbanístico. Los resultados indican que las visualizaciones que son presentadas a los LTOs no son objetivas ni precisas por lo que se argumenta que esta situación es un factor importante que impide una toma de decisiones adecuada y una correcta transmisión de información al público y al resto de partes implicadas. Se sugiere la creación de un código que regule el uso de visualizaciones en el campo de la gestión y planificación del arbolado urbano.

Abstract

This thesis examined the use of computer visualizations in urban forestry management and planning. Potential roles of visualizations were determined the benefits that its use would provide. Additionally, the possible barriers in the implementation of visualizations in urban forestry management and planning were also studied and recommendations on how to overcome them were provided

The research conducted was an exploratory study using survey research methods and personal semi-structured interviews. The perspectives and reactions of London (UK) boroughs' tree officers (LTOs) were analysed combining quantitative and qualitative research methods. The study surveyed 41 percent of all Tree Officers in London, obtaining responses from 88 percent of the boroughs and performed 17 personal interviews.

Statistical analysis of the data and cross-variables analysis provided rich information that was then complemented with the conclusions from thematic analysis of the qualitative data from the interviews. Potential roles of visualizations were determined first by understanding the challenges that LTOs are facing today and comparing them with how visualizations have helped in similar situations in urban forestry and other related fields like landscape architecture, urban planning and forestry; second, the reactions of LTOs to a set of examples of proposed uses of visualizations were also complemented with the additional uses proposed by LTOs after seeing the visualizations. The visualizations were created ad hoc to show a variety of representative examples of the sue of visualization in urban forestry management and planning and were presented during the interviews to LTOS.

Results show that the current production of visualizations is very reduced among tree officers but that they are frequent receptors of visualizations coming from other departments and as part of the documentation of planning applications. Findings show that the current visualizations that get to Tree Officers are biased and inaccurate and therefore it is argued the the current use of visualizations is a threat to legitimate informed decision making and public information. The development of a code for the use of visualizations in urban forestry management and planning is suggested.

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INTRODUCTION

1. STATEMENT OF THE PROBLEM

More than 50% of the world's population and 70% of the European population lives in urban areas (EEA, 1999). The reality is that the majority of the world's population lives in cities and that further urbanization cannot be halted. By 2030, 60% of people around the world are expected to dwell in cities and towns (Topfer, 2001) and urban areas are growing three times faster than their rural counterparts (Palijon, 2002; WRI 2004).

Climate change is going to accentuate this situation with predicted migratory movements of environmental refugees. Under this changing climate, cities are going to face many new and important environmental challenges, with repercussions at many levels of city governance and administration including the need for adaptation and mitigation strategies.

In an urbanized society urban green areas are important for people, as a place for leisure and to facilitate contact with nature, thereby, increasing understanding for natural processes and ecosystem dynamics (IUFRO, 2001). Indeed, the positive benefits of urban forests extend to aesthetics, recreation, education, the economy, climate control, urban biodiversity and environmental quality control (e.g. Miller, 1997; Rydberg, 1998). Urban trees are also a valuable tool for mitigating climate change and improving the urban environment at the place where they are needed most.

With such inherent and extant value to the urban population, the development and delivery of urban forest management plans may be an emotive and contested process requiring significant and well executed community consultation. Yet the importance of urban forests and their management remains poorly debated in the public realm and still a high level of research support is required to improve dialogue among urban foresters, users and managers, and to improve the dissemination of needed information about urban forests (Dwyer *et al.*, 2001).

But to establish a dialogue, understanding of comprehensive information related to the subject of discussion is needed and urban forestry plans and technical documents are not always easy to comprehend for non-experts. While scientists and experts are familiarized with the abstract representations used in their fields, lay people are not, and usually find them confusing (e.g. Kozma and Russell, 1997; Lewis and Sheppard, 2004; Lange, 2005). Additionally, urban forest management decisions are often based on long-range future projections, the conditions and effects of which can be difficult to comprehend for those not trained in urban forestry.

Visualization can help make complex concepts, such as long term consequences, easily understandable to lay people; therefore, they are increasingly being used in decision-support and capacity-building roles to attempt to bridge the gap between expert knowledge and public understanding (Sheppard and Salter 2004).

In recent years, urban forestry models have been made available to calculate many of the environmental benefits that urban trees provide. Despite some successful attempts to engage the public using economic valuation techniques (Rogers et al., 2011; Rogers and Jarratt, 2012; Rogers *et al.*, 2015), most of this knowledge remains within the scientific community. There continues to be a recognized need among experts and policy makers for clear communication and engagement with society, particularly on the important role and the benefits of urban trees. Visualizations can help raise awareness and change attitudes (Slovik *et al.* 2002; Sheppard 2005, 2012).

Visualizations including portrayal of urban vegetation are frequently used in urban environments for purposes of depicting new architectural designs, but the research on the extent of use and quality of visualizations in urban forestry is very limited, with a focus on participatory greenspace planning (eg. Laing, 2003; Lange, 2008). There is a need to understand if/how visualizations are being used, who are the professionals producing and presenting the visualizations, what is the level of implementation of these tools, and what is the potential for the use of visualizations in urban forestry.

This research identifies those areas of urban forestry where the aid of visualizations would be more beneficial and explores the possible barriers to implementation of visualizations in urban forestry management and planning.

The novel aspect of this dissertation is that it seeks to address these issues by exploring urban forestry managers' and planners' views using a combination of quantitative and qualitative techniques. The study of urban forestry practitioners' perspectives on the use of visualizations provides valuable information that is used to research the potential roles of visualizations in urban forestry management and planning, and to provide a list of recommendations for effective implementation to ensure that visualizations are used in an accurate, credible and productive way.

2. RESEARCH QUESTIONS AND OBJECTIVES

First, this thesis seeks to identify the potential of visualizations and their role in the urban forestry sector. An initial analysis of the potential applications of visualizations to urban forestry based on the current state of the art and experiences from other fields will allow to create a set of examples of visualizations to be later evaluated by the urban forestry managers and planners themselves. In this way, the initial analysis will be complemented with the urban forestry managers and planners' views and perspectives obtained from the questionnaires, with their feedback on the proposed examples of visualizations, and with new applications put forward during the interviews.

Second, this research will explore the possible barriers to be overcome in the implementation of visualizations in urban forestry management and planning. For that purpose, the reactions and perspectives of tree officers from London boroughs will be analysed and discussed, using a combination of quantitative and qualitative methods.

Consequently, this dissertation aims to answer the following research questions related with the use of visualizations in the field of urban forestry management and planning:

Research question 1:

What are the actual and potential roles of visualizations in the context of urban forestry management and planning?

Research question 2:

What are the potential benefits and barriers for the implementation of visualizations in urban forestry management and planning?

This thesis will answer the research questions through the completion of the following **objectives**:

1. Undertake a critical review of literature on experiences with the integration of visualizations in urban forestry and in other fields with similar issues and needs.
2. Investigate urban forestry managers and planners' priorities, challenges and concerns in urban forestry, as context for the potential role of visualization.
3. Understand how well these professionals think their priorities, challenges and concerns are being tackled by existing tools and processes.
4. Develop a methodology for testing different visualizations types with urban forestry managers and planners.
5. Investigate urban forestry managers' and planners' views with regard to using visualizations in urban forestry:
 - 5.1. Establish if/how visualizations are being used by urban forestry managers and planners
 - 5.2. What preconceptions do they have about visualizations?
 - 5.3. How do they react when confronted with this new tool?
 - 5.4. What potential benefits and difficulties do they see with the use of visualizations in urban forestry?
6. Provide recommendations for the effective integration of visualizations in urban forestry management.

3. ORGANIZATION OF THE STUDY

The thesis is divided into six chapters:

- Introduction
- Chapter 1. Literature review
- Chapter 2. Research methods
- Chapter 3. Case study
- Chapter 4. Results
- Chapter 5. Discussion
- Chapter 6. Conclusions
- Bibliography
- Appendices

The introduction has presented the statement of the problem, the research questions and the objectives, and the organization of the study.

Chapter 1 Literature Review contains the review of literature on the use of visualizations in urban forestry. It also explains the challenges that urban forestry is now facing. Examples of other disciplines using visualizations such as urban planning, landscape architecture, and forestry, are described.

The methodology and procedures used to gather data for the study are presented in Chapter 2. A combination of quantitative and qualitative approaches has been adopted to answer the research questions. A questionnaire and semi-structured interviews have been chosen as methods for collecting data. Also discussed in Chapter 2 is the chosen approach to data analysis and a discussion about ethical considerations and the issues of reliability, validity and generalization.

The case study is described in Chapter 3, detailing how the methodology is applied to a specific study area in London, which is described in detail, and to a specific population: the London Tree Officers. The chosen study area for the visualizations is detailed and the application of the methodology for the creation of the visualizations and the chosen visualizations are also described.

Chapter 4 contains the results of analyses and findings that emerged from the questionnaire and the interviews.

Chapter 5 Discussion of the Results contains the discussion of the results in relation to similar studies and to the initial research questions, recommendations for practice, limitations and strengths.

Finally, Chapter 6 Conclusions contains conclusions drawn from the findings in relation to the research questions, and directions for further research.

CHAPTER 1

LITERATURE REVIEW

1. INTRODUCTION

The main objective of the literature review is to review the use and potential of visualizations in urban forestry and related management and planning disciplines, drawing on both research and practice, and to review studies exploring urban forestry practitioners' perspectives as context for the use of visualization.

The Chapter starts with an introductory Section where basic definitions of visualizations and the different types of visualizations are provided. The next Section includes a review of the literature and research related to the current use of visualizations in urban forestry management and planning. Examples from other related disciplines such as urban planning, landscape architecture, and forestry, using visualizations to facilitate participatory processes and bridge the expert-non expert gap, are described. The third Section provides a theoretical basis for the use of visualization, and describes possible concerns over the use of visualizations and an interim code of ethics for visualizations preparers.

Then, the fifth Section describes the challenges that urban forestry is now facing, and finally, the literature on studies exploring urban forestry managers' and planners' perspectives is reviewed in the last Section.

2. WHAT IS A VISUALIZATION? BASIC DEFINITIONS AND TYPES OF VISUALIZATIONS

To clarify the contents of this thesis and to avoid confusion, it is important to establish a series of definitions of some of the key terms used.

"Visualizing is the action of forming a mental image or becoming aware of something through graphical aids," (Blaser *et al.* 2000: 4)

Visualizations are "visual pictures or images of proposed projects or future conditions, shown in perspective views in the context of actual sites" (Sheppard, 1989: 6). They can also be defined as images of real places seen from a particular perspective, which can be manipulated

in several ways to show important features or to simulate future conditions used on different management conditions (Sheppard, Lewis, and Akai, 2004).

Landscape visualizations represent the visual landscape in 3D perspective views and with varying degrees of realism. These visualizations can vary in terms of level of interactivity, can be static or dynamic, and be on immersive or non-immersive displays (Sheppard and Salter, 2004; Bishop and Lange, 2005).

Photo simulations, computer generated images and perspective drawings (also known as hand draws or hand renders), are commonly used types of visualizations. Whilst the terms visualizations and visual simulations are often used indistinctly, in this thesis, the term visualizations will be used primarily.

Visualizations can be produced using non-digital and digital techniques. Non-digital techniques include among others hand drawings, hand drawings over photographs and scale models. In recent years, computer generated visualizations have reached very high levels of realism, becoming comparable to photographs of actual scenarios in real life, as visualization software has improved significantly. These tools have also become more accessible to a wider number of professionals and users. For these reasons, this thesis will focus on digital techniques only, where software is used to digitally alter images or to create three-dimensional scenes. Two main groups of techniques can be considered: photo editing or photo-montage techniques and three-dimensional (3D) modelling techniques.

Photo editing consists of the use of digital alteration techniques to obtain realistic 2D images that alter the original photograph to show the expected result for a specific project or development. It involves drawing or using photo-montage techniques on digital photographs of the landscape to simulate possible interventions. The points of view are limited to available photographs of the case study area and it is not possible to create animations.

3D modelling techniques are computer-generated landscape visualizations based on geodata that allow the generation of 3D perspective views from a potentially limitless number of different viewpoints and which can range in terms of realism from abstract to photo-realistic (Ervin, 2001; Sheppard and Salter, 2004).

Animations can be generated to allow us to give the impression of walking or flying through or above a scene. In addition, with new technologies it is possible to obtain virtual reality models where a user may choose how to “move” within the scene. This type of interaction can allow a “a la carte” design, giving the creator of the model unprecedented flexibility without additional cost. However, the creation of a 3D scene made of multiple objects introduces a set of difficulties. Scene visualization, realistic or not, requires complex processes, both in terms of time and resources, due mainly to the large amount of information handled, which makes the search for more efficient techniques a challenge for researchers (Celso, 2002).

The basic structure of a three dimensional virtual model generally consists of four main elements (Appleton and Lovett, 2003; Ervin and Hasbrouk, 2001):

- The digital terrain model (DTM)

- The surface texture model
- Vegetation models
- Models of built structures

The DTM is usually built using a digital elevation model (DEM) or triangulated irregular network (TIN) to create the base of the virtual landscape. The landscape's ground cover is represented by a surface texture model. This can take the form of simple colours or fractal textures created by the software (Discoe, 2005). A vegetation model is then applied to the surface texture. These range in complexity, from a simple billboard or photograph to particle generators or complex 3D tree models. Billboards use an alpha channel to create a transparent background on the photograph of the element. Vegetation created by particle generators or 3D tree models tends to be less common due to the high processing demand these models place on computer hardware (Muhar, 2001). Built structures such as buildings are then typically represented using volumetric vector models, textured with photographs or fractal techniques (Appleton and Lovett, 2003; Bergen *et al.*, 1998; Bishop and Lange, 2005; Lange, 2001; Neto, 2006).

Other elements are increasingly being used by visualization practitioners, including algorithms for lighting, water and atmospheric conditions, and the inclusion of billboards or 3D models to represent humans and other animals (Appleton and Lovett, 2003; Ervin, 2001; Laing *et al.*, 2009). In addition, items such as vehicles people, street furniture, weather effects, etc. can be added in static or dynamic mode, as used with game engines (eg. Angel et al, 2015).

During the process of creation (modelling) and visualization of a 3D scene, there are various phases that require specific information, such as the geometry and topology of objects, the sources of light and the viewpoint of the observer. If the objective is to obtain a realistic scene, the problem is greater, as in addition to the complexity of the processes and amount of information required, there is the added difficulty of finding the right model to represent the objects, location and characteristics of light sources and the aspect of materials

Making digital models, as with any representation-making, will always be an act of abstraction and simplification and might even contain distortions (Ervin and Hasbrouck, 2001). Choosing the right model for a given purpose is an important part of the modelling process.

3. THE USE AND EVALUATION OF VISUALIZATIONS IN URBAN FORESTRY AND RELATED FIELDS

As important element of the urban landscape, urban trees and urban vegetation appear frequently in visualizations produced by developers, landscape architects and urban planners to show new schemes and designs. These visualizations could be of the design of a new park or green area, in which case the plants and trees would be a central element. The visualizations could also be part of a new highway scheme or a new development in which case vegetation may or may not be represented, as the main focus typically is on the buildings and traffic infrastructure.

An example of one of the numerous visualizations used in highway design projects portraying vegetation are the visualizations provided as part of a presentation to residents for the intersection of London's Tottenham Court Road with Euston Road (Transport for London, 2012), included in Figures 1 and 2. Aerial photographs from Figure 3 allows a comparison of the visualization of the proposed project with the actual execution and the results. While mostly accurate, that visualization showed some trees in the South-West corner of the crossing (lower left in the figures 1 and 2, and top right in figure 3) that do not appear in the 2014 photograph. This useful comparison is not often done and has proven to be critical to evaluating the adequacy and fairness of visualizations (Sheppard, 1989). Ethics and concerns about the use of visualizations are further discussed in following sections.

Figure 1. Photograph of Euston Circus before the redesign.

Source: Improving Euston Road Brochure (Transport for London 2012)

In the following sections, the literature reporting studies about the use and evaluation of visualizations are described, identifying four main areas of research:

- Technical developments in urban vegetation visualization methods.
- Visualizations used by experts in urban forestry management and planning.
- Visualizations used to assess public preferences for greenspace landscapes and planning options.
- Visualizations used in communication and participatory urban forestry planning.

Examples from other associated disciplines such as urban planning, landscape architecture, and forestry, using visualizations have also been included when considered necessary, drawing on selectively reviewed papers that seem the most relevant or likely to apply to urban forests situations.

Figure 2. Visualization of the projected redesign.

Source: Improving Euston Road Brochure (Transport for London 2012)

Figure 3. Actual aerial photographs comparing Euston Circus before (2004) and after the redesign (2014).

Source: London Cycling Campaign (<http://lcc.org.uk/articles/elephant-and-castle-to-be-transformed-but-missed-opportunity-at-euston-circus>)

3.1. Technical developments in urban vegetation visualization

Most of the studies of the use of visualizations in urban forestry are mainly focussed on technical developments in software, data, and modelling procedures, in areas like tree growth visualization, plant geometry, LIDAR scanning technologies, and procedural methods.

Virtual 3D city models can also be of help in visualizing urban trees. CityGML includes vegetation as well buildings and other man-made artifacts, waterbodies, and transportation facilities like streets and railways (Kolbe, Gröger, and Plümer, 2005).

Urban tree growth has been modelled in a video animation using L-System growth models (Rudnick *et al.*, 2007). Lindenmayer-Systems (L-Systems) are a mathematically-based theory of biological development used to model tree growth by using production rules that govern branching and growth at successive time steps (Prusinkewicz and Lindenmayer, 1990). Rudnick *et al.* (2007) used 20 time steps per year for 40 years, and branch production rules were applied to all branch segments based on the biological response of each organ to competition for light and space. This work was the first to combine urban tree growth equations with L-Systems and computer animation software.

Animated tree growth can also be linked with environmental benefits evaluation and integrated into a tool that visualizes these parameters over time (Brasch, McPherson, and Linsen, 2009). The parameters include measures of tree dimensions like heights, diameters, and crown shape, and measures of costs and benefits for growing the tree. The tree dimensions are visualized while animating tree growth over time, while the accumulated costs and benefits are visualized using animated bar charts.

Deussen (2003) presented a generation method for plant geometry that allowed the creation of virtual vegetation using techniques of computer graphics with applications in landscape architecture.

Airborne and portable on-ground scanning light detection and ranging (LIDAR) can be used for three-dimensional visualization of urban parks and quantification of biophysical variables of trees in urban environments (Omasa, Hosoi, Uenishi, Shimizu, and Akiyama, 2007). The authors combined airborne and on-ground LIDAR images to overcome blind regions and created a complete three-dimensional model of three standing trees which allowed not only visual assessment from all viewpoints but also quantitative estimation of canopy volume, trunk volume, and canopy cross-sectional area. LIDAR can be used for 3D visualization by using airborne scanners to measure points in 3D which are then displayed on a digital terrain surface. Trees and other urban vegetation can be depicted through a combination of 3D points and colour imagery whilst topographic features are extracted automatically (Haala and Brenner, 1999; Toutin, 2004). Mobile laser scanning (MLS) has been used to acquire massive 3D point clouds in urban areas and along road corridors for the collection of detailed data for 3D city modelling, building façade reconstruction and capture of vegetation and road features for inventories. Tree features can be extracted from such data-sets to create modelling of trees for the purpose of visualization in 3D city models (Rutzinger, Pratihast, Elberink, and

Vosselman, 2011). Laser scanning can also be used to model tree architecture to study urban microclimate (Landes et al., 2015).

Procedural modelling methods for the automatic creation of large-scale 3D city models offer unprecedented opportunities to understand and encode urban patterns. They allow for the easy production of multiple design alternatives based on design rules leading the simulation procedure (Müller *et al.*, 2006; Halatsch *et al.*, 2008). Hayek *et al.* (2010) explored the use of shape-grammar-driven procedural models for effectively linking natural resource indicators into the urban greenspace design process.

Urban green space typologies can be linked to ecosystem services provision for facilitating collaboration between stakeholders of different backgrounds (Raumonen *et al.*, 2013). Greenspaces can be mapped and linked with information about potential ecosystem services and their parameters. 3D visualizations of the green space patterns and correlating ecosystem services indicators can be created by integrating both the map of green space types and the pattern designs into the parametric modelling and visualization chain of ESRI CityEngine (Neuenschwander, Hayek, Grêt-Regamey, 2014).

The main body of research focuses on technology developments, which are not specific to urban forestry management and planning, as well as on the use of visualizations in urban planning (Lange *et al.*, 2008; McFarlane *et al.*, 2005; Wissen *et al.*, 2008). The necessity to evaluate the use of visualizations and to establish standards for effective and ethic visualizations has been highlighted (Hughes, 2005; Sheppard, 2001). The development of new software tools and their integration with among others LIDAR data, georeferenced GIS platforms, and growth simulations (4D visualizations), have however made them become too complex, difficulting public's comprehension of the visualization creation process, and the adoption of these new techniques by practitioners (McFarlane *et al.*, 2005; Lewis *et al.*, 2012). Still more research is needed to understand how to adapt the visualizations technologies to improve their usability, their efficiency, and the technical feasibility of the methods.

3.2. Visualization use by experts in urban forestry management and planning practice

Research about the use of visualizations for urban forestry management and planning practice is very limited and the literature has been focused on describing the advantages for professional planners in visualizing tree growth as part of the design process, to allow for the choice of adequate species for the space, and expert use of GIS systems integrated with 3D visualizations and LIDAR technology (e.g. Haala and Brenner, 1999; Toutin, 2004). Tree models created with the AMAP technology have been used in visualizations for architectural projects where trees were a focal point in the design and also outlined the advantages of integrating this technology in the design process. Tree models based in the AMAP modelling and commercialized by Bionatics allowed for the accurate simulation of tree growth (Yan, Kang, de Reffye, and Dingkuhn, 2004). This characteristic was especially valuable as it allowed users to experiment with different species and different planting designs (Auclair, 2002).

Non-visible urban forest attributes such as land cover, forest structure, species composition and condition, heat island effects, and carbon storage can be derived from the timely and extensive data provided by GIS geospatial tools (Ward and Johnson, 2007). Geospatial tools adapted for urban forest applications can include data fusion, virtual reality, and 3D visualization. Similarly, 3D visualizations can also assist in urban forestry planning and management by displaying modelled air pollution and air flow (Maktav *et al.*, 2005).

Visualization techniques, in conjunction with GIS and the Internet, can also promote citizen science projects in urban forestry. Kelly and Tuxen (2003) outlined an example of this with OakMapper, an Internet application used by a wide community of users to input data on trees suspected of being infected with Sudden Oak Death in California. As well as data input, the application provided maps and database queries that enabled the community to be involved in monitoring its environment.

Forestry, both in non urban and urban contexts, is a discipline where the veracity of scientific predictions and the effectiveness of decision-making are assessed by the results on the ground. Unfortunately, the time taken for ecosystems to respond to inappropriate measures means that current decisions will not be able to be judged for a number of decades. To resolve this problem, computer-generated models and visualizations are being relied on to estimate the impact of proposed interventions, before carrying them out and visualization and virtual reality techniques are being increasingly used by forest managers (primarily in non-urban landscapes) to support decision making. Landscape visualizations have been effectively used for the communication of environmental impact (Orland, 1990), to evaluate the visual impact of forest work (Heasley, 1990; Orland, 1992), to describe the special characteristics of forest ecosystems (Kellomäki, 1989) and have been proven as well to be valid to evaluate the scenic quality of the landscape (Bergen *et al.*, 1995; Thuresson, 1996). Lim and Honjo (2003) described how virtual reality 3D systems capable of realistic walk-through simulations of forest landscapes have also been developed. The use of landscape visualizations together with data visualization enabled a more efficient management of landscapes by forest managers, by providing a realistic views of alternative plans.

Visualization techniques have also been used in the study of peri-urban forests which are closer to the urban setting in which urban forestry takes place (Alinat, 2002). The scenic quality of green areas over time was visualized using vegetation models generated with AMAP technology. The resulting visualizations and the aesthetic evaluation of the different alternatives and their temporal evolution were used by planners as an relevant input for subsequent land planning.

Though visualizations are very commonly used by architects and urban planners not only for built infrastructures but also applied to the planning and design of green spaces (see next Section for more information on this topic), their use is still not common among urban forestry managers and planners. The use of landscape visualizations in forestry management is lately being adopted by forestry managers in non-urban and peri-urban environments, instigated by the solid body of research studies demonstrating its effectiveness and advantages (eg. Orland, 1992, Meitner *et al.*, 2001; Sheppard and Salter 2004). Research about how these techniques can be implemented by urban foresters is still very reduced, mostly focussed on presenting practical applications of technical developments. Still more

research is needed to evaluate the effectiveness and practical implications of the use of visualizations in urban forestry management and planning.

3.3. Visualization use in assessing public preferences for greenspace landscapes and planning options

The main part of aesthetic perception occurs through the sense of sight and therefore, visualization of landscapes is a central part of forest landscape perception and preference research. Landscape perception studies using visualization are sometimes used to understand people's responses to real-world environments. Video imaging technology has been tested to examine several tree attributes that influence people's visual preferences (Orland, 1988; Bishop and Leahy, 1989). Schroeder and Orland (1994) used video imaging technology to explore viewer preference for the special arrangement of park trees. Today, computer generated visualizations in 3D and 4D, and virtual landscape simulators offer the most sophisticated means of visualization for landscape research (Karjalainen and Tyrväinen, 2002).

Visualizations have also been used in studies exploring aesthetic preferences in greenspace planning. They have been proved to be valid to find out public preferences for different transit design where the planting of street trees was one of the scenarios considered (Ewing, 2001). Laing (2003) reported results from a research project which used 3D models to produce visualizations of environmental conditions of open public greenspace. The methodology used contingent ratings which aimed to establish the values that of green areas and residents placed on specific greenspace sites. The study focused on the influence of variables including lighting, season, time of day and weather on the perception of respondents.

Lange (2008) carried out a study investigating a prospective approach to green space planning through the combination of 3D visualization of green space scenarios and survey techniques to facilitate improved participation of the public. A number of scenarios, including the 'Status quo', 'Agriculture', 'Recreation', 'Nature conservation' and 'Wind turbines' were visualized in 3D. Responses were tested by way of a survey in print format and on the Internet. Overall, 49 different visualizations relating to the scenarios were rated in the survey in terms of their perceived aesthetic, recreational and ecological values. The results showed how the highest ratings were given to scenes with vegetation elements like meadows, trees and shrubs, whereas the lowest ratings were given to scenes where buildings predominated or there were no vegetation elements.

Environmental judgements using visualization have however been criticized regarding their validity. Objections are often based on the argument that that photographs are less complex, less multi-dimensional and offer less interaction compared with real scenes (Abello et al, 1986). Objections are often raised in the sense that photographs are less complex, less multi-dimensional and offer less interaction than do real scenes (Abello et al, 1986). Hence, many studies have tried to establish the validity of the representation medium as a simulation of the real environment. The validity of using photographs as surrogates of actual environments has been largely researched (Shuttleworth, 1980; Nassauer, 1983; Zube *et al.*, 1987; Bosselmann *et al.*, 1989). For example, Daniel and Booster (1976) established the validity of

colour slides as surrogates for scenic beauty evaluation. These studies have shown that people's responses to real environments are similar to their responses to photographs.

Bishop and Hull (1991) cited three different studies to support the validity of using computer simulations as surrogates of the actual environment (Bishop and Leahy, 1989; Orland, 1987; Vining and Orland, 1989). Bishop and Leahy (1989) reported the validity of substituting computer generated images for photographs of landscapes. They showed a moderately strong relationship between photographs and computer simulations of landscapes based 256 colours and medium resolution. Vining and Orland (1989) reported good correlations between computer simulated images and photographs of three different environments. Orland (1987) found very good correlation between preference for photographs and computer simulated images. Orland reported that high level colour fidelity is more important than low resolution quality for simulating built environments.

In conclusion, landscape visualizations have been used effectively in greenspace planning and design as well as in landscape planning for testing landscape preferences, especially aesthetic preferences. In particular, landscape visualizations with a high level of realism are now widely accepted as a valid tool in research on people's aesthetics preferences. Still these studies are mostly used by researchers and rarely adapted to practice.

3.4. Visualization use in public communications and participatory urban forestry planning

As well as helping technical experts such as managers and planners as we have seen, visualization techniques also facilitate communication between specialists and with the general public, increasingly involved in the management of green spaces. Computer graphical tools can be a good medium for communicating for example aesthetic impacts of a proposed project and can be used to improve understanding of the dynamics at work in urban forest ecosystems.

Planners typically visualize physically visible elements, though abstract and invisible elements can also be visualized to help raise the awareness of the potential impact of planning, even when they reach far into the future (Lange 2005). Natural landscapes are complex systems with dynamics that occur over large spatial and temporal scales (Meitner and Gandy, 2004). Humans have difficulty thinking on these broad scales, because they are outside our normal frames of reference (Eaton, 1997; Kimmins, 1997).

Lange and Bishop (2005) outlined how using understandable communication media could help bridge the potential communication gap between experts and lay persons (the expert vs. lay person paradigm). Visualizations can be seen as a medium that can help to overcome this problem as a capacity building tool (Meitner *et al.*, 2001; Sheppard and Salter 2004; Meitner *et al.*, 2005).

Dialogue between the general public and policymakers, planners and designers and the decision-making process and understanding of all the parties can be bolstered through the

use of visualisations representing the plans and designs. As stated by the EPA (2002, p.15) “clear communication about environmental protection strategies is especially important for generating enthusiasm and participation and for preventing confusion”.

A number of studies have investigated the role visualizations could play in participatory planning processes, finding that a combination of diverse visualization methods can bolster communication and improve the effectiveness of the process. Al-Kodmany (1999) carried out a set of neighbourhood design workshops to evaluate different tools and to understand how they promoted resident participation in the planning and design process. Initial workshops used GIS in conjunction with an artist. The GIS provided interactive visualizations of the neighbourhood through maps and images. The artist sketched ideas and suggestions proposed by the public. Later workshops added in photo-manipulation as a third tool, with photorealistic examples of proposed design prototypes inserted into photographs of the area. The study found that each type of tool was appropriate for different phases of the planning process. Problem identification and brainstorming were most effectively addressed using freehand sketching and GIS, whereas investigation of potential solutions for design issues was addressed more effectively through photo-manipulated computer imaging.

Warren-Kretzschmar and Tiedtke (2010) investigated the potential of new media to support public participation in landscape planning and to improve the public’s understanding and acceptance of environmental measures. Different visualization methods were tested in town meetings and on an Internet platform to test their role in the communication process with the public during the planning process. In a town meeting the authors studied the public’s reactions to four types of visualizations (sketches, photomontage, VNS-renderings and Lenné3D), concluding that no single visualization method on its own covered all the communication needs, and that a combination of methods allowed to better do so. For orientation and documentation of comments, 2D maps and aerial photographs were preferred, whereas the 3D-map editor’s dynamic navigation was preferred for improving participants’ spatial awareness as it allowed them to view sites from different points of view. “Before and after” visualizations of the scenarios were considered best for assessing the aesthetic effects of proposals. The authors also concluded that strong project management of the process, plus an effective moderator aided by an assistant and a “dress rehearsal”, played crucial roles in the success of the participatory planning meetings.

Land development policy alternatives can also be displayed as maps and tables by some emerging tools. By linking them with 3D models, scenarios can then be explored interactively, even with underlying process models (e.g. Kwartler 2005; Stock and Bishop 2005).

The role of computer based visualizations methods to improve collaborative urban forest planning and design in Europe has been explored by Tyrväinen *et al.* (2006). They suggested that combined with the use of demonstration forests and landscape laboratories, visualizations were able to be verified with actual landscapes and suggested that further research was needed to assess the value and usefulness of these tools. More recently, participatory planning experiences have moved from landscape planning and forestry to urban forest planning and, finally, to urban greenspace collaborative planning. Literature is once again limited, and focused on testing the validity of new visualization tools combining rephotography, LIDAR, SketchUp and GIS platforms, as described in the following paragraphs.

West *et al.* (2013) described a community-based and participatory approach based around augmented rephotography of ecosystems. Rephotography is defined as the process of taking a picture of the same scene, from the same viewpoint to highlight changes in the scene over time. The study's goal was to explore the integration of ground level rephotography of the urban tree canopy with LiDAR data, creating a dynamic view of the urban forest, over time and space and to support public participation in data collection. For that purpose an augmented reality mobile app was created to help take the photographs from the exact same point and to access a picture database where the locations where new photographs were needed were highlighted. By analysing various augments to help calibrate imagery, the study provided a set of protocols to support 3D inference and visualizations of the temporal change over time.

The use of different types of 3D iconic symbols with interactive communication influences participation and decision making in land use planning (Wang, Miller, Jiang, and Donaldson-Selby, 2015). The study tested responses to scenarios and how models (built with Autodesk Maya, Google SketchUp and ArcGIS), using qualitative interviews. Feedback on the contribution made by the inclusion of movement within a scene was obtained, in relation to: the types of features include; the characteristics of their movement; views of the scene from fixed positions, or from the virtual human or vehicle; visual legibility of the scene; credibility of the features. The results were used as input to design tools for raising public awareness of changes in urban areas, particularly in greenspaces and focused on designing outdoor features for community planning and engagement in urban and peri-urban environments, including development of small-scale renewable energy and changes in urban greenspaces.

Visualizations have also been proven to be very effective tools in supporting active implementation of adaptation methods in the context of climate change planning. Sheppard (2005) has studied and described the benefits of using visualization to put across climate change issues and to promote community changes toward sustainability. Visualizations can (1) improve people's understanding of climate change by communicating complex scientific model more clearly; (2) convey the experience of what could mean to live in a future with climate change in their specific communities; and (3) can help to explore different solutions and inspire action (Sheppard, 2012). The effectiveness of visualizations and the described benefits have been proven in the Local Climate Change Visioning Project in the region of British Columbia, in Canada (Shaw *et al.*, 2009). Schroth, Pond and Sheppard (2015) demonstrated a methodology for the use of different visualizations' presentation formats and the long term impacts of the participatory planning process using visualizations. Results showed that the visualizations contributed to increased awareness and understanding. The landscape visualizations were useful to inform policy resulting in operational and built changes in the area of Kimberley. Key decision makers remembered most of the visualizations during the post interviews and some were using them, in particular the posters. On the other hand, some formats, such as the virtual globe, proved not to be "sustainable" display formats for formal decision-making such as at council meetings.

As has been described in this Section, there are multiple examples across many fields, including landscape planning, climate change community planning and urban forestry planning, where visualizations have been proven to be very effective and valuable tools to

improve communication between experts and the public as well as to facilitate participatory planning processes through increased engagement and capacity building.

4. TOWARDS A THEORETICAL FRAMEWORK AND PRINCIPLES FOR THE USE OF VISUALIZATION IN URBAN FORESTRY

Visualizations are increasing in popularity and are extensively used to represent new plans and designs of green areas and vegetation in urban environments but still little is known about their potential role in the urban forestry management and planning context and the considerations, variables and principles that should guide their application.

Less than three decades old, the field of computer generated visualizations is still a relatively new field, in which theories, frameworks and principles are still emerging and evolving. Sheppard (2005b) developed a theoretical framework for landscape visualizations and is the author who has contributed the most to the area of ethics in visualization, creating an interim code of ethics for visualizations in project planning (Sheppard, 2001). The use of virtual globes as visualization tools is spreading significantly, though where this is for scientific purposes there are certain considerations than need to be taken into account. The realism, perspective views, and social meanings of the landscape visualisations embedded in virtual globes invoke not only cognition but also emotional and intuitive responses, with associated issues of uncertainty, credibility, and bias in interpreting the imagery. Possible approaches for balancing these benefits and risks include codes of ethics, software design, and metadata templates (Sheppard and Cizek, 2009).

Derived from the mentioned previous works, this Section will apply those principles and cover the following questions:

- Why visualize?
- Variables to consider when using visualizations in urban forestry.
- When to use visualizations in urban forestry?
- Principles and ethics in visualizations.

4.1. Why visualize?

Visualization provides additional insights to results which would otherwise be displayed as text or numbers (Loh et al, 1992). It is a form of communication which is universal, and which has the ability to form an abstraction of the real world into a graphical representation which is comprehensible to a wide range of people.

Since it would be difficult to obtain actual 'before' and 'after' construction photographs using a complementary approach to investigate observer response to the impact of man-made structures on landscape quality, some technique of simulating such environments is clearly desirable.

Though it is possible to photograph a real landscape as it appears in current conditions, visualization techniques are necessary in order to visualize that landscape in the future or to visualize the impact of a proposed development. Killeen and Buhyoff (1983) stated that from an experimental standpoint it would be desirable to be able to selectively manipulate a certain characteristic of a scene while holding all other constant, which can be easily achieved by the use of visualization techniques.

Many studies have been conducted into the value and effectiveness of visualizations in landscape planning and forestry management (Wood 1972; Daniel and Boster 1976; Appleyard 1977; Sheppard 1982; Kroh and Gimblett 1992; Perkins 1992; Pitt and Nassauer 1992; Oh 1994; Bergen *et al.* 1995; Lewis 2000; Tress and Tress 2003). In general, both the research literature and practical experience indicate that landscape visualizations can significantly improve the public's access to information and understanding of proposed plans and projects and can help to predict public reactions to those proposed projects (Lewis *et al.*, 2004).

Additionally, the use of visualizations can maximize interest and engagement, attain quick learning, and foster public interaction with proposed plans (Sheppard *et al.*, 2011). Nicholson-Cole (2005), described how the form and framing of information can affect awareness levels as well as attitudes and emotions. It has been demonstrated that visual communication media, particularly scientific visualizations, increase engagement, enhance learning, and strengthen conceptualization of complex and non-complex environmental issues (e.g. Sheppard and Meitner, 2005; Salter, 2005). One medium that can confer an advantage in terms of portraying useful information and engaging emotions required to foster action is landscape visualization of recognizable places (Sheppard, 2005a; Nicholson-Cole, 2005). Visualizations are more powerful at conveying cultural, personal and emotional qualities associated by the public with the landscape than traditional cartographic formats (Lewis *et al.*, 2004).

4.2. Variables to consider when using visualizations in urban forestry

Research has shown that perception and interpretation of visualizations are influenced by a multitude of technical and human variables, such as the background of the user or the setup used. The level of reality, the choice of perspectives, the type of display or the interactive features used can all influence the user's perception and interpretation, making the design of the visualization subject to ethical considerations. Sheppard (1989) outlined the process and the variables to consider for each step for the use of visualizations in project planning and review (Figure 4).

The following list identifies key theoretical aspects that need to be considered that could be relevant to urban forestry applications:

- Purpose
- Type of visualization
- Type of audience
- Role of presentation format and media
- Available resources

Figure 4. Recommended process for use of visualizations in project planning and review.
Source: Sheppard 1989

The first step is to determine the purpose of the visualizations deciding which application the simulations need to fulfil and which responses are expected/sought from the audience. The type of responses can include cognition, evaluation and decision-making, emotion, attitudes, or motivation and actual behaviour change. For example, Sheppard (2005) advocated for the use of realistic visualizations to achieve bigger impact on both cognition and action on climate change. It is important to consider the issues of bias and validity (described in detail on following sections) which are always going to be present because visualization experts and landscape planners are not neutral (Rydin 1998).

To determine the type of visualizations, the appropriate level of abstraction should be determined. Simulations can be conceptual, showing basic structures and relationships in an abstract or schematic style; or experimental, which are more realistic and with a higher level of detail, more similar to what an observer would experience in a real environment (Sheppard 1989). There are different roles for different levels of detail/ abstraction/ realism, where a high level of realism is effective for testing aesthetic preferences and to increase sense of place, through the recognition of one's own community. More abstract visualizations have proven useful for cognition, as they allow to "eliminate" details that may distract from certain aspects of the image on which the practitioner wants the audience to focus.

It is believed that different audiences and users have different needs (eg expert versus public, needs) and therefore visualizations should be tailored to the different audiences. For example, abstract visualizations are less useful to the public to test aesthetic preferences as stated before.

The chosen presentation format and media will be determined by the audience target and purpose of the visualizations. Visualizations can be communicated via different presentation formats such as online websites, mobile devices or big screens. They can be formally presented by a facilitator or presenter in front of an audience (eg. in a formal public meeting or on television); or they can be disseminated as self explanatory materials for people to access on their own whenever they chose as for as long as they like (eg. posters, reports) (Sheppard, 2012). The role of supporting information accompanying and complementing the visualizations is essential in the case of self explanatory materials.

Last, it is important to evaluate the available resources in terms of time, personnel and data to make the correct decisions balancing usability, efficiency and cost with the necessary quality, validity and credibility of the visualizations. The balance is not always easy and it usually tend to lean in to favour technological investments and highly elaborated visualizations that are not always needed and could increase the costs while reducing usability and validity (Lewis, Casello and Groulx, 2012). The fast development of visualization software has led computer generated visualizations to attain very high levels of realism, reaching the point at which it can be difficult to distinguish between a real photograph and a computer generated image. This high level of realism sends the message of a high level of certainty, of accuracy that is not always supported by data (Sheppard, 1989; Groulx, 2010).

4.3. When to use visualizations in urban forestry?

The purpose of the visualizations is inherently linked to who would be the person using the visualizations and who would be the audience those visualizations are created for (Sheppard, 2012). In the context of urban forestry management and planning, the users of the visualizations can be the experts (the urban forestry managers and planners) and the non-experts, that include the public, the politicians or decision makers, and other stakeholders different from the public that might have economic interests (eg. developers).

Based on current theory, there are three expert purposes for when and how visualizations could be used in urban forestry management and planning as can be seen on Table 1. First, visualizations could be used to support design and analysis by the urban forester. This would not necessarily require for the visualizations to be created by the urban foresters themselves. Second, they could be used by the experts to test public preferences. Third, they could be used by the experts to engage, inform and collaborate with the public (as will discussed in more detail in the Section on Communication).

Furthermore, visualizations can be used by stakeholders to present to both the experts and the public a specific project or development. An additional non-expert use could be the one by the public themselves as their own medium as a form of citizen science, or input to official processes. This last use is not relevant to this thesis but is an emerging possibility with potential to grow.

Table 1. Purposes for the use of visualizations in urban forestry management and planning

User of the visualizations	Producer of the visualizations	Audience	Purpose of the visualizations
Experts	Experts Professional visualizations preparers	Experts	To use in design and analysis
Experts	Experts Professional visualizations preparers	Non-experts	To test public preferences
Experts	Experts Professional visualizations preparers	Non-experts	To communicate with the public
Public	Public	Experts	To use as input to official processes
Public	Public	Public	Citizen science
Stakeholders	Professional visualizations preparers	Experts Public	To present a proposed project

Source: Own elaboration

4.4. Principles and ethics in visualizations

In order to meet their role, visualizations need to reach three fundamental objectives (Sheppard, 1989): convey understanding of the proposed project, demonstrate credibility of the visualization itself, and avoid bias in responses to the proposed project.

Therefore, to ensure homogeneity and objectivity, preparers and presenters of landscape visualizations should adhere to six general principles as summarized in Table 2: accuracy, representativeness, visual clarity, interest, legitimacy and access.

Table 2. General principles

Principles for visualization	
Accuracy	Realistic visualizations should simulate the actual or expected appearance of the landscape as closely as possible (at least for those aspects of the landscape being considered)
Representativeness	Visualizations should represent the typical or important range of views, conditions, and time-frames in the landscape which would be experienced with the actual project, and provide viewers with choice of viewing conditions
Visual clarity	The details, components, and overall content of the visualization should be clearly communicated
Interest	The visualization should engage and hold the interest of the audience, without seeking to entertain or "dazzle" the audience
Legitimacy	The visualization should be defensible through making the simulation process and assumptions transparent to the viewer, and by clearly describing the expected level of accuracy and uncertainty
Access	To visual information: visualizations which are consistent with the above principles should be made readily accessible to the public via a variety of formats and communication channels

Source: Sheppard 2001, Sheppard 2005b

Sheppard (2001) proposed a code of ethical conduct for the use of landscape visualizations for project planning. The visualization preparer should take into account the stage of development of the project under consideration, the landscape being shown, the types of decisions to be made, the audience observing the visualizations, the setting in which the visualizations are being presented, and the experience level of the preparer.

Within this context, preparers and presenters of landscape visualization should (Sheppard 2001):

- Demonstrate an appropriate level of qualifications and experience.
- Use the appropriate visualization system(s) and media for the purpose.
- Choose the appropriate level of realism.
- Identify, collect, and document supporting visual data available for or used in the visualization process; conduct an on-site visual analysis to determine important issues and views.
- Seek community input on viewpoints and landscape issues to address in the visualizations.
- Estimate and disclose the expected degree of error and uncertainty.
- Use more than one appropriate presentation mode and means of access for the affected public.
- Provide the viewer with a reasonable choice of viewpoints, view directions, view angles, viewing conditions, and timeframes appropriate to the area being visualized.
- Present important non-visual information at the same time as the visual presentation.
- Avoid the use or the appearance of "sales" techniques or special effects.
- Avoid seeking a particular response from the audience.
- Provide information describing how the visualization process was conducted and key assumptions/decisions taken.

- Record responses to visualizations as feedback for future efforts.
- Conduct post-construction evaluations to document accuracy of visualizations or changes in project design/construction/use.

These principles were created for visualizations used in decision making and project planning. In this setting, it was important to avoid influencing or biasing the responses from the audience. As described in previous sections, visualizations can also be used with an educational purpose or to raise awareness and change attitudes (Sheppard, 2012, 2015) and in those contexts it is, not only admissible, but necessary to seek a particular response from the audience.

As outlined in the previous Section, recent software development has resulted in tools that are more intuitive and capable of producing highly realistic visualizations. Visualization software is now accessible by a wider population of both professional and non-professionals, leading to a greater democratization of the technology and the information but, at the same time leading to very powerful tools being used potentially incorrectly by untrained people. Additionally, highly realistic visualizations can lead to the false idea that a high level of realism implies high accuracy, making people more vulnerable to biased visualizations (Groulx, 2010). A code of ethics is now more necessary than ever.

5. URBAN FORESTRY IN A CHANGING CLIMATE: CHALLENGES AND OPPORTUNITIES

Urban forestry is still a relatively new discipline that was born during the 1960's in North America. Miller (1997) defined it as "an integrated, city wide approach to the planting, care and management of the trees in the city to secure multiple environmental and social benefits for urban dwellers". A more elaborate definition was coined by Grey and Deneke (1986), stressing the multifaceted character of urban forestry:

"Urban forestry is the management of trees for their contribution to the physiological, sociological and economic well-being of urban society. Urban forestry deals with woodlands, groups of trees and individual trees, where people live - it is multifaceted, for urban areas include a great variety of habitats (streets, parks, derelict corners, etc.) where trees bestow a great variety of benefits and problems." (Carter 1993, adapted from Grey and Deneke 1986)

Despite the term not being accepted at first in the UK where it was considered an Americanism (Johnston, 2005), urban forestry is now firmly established within forestry policy and management in Britain. Urban forestry is seen to be able to make a significant positive contribution to tackling a wide range of problems, such as rising inequality, persistent under-development of deprived urban communities, and the pressures of climate change.

Urban forestry is concerned with the whole of urban green space and not the sum of individual green space elements. It focuses on urban green space comprised of tree stands as well as individual trees and its approach is multidisciplinary and interdisciplinary.

The challenges of urban forestry that are going to be described in following sections are:

- Climate change
- Benefits of urban trees in a changing climate
- The loss of big mature trees
- Communication in urban forestry

5.1. Climate change

It is generally accepted that our climate is changing. In northern Europe, winters are projected to be milder, and summers hotter and wetter (IPCC, 2007). Under this changing climate, cities are going to face many new and important environmental challenges, with repercussions at many levels of city governance and administration including the need for adaptation and mitigation strategies.

Cities take up less than two percent of the world's landmass but they have a huge impact. C40 Cities Climate Leadership Group estimates that cities consume two thirds of the world energy and account for 70% of global emissions of greenhouse gases (Pires de Miranda and Powell, 2013). Identifying how cities function can be improved such as water use, reduce energy consumption reduction or waste management would be essential to ensuring sustainable liveable cities that have lower impacts on the natural environment are created.

Living in cities can bring efficiencies in the use of resources. Commute distances are shorter as the population density allows the development and a greater use of the public transport. London's CO₂ emissions per capita are 5.9 tonnes, one tonne lower than the rest of the UK.

If global emissions of greenhouse gases (GHGs) are left unchecked, average global temperatures could rise by up to 6°C by the end of the century. Regional variations could be even greater. If this happens, the UK will experience progressively warmer and drier summers, wetter and milder winters and more frequent extreme weather. London, in particular, will be vulnerable to floods, droughts and heat waves (Greater London Authority, 2008).

Cities will have to adapt and methods of building design and construction need to be reviewed and revised, as the buildings and spaces in which we currently live and work are unlikely, in the medium term, to provide adequately for our needs if the expected impacts of climate change in the UK are realised. Vernacular architecture found elsewhere in the world for coping with high temperatures may not be readily transferable to the UK situation for cultural, spatial and economic reasons (Shaw *et al.* 2007).

Trees and greenery have been an integral element of civilised settlements throughout history and are a key element of any foreseeable urban climate change adaptation strategy (Greater London Authority, 2008; DEFRA, 2007; London Tree Officers Association, 2007; Pitman *et al.* 2015). They play an essential role in urban settlements in hotter climates such as we are likely to be facing in the future, providing shading and cooling mechanisms. Trees are uniquely

placed to be widely integrated into the urban fabric, which will help make the cities of the future, and London in particular, more hospitable places.

Climate change also represents a threat to urban tree species. Changes in temperature and rainfall, together with the special environment conditions of cities, like the abundance of impervious surfaces, atmospheric pollution and the urban heat island effect will have consequences on plagues and disease control and on adequate tree species choices for planting.

5.2. Benefits of urban trees in a future with climate change

In an urbanized society urban green areas are important for people, as a place for leisure and to facilitate contact with nature, thereby, increasing understanding for natural processes and ecosystem dynamics (Dustin *et al.*, 2009). There is growing recognition worldwide of the significance of the intangible values of the urban forest. In part this recognition is based on an intuitive sense that nature has remarkable beneficial effects on people (Kaplan, 2002). The values and benefits of urban forests and trees are multiple (e.g. Miller 1997; Rydberg, 1998) including recreation, education, economy, climate, urban biodiversity, run-off control and air quality.

The contribution of urban trees to the beauty of city environment has been well documented (Schroeder, 1998). Most people experience urban green areas visually and hence, visual aspects are an essential element to consider in formulating management strategies for this resource (Miller, 1995). Several studies have been carried out about aesthetic preferences in urban environments (Ode and Fri, 2002; Tyrväinen *et al.*, 2003; Dyess, 2006; Wolf, 2006).

Urban forests' aesthetic benefits include providing communities with a unique sense of place. Community attachment can be taken as an indicator of its social health. In the aftermath of hurricane Hugo, 30% of local residents surveyed identified the urban forest as the most significant element that had been lost, followed by churches with 27 percent of people recognizing them as significant losses (Hull, 1992).

Many benefits of forests and trees in an urban environment have been variously reported (Table 3) (Brack, 2002). Most of them entail improvements in urban environment quality such as air pollution mitigation, run-off reduction or carbon sequestration, but benefits of urban trees reach other fields and have many important meanings to urban residents (Dwyer *et al.* 1991). In urban settings, trees have been shown to improve health and well-being. They mitigate temperature extremes (Gill *et al.*, 2007), reduce pollution (Broadmeadow and Freer-Smith, 1996; Stewart *et al.*, 2003; Forest Research, 2007) and increase real estate values (Morales, 1980; Anderson and Cordel, 1988; CABE Space, 2005).

Urban green space and the related green elements of the urban environment have conventionally been associated with urban recreation (Anderson *et al.*, 1984; Tjallingii, 1995) and the visual quality of towns (Commission of the European Communities, 1990; Hough, 1990), the social aspects of environmental quality. However, recent research results have provided evidence for the current view that urban trees and other urban vegetation also

directly benefit the physical aspects of the urban environment. Also most wildlife species within urban areas are directly related to the amount of vegetation in the urban environment (Agger, 1989; Gilbert, 1991).

Table 3. Benefits of urban forests and trees.

Benefits of Urban Forests and Trees	
Environmental benefits	<ul style="list-style-type: none"> Amelioration of urban climate extremes Mitigation of urban heat islands Store and sequester carbon Reduce noise pollution Improve air quality Lower temperatures on parked cars Reduce volatilization of bitumen Reduce electricity consumption for heating and cooling Increase urban biodiversity Attract birds and other wildlife
Economic benefits	<ul style="list-style-type: none"> Improve property values Reduce need to invest in new power utilities Increase tourism
Aesthetic benefits	<ul style="list-style-type: none"> Scenic beauty Visual amenity Architectural enhancement of buildings Visual barrier against unpleasant scenes
Comfort and quality life	<ul style="list-style-type: none"> Control urban glare and reflection Improve general liveability and quality of urban life Opportunities of outdoor recreation Contribute to human health and relaxation, reduce stress and anxiety

Source: Adapted from Brack 2002.

Research has shown that increasing green space and high tree cover in an urban setting can partially mitigate the urban heat island effect (Forest Research 2007). Trees benefit urban climate in relation to heat, air movement and humidity, and leaves absorb airborne particles and CO₂ (Oke, 1978; Landsberg, 1981; Rowntree and Nowak, 1991; McPherson and Rowntree, 1993). Trees are essential in the greening strategy (Greater London Authority, 2008). Trees provide larger volumes of leaf area and evapo-transpirational cooling effect than other green landscape features, whereas, thanks to their shape, they occupy relatively little ground level area. Surface space can be used for other functions, as long as the trees' root systems and crowns are given sufficient support and space to grow. Furthermore these other functions often benefit, directly or indirectly from the cover trees provide (Trees and Design Action Group, 2008).

Urban trees directly reduce the amount of air borne pollution by capturing particulate pollutants on their leaf surface and either trapping them there or directing them into the ground during rain. Gaseous pollutants (e.g. ozone and nitrogen dioxide) may be directly absorbed into the leaf. They sequester CO₂ in their biomass and reduce heat-island effect during the summer with the consequent ozone levels decrease. But, on the other hand, urban trees can reduce air quality too, since they impede the dispersion of pollutants inside the trees' canopy, and emit volatile organic compounds (VOCs) that contribute to the formation of ozone and carbon monoxide.

Energy savings attributable to urban forests are largely due to a reduction in the use of air conditioners or heaters in homes and offices when temperatures fall outside human comfort zones (Akbari *et al.*, 1989; Huang *et al.*, 1987; McPherson, 1994). The range of values reported in the literature reflects the different sources of energy (e.g. coal, hydrological, or gas), tree habitats, and climatic conditions. Evergreen and deciduous trees would both contribute to reducing cooling costs during the hotter months through shading and evapotranspiration. Evergreen trees may reduce the need for heating by reducing the cooling effects of the winds although this effect may be balanced by their shading of the winter sun. A reduction in energy consumption, as well as providing a cost saving, may also result in the avoidance of producing pollutants. A sufficient reduction in demand may also delay or avoid the need for the development of new power stations (Dwyer *et al.*, 1992).

Trees intercept rainfall and slow down water run-off, which allows particulate matter to precipitate out and therefore not contaminate watercourses (Xiao *et al.*, 1998). Slowing run-off also means that less effort and expense is required to build sophisticated flood control and mitigation engineering works.

More is now known about how vegetation in cities influences human welfare. Several studies show that a green urban environment influences the well-being of the urban population. For example, the length of hospital stays decreases if patients can see a well-vegetated green environment from the hospital windows (Ulrich, 1984; Ulrich and Simons, 1991), and children's health and emotional status benefit from day-care centres with diverse vegetation (Atwell, 2000).

There are two ways in which urban trees can reduce the amount of CO₂ released to the atmosphere. In Table 4 the different factors that affect that capability are listed.

Table 4. Factors that determine the amount of CO₂ reduction through urban trees.

Factors that determine CO ₂ reduction through urban trees	
Direct sequestration	Species election Life span Tree size at maturity Growth rate (only if tree does not live enough to reach mature size) Maintenance Decomposition: Decomposition Sealed landfill Long-term products Energy (reducing fossil-fuel combustion)
Carbon emission avoidance (Energy conservation)	Location: N/S/W/E Distance from buildings Evergreen/Deciduous

Source: Based on McPherson *et al.* 1997 and McPherson 1999

Street trees and other urban trees play a significant role in lowering urban temperatures and mitigating the intensity of urban heat island effects (Chow and Roth, 2006), thereby providing significant savings in electricity (McPherson *et al.*, 1997; Maco and McPherson, 2003). These trees help in reducing storm water runoff, thus reducing the likelihood of flooding and damage to urban properties (McPherson *et al.*, 1997). They act as noise filters, purify air and

sequester carbon. Further, due to their proximity to traffic and consequently to higher loads of atmospheric pollutants, street trees are likely to capture higher amounts of particulate matter, carbon dioxide, ozone and other air pollutants than trees located in parks and green spaces distant from traffic, thus contributing more significantly in reducing atmospheric pollution in the city (McPherson *et al.*, 1997; Beckett *et al.*, 2000). This scientific evidence is also being implemented in policy as climate adaptation strategies are increasingly highlighting urban tree cover as being an important contributor to the objective of reducing the urban heat island effect (Greater London Authority, 2008; London Tree Officers Association, 2007).

Yet, despite extensive evidence of the critical role played by street trees in city environments, urban planners and managers have often undervalued the role played by street trees. Street-side trees are often the first to be sacrificed when infrastructural developments such as road widening take place, especially in fast growing cities. City managers are concerned about the possible hazards posed by street trees to traffic management and pedestrian safety, and are often unwilling to spend money on the maintenance and renewal of trees on city streets (Pauleit, 2003; Dumbaugh, 2005). Roadside trees are also especially subject to stresses due to their proximity to atmospheric pollutants, poor drainage, inhospitable soil, and lack of space for growth (Li *et al.*, 2011).

Increasing green space and, in particular, the canopy cover of trees is likely to remain one of the more cost effective means of adaptation to climate change. But, unless future developments are designed and constructed to accommodate the presence of large trees, which deliver the greatest environmental benefits, we will be foreclosing this opportunity for the future (Trees and Design Action Group, 2008).

5.3. Trees and subsidence damage to buildings

In the UK, Trees in Towns II (Britt and Johnston, 2008), the report on urban trees and tree management commissioned by Communities and Local Government, reported the loss of mature and big trees across England. This report covered the whole range of urban greenspaces, from streets and estates to parks and private gardens. The report particularly highlighted the threat to trees from all types of built development.

In 2007, The London Assembly Environment Committee published “Chainsaw massacre: a review of London’s street trees”, addressing many of the issues with London’s disappearing trees,

“London has been losing its mature broad leaf tree stock, due largely to trends and practices to plant smaller trees which are easier and cheaper to maintain, limited budgets, subsidence claims from the insurance industry and a failure of the general public to support the extensive benefits of street trees. [...] The insurance industry must provide better quality investigations, ensuring that accurate and reliable tests are used in order to provide evidence showing that a tree is causing subsidence damage to a property. If they cannot provide the required evidence then they should not be requesting that the local authority remove the tree in question. [...] Our report

calls for a broadleaf tree planting strategy across London to help replace those native species we are losing, such as plane, lime and oak.”

In London, and many other parts of the UK, trees on shrinkable clay subsoils may cause foundation movement to structures during periods of drought, also known as subsidence. Despite not being prevalent (London Tree Officers Association, 2007), it represents one of the biggest threats to urban trees, because the perceived fear of damage to buildings from trees is creating a number of issues (London Assembly Environment Committee, 2007).

The report was followed by responses from the insurance sector (Briggs, 2007) and opened a dialogue that resulted in a substantial body of research and information relating to the effects of tree roots on built structures, particularly relating to subsidence damage (eg. Phillip and Craul, 1992; Institution of Structural Engineers, 2000; Roberts *et al.*, 2006; BRE 7/06; Driscoll and Skinner, 2007) and the negotiation and publication of the Joint Mitigation Protocol by the London Tree Officers Association (2008) to regulate procedures in subsidence claims. The risk is very low where the subsoil is not shrinkable clay. Where there is a real risk, the onus should be on buildings and their foundations being designed to withstand potential soil movement in the future, whether or not this is caused by trees. The perception of trees as a risk to stability and the insurance industry’s exposure to future claims would be significantly reduced with a longer-term approach to the quality of building in areas with shrinkable clay (Trees and Design Action Group, 2008). Where there are already trees and buildings on shrinkable clay, house owners and representatives of the arboriculture, surveying and insurance sectors should be better informed of the actual risks, including early identification of potential problems and of potential remedies not requiring the removal of trees (London Tree Officers Association, 2007).

The Trees and Design Action Group in their report “No trees, No future” (2008) suggested the responsible use of water as key to resolving the subsidence problem. Climate change is causing a less stable water supply with lower and more erratic rainfall patterns along with a warming climate and is not helped by the growing population in the UK. All this factors make it likely that subsidence problems will only increase in areas with clay soils if left unaddressed.

5.4. Communication in urban forestry

The literature considers communication between all stakeholders involved in urban forestry as crucial and as an area that requires deeper understanding and research (e.g. Herzele, Salbitano, and Iskrev, 2004; Janse and Konijnendijk, 2007; Konijnendijk, 2000; Ronge, 1998). Konijnendijk (2000) identified the fact that urban forestry operates in highly populated areas under constant scrutiny from a variety of stakeholders who want to have a say in urban forestry management, planning and policy-making, as the main characteristic that separates urban forestry from traditional forestry.

The urbanisation process has dramatically changed the relationship between human society and the natural environment. Cities are becoming larger and urban dwellers are becoming more and more disconnected from natural processes. Normal occurrences such as leaves falling in the autumn, or birds living in the trees become a nuisance for people who flood tree

officers with complaints. Urban inhabitants specifically object to the cutting of trees, for urban development as well as for regular forest management purposes (e.g., Krott, 1998; Konijnendijk, 2003). There are often strong negative feelings towards the cutting of trees, which appear to be linked to the strong psychological relationships people form with the trees in their environment (e.g., Kaplan and Kaplan, 1989).

Lack of knowledge by others has been identified by urban forestry managers as a key limiting factor, both of the requirements of trees, and the benefits they deliver. This includes politicians, colleagues from other departments such as engineers, planners and asset managers, and the wider community (Ely, 2009). It is necessary to educate people on proper species selection, site design, plant quality, and the benefits as well as costs of urban trees (Escobedo *et al.*, 2011; Driscoll *et al.*, 2015).

Communication methods are useful for raising awareness and increasing public education in urban forestry (e.g., Johnston, 1985). The public's understanding of forestry practices and foresters' understanding of what the urban public expects and demands from forests and forestry, can both be increased through communication methods, minimising misunderstandings.

Johnston (1985, 1989) described three main communication elements of community forestry programmes with the public:

- Education and information: Notifications of proposed work, technical information, exhibitions and displays, and talks and guided walks can be used to generate interest in trees and motivate the public to become involved. This is not limited to the media but can also be done using innovative methods (e.g., Otto, 1998). Communication methods should be adapted to the specific social group addressed. An example of this are the numerous forest schools in European urban forests, which are used to bring school children into contact with nature and forestry (Konijnendijk, 1999).
- Consultation: Public meetings, community group discussions and tree committees can all be useful channels to demonstrate to residents their responsibility for their trees and can influence management. An example of this is seen in Denmark, where local users wishes are taken into account for planning and management through so-called local forest user boards (e.g., Konijnendijk, 1999).
- Practical participation: Involving the public in tree planting schemes, sponsor-a-tree schemes, work as tree wardens and other management schemes can raise the public's awareness and appreciation. Such participation in community forestry is a way to strengthen communities (e.g. Burch and Grove, 1993). Curry (2000) discussed how community participation in green area management increased as a result of the shift in the UK government style from executive to enabling in the 1980s and 1990s.

6. URBAN FORESTRY MANAGERS AND PLANNERS PERSPECTIVES

The main body of research surveying urban forestry practitioners' perspectives is focused on: 1) technical aspects of arboriculture and tree care, such as pest and disease treatments, health and care and policy (e.g. Wu, Jamieson, Kielbaso, 1991; Pauleit, 2003; Roman *et al.*,

2013); or 2) comparing the attitudes of arborists and other professionals. For example, the degree of agreement among arborists, professional gardeners and landscape architects regarding the suitability of eight species of street trees has been evaluated by a mail survey finding a high level of consensus among the different professions (Sommer, Cecchetti, and Guenther, 1992).

Regional and national studies surveying local authorities have been done to evaluate tree programs, tree inventories and urban tree departments. *Trees in Towns and Trees in Towns II* (Britt and Johnston, 2008) are the most relevant studies of this kind performed in the UK. The objective was to provide up-to-date information on the national urban tree stock and urban tree management by local authorities. The second study included a national tree survey and survey of local authorities. Stevenson *et al.* (2008) analysed survey responses from 528 officials in 356 municipalities in Pennsylvania (USA) and defined the developmental status of municipal street tree programs and the attitudes of different types of officials. Other similar studies have been performed in Germany (Gerhardt, 2010) and New Zealand (Stobbert and Johnston, 2012).

Though the use of qualitative research methods can enrich our knowledge of the urban forest (McLean *et al.*, 2007), not many studies have employed qualitative methods to explore urban forestry managers' and planners' perspectives. Keller and Konijnendijk (2012) performed a comparative analysis of municipal urban tree inventories across selected North American and European major cities. This study included semi-structured expert interviews in each city, as well as an analysis of the level of detail, approach and use of their tree inventories.

Planning for trees in cities should be based on a sound understanding of the attitudes, perceptions and practices of those involved in the planning and design of urban environments. In 2009 a study was undertaken of the attitudes of residents and practices of urban tree managers in the Adelaide metropolitan region, in Australia, finding out that while environmental benefits were acknowledged by both groups, residents focused primarily on aesthetics benefits. Additionally, urban trees were also considered as having negative effects by residents, specially among the ageing population (Ely, 2009).

Recent studies focusing on urban foresters' perspectives found inadequate funding and lack of public support to be important barriers to implement tree programs and policy. Gwedla and Shackleton (2015) studied the influence of town size, relative wealth and current extent of trees in public places on the visions of public officials, by conducting semi-structured interviews with officials responsible for urban planting in 24 South African towns, in which the abundance of street trees had been assessed via GIS. The authors found significantly positive relationships between town size, relative wealth measures and street tree density. Most of the managers considered environmental issues or trees in their vision of the future for their town. The study found no relationship between the managers' visions for the future and attitudes and current street tree density. The study also highlighted multiple constraints that the officers faced in implementing their vision, such as lack of funds for urban forestry, limited space for tree planting in low-cost housing developments, vandalism, and lack of skilled personnel. Driscoll, Ries, Tilt and Ganio (2015) carried out a needs assessment survey of community officials and managers in 30 cities and 4 counties in the Portland – Vancouver area. The survey was designed to identify attitudes and practices in urban forestry, and

determine program needs, barriers, and priorities. Inadequate funding and lack of political and public support were the main obstacles mentioned by community officials and program managers to implement and expand tree programs. Officials identified as the highest priority an increase in community education and new or revised urban forest management plans and tree related ordinances.

The literature on studies examining practitioners' perspectives on the use of visualizations is very limited and mostly focused on urban and greenspace planning. Donaldson-Selby (2007) used a survey to check residents and experts' opinions on the use of visualizations in urban planning. While residents and experts both valued the potential of accurate and credible visualizations in participatory decisions systems, experts only expressed moderate for visualizations in professional decision-making. Groulx (2010) attempted to determine how the human element in visualizations could influence the public's evaluation of future landscapes using qualitative instruments. The study concluded that the use of computer visualizations in urban planning are effective at facilitating decision-making and communication in the realm of community engagement but that the current context of visualization use in planning practice is a threat to legitimate public engagement and the health of stakeholder relationships. He suggested that the approach for an effective use of visualizations should include both changing professionals' attitude towards the technology to stop them from producing biased and misleading visualizations, and, at the same time, improving the public's understanding of the visualization process, to protect them from eventual malpractice.

Still the current and potential roles of visualizations in the context of urban forestry management and planning remains largely unexplored, and little research has been done to understand urban forestry practitioners' perspectives on the use of visualizations in urban forestry.

7. SUMMARY

This Chapter has reviewed the state of the art in the use of visualizations in urban forestry management and planning and in studies exploring urban forestry practitioners' perspectives.

The following Chapter introduces the research methodology used on this study and how it has guided research design, data collection and analysis.

CHAPTER 2

METHODOLOGY

1. INTRODUCTION

The previous Chapter contained a literature review on the use and potential of visualizations in urban forestry and related management and planning disciplines, drawing on both research and practice, and reviewing studies exploring urban forestry practitioners' perspectives as context for the use of visualization.

This Chapter introduces the research methodology used for this study and how it has guided research design, data collection and analysis. It continues describing the differences between quantitative and qualitative research methods and explains the reason why a mixed methods approach was adopted. The research design is outlined, followed by the sections describing the study procedures: study population and sampling, questionnaire design and analysis, visualizations' purpose and creation process, and the qualitative interviews plan and analysis. Next, I outline how the empirical data was collected, including the details of the research methods used, sampling techniques for recruiting participants, and how the research was conducted.

The Chapter finishes with ethical considerations and addresses the issues of reliability, validity and generalizability.

2. RESEARCH DESIGN

This Section outlines the process of the research design development and its theoretical basis. It starts explaining the differences, weakness and strengths of qualitative and quantitative research methods. The rationale for the approach and methods selected is provided to end the Chapter explaining in detail the different parts and the different steps of the research design. It is organized into the following subsections:

- Qualitative vs quantitative methods
- Choosing the approach and methods
- Research design
- Frame categories

2.1. Qualitative vs quantitative methods

The distinction between qualitative and quantitative research is a methodological issue. The decision to choose a specific methodology should be based on its suitability to answer the research questions (Bryman, 1988). The differences between qualitative and quantitative research have been explained by a number of different authors (e.g. Maxwell, 1998; Thomas, 2003; Corbetta, 2003). Berg (2001) discriminated between qualitative and quantitative research arguing that qualitative research referred to the meanings, concepts, definitions, characteristics, metaphors, symbols and descriptions of things, while quantitative research referred to the measures and counts of things. Qualitative and quantitative research approaches differ basically in some major areas, including: their analytical objectives; types of questions posed; types of data collection methods used; types of data produced; degree of flexibility in study design (see Table 5) (Mack *et al.*, 2005).

One of the key issues differentiating between qualitative and quantitative research approaches is the nature of data. In quantitative, it is hard, objective and standardized but in qualitative, it is soft, rich and deep (depth vs. superficiality) (Corbetta, 2003). Maxwell (1998) and Bickman *et al.* (1998) added the interactivity to these features of qualitative research. Corbetta (2003) demonstrated that qualitative research is open and interactive and observation precedes theory whereas quantitative research is structured and theory precedes observation.

Table 5. Comparison of quantitative and qualitative research approaches

	Quantitative	Qualitative
General framework	<ul style="list-style-type: none"> - Seek to confirm hypotheses about phenomena - Instruments use more rigid style of eliciting and categorising responses to questions - Use highly structured methods such as questionnaires, surveys and structured observation 	<ul style="list-style-type: none"> - Seek to explore phenomena - Instruments use more flexible, iterative style of eliciting and categorizing responses to questions - Use semi-structured methods such as in-depth interviews, focus
Analytical objective	<ul style="list-style-type: none"> - To quantify variation - To predict casual relationships - To describe characteristics of a population 	<ul style="list-style-type: none"> - To describe variation - To describe and explain relationships - To describe individual experiences - To describe group norms
Question format	Closed – ended	Open – ended
Data format	Numerical (obtained by assigning numerical values to response)	Textual (obtained from audiotapes, videotapes and field notes)
Flexibility in study design	<ul style="list-style-type: none"> - Study design is stable from beginning to end - Participant responses do not influence or determine how and which questions researchers ask next - Study design is subject to statistical assumptions and conditions 	<ul style="list-style-type: none"> - Some aspects of the study are flexible (for example, the addition, exclusion or wording of particular interviews questions) - Participant responses affect how and which questions researchers ask next - Study design is iterative, that is, data collection and research questions are adjusted according to what is learned

Source: Mack *et al.*, 2005

Snape and Spencer (2003) indicated that qualitative research is a naturalistic/interpretative approach concerned with understanding the meaning people give to the phenomena within their social setting. They outlined a number of key elements which distinguish the qualitative approach, among these: it is the approach which provides a deeper understanding of the social world; it is based on a small scale sample; it uses interactive data collection methods, (i.e. interviews); it allows new issues and concepts to be explored.

2.2. Choosing the approach and method

As outlined in the introduction, this thesis has two main research questions:

- **Research question 1: What are the actual and potential roles of visualizations in the context of urban forestry management and planning?**
- **Research question 2: What are the potential benefits and barriers for the implementation of visualizations in urban forestry management and planning?**

For the purposes of answering the research questions a mixed methods approach was adopted, combining both quantitative and qualitative methods. As stated in the literature (Denzin, 1989; Strauss and Corbin, 1990), this combination allows researchers not only to develop or extend theories and test their applications, but also to achieve triangulation between methods through enhancing the quantitative output with rich interview data. Although some authors find the notion of mixing paradigms problematic (Bazeley, 2004), it is accepted and recommended for exploratory studies (Greene *et al.*, 1989).

The sequential combination on both methods can help to better understand the collected data. Accordingly, a basic quantitative outcome can be reinforced through in-depth investigation (Beedles, 2002). Additionally, combining these two approaches overcomes some inherent limitations in each of the methodologies used alone.

2.3. Research design

As described in previous Section, it was decided to opt for a mixed approach to answer the two research questions. The research can be divided in two main parts: the quantitative study and the qualitative study. The quantitative study is developed into a questionnaire, and the qualitative study takes the form of a set of semi-structured interviews. Figure 5 provides a graphical representation of the thesis' research design.

A quantitative method of data collection was chosen for the first part of the research because it allowed to gather data that were representative of the study population. These data were then used in the visualizations development and identified topics to be explored further in the second part of the research. The questionnaire was designed to identify the tasks and challenges that urban forestry professionals face in their jobs and how efficiently they think those are being tackled.

Figure 5. Graphical representation of the research design

Source: Own elaboration

A qualitative method of data collection, and specifically semi-structured interviews, were chosen for the second part of the research because 'how' and 'why' questions are better asked through a flexible and open method for the collection of qualitative data. Semi-structured interviews allow for the capture of nuance, as well as contextual knowledge, and other information that might not otherwise be revealed in a survey. From the existing qualitative methods, a semi-structured protocol was chosen as a compromise between the need to cover certain predetermined topics and the ability to do so in a more flexible format that allowed to explore new themes that might arise during the interviews. Face-to-face interviews were chosen to facilitate rapport and to observe the interviewee.

The information collected on the questionnaire was contrasted and complemented with a number of qualitative interviews which aimed to let the urban forestry managers and

planners clarify their answers and further explain their opinions in their own words. The interviews have, at the same time, two clearly differentiated parts: Part I, in which same indicators of the questionnaire are explored further and in more detail, and Part II, which is the “visualizations evaluation experiment” where photo elicitation techniques are used.

The second part of the interview tested the opinions of urban tree managers and planners on the use of visualizations in their job. The objective of this part of the interview was to confront the professionals with urban tree visualizations and gather their reactions and views on them by employing photo elicitation techniques. By the use of series of visualizations specifically produced for this project as visual stimuli, a series of photo-elicitation interviews took place. The research design was also suitable for examining tree officers’ opinions in detail in order to reach a better understanding of the factors involved and that data obtained from the analysis of the interviews was used to answer both Research Question 1 and Research Question 2.

The messages of the visualizations were based on information from the literature review and complemented with the information collected from the questionnaires. The visualizations were planned and produced to represent an overview of techniques and applications targeted to urban forestry managers and planners.

Both the questionnaire, from the quantitative side of the thesis, and the interviews from the qualitative branch of the thesis, were design to answer Research Question 1. Research Question 2 was answered analysing the information from the second part of the interviews. Nevertheless, and due to the mixed methods approach, both parts of the research complement each other and help shed light on both research questions.

2.4. Frame categories

An initial list of categories has been developed to provide a broad framework of areas for analysis based on the challenges in urban forestry management and planning and the main applications if visualizations in urban forestry that were identified during the literature review. The categories have guided the design of the data collection methods and have also served as the starting point for data analysis of the interviews.

The frame categories for analysis proposed for this research and the method of measurement are summarized in Table 6, and are as follows:

- Activity analysis: time distribution
- Resource analysis and challenging issues
- Climate change
- Communication with non-experts
- Technology and existing use of visualizations
- Preconceptions about visualizations
- Reactions to the visualizations from the presentation
- Overall evaluation of VIZs as a tool: benefits and barriers

Table 6. Indicators for the research questions and the method of measurement.

Frame categories for analysis	Method of measurement	
	Questionnaire	Interviews
Activity analysis: time distribution	Question 1 from the questionnaire	Open ended questions at the beginning of the interview
Resource analysis and challenging issues	Question 2 from the questionnaire	Participants are prompted to develop further the information collected in the questionnaire
Climate change integration	Question 6 from the questionnaire The importance of urban trees in climate change mitigation	Participants are asked whether climate change was part of their management and planning decisions
Communication with non-experts	Questions 3, 4, 5 and 6 from the questionnaire People attitudes toward trees Effectiveness of communication with non-experts	Participants are asked about the ways they usually interact with public, developers and decisions makers, how fluent and effective was that communication, and to explain the more frequent issues that arise
Technology and existing use of VIZs	Question 7 from the questionnaire Familiarity with technology Participants were asked whether they used before any visualization software	Participants are prompted to develop further the information collected in the questionnaire
Preconceptions about VIZs	Not measured	After the first set of images, participants are asked whether they ever interact with similar materials or tools and their opinions on them
Applications of VIZs in urban forestry	Not measured	Evaluation of the presented VIZs from the presentation and evaluation of the proposed applications. Participants are asked to think of new applications of VIZs.
Overall evaluation of VIZs as a tool: benefits and limitations	Not measured	Participants are asked to give an overall opinion on the potential benefits and limitations of the integration of the use of VIZs in their line of work.

Source: Own elaboration

1) Activity analysis: time distribution

This category includes the information regarding the time tree officers dedicate to the different tasks they perform. Understanding the activities and tasks they perform helps to identify potential applications of visualizations.

2) Resource analysis and challenging issues

This category includes information about how the urban tree managers and planners think the resources such as time, personnel and money should be distributed among different issues. The identification of ongoing challenges allows the researcher to establish potential areas where visualizations can be of help.

3) Climate change

Due to its relevance as a threat and as a factor that is going to influence several areas inside urban forestry, climate change was considered as a category on its own. It was important to understand how integrated climate change is in management and planning strategies and

processes, in order to identify it as an ongoing challenge or not, and therefore as a potential area for the use of visualizations or not.

4) Communication with non-experts

I include here as non-experts the general public, decision makers or politicians, and colleagues from other departments. This category encompasses information on the following topics:

- Attitudes of public toward urban trees (which would potentially influence how the information is received)
- How often do they need to interact with non-experts
- How effective they think that communication currently is

The use of this category allows the researcher to identify opportunities for the use of visualizations as a communication tool and the capacity-building potential of visualizations in urban forestry.

5) Technology and existing use of visualizations

More precisely, familiarity with technology by inquiring about what types of software and computer tools they use in their jobs. Previous familiarity with technology could influence participants' willingness to see visualizations as a promising tool. Tree Officers were asked whether they have ever produced visualizations, asked someone else to produce them, been presented with visualizations as part of the documentation of a project, or interacted with them in some other way. If they had, they were asked to describe those visualizations and their purpose.

6) Preconceptions about visualizations

To investigate urban forestry managers' and planners' previous experiences and opinions on visualizations, they were asked whether they have ever seen or interacted with similar materials and their opinions and views about them.

7) Application of visualizations in urban forestry

After the participants had been exposed to the visualization package, reactions to the presentation can be categorized in the following categories:

- Evaluation of the presented visualizations
- Opinions on the proposed applications
- Other applications they can suggest for the use of visualizations in urban forestry

8) Overall evaluation of VIZs as a tool: benefits and barriers

This category includes all information related to the overall evaluation of visualizations as a tool in urban forestry management and planning, not about specific applications as discussed before. Evaluations include the benefits of the use of visualizations and the barriers that would impede effective integration.

3. VISUALIZATION RESEARCH DESIGN

This Section describes the overview of the visualization research design. The detailed process of creating the visualizations that were used during the second part of the qualitative

interviews would be directly in relation to the chosen study area for visualization and , therefore, would be described in detailed on Chapter 3.

As already stated on the Introduction and Literature Review Chapter, the term visualization is used in this research in reference to computer generated landscape visualizations that could use 3D simulation techniques or 2D image editing techniques.

In a study of this nature, the selection of the images to be presented to the interview participants and the rational of the process is an essential part of the methodology. The defensibility of the stimulus materials needs to be established by providing detailed descriptions of the decision making process for image selection, image production methods, and image presentation to participants.

Therefore, this Section is organized under the following headings:

- Photo-elicitation as a qualitative research technique.
- Purpose of the visualizations.
- Visualization production methodology.

3.1. Photo-elicitation as a qualitative research technique

Photo elicitation is basically the idea of inserting a photograph into a research interview. The difference between interviews using images and text, and interviews using words alone lies in the different ways we respond to these two forms of symbolic representation (Harper, 2002). Visual methods are accepted tools for qualitative research (Ball and Smith, 1992) and are increasingly used in a wide range of disciplines, such as sociology, psychology, geography, health care, and outdoor experiences (Loeffler, 2004; Pain, 2012).

Photo-elicitation has been mainly used in ethnographic and social studies research (Banks, 2001; Harper, 1997) and has involved “using photographs to invoke comments, memory, and discussion in the course of a semi-structured interview” (Banks, p. 87). Traditionally, visual materials employed as stimuli have been photographs, but they do not need to be restricted to only those and also drawings, participatory photo-maps (Dennis, Gaulocher, Carpiano, and Brown, 2009) and computer generated landscape visualizations (Lewis and Sheppard, 2005; 2006) have been successfully used.

In this research, photo-elicitation was employed in the interviews with the London’s tree officers for several reasons. First, visual materials can be useful in semi-structured interviews since they can help participants elucidate perceptions or concepts that may otherwise be difficult to articulate (Lewis, 2008). Second, visualizations help to engage participants in conversation and to respond to them without vacillation because of the familiarity of talking about images (Meo, 2010). And last, they can also increase the participant’s comfort with the interview process by transferring focus away from the participant and towards a common reference point for both researcher and participant (Lewis, 2008).

For this thesis, landscape visualizations were chosen as visual stimuli. Participants in the interviews were presented with: 1) a series of images integrated in a presentation and 2) a collection of printed images, selected from those already in the presentation, to elicit

participant evaluations of the different types of visualizations and the different uses of visualizations in urban forestry.

3.2. Purpose of the visualizations

The visualization package produced for this research had two main purposes: First it was planned to present a comprehensive and interesting array of the different applications or uses of visualizations from an urban forestry perspective. Second it was used as visual stimuli during the semi-structured personal interviews, to elicit responses from participants about the presented visualizations from the package, about the proposed applications of the visualizations, about new applications they might suggest, and about the benefits, concerns and barriers they thought the use of visualizations might encounter.

3.3. Visualizations production methodology

The methodology to produce the visualizations to be used as stimuli during the interviews has been adapted from that proposed by Sheppard (2012) for visualizing climate change in local communities. It involves the following steps, also summarized in Figure 6.

Figure 6. Graphical representation of the visualization production methodology

Source: Own elaboration

1) Selecting study area for visualizations

The study area for the visualizations should be recognizable by all the interviewees. It should also be representative of the conditions the urban forestry managers would work in. The study area description and rationale for selection are described in the following Chapter (Chapter 4 - Application of the methodology and results).

2) Collecting data

The data necessary to produce the visualizations will depend on the type of visualizations and techniques chosen for the study, but should include:

- Geo-referenced CAD maps.
- Aerial photos of the study area.
- Location and inventory data about the trees to be the object of the visualizations.
- Information about tree species: growth rate or, at least dimensions at maturity for simulations of future conditions.
-

3) Planning the visualization effort

To plan the visualizations there are a number of considerations that need to be taken into account:

- Purpose and audience of the visualizations.
- Scope of the visualizations: content, themes and messages to be communicated.
- Types of visualizations media.
- View points selection.

Themes and messages of the visualizations are derived from the literature and from the questionnaire results. Content, types of visualizations and view points selections are determined by case study data and are further described in detail in Chapter 3.

4) Creating the visualizations

Once the set of needed images has been identified, in this case to present an overall display of the different techniques and possibilities for use by urban forestry managers, the next step is to determine the chosen software packages and the visualization modelling process, and produce the visualizations. Problem identification and brainstorming were most effectively addressed using freehand sketching and GIS, whereas investigation of potential solutions for design issues was addressed more effectively through photo-manipulated computer imaging (Al-Kodmany, 1999). For that reason, the visualization techniques used for this research are:

- 2D photo editing techniques.
- 3D landscape simulations.

5) Reviewing the visualizations

The visualizations need to be evaluated at least by a person different from the modeller. The visualizations for this thesis have been produced and modelled by the author and reviewed by the supervisors of the thesis, with revisions made where necessary. The final set of reviewed/revised visualizations were presented to urban forestry managers and planners.

6) Presenting the visualizations

The visualizations were created to be presented and introduced in person during the interviews, together with background information about:

- The structure of the presentation and the relation of one visualizations with the others.
- The data on which the visualizations were based, assumptions made and inevitable inaccuracies due to lack of data.
- The purpose and audience that the visualizations were meant for.

Providing a context and the data used to create the visualization reduces the perceived bias and increases the defensibility of the visualizations (Sheppard *et al.*, 2004).

4. QUESTIONNAIRE

The first phase of the research design was the quantitative study in the form of a questionnaire. The questionnaire was designed primarily to answer Research Question 1.

This Section describes in detail the quantitative part of the study, according to the following steps:

- Sample frame.
- Questionnaire structure and design.
- Pre-testing.
- Data collection.
- Analysis.

4.1. Sample frame

The study utilized a census sampling approach (McMillan and Schumacher, 2010) to survey all urban tree managers and planners working for the public administration in London which are called tree officers (approximately N=152) throughout London's 34 boroughs.

Tree Officers names, and their contact information, were located and affirmed using the London Tree Officers Association (LTOA) website as well as individual borough websites. All participants in the study were contacted individually via e-mail and participation in the study was voluntary.

4.2. Questionnaire structure and design

The Urban Forestry Practitioners' Perspectives Survey (Appendix A) was developed by the researcher and administered via e-mail and via a web survey to participants. The approximate time for completion of the survey was 5-10 minutes. The survey included a total of 13 questions divided into three main sections (see Table 3.6).

The questions included were designed to answer the research questions as seen in previous sections (find full questionnaire in the Appendices Chapter).

Questions were organized into three main sections followed by one last question, according to the following structure:

- Profiling questions/personal data: 4 questions.
Profile questions about the local authority they work for, their department and team and their background.
- Perceptions/opinions: 7 questions.
The main body of the questionnaire, with a total of seven quantitative questions in multiple choice and matrix formats.

- Feedback: 1 question.
Questionnaire evaluation questions, where subject is asked to add freely any comment about the research topic or about the questionnaire itself.
- Interest in participating in a follow-up personal interview: 1 question.
Participants for the second part of the research were recruited by this last question from the questionnaire.

When possible, questions with similar themes were grouped together, trying this way to facilitate the cognitive process of answering the questionnaire (Knowles 1988; Knowles and Byers, 1996). The questionnaire combined several types of questions, depending on the type of information to be gathered:

- Open ended questions, in which respondents are allowed to respond using their own words.
- Closed questions, requiring respondents to select responses from a set of choices. Two types of questions are included in the questionnaire into this category:
 - a) Multiple choice, where participants are given the choice to choose one (or all that apply) from a closed list of options.
 - b) Grading questions, where participants rated their responses from a range of graduated options using a Likert-type-scale (e.g. Rate from 1 to 5 the following statements being 1 “totally agree” to 5 “totally disagree”).

Grading questions were measured using a Likert-type-scale. Participants rated their level of satisfaction or agreement with each item using a semantic differential scale. The scale ranges on a continuum from 1-5, with 1 being “Very Dissatisfied” and 5 being “Very Satisfied”. The grading scale was disposed horizontally as suggested as appropriate for several questions in a battery format (Bryman, 2012). Based on the limited number of potential respondents for the proposed research, 4 to 5 point scales were chosen for the grading questions. The matrix format was chosen for the grading questions because they are faster to complete and increases the comparability of the responses given to different questions both for the respondent and for the researcher (Babbie and Benaquisto, 2002).

The option “I don’t know” was included for the grading questions. There is some debate in scientific literature on whether to include or omit them. Some researchers argue that respondents might opt for the “don’t know” answer 1) if they are not fully certain of the meaning of a question (e.g. Feick, 1989); 2) to avoid thinking and/or committing themselves (e.g. Oppenheim, 1992); or 3) when the survey exceeds their motivation or their ability (Krosnick, 1991). Because tree officers could be performing quite different tasks, depending on the team or section they were linked to, some of them might honestly not know the answer to some of the questions from the questionnaire. Also, most of the studies that advise against their use are focused on attitudinal questions, and not on factual questions. For these reasons, it was decided to include the “I don’t know” answer, accepting the risk of losing a small percentage of valid answers.

The option to provide comments to clarify their responses and the option to include any important matters that could have been forgotten was always there for the respondents, even on the closed and grade type questions, via de “Other” and “Add comments” options.

4.3. Pre-testing

A panel of experts reviewed the original version of the questionnaire before pre-testing. According to the reviewers' comments, the questionnaire was revised and modified. This version was pre-tested for its clarity and scale reliability on a small sample of tree officers from other cities in UK. Based on the pre-test feedback, the wording of the questionnaire items was slightly modified.

4.4. Data collection

The method chosen for collecting data during the questionnaire phase of the research was a web survey. Participants were sent by email a link that directed them to a web page where they were able to fill out the questionnaire and submit their responses.

The main strength of web surveys is the ability to collect data economically in a short period of time. However, it cannot be safely said that among all data collection methods one is the best, and the selected method is not without limitations. Advantages and disadvantages of on line surveys when compared with postal surveys are summarized in Table 7 (Bryman, 2012).

Table 7. Advantages and disadvantages of online surveys compared to postal questionnaire surveys.

Online surveys vs postal questionnaire surveys	
Advantages	Low cost
	Faster response
	Attractive formats
	Mixed administration
	Fewer unanswered questions
	Better response to open questions
Disadvantages	Low response rate
	Restricted to on-line populations
	Confidentiality and anonymity issues
	Multiple replies possible

Source: Adapted from Bryman 2012

The disadvantages described by Bryman (2012) had been resolved or minimized by adopting several strategies. Low response rate was tried to be minimized by making the questionnaire visually attractive, and easy and fast to complete; by providing a monetary incentive; and by sending several follow-up reminders. The fact that the study population was restricted to on-line population was not a problem in this case, as all tree managers and planners were expected to have access to internet. Confidentiality and anonymity were taken into account when designing and stating the research protocols (described in Section 5). Finally, multiple replies possible were avoided by asking participants to provide their email address in a separate field from the rest of the questionnaire.

The platform chosen for the on-line survey was Smart Survey (<https://www.smartsurvey.co.uk>). It was chosen because it was reliable, offered all the questions categories that were needed and offered a free plan with a limit of 100 responses

per month that was enough for the present study. The template created for the survey with the questionnaire design can be seen in Figure 7.

The web design template was created based on the following criteria:

- Clear design and fonts
- Non very vivid colours
- Easy to follow structure of the questionnaire divided in three sections: personal data, questions, feedback, thank you
- Progress bar, to motivate and allow respondents to track the percentage of questionnaire left

Though participants were encouraged to complete the questionnaire on-line, the invitation email contained a word document with the questionnaire that could be printed (see Figure 3.5). This gave participants the option of filling it out and returning it by email, or printing it out, filling it out by hand, scanning it, and emailing it. Mixed administration was chosen to increase response rate, and although evidence suggests that the mode of administration can make some difference to kind of responses generated, in many cases that difference is not great (Bryman, 2012).

The survey was expected to take participants approximately 10 minutes to complete. As a strategy to improve response rate, a monetary incentive was provided (Bryman, 2012) in the form of participating in free prize draw of a bottle of champagne.

The survey was administered in May 2014 via the secretary of the London Tree Officers Association (LTOA) who contacted via e-mail all Head Tree Officers from all the boroughs. This e-mail included a short message (Appendix B) indicating the purpose of the survey, a statement of significance, a request for their participation, a statement regarding how their responses will be kept confidential, instructions for completing the survey, and lastly, a statement thanking them for their participation (Dillman, Smyth, and Christian, 2009). A follow-up e-mail was sent to all non-respondents four weeks later. Head Tree Officers were asked to send the email about the survey to their co-workers to be able to expand the number of potential respondents. As the strategy wasn't getting the number of responses needed, I decided to contact all of the rest of tree officers directly via their work emails as listed in the LTOA webpage.

Each respondent was contacted individually via e-mail so the message was not mistaken as a mass mailing and, also, to ensure anonymity of respondents. The content of the subject line and e-mail was copied from a previously created cover letter (Appendix B) so every respondent received the same message.

There is evidence that online surveys generate lower response rates than postal questionnaire surveys (Tse, 1998; Sheehan, 2001). Bryman (2012: 677) suggests to "follow up non-respondents at least once as a strategy to boost response rates". Four more follow-ups were sent to non-respondents until the survey was closed finally on November 2014.

Urban forestry practitioners' perspectives - phase 2

Page 1 of 4

1. Personal data

Are you interested in learning more about the use of innovative tools to facilitate decision-making and public communication in urban forestry?

We are asking urban tree managers and planners working in London to take a 10 minute questionnaire, for which you will be entered into a free prize draw to win a bottle of Champagne.

Your answers will help us understand urban forestry practitioners' priorities, and how efficiently and satisfactorily you feel these are being tackled.

Those interested will also be able to take part in a 1 hour semi-structured interview to further discuss the use of computer generated media in urban forestry.

Please give your name (only used to avoid duplicates) *

Which London borough do you work for? *

What team do you work in? *

- ☐ Trees on council owned / other public land
- ☐ Trees on private land
- ☐ Other (please specify):

What is your academic background/training? *

- ☐ Forestry
- ☐ Arboriculture
- ☐ Urban planning
- ☐ Other (please specify):

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Figure 7. Questionnaire design in Smart Survey.

As participation in the study was completely voluntary, the possibility of a non-response bias has to be acknowledged. Estimates from any survey are subject to bias when some selected persons fail to participate in the survey and when non-respondents are found to be different from respondents. Non-response bias can be substantial when two conditions hold: the response rate is relatively low, and the difference between the characteristics of respondents and non-respondents is relatively large (Krenzke, 2005). The non-response bias was minimized by increasing the response rate as much as possible, sending several reminders during the data collection period.

4.5. Analysis

Responses from completed questionnaires received were manually input into a spreadsheet in Excel. Data was input into the spreadsheet in a format that enabled analysis of the responses against all the potential variables. Data input was subjected to four-eye spot checks to limit data entry mistakes.

Respondent names were included in the spreadsheet to permit traceability but not included in any of the output analyses produced, to maintain anonymity.

Responses to questions were coded into the spreadsheet depending on the type of question and according to the following criteria:

- For questions where the respondent had to select one or multiple categories to describe them or their work (e.g. whether they worked on public and/or private land), the different categories were input as column headings and the categories selected by the respondent were captured in the Spreadsheet by inputting a "1" or leaving blank.
- For questions where the respondent had to grade a specific statement based on their opinion or experience on a scale of 1 to 4 or 1 to 5, the statement was input as a column heading and the number specified by the respondent was captured in the relevant cell. Where a respondent left a question blank, the cell was left blank. Where a respondent selected the "I don't know" option, "DK" was input in the relevant cell

To allow cross analysis and population stratification, two extra variables were added: borough location and income. For each completed questionnaire, the data was enriched with the following information about the respondent's borough:

- Borough's location: Inner London vs Outer London
Based on the official definition at <http://www.londoncouncils.gov.uk/node/1938>. There are 13 inner London boroughs and 20 Outer London boroughs.
- Borough's income: Higher Income vs Lower Income
Based on the average taxable income of the borough's tax payers.

Higher vs Lower Income, was calculated using the latest data available (2012-13) for Average Income of Tax Payers by borough from HM Revenues and Customs Survey of Personal Incomes (<http://data.london.gov.uk/dataset/average-income-tax-payers-borough>). High income boroughs were defined as those with average income of tax payers above the London average of £39,900. Using this threshold results in 11 High Income boroughs and 22 Low

Income boroughs. Detailed information for each borough location and calculated income values are reported in Tables 8 and 9.

Descriptive statistics were generated on each of the individual questions and sub-questions and the normality of the data was tested. These descriptive statistics included the median scores and standard deviation for each question, as well as the frequency distributions for each response.

Two types of significance tests were performed to establish if there was a statistically significant difference:

- between the different statements' median values within a question (Wilcoxon Signed-Rank test for Paired Samples across selected pairs of statements), and
- between the different ranges of responses of the same statement and question across different groups of respondents (Wilcoxon Rank-Sum test across the responses of the two populations to each statement)

T-tests were not used to test for significance as the data failed the Shapiro-Wilk test of Normality and as a Likert-type scale, it was considered that a non-parametric test would be preferable.

A range of non-parametric tests were considered but found not to be applicable:

- Chi-squared: requires individual "buckets" with $n > 5$. The results violated this condition
- Canonical Component Analysis / Ordered Logit: both methods were considered better suited to carry out multinomial regressions. The objective was only to establish significance of the data and of individual variables. CCA / Ordered Logit were considered more complex than required for the objectives
- Wilcoxon Rank-Sum test and Wilcoxon Signed-Rank test (also known as Mann Whitney tests) were selected as they are commonly used for non-parametric data such as Likert-type responses to provide tests of significance

4.5.1. Overall results

Analysis of the total results to identify overall trends in the population and perceptions across London Tree Officers. Data calculated per question / sub-question:

- Descriptive Statistics (including Mean, Median, Mode, Standard Error, Standard Deviation, Minimum, Maximum)
- Distribution of responses
- Statistical Analysis of results

The statistical analysis of the results performed are the following:

- Objective: Determine ranking of selected statements within each question. This was not done for all statements and all questions but rather for a selection of statements where it was considered by the author that the difference or similarity could be informative.
- H_0 : Ranges of responses to different statements within a question are equal.
- H_A : Ranges of responses to different statements within a question are significantly different.

Table 8. Inner vs Outer and Higher vs Lower Income London's boroughs classification.

Borough	Inner / Outer (1)	Tax Payers Income - Mean (£) (2)	High / Low Income (3)
City of London	Inner	131,000	High
Barking and Dagenham	Outer	23,700	Low
Barnet	Outer	41,000	High
Bexley	Outer	28,600	Low
Brent	Outer	28,300	Low
Bromley	Outer	37,200	Low
Camden	Inner	71,200	High
Croydon	Outer	30,700	Low
Ealing	Outer	32,600	Low
Enfield	Outer	30,800	Low
Greenwich	Inner	31,500	Low
Hackney	Inner	32,700	Low
Hammersmith and Fulham	Inner	54,300	High
Haringey	Outer	35,400	Low
Harrow	Outer	33,300	Low
Havering	Outer	30,600	Low
Hillingdon	Outer	30,100	Low
Hounslow	Outer	32,200	Low
Islington	Inner	48,400	High
Kensington and Chelsea	Inner	131,000	High
Kingston-upon-Thames	Outer	39,900	High
Lambeth	Inner	37,600	Low
Lewisham	Inner	30,400	Low
Merton	Outer	44,400	High
Newham	Outer	23,100	Low
Redbridge	Outer	31,800	Low
Richmond-upon-Thames	Outer	58,800	High
Southwark	Inner	37,500	Low
Sutton	Outer	32,400	Low
Tower Hamlets	Inner	39,000	Low
Waltham Forest	Outer	26,200	Low
Wandsworth	Inner	54,700	High
Westminster	Inner	92,200	High

(1) Source: Official definition at londoncouncils.gov.uk

(2) Source: HM Revenues & Customs Survey of Personal Incomes (2013)

(3) High income boroughs defined as those with average income of tax payers above the London average of £39,900

Table 9. Number of boroughs that by Location and Average Income.

	High Income	Low Income	Grand Total
Inner	7	6	13
Outer	4	16	20
Grand Total	11	22	33

Source: own elaboration

- Test used: Wilcoxon Signed-Rank Test for Paired Samples across selected pairs of statements.
- Interpretation of results:
 - Where $p < 0.05$, the null hypothesis was rejected, i.e. it was considered that the difference between the two ranges of responses was significant.
 - Where $p > 0.05$, the null hypothesis was not rejected, i.e. it was considered that the two ranges of responses were not different

4.5.2. Results for Public only

Same analysis as for the overall results, looking only at the data for respondents who work on public / council land.

4.5.3. Grouped results

Analysis of the results by groups (Location and Income as outlined above). This was done to try and identify trends and differences across the different groups. Data calculated per question / sub-question:

- Mean and median response by grouping
- Statistical Analysis of results

The statistical analysis of the results performed are the following:

- Objective: Determine whether observed different medians for the same statement across groups are significant (carried out for all questions / statements)
- H_0 : Ranges of responses to the same question / statement across different groups are equal
- H_A : Ranges of responses to the same question / statement across different groups are significantly different
- Test used: Wilcoxon Rank-Sum test across the responses of the two populations to each question / statement
- Interpretation of results:
 - Where $p < 0.05$, the null hypothesis was rejected, i.e. it was considered that the difference between the two ranges of responses was significant.
 - Where $p > 0.05$, the null hypothesis was not rejected, i.e. it was considered that the difference between the two ranges of responses was not significant

5. QUALITATIVE INTERVIEWS

The second phase of the research design was the qualitative study in the form of semi-structured interviews.

This section describes in detail the qualitative part of the study, according to the following steps:

- Population and sampling
- Data collection
- Interview schedule
- Data recording procedures
- Transcriptions
- Analysis

5.1. Population and sampling

Potential participants in the study included all 152 London's tree officers working among the 34 boroughs. Participants were recruited from the 152 tree officers contacted to participate in the questionnaire who were also offered, via the one of the questions, the choice to volunteer for a personal interview.

5.2. Data collection

Interviews were chosen for the purpose of complementing the information from the questionnaire and to explore tree officers' views regarding the implementation of visualizations in urban trees management and planning.

Interviews have been described as a form of conversation that are 'initiated by the interviewer for the specific purpose of obtaining research-relevant information and focused on content specified research objectives of systematic description, prediction or explanation' (Cohen and Manion, 1989, p307). They provide the opportunity to explore ideas or concepts that cannot be directly observed (Patton, 1980) from the participants' point of view, not how they are perceived by the researcher (Marshall and Rossman, 1989).

Interviews can take a variety of formats including structured, unstructured or semi-structured. The aim of semi-structured interviews is to determine some initial topics, so that the researcher can decide what factors need additional in-depth exploration (see, Sekaran, 2003). In these interviews an interview schedule outlining open questions to be explored is used. When conducting a semi-structured interview, the interviewer, based on their own perceptions, has the opportunity to modify the order in which questions are asked, change the way that they are worded, include additional questions should further exploration of a concept or idea be required or indeed leave out a question if it is regarded as not appropriate in order to enhance the context of the conversation.

The semi-structured, in-depth interview approach was selected because it is believed to produce a more positive exchange between the researcher and participant, is less threatening, and can empower those involved to provide their own interpretations and meanings (de Laine, 1997). Robson (1993) argued that the benefits of such interviews can be strengthened even further by conducting them in a face-to-face manner where the interviewer has the ability to respond to the participants' non-visual cues or other responses by modifying their questions appropriately. Therefore, the interview format chosen was in person semi-structured interview.

The duration of the interviews ranged from 50 minutes to 120 minutes. I tried to be as flexible as possible with dates and locations of interviews, in recognition that people were generously giving up their time to be interviewed. Consequently, interviews were conducted at the place and time chosen by the participants.

Interviews took place at the respondents' workplace. Most of the respondents booked an office to carry out the interview without the presence of other colleagues and with no other people overhearing the conversation. The three people that did not chose a private office were able to allocate a space in common areas where some level of privacy was achieved. This also facilitated a noise-free environment which increased the quality of the recordings.

5.3. Interview schedule

The interview protocol was designed to be able to answer the research questions by following the themes described in the research design section. The themes had to be covered in each interview but not in a specific order. At the same time, it was designed to be open-ended enough as to allow the interviewees to open new themes not necessarily related to the ones previously identified. The interview protocol, which can be found in the appendices section, was structured in the following sections:

- Introduction.
- Part I: LTOs priorities, challenges and concerns.
- Part II: Visualization evaluation experiment.
- Closure.

The benefit of the interview protocol was to provide prompts for the researcher during the interview, but to be flexible enough to allow participants the freedom to express their own thoughts and experiences (Minichiello *et al.*, 1995, pp. 81-83). Questions were not always asked in a particular order and not every question was asked in each interview. The line of questioning was very much directed by the participant's answers with the interview schedule providing a framework for the interview. Interviews were planned to be one-hour long and I started them by:

- Introducing myself as a PhD student from the UPM.
- Reviewing the consent form.
- Reminding participants that they were being asked about their personal opinions, so there were no right or wrong answers, and both positive and negative feedback would be helpful for the purposes of the research.

5.3.1. Part I

I started the first part of the interviews with fairly general questions which were designed to engage the participant and establish rapport. They helped me familiarize myself with the role of tree officers in London and the type of tasks they performed. They were followed by questions derived from their responses to the questionnaire. These questions varied in form for the different respondents but always covered themes related to questions 1 to 7 of the questionnaire.

This part of the interview was the most flexible one in which the questions were not formulated in any specific order and my role was mainly to guide the respondents as they were explaining: what they did, their main roles in the tree department, how efficiently they think those tasks were performed by the existing tools and processes, and the interaction with other groups such as decision makers, colleagues from other departments, developers or general public.

5.3.2. Part II: VIZ evaluation experiment

The second part of the interview tested the opinions of urban tree managers and planners on the use of visualizations in their job. This part of the interview used a set of visualizations specifically developed for this research as visual stimuli, to confront urban forestry managers, with this tool applied to urban forestry and gather their reactions and views. Photo elicitation techniques, or the use of visual stimuli during qualitative interviews, is a commonly used technique. It allows to obtain richer responses and to facilitate the flow of the interview. More information on rationale of the use of this approach can be found on Section 5.1 Photo-elicitation as a qualitative research technique, in the Methodology Chapter.

The slide-show presentation created to visualize the different renders was structured in five sections. The interview protocol and presentation were created to work together following this structure:

1. STUDY AREA OVERVIEW
2. VISUALIZING TREE CONDITION
3. VISUALIZING TREE MANAGEMENT LONG TERM EVOLUTION
4. VISUALIZING TREE SHADE
5. MODELLING TREE SHADE

First participants were informed that the second part on the interview was going to start and that they would see a series of short slideshows presenting different types of visualizations oriented to urban forestry. The first set of visualizations showed tree officers several types of renders and a display of tools that they might already be familiar with, such as Google Earth and Google Street Maps. The aim was to start them talking about visualizations and find out if they currently produce or receive materials with similar materials, and to find out their preexisting opinion on them.

The following parts of the presentation covered different concepts and roles of visualizations in urban forestry (more information on this on Chapter 3 on visualizations parameters and production methods):

- Tree condition
- Long term evolution
- Shade as benefit
- Shade as technical tool

The presentation had a linear structure but it allowed the researcher to be able to repeat an already viewed image in case the respondents asked for it or in case I thought some important concept of the slide-show had been missed.

After watching each of the different parts of the presentation, participants were asked two questions and then, the printed images corresponding to that part of the presentation were set on the table. The questions participants were asked after every section were:

- 1) *Have you already used similar materials?*
- 2) *What are your first impressions of them?*

After seeing the presentation, all the printed images (DIN-A4 prints) were placed on the table. Interviewees were asked the following questions using as a reference the printed images, while they were encouraged to sort and look at the prints:

- 3) *Do you see yourself or anybody in your team **producing any of them**?*
 - a. *Would you ask an expert to produce something similar?*
- 4) *Which ones would be more **useful** for your job?*
- 5) *Which ones would you use for:*
 - b. *Personal analysis*
 - c. *Public meetings*
 - d. *Presentations to decision makers*
- 6) *Are there any **situations** where you think **VIZs** could be particularly **useful**?*
- 7) *What do you think are the most **effective** ones?*
- 8) *Which are the most **compelling** images?*
- 9) *Which ones do you find more...?*
 - e. *accurate*
 - f. *clear*
- 10) *How **plausible/credible** do you think the visualizations are?*
- 11) *Do you think any of the images/videos could be considered as **misleading**?*
- 12) *Would you have any **concerns** about using visualizations?*
- 13) *These VIZs have modelling work behind them and have a **scientific background** to support them,*
 - g. *do you think that would make a difference when presented to the public?*
 - h. *would that make **you feel more confident** when using them?*
 - i. *In terms of credibility, how important it is to present the images together with the data to support them?*
- 14) *What do you think are the **potential benefits** or **limitations** of using VIZs in urban forestry?*
- 15) *Do you have any other thoughts about the videos or the images that we haven't covered yet?*

The concepts used to question interviewees about the evaluation of the visualization used the criteria proposed by Sheppard (1989), which are:

- Accuracy: visualizations should simulate the actual or expected appearance of the landscape, or at least those which are studied.
- Representativeness: visualizations should represent typical or important views/conditions of the landscape.
- Visual clarity: the details, components, and overall content of the visualization should be clearly communicated.
- Interest: the visualization should engage and hold the interest of the audience
- Legitimacy: the visualization should be defensible and its level of accuracy demonstrable.

To close the interview, participants were asked to answer if they wanted to add something to their responses, if they would be willing to be contacted again in case any clarification was needed, and were thanked for their time.

A summary with all the steps of Part II of the interviews and the purpose of each of them are presented in Table 10.

Table 10. Steps and objectives of the interview protocol for Part II

Steps	Objective
Verbal introduction	Explain experimental procedures to interviewees
A. Presentation	
Chapter 1 + Questions 1, 2	Preconceptions on VIZs
Chapter 2 + Questions 1, 2	Preconceptions, first impressions
Chapter 3 + Questions 1, 2	Preconceptions, first impressions
Chapter 4 + Questions 1, 2	Preconceptions, first impressions
Chapter 5 + Questions 1, 2	Preconceptions, first impressions
B. Printed images	
Question 3	Computer skills (or time/resources) to produce VIZs
Questions 4, 5, 6	Usefulness
Questions 7, 8, 9, 10, 11	Evaluation of VIZs from the presentation
Question 12	Possible concerns applying VIZs
Question 13	Credibility issues, effect of scientific background supporting VIZs
Questions 14, 15	Overall evaluation: potential benefits and limitations

Source: own elaboration

5.4. Data recording procedures

With the permission of participants, interviews were tape-recorded. In addition, I took hand-written notes in case the recording equipment failed. Notes taken during and following every interview provided extra context to the transcripts, including facial expressions, intonation, body language and pauses (Poland and Pederson, 1998). Also, notes written at the end of each interview sometimes provided interesting comments that were made after the formal

interview was finished and the recording equipment was turned off. These notes were later added to the transcript and included with the text of the interview during coding and analysis.

5.5. Transcriptions

Audio files recorded during the interviews were transcribed to be able to proffer subsequent analysis. The notes taken after the interview were also revised and incorporated, when considered necessary to the interview transcripts.

The qualitative analysis method chosen for the research was a thematic analysis which did not require the same level of detail in the transcript as conversation, discourse or even narrative analysis. For that reason, intonation, body language and non verbal utterances were not taken into account in the transcription process. What is important is that the transcript retains the information needed, from the verbal account, and in a way which is 'true' to its original nature (Braun and Clarke, 2006)

5.6. Analysis

Analysis is the process of coming up with findings from your data. The complete process of analysis requires that the data be organized, scrutinized, selected, described, theorized, interpreted, discussed and presented to a readership.

For this thesis, the transcribed data from the interviews was analysed using a thematic top-down analysis, also known as thematic theoretical analysis. Thematic analysis is a method for identifying, analysing, and reporting patterns or themes within data. It organizes and describes the data set in detail and interprets various aspects of the research topic (Boyatzis, 1998). The interview transcripts were coded using the software NVivo by repetitive readings, developing of a list of initial themes, and sorting similar comments into groups. The coding scheme was developed through an iterative process informed by the literature presented in previous sections, the research questions, initial frame categories and some themes that emerged during the interviews.

The initial frame categories that were used for the analysis are those presented in the Research Design Section of the Methodology Chapter. The coding structure, initially based on the frame categories, did evolve as the analysis progressed, reflecting new information provided by the interviewees (Strauss and Corbin, 1998).

6. ETHICAL CONSIDERATIONS

Confidentiality was an important issue for participants in this study and they were assured that their identities would remain anonymous.

Similarly, participants are not described in relation to the boroughs where they work in order to protect their anonymity. Keeping this in mind, when I have used direct quotations in my results, pseudonyms have been used to protect the identity of participants. The quotations have also been edited, without changing their meaning, to improve readability. In my role as researcher I aimed to treat participants with honesty and respect (Minichiello *et al.*, 1995, p. 206; Rice and Ezzy, 1999, p. 41). I answered questions as they were asked of me.

7. QUALITY OF THE RESEARCH

There are different opinions about the criteria that should be used for evaluating and criticizing a research project. Jacobsen (2002) considers that validity and reliability can be used for assessing qualitative studies. In quantitative studies, generalisability and replicability are the main criteria for evaluating research quality.

The rest of the Chapter explains how the following criteria have been considered for evaluating the quality of the research proposed in this thesis:

- Validity.
- Reliability.
- Generalisability.

7.1. Validity

Validity is, according to Bryman *et al.* (2005), to what extent the collected data is valid, relevant and determines if the researchers really are measuring what they had in mind. Validity is concerned with two main issues: whether the instruments used for measurement are accurate and whether they are actually measuring what they want to measure (Winter, 2000). Ritchie and Lewis (2003) indicated that the validity of research is conceived as the precision or correctness of the research finding. Arksey and Knight (1999) and Winter (2000) identified two different dimensions of the concept of validity, namely internal and external validity. Internal validity ensures that the researcher investigates what he claims to be investigating. External validity concerns the extent to which the research findings can be generalised to wider population. Denscombe (1998) added that the use of multi-methods for examining one issue corroborates the findings of the research and increases the validity of the data.

In terms of the current research, validity was achieved by undertaking multiple methods to investigate the problem from different angles and strengthen the validity of the findings. Moreover, all the questions posed in the questionnaire and the interviews were directly linked to the research aim and objectives, and covered all aspects of the topic. Data was also transcribed and analysed with a high degree of accuracy; for instance, English native speakers assisted me to recognise the unclear taped conversations of some interviewees.

Triangulation is a strategy that can be used to strengthen the confidence of the research findings (Arksey and Knight, 1999). Decrop (1999) indicated that triangulation can reduce

and/or eliminate personal and methodological biases and increase the probability of generalising the findings of a study, as the data is gathered from different angles and by different methods. Easterby-Smith *et al.* (1991) referred to data triangulation as the process of collecting data over different times or by using multiple methods. Decrop (1999:159) asserted that “using multiple methods pave the way for more credible and dependable information”.

In respect of the present research, data and methodological triangulations had been accomplished through collecting the data from different sources and by using multiple methods, including: questionnaire and semi-structured interviews. The use of multiple methods assisted in data triangulation and at the same time was an effective way to overcome most of the weaknesses of each method used (Gray, 2004).

7.2 Reliability

Reliability is defined as the extent to which the research findings can be replicated, if another study is undertaken using the same research methods (Ritchie and Lewis, 2003). To ensure the reliability of the quantitative part of the research the procedures and methods of questionnaire design, data collection and analysis have been explicitly explained in detail.

In a quantitative study, “the reliability of the findings depends on the likely recurrence of the original data and the way they are interpreted” (Ritchie and Lewis, 2003). Marshall and Rossman (1999) and Seale (1999) argued that the absolute replication of qualitative studies is very difficult to achieve since they reflect realities at the time they were collected and in a situation which is likely to change. It is often referred to as an unrealistic demand.

It is recognised that the conditions surrounded the research might be different when replicating the current study but in an attempt to help others understand the various decisions and processes adopted along the research journey and increase the probability of replicating the present study, all decisions and procedures have been set out clearly. The study provides detailed information about the aim and objectives of the research, how the research was undertaken, and the justifications of the adopted research strategy and methods.

A number of measures were undertaken to enhance the reliability of the current research, including: all interviews were recorded to present more reliable evidence and avoid any bias which might happen if the researcher attempted to remember the conversation. Gray (2004:345) asserted that “in terms of reliability, it is fairly obvious that taped conversations will tend to present more reliable evidence than hastily written field notes”. Also, all the questions were worded clearly and asked in a natural tone of voice. If there was any misunderstanding the question would be repeated in order to enable the interviewee understand what s/he was asked for. Moreover, all interviewees were given the opportunity to explain their own opinions freely without any intervention either with comments or gestures, which would create bias in the interviewee’s response to the question being asked.

7.3. Generalisability

Generalisability, also referred to as external validity, refers to the degree to which a study's findings can be extended to or compared across groups. Generalisability has been strengthened for the quantitative part of this research by implementing several strategies to increase the number of respondents: offering a monetary compensation and various questionnaire follow-ups sent to non-respondents.

The results from a quantitative study of a sample representative of a determined population can be generalised to the population from where it had been selected (Bryman, 2012). In this case, results from the questionnaire would be generalisable to the population of London's Tree Officers, but not necessarily to tree officers from other cities in the UK or for urban tree managers or planners from other countries.

In qualitative research, generalisation can be defined as "the assertions of enduring value that are context-free" (Lincoln and Guba, 1985:110). For qualitative researchers, generalizability can be perceived as the "fit" between the cases studied and the other situations to the extent that make it possible to generalise the findings of the research (Schofield, 1994). Ritchie and Lewis (2003) named this type of generalisation as 'representational'. It can be assessed based on two main issues: firstly, the precision of interpreting and capturing the phenomenon, i.e. quality of fieldwork, analysis and interpretation. Secondly, the extent to which the sample studied is representative to the original population.

While using a case-study approach the researcher has to be aware of the lack of generalizability (Bryman et al, 2005). It is important that the researcher keeps in mind that it is not possible to find an object (case) that can represent all the objects in the same class (sector). What the research can do is to strive to find objects to represent a certain degree of theoretical generalization (Bryman et al. 2005:73). They continue to claim that a case study is about the following: "The important question is not how the results can be generalized to a further conclusion but how well the researcher can generate theoretical statements from the results." (Bryman et al. 2005:73). This study can therefore only be seen as valid for the group of London tree officers at this given time. The representativeness to other cities or groups of urban tree managers is unknown.

8. SUMMARY

The Research Methods Chapter has introduced the research methodology used for this study and how it has guided research design, data collection and analysis. First it described the differences between quantitative and qualitative research methods and explained the reason why a mixed methods approach was adopted.

Then research design has been outlined followed by the sections describing its steps: population and sampling, questionnaire design and analysis, visualizations' research design, and the qualitative interviews plan and analysis. It explained how the empirical data was collected, including the details of the research methods used, sampling techniques for

recruiting participants and how the research was conducted. The Chapter finished with the ethical considerations and addressed the issues of reliability, validity and generalization.

The next Chapter contains a detailed description of the application of the methodology, description of the case study and study area for the visualizations, the visualization production methods and the results obtained from the questionnaire, the interviews and the cross questionnaire-interviews analysis.

CHAPTER 3

CASE STUDY DESCRIPTION AND VISUALIZATIONS

1. INTRODUCTION

The previous Chapter introduced the research methodology used for this study and how it has guided research design, data collection and analysis.

First, the research design was outlined followed by the sections describing its steps: population and sampling, questionnaire design and analysis, visualizations research design, and the qualitative interviews plan and analysis. It outlined how the empirical data was collected, including the details of the research methods used, sampling techniques for recruiting participants and how the research was conducted. The Chapter finished with the ethical considerations and addressed the issues of reliability, validity and generalization.

This Chapter starts with Section 2 describing the case study population. It provides an overview of the administrative organization of urban tree management and planning in the city of London. Section 3 describes: the study area chosen for the visualization and the process of applying the methodology outlined in Chapter 2; the resulting visual materials created; and the presentation design.

2. CASE STUDY: LONDON TREE OFFICERS

This Section describes in detail the case study chosen for this research, the rationale for the election and provides some general data about the city of London, a demographic and economic panorama and information regarding urban trees management and planning.

It is organized into the following subsections:

- Study population
- London boroughs
- London's economic and demographic data
- London's urban trees

2.1. Study population

The study population included all tree officers in London working for the 33 boroughs as well as tree officers working for Transport for London (TFL). All the 152 tree officers were contacted to participate voluntarily in the research.

The rationale for selecting London as case study was based on relevance of London's urban forests, being one of the biggest and most populated cities in Europe, with a high concentration of tree officers that were easily accessible to the researcher who was based in London at that time.

I decided to study the London's Tree officers because they are the body of professionals that take care of the management and planning of urban trees in the city of London that belong in the public realm or that are located in a protected area and subject to regulations (Tree Protection Orders) from the Local Authorities.

The study was limited only to London because other British cities would have differed significantly in size, population and urban vegetation characteristics and issues. It would have been interesting to consider other groups, such as arborists from the private sector or charity members, but it this was beyond the scope of the study and available resources.

2.2. London Boroughs

London is the largest urban area and capital city of the United Kingdom, located in south-eastern Great Britain (see map in Figure 8). It is divided into 33 administrative regions called boroughs. This includes the 32 London boroughs within Greater London plus the City of London. The London boroughs are: City of London, Barking and Dagenham, Barnet, Bexley, Brent, Bromley, Camden, Croydon, Ealing, Enfield, Greenwich, Hackney, Hammersmith and Fulham, Haringey, Harrow, Havering, Hillingdon, Hounslow, Islington, Kensington and Chelsea, Kingston upon Thames, Lambeth, Lewisham, Merton, Newham, Redbridge, Richmond upon Thames, Southwark, Sutton, Tower Hamlets, Waltham Forest, Wandsworth, Westminster.

The London boroughs were all created on 1 April 1965. Upon creation, twelve were designated Inner London boroughs and the remaining twenty were designated Outer London boroughs. The Office for National Statistics has amended the designations of three boroughs for statistics purposes only, resulting in 14 in Inner London and 19 in Outer London. Three boroughs have been granted the designation royal borough and one has city status.

A list of all London's boroughs and its division in inner and outer can be seen both in Table 11 and Figure 9.

Figure 8. Map of London's geographic location

Source: Own elaboration with data from data.london.gov.uk

Figure 9. Map of London's inner and outer boroughs

Source: Own elaboration with data from data.london.gov.uk

Table 11. London's boroughs

Borough	Inner	Status	Political control	Area (km2)	Population (2013 est)	Population density (hab/km2)
City of London	(Yes)	City/Ceremonial county	na	1.64	7,000	4,269
Barking and Dagenham			Labour	20.39	194,352	9,531
Barnet			Conservative	49.03	369,088	7,528
Bexley			Conservative	34.23	236,687	6,915
Brent			Labour	24.45	317,264	12,977
Bromley			Conservative	84.86	317,899	3,746
Camden	Yes		Labour	12.30	229,719	18,681
Croydon			Labour	48.91	372,752	7,621
Ealing			Labour	31.39	342,494	10,912
Enfield			Labour	46.46	320,524	6,898
Greenwich Note 2	Yes	Royal	Labour	26.76	264,008	9,866
Hackney	Yes		Executive Mayor: Labour	10.77	257,379	23,888
Hammersmith and Fulham	Yes		Labour	9.27	178,685	19,283
Haringey			Labour	16.72	263,386	15,755
Harrow			Labour	28.53	243,372	8,530
Havering			NOC	63.46	242,080	3,815
Hillingdon			Conservative	65.39	286,806	4,386
Hounslow			Labour	31.64	262,407	8,295
Islington	Yes		Labour	8.40	215,667	25,666
Kensington and Chelsea	Yes	Royal	Conservative	6.85	155,594	22,711
Kingston upon Thames		Royal	Conservative	21.05	166,793	7,923
Lambeth	Yes		Labour	15.17	314,242	20,720
Lewisham	Yes		Executive Mayor: Labour	19.87	286,180	14,406
Merton			Labour	21.26	203,223	9,561
Newham			Executive Mayor: Labour	20.47	318,227	15,549
Redbridge			Labour	31.88	288,272	9,041
Richmond upon Thames			Conservative	32.45	191,365	5,896
Southwark	Yes		Labour	16.31	298,464	18,302
Sutton			Liberal Democrat	24.78	195,914	7,905
Tower Hamlets	Yes		Executive Mayor:	11.17	272,890	24,431
Waltham Forest			Labour	21.94	265,797	12,112
Wandsworth	Yes		Conservative	19.37	310,516	16,033
Westminster	Yes	City	Conservative	12.14	226,841	18,692

Source: data.london.gov.uk

2.3. London's economic and demographic data

London is the wealthiest part of Britain. It is the engine of the UK economy, contributing 36% more per capita of population than the next most productive region (Office for National Statistics, 2008). London is also unique in both its scale and its diversity.

The population of London accounts for about 15% of the total population of England and is more than seven times the size of Birmingham, the next largest city in the country. The South London borough of Croydon is London's largest, with a population of over 350,000. There are only seven cities larger than it in England.

Social and demographic data varies significantly along the different boroughs. A recent study about poverty in the city of London that used 16 different indicators (MacInnes and Kenway, 2009) showed some interesting conclusions:

- London is the most unequal region in England and income is more concentrated at the top than elsewhere. It has the highest proportion of households in the top tenth of incomes nationally, and the highest proportion in the bottom tenth.
- Most of London's population is concentrated in the Inner London's boroughs, where population density is significantly higher than Outer London boroughs.
- Although Inner London is worse than any English region on many poverty indicators, it has seen improvements in recent years. However, Outer London has experienced a significant deterioration across a number of indicators since the late 1990s, including child and working-age poverty. More of the capital's low-income population now live in Outer London than Inner London.
- Boroughs in the Inner East and South of the capital fare worse across a range of indicators in comparison to London's other boroughs. The classical division between Inner and Outer London therefore masks a stronger contrast between the Inner East and South and the rest of London.

Demographic data of London by borough such as political control, area, population and population density can be seen in Table 11 in previous section. Maps of Figures 10 and 11 represent population density by borough where can be seen how inner London boroughs are those with a higher population density; and the geographic representation of high vs low income boroughs offer an interesting distribution.

2.4. London's urban trees

London's urban trees are divided into the 33 boroughs and Transport for London. Each of these territories and their corresponding trees are managed in a completely independent manner. Each of them with their own management policies and strategies and with different levels of resources, both in terms of personnel and budget.

Figure 10. Map of London's demographic data per borough.
Source: Own elaboration with data from data.london.gov.uk

Figure 11. Map of London's income data per borough.
Source: Own elaboration with data from data.london.gov.uk

The boroughs are responsible for the management of the following trees within their area:

- Street trees
- Trees in public parks
- Trees in schools (not by all the boroughs)
- Trees in state buildings

In addition to local authority-maintained street trees, Transport for London maintains approximately 19,300 trees in highways (street trees) on the Transport for London Road Network (red routes).

Trees on private land are not maintained by local authorities but Tree Preservation Orders, Conservation Areas, Planning Conditions, Felling Licenses or Restrictive Covenants legally protects many trees in the UK both in public or private land.

Trees can be protected by Tree Preservation Orders (TPO), that are made on specific trees or groups of trees, and Conservation Areas (CA) which affords a level of protection to all but the very smallest trees within a geographical area. In addition, planning conditions are often used by local planning authorities when approving planning applications to make specific requirements regarding the protection or retention of trees that may be affected by construction or development works. In some cases, the removal of trees may be controlled by Felling Licences which are administered by the Forestry Commission or restrictions may apply if the tree or trees are within a Site of Special Scientific Interest (SSSI) or where the land on which they grow is subject to a Restrictive Covenant relating to trees.

The list of all the London boroughs and Transport for London with their corresponding number of tree officers and the number of street trees can be seen in Table 12. The density of green areas (expressed in %) can be observed in the map in Figure 12 where it is evident how outer London boroughs have a considerable higher density of green areas vs. inner London boroughs.

Map from Figure 13 shows the relation of the number of street trees and the total number of tree officers per borough. It is interesting how inner London boroughs have a lower number of street trees per tree officer when compared with outer London boroughs which can be explained by the complexity of the management of those trees in such high populated and densely built areas.

London also has a City Hall and a Mayor, but these local authorities are not in charge of urban trees or green areas management and planning. Nevertheless, London's City Hall and the Mayor of London have implemented and funded several initiatives regarding urban trees. The most relevant of those initiatives has been the Mayor's Street Tree Initiative that recently reached its goal of 20,000 street trees planted.

Table 12. London boroughs tree officers, street trees and green areas.

Borough	Estimated number of tree officers (1)	Estimated total street trees in 2011 (2)	Trees per tree officer	Area of Greenspace (%) (3)	Area of Domestic Gardens (%) (3)
City of London	6	531	88.50	4.83	0.12
Barking & Dagenham	1	4,800	4,800.00	33.58	22.76
Barnet	5	29,119	5,823.80	41.32	28.10
Bexley	4	10,500	2,625.00	31.69	25.15
Brent	3	20,000	6,666.67	21.94	30.34
Bromley	6	36,000	6,000.00	57.78	23.35
Camden	9	8,282	920.22	24.79	19.09
Croydon	6	33,000	5,500.00	37.10	32.81
Ealing	5	24,511	4,902.20	30.89	25.57
Enfield	5	25,000	5,000.00	45.62	21.72
Greenwich	5	13,000	2,600.00	34.38	23.22
Hackney	4	9,500	2,375.00	23.23	18.52
Hammersmith & Fulham	3	8,738	2,912.67	19.08	17.09
Haringey	4	11,500	2,875.00	25.50	26.61
Harrow	2	16,810	8,405.00	34.56	34.74
Havering	3	23,000	7,666.67	59.32	19.46
Hillingdon	5	16,000	3,200.00	49.23	18.59
Hounslow	1	11,034	11,034.00	39.62	21.53
Islington	6	10,455	1,742.50	12.37	19.73
Kensington & Chelsea	3	6,505	2,168.33	15.11	17.48
Kingston upon Thames	3	11,000	3,666.67	36.44	30.90
Lambeth	6	6,888	1,148.00	17.25	25.98
Lewisham	5	9,278	1,855.60	22.51	31.14
Merton	7	16,150	2,307.14	34.58	27.17
Newham	3	17,555	5,851.67	23.86	16.86
Redbridge	6	21,195	3,532.50	40.61	27.43
Richmond upon Thames	3	15,000	5,000.00	50.76	19.39
Southwark	6	16,500	2,750.00	24.90	17.64
Sutton	4	19,848	4,962.00	32.05	34.47
Tower Hamlets	3	4,000	1,333.33	15.20	7.35
Waltham Forest	3	20,000	6,666.67	31.39	24.42
Wandsworth	7	13,915	1,987.86	26.93	21.51
Westminster	6	8,072	1,345.33	21.50	7.92
Transport for London (3)	4	19,300	4,825.00	-	-
London (3)	152 (4)	517,000 (4)	3,401.32 (5)	38.2 (5)	23.8 (5)

[1] Estimated by the number of people subscribed by each borough to the London Tree Officers Association.

[2] Estimated total street trees in 2007 and 2011 are not directly comparable because the 2007 data included a large number of estimates.

[3] Not a London borough.

[4] Total for all London

[4] Average for London

Source: "London Borough Street Trees", London Greater Authority, 2011 and LTOA data.

Figure 12. Map of London's green areas density percentage data per borough.

Source: Own elaboration with data from data.london.gov.uk

Figure 13. Map of London's street trees and tree officers per borough.

Source: Own elaboration with data from data.london.gov.uk

The Mayor's Street Tree Initiative, delivered in partnership with the Forestry Commission, was open to all London boroughs and private landowners who own or manage land in the public realm (including businesses, registered social landlords, etc.). It was also open to civil society organizations and community groups working with or on behalf of boroughs and private landowners. The Mayor has spent £5.7m on the Street Tree Initiative since 2008 with over £3m having been match funded by the recipients of the grant (london.gov.uk, 2015).

In June 2012, the Trees and Design Action Group has promoted the importance of a tree strategy for towns in "Trees in the Townscape: A Guide for Decision Makers" and many boroughs have been working in their tree strategies.

The only public body that groups all of the tree officers from the different boroughs is the London Tree Officer Association (LTOA). The LTOA acts as an umbrella organization that provides a common forum for all the managers to share their experiences. It also organizes regular training seminars and courses.

Other initiatives at London scale had been i-Tree London and Treezilla. i-Tree is a peer reviewed software suite developed by the USDA Forest Service and co-operators that analyses and quantifies urban forest structure, composition and benefits (USDA Forest Service 2012). It is public domain and has been employed by many cities in and outside of the U.S. An i-Tree inventory London has been done in the summer of 2015 using i-Tree Eco to analyse London's urban forest benefits.

Treezilla is a citizen science platform that people can use to record the trees near them and to find out how they benefit the local environment. Treezilla aims to map all trees in UK, both in public and in private soil and is asking local authorities to help by sharing their tree inventory data. Treezilla can be used to serve a wide variety scientific objectives. For example, studies of the epidemiology of new and emerging tree diseases, evaluation of ecosystem services provided by trees, effects of climate change on tree growth and condition and macroecology.

3. VISUALIZATION PRODUCTION PROCESS

The visualization production methodology described in the previous Chapter is applied to the specific case study and study area for visualization and the visualization production process and the resulting visualizations are described in following sections:

- Study area for visualization
- Planning of the visualizations
- Image creation
- Presentation

3.1. Study area for visualizations

The chosen study area for visualisation is Buckingham Palace Road in London, UK. Buckingham Palace Road is one of the main avenues of the city of London (see Figure 14); it is 1.08 km in length and has a North-South orientation.

The rationale for the selection was to find a place that was easily recognizable by any Londoner (including tree officers), and representative of intensely urban, densely populated street tree corridors as found in both inner London and urban centres in outer London boroughs. Additionally, a complete tree inventory of the area had been recently carried out by the Victoria Business Improvement District which provided valuable data for the visualizations.

The specific area chosen was a one block section of the street between the Victoria Station building and the Google Headquarters. It is the part of Buckingham Palace Road in between Eccleston Street and Grosvenor Gardens, with its centre at 51°29'41.31"N and 0°08'46.48"S.

Photos and graphical representations of the area are provided in Figures 15 to 19 for orientation and to show the urban form characteristics and context of the study area.

Figure 14. Location of study area for visualizations

Source: Own elaboration.

Figure 15. High oblique perspective from North to South of study area in Buckingham Palace Road
Source: Bing Maps

Figure 16. Picture of the study area, West side
Source: Own elaboration

Figure 17. Picture of the study area, East side
Source: Own elaboration

Figure 18. Perspective of the study area looking from South to North of Buckingham Place Road

Source: own elaboration created with Trimble SketchUp

Figure 19. Transversal section of the study area

Source: own elaboration created with Trimble SketchUp

Though most of Buckingham Palace Road is populated by mature London plane trees (*Platanus x acerifolia*), the area chosen is populated by eight young Italian alder (*Celtis australis*), around 5 metres high, that had been planted recently. Tree inventory data and the position of the trees can be observed in Figure 20 and Table 13. The tree line is located on the West side of the street, while the West sidewalk has no trees at all.

This area was of special interest because young trees offered the potential to simulate tree growth and other characteristics associated with tree age in a clearer and more evident way than mature trees (see Section 3.2 for information on the purpose and the scope of the visualizations).

Italian alder is a medium sized tree that is 10-15 metres high at maturity (Chanes, 2000). It has a round shaped crown but the trees in the study area would have to be pruned to have a more columnar shape due to space and traffic site conditions.

Data and data sources used for the creation of the visualization were:

- Road limits data, provided by Westminster Borough.
- Tree data and position, from the Victoria BID i-Tree Inventory (Rogers and Jarratt, 2012).
- 3D models of the Victoria Station and Google Headquarters buildings, from Google Earth.
- Objects to populate the scene (e.g. traffic lights, street lamps, people, vehicles), from the Google SketchUp warehouse.

Additionally, visits to the study area were made and several photographs of the street and other details used for the scene modelling were taken.

3.2. Planning of the visualizations

The considerations that were taken into account for the creation of the different visualizations were the following:

- Purpose and audience.
- Scope of the visualization: image content.
- Type of visualization: rendering style and level of detail.
- View –point selection.

3.2.1. Purpose and audience

The purpose or function of the images stems from the audience(s) they were intended for. Two main roles are defined for the use of visualization in urban forestry: its role as a communication tool, and its role as a technical analysis and design tool.

As a communication tool, visualizations are used to bridge the gap between experts and non-experts by translating complex plans and concepts into more understandable images. They are therefore intended ultimately for a non-expert audience, composed in this case of general public and decision makers, though they may be used for that purpose by tree officers.

Figure 20. Map with location of the trees located in the study area from the Victoria BID i-Tree inventory.

Table 13. Data from the Victoria BID i-Tree inventory for the trees inside the study area.

Tree ID	Species Name	DBH (cm)	Height (m)	Tree Condition	Leaf Area Index	Carbon Storage (kg)	Gross Carbon Seq (kg/yr.)	Tree Value (\$)	Structural Value (£)
37	Italian alder	7.00	5.00	Good	1.59	5.50	1.69	59.00	37.29
38	Italian alder	7.00	5.00	Good	1.78	5.50	1.69	59.00	37.29
39	Italian alder	15.00	5.00	Good	2.20	33.45	5.71	86.00	54.35
40	Italian alder	12.00	5.00	Fair	1.25	19.66	4.23	51.00	32.23
41	Italian alder	9.00	5.00	Good	2.54	9.94	2.88	59.00	37.29
42	Italian alder	13.00	5.00	Good	2.42	23.78	4.71	65.00	41.08
43	Italian alder	13.00	5.00	Critical	2.22	23.78	1.92	25.00	15.80
44	Italian alder	10.00	5.00	Poor	2.07	12.75	2.48	39.00	24.65

Source: Victoria BID i-Tree inventory

As a technical tool for analysis and design, visualizations can be used to create a model to identify street tree planting locations that maximize shading provision (Macias, 2014). In this role, they are intended for an expert audience composed of urban forestry managers and planners.

3.2.2. Scope of the visualization

The scope or the contents of the visualizations includes: (1) those areas of urban forestry management considered as those most difficult to communicate to lay people and (2) the use of visualizations as a technical for analysis. The contents were determined by the literature and the results from the first round of questionnaires.

The chosen themes or specific functions for the use of visualizations as a communication tool are:

- Explaining management and planning decisions:
 - Tree condition, reflecting the importance of maintaining healthy trees and addressing sick or hazardous trees
 - Tree growth or long term evolution of the site, projecting the long term transitions through growth, death and cycling of trees
- Communicating urban tree environmental benefits:
 - Shade, reflecting the increasing importance of shade as the climate warms, in the context of dense urban form (adjoining buildings).

The chosen theme for the use of visualizations as a technical tool for expert analysis is modelling that uses visualizations to calculate shaded area when considering different street orientation, different planting design and different tree sizes.

3.2.3. Type of visualization

The different techniques and procedures used to produce the visualizations were chosen so that it would have been possible for Tree Officers to make them themselves. Therefore, the visualizations rendering style and level of detail were selected to be adapted for less experienced preparers.

Sheppard (1989) suggests less experienced users opt for moderately abstract simulations and avoid precise rendering. Following those guidelines, the rendering style chosen for the visualizations ranged from semi-realistic to abstract, depending on the situation.

The level of detail and the number of elements of the scenes were simplified, cleaning the scene from unnecessary street furniture, cars and people to center attention on the trees. Some elements of street furniture were left for scale reference, however.

It was considered important to present an example of different visualizations as an overview of different techniques as an introduction before the specific uses of visualizations were

presented. Visualizations from the introduction covered the array from semi-realistic with a high number of elements to abstract with no elements in the scene other than the buildings and the trees.

3.2.4. View-point

One of the key decisions when creating the visualizations was how many and which viewpoints to use. Because the chosen image information set is urban forestry, and urban tree management occurs at street scale, it was necessary to select viewpoints that represented either an overview of the entire street (at block scale) or represented how people typically experience a street.

Planners and managers often use graphic materials with viewpoints that visualize the entire study area. The entire study area could be viewed from the following perspectives:

- Overhead (plan view): this view gives an entire view of the whole street unit. The plan view looks straight down from a high elevation, as in a map.
- Oblique aerial view: this view also looks down from a high elevated point but at an angle smaller than 90°, showing 3D objects in perspective.

People generally experience the urban environment at the user level, so visualizations that try to simulate immersion in the scene use viewpoints from which people can see the scene in real life:

- From a nearby building roof top (medium-level oblique view).
- From a nearby building window (low-level oblique view).
- From the street (ground view at eye level).

3.2.5. Image selection

Considering all the parameters described in the previous sections and the characteristics of the tree species present in the study area, the visualizations priorities selected for development of images and presentation to the tree officers were the following:

1. Aerial plan view photograph with existing trees represented by colour-coded points representing tree condition.
2. Ground level photograph in which existing trees are coloured to represent their condition.
3. A series of 6 images representing a temporal sequence where one tree needs to be replaced in a tree line of young Italian alders (*Celtis australis*):
 - Pre-existing unhealthy tree has just been removed.
 - Tree has been replaced with small sapling of the same species, of approximately 3 metres.
 - After some years sapling reaches approximately 7 metres, still smaller than the rest that are now closer to 9 metres.
 - At maturity, sampling reaches same size as the other trees and the homogeneity of the tree line is restored.
4. Shade simulation over 24h for an alternative scenario with a different bigger species (*Platanus x acerifolia*).

5. Example of one of the images used to calculate area shaded by trees.
6. Graph showing the shaded area created by trees for the different seasons, measured using the visualizations.

Table 14 summarizes the chosen visualizations classified by viewpoints, rendering style, and image content, targeted for the different audiences. Further details of the methods and resulting images are provided below.

Once the set of images to produce had been identified, the next step was to prepare the visualizations. This Section includes information about the decisions made to produce the visualizations for the research. It is organized in the following sections:

- Software.
- Visualization modelling and rendering.

3.2.6. Software

One important criterion for the visualization development was to create them in a way that could be easily achieved by someone with no previous training in 3D modelling techniques. It was also important that the software had an easy learning curve, was affordable, had readily accessible object libraries for the models, and that the time required to produce the visualizations was as little as possible.

To introduce symbols and colour photographic images, the photographic editing software chosen was Gimp 2.8 (GNU Image Manipulation Program). Gimp is a freeware open source program for image editing and processing, similar to Adobe Photoshop.

For the 3D modelling and rendering of the landscape visualizations, the software chosen for this study was Trimble SketchUp Pro 8. It allows easy importation of CAD files and geo-location of the models based on actual coordinates and Google Earth integration.

To simplify the learning curve and the process, the renderings were entirely created in SketchUp, without using any additional plug-ins or other additional rendering software. This decision limited the level of realism of the images produced, but reduced the number of steps and the complexity of the visualization production methods.

3.2.7. Visualization modelling and rendering

To produce the visualizations as specified in previous sections, two different techniques were used: photo editing and 3D modelling. The rationale was to provide several visualization options to present to the tree officers.

Photo-editing

Photo-editing techniques included the addition of symbols and coloured areas to photographs of the study area. Further details about the different type of images created are included in Section 3.2.4.

Table 14. Types of visualizations selected and their characteristics

Purpose	Target audience	Theme	Content	Rendering style	Viewpoints	Visualizations
Communication tool	- Public - Decision makers	Explaining management and planning decisions	Tree condition	Augmented reality (photomontage)	Overhead	Aerial photograph with trees represented by colour coded points representing tree condition.
					Ground-level	Photograph in which trees are coloured representing their sanitary condition.
			Tree replacement temporal evolution	Semi-realistic	Ground-level	A series of 4 images representing a tree line where one tree needs to be replaced: 1) Tree has just been fell 2) Tree has been replaced with small sampling 3) After some years sampling is growing, still smaller than the rest 4) At maturity, sampling reaches same size as the other trees
		Communicating urban trees environmental benefits			Low level oblique	Shade simulation along 24h
Technical analysis tool	- Researchers - Managers	Create street tree shading potential numerical model	VIZs used to create the shade model	Abstract	Overhead	Example of one of the images used to calculate shaded area by trees: Overhead render of wide avenue, N-S orientation, with big trees planted on W side.
			Graph of the results	Graph	-	Graph showing the shaded area coming from the trees for the different seasons, measured using the visualizations

Source: Own elaboration

3D modelling

The 3D model was created in SketchUp by opening a blank SketchUp file where the digital elevation model (DEM) and aerial photo of the area were imported and geo-referenced.

The three-dimensional terrain was downloaded from Google Earth via SketchUp. Digital cartography of the area was provided by the Westminster Borough as .spe files and was used as a guide for side walk contours. The aerial photo of the area was also used as a guide for buildings and road contours.

The terrain model was then populated by all the objects contained in the urban landscape: buildings, sidewalks, pavement, and trees. Buildings were imported from the Google SketchUp Warehouse together with the rest of the street furniture and tree libraries as .obj files. Object distribution in the scene was made using the aerial photograph, the Westminster Council's digital cartography and the notes and pictures taken on the field.

The remaining street elements such as street lights, traffic lights, bollards, bus stops, fences or phone boxes were added into the 3D model and placed in different layers that could be switched on and off, allowing to change the level of detail for the requirements of the different renderings.

Shade modelling was done in SketchUp using the shadows module. It permits the simulation of accurate shadows for the objects in the scene selecting month and hour of the day. Shadows are adjusted for the geographic location of the model determined via Google Earth.

3.3. Presentation of the visualizations

The visualizations were created to be presented and introduced in person during the interviews, and needed to be presented together with information to provide context for the images. This Section includes information about the decisions made to design the presentation of the produced visualizations. It is organized in the following sections:

- Image size and display for images.
- Presentation structure and contents.
- Printed images.

3.3.1. Image size and display for images

The visualizations were created to be presented during the interviews which took place at locations determined by the interviewees. Also, the interviews would be performed one person at a time. Thus the display for the presentations had to be something portable and suitable for an audience of one person. Lighting conditions were unknown and variable, so the fact that it could be visualized under different conditions was an important factor.

Considering all these circumstances, the display chosen to present the visualizations was a laptop with a high resolution display and a size of 17" to be view at a distance of 45.75 cm, or 50 cm approximately. The correct viewing distance was calculated as 1.373 times simulation width (Sheppard, 1989) to ensure the visualizations were viewed at an angle that matched the actual field of view of the scene.

3.3.2. Presentation structure and contents

The visualizations were created to be presented and introduced in person during the interviews and needed to be presented in a context providing background information about:

- The structure of the presentation and the relation of one visualizations to the others.
- The data in which the visualizations were based, assumptions made and inevitable inaccuracies due to lack of data.
- The purpose and audience the visualizations were meant for.

The format chosen was a slide-show presentation divided into sections. The presentation had no audio, and the interviewer introduced and explained the images.

The presentation was structured into the following sections:

1. STUDY AREA OVERVIEW
2. VISUALIZING TREE CONDITION
3. VISUALIZING TREE MANAGEMENT OVER THE LONG TERM
4. VISUALIZING TREE SHADE
5. MODELLING TREE SHADE

The following information was presented as a structured but informal verbal presentation supported by images with labels.

Introduction

This section provided several examples of visualizations of the study area using different tools, different techniques and different styles with the objective to introduce the concept of visualizations and elicit responses about their familiarity with visualizations and their previous experiences and preconceptions on them.

Images included were:

- Google Earth aerial photo of the study area
- Google Earth high-level oblique view with 3D buildings
- Google Earth medium-level oblique view with 3D buildings
- Street View image
- SketchUp 3D model semi realistic render, low-level oblique view
- SketchUp 3D model abstract render, low-level oblique view

The progression of the images goes as follows:

- Far to close: from the far top view to the close ground view photo of Street View and then,
- Realistic to abstract: from the real photo of Street View to the last abstract render from SketchUp

Tree condition

Photo editing techniques were used for this Section to represent tree condition. Two images were chosen: a plan-view aerial photo and a ground view image. Tree condition is represented by augmented reality colouring the trees visualizing its overall health condition.

First, an overhead view was chosen. Using an aerial picture of the study area as base layer, trees were represented first by numbers and then by coloured dots. The image was presented together with a table containing a simplified version of the I-Tree inventory data base. The numbers identified each tree by a numeric code. That same code was used in the accompanying table which included information about tree ID number, species, height, diameter at breast height (DBH) and overall health condition.

Next, numeric codes were replaced by dots that were colour coded using data from the I-Tree inventory about overall health condition of each tree.

The selection of the colour to represent tree phytosanitary condition was considered carefully. The topic of colour selection is very important because colour has different and sometimes powerful meanings for different cultures (Ware, 2013). The use of a meaning laden colour was chosen to intuitively add meaning to the data and the icons represented in the visualizations. The combination of green, red and amber is internationally recognized and used in traffic lights all around the world. In this case:

- Green = good condition
- Amber = poor
- Red = critical

The same three colour code was used to fill the accompanying table cells from the health condition column.

Long-term

3D modelling techniques were used for this section to represent long term transitions in urban tree management. Using the same trees represented in the previous part of the presentation, the tree, shown in red, categorized as in critical condition, is assumed to be replaced with another tree. The one with poor condition is treated and it is assumed that it will survive.

A series of six images was used from the actual moment (symbolized by $T=0$) when the critical tree is replaced by a young sapling, to an intermediate state after “x” years (symbolized by $T+x$), to the final stage, after “y” years (symbolized by $T+y$) where the sapling has reached its maturity and therefore a similar size to the other trees on the street (see Figure 21 for a sequence of all the images). At the beginning of the series, an image from Street View of the area was provided as the “Before” image for simulations.

Although the tree species for the simulation area was known, no growth curves were available to estimate time to maturity. Therefore, the simulation could not show the years in between one image and the other, and that uncertainty was communicated both verbally when presenting the visualizations and also by representing the years as “x” and “y”.

Shade as benefit

3D modelling techniques were used for this Section to represent the shade produced by the street trees and its evolution along the day. The rendering style chosen was abstract to focus entirely on the evolution of the shade and its changes along the day.

Figure 21. Sequence of all the visualizations from the Long Term chapter of the presentation
Source: first image Street View, rest of the images own elaboration created with Trimble SketchUp

Shade as technical tool

This Section introduces a different use of visualizations: here visualizations are not presented as a communication tool but as a technical tool for analysis.

The images used for this section are part of an ongoing research project with the UK Forestry Commission that seeks to develop a model to assist urban foresters and decision makers in the selection of priority planting locations for street trees according to shading potential. Three-dimensional landscape visualizations are used to calculate shaded provision at selected time frames, distinguishing the shade projected by the trees and that projected by the adjacent buildings (Macias 2014).

The images included in this chapter of the presentation are:

- Abstract renders of a ground view of the study area with trees similar to existing in the study area, planted on the West side, simulating shade along the day for the 14th of June.
- One of the renderings used on the project to calculate shaded areas by the trees, showing a top view of the study area under the following set of variables: big trees (*Platanus x acerifolia*) are planted on the West side, simulation for the 14th of June at 14 h.
- Graphic with preliminary results of the project showing shaded area provided exclusively by the trees (big trees, planted on West side), calculated subtracting the area shaded by the surrounding buildings.

3.3.3. Printed images

Additionally to the video format, hard copies of the images were provided to the participants, enabling them to examine the images in a more informal way and repeat viewing of the materials (Stephen R J, 1989).

One or two images were chosen as representative of each of the sections from the presentation. They were presented to the interviewees after each of the presentation sections was visualized. They remained on the table and acted as a reminder of the different types of images visualized, allowing participants to compare them, going back to them during the course of the interview.

The images were rendered in high resolution. They were printed on DIN-A4 high grade photographic paper and identified with a number from one to ten located in the upper left corner. The ten images finally selected from the presentation to be printed are represented in Figures 22 to 31. Generic numeric and non-descriptive titles were given to the images to place emphasis on the verbal descriptions.

Figure 22. Image number 1 provided as hard copy to the interviewees.

Source: Google Earth

Figure 23. Image number 2 provided as hard copy to the interviewees.

Source: own elaboration created with Trimble SketchUp

Figure 24. Image number 3 provided as hard copy to the interviewees.
Source: own elaboration created with Trimble SketchUp

Figure 25. Image number 4 provided as hard copy to the interviewees.
Source: image Google Earth, data Victoria BID i-Tree inventory

Figure 26. Image number 5 provided as hard copy to the interviewees.

Source: image Google Earth, data Victoria BID i-Tree inventory

Figure 27. Image number 6 provided as hard copy to the interviewees.

Source: own elaboration created with Trimble SketchUp

Figure 28. Image number 7 provided as hard copy to the interviewees.
Source: own elaboration created with Trimble SketchUp

Figure 29. Image number 8 provided as hard copy to the interviewees.
Source: own elaboration created with Trimble SketchUp

Figure 30. Image number 9 provided as hard copy to the interviewees.

Source: own elaboration created with Trimble SketchUp

Figure 31. Image number 10 provided as hard copy to the interviewees.

Source: own elaboration created with Trimble SketchUp

4. SUMMARY

This has Chapter described the case study population. It provided an overview of the administrative organization of urban tree management and planning in the city of London. Next, the study area chosen for the visualization was described and the process of applying the methodology outlined, detailing the resulting visual materials created and the presentation design.

Next Chapter includes the results obtained in this study, presenting the results from the survey analysis, and the results from the interviews analysis.

CHAPTER 4

RESULTS

1. INTRODUCTION

The previous Chapter described the case study and the application of the methodology to the chosen case study and study area for visualizations. First, started with Section 2 describing the case study population. It provided an overview of the administrative organization of urban tree management and planning in the city of London. Section 3 described the study area chosen for the visualization and the process of applying the methodology outlined in Chapter 2, the resulting visual materials created, and the presentation design.

This Chapter includes the results obtained in this study. Section 2 presents results from the survey analysis, and Section 1 presents results from the interviews analysis.

2. QUESTIONNAIRE ANALYSIS RESULTS

The questionnaire results are organized under four sections. Section 1 contains data about the data collection response rate. Section 2 contains a summary of the questionnaire results.

Sections 3 and 4 include the findings from the analysis of the questionnaire responses according to the type of question:

- Profiling / descriptive questions
- Perceptions/opinions

2.1. Response rate

The 136 emails sent to all London tree officers, followed by 3 follow-up emails to non-respondents, yielded a total of 56 responses. Information was gathered from 30 boroughs out of 34 with represents an 88% percentage of boroughs and a response rate of 41% for tree officers.

From those who responded to the questionnaire, 18 agreed to a personal interview. One of the potential interviewees did not answered to emails to schedule an interview; 17 interviews were done, so considering the sample of tree officers that responded the questionnaire the response rate for the interviews was 30%.

The detailed response rates for the questionnaire and the interviews are reported in Table 15.

Table 15. Response rate for the questionnaire and the interviews

Questionnaire	Total	Responded	%
Boroughs	34	30	88
Tree officers	136	56	41
Interviews	Total	Responded	%
Tree officers	136	17	13
Questionnaire respondents	56	17	30

Source: own elaboration

There were 56 respondents to the questionnaire but not every question was completed by every respondent for the following reasons:

- One question's heading was corrected after eight of the respondents had completed it, due to a technical issue, those first 8 answers were not considered.
- Some respondents chose not to answer some questions.
- Two questions were added after the first round of questionnaires was sent and after reviewing the preliminary results. They were included at the end to not influence responses to the other questions.

Please, see Table 16 for a detailed summary of the number of responses for each question of the questionnaire.

Table 16. Number of respondents per question.

Type	Question	Responses
Personal Data	1.1. Please give your name (only used to avoid duplicates)	56
	1.2. Which London borough do you work for?	56
	1.3. What team do you work in?	56
	1.4. What is your academic background/training?	56
Questions	2.1. How much time do you dedicate in the average year to the following issues?	56
	2.2. To what extent do each of the following subjects present an ongoing challenge to your role?	47
	2.3. How often do you work directly with the public?	56
	2.4. Based on YOUR experience, please rate the following sentences from (1) strongly disagree to (5) strongly agree	55
	2.5 Please rate the following messages with regard to ease of communication to the public.	54
	2.6 Based on your interaction with them, how well do the following groups understand the importance of large mature trees for SHADING and COOLING in a future with climate change?	38
	2.7. Are there any tools that you currently use for analysis or communications with others on urban forestry issues?	38

Source: own elaboration

2.2. Summary of the results

The median LTO respondent¹:

- Has a background in Arboriculture (83%).
- Works with trees on Public / Council land (76%).
- Works with the public on a daily basis (54%).
- Uses Tree Management Software for analysis or communications with others on urban forestry issues (53%).
- Dedicates most of their time to tree maintenance and dealing with public complaints and the least time to public participation programs.
- Feels public communication and hazardous trees are the two challenges that have the greatest need for more resources / time / research while Chalara / Ash dieback is practically under control.
- Believes that “a better understanding of urban trees’ characteristics and the benefits they provide would make people more open to coping with minor inconveniences such as leaves/fruits/sap/honey-dew” and that “people usually want trees to be planted in their neighbourhood but not in front of their houses”.
- Does not believe that “the public in general are very knowledgeable about urban trees and their phenology”.
- Thinks it is easy to communicate to the public “the need to fell diseased or structurally unstable trees” but difficult to communicate “the long term consequences of today’s management decisions”.
- Feels that other borough staff and councillors / local politicians have some understanding of the importance of large mature trees for SHADING and COOLING in a future with climate change, whereas Developers and the general public have a poor understanding of this.

2.3. Profiling / descriptive questions

Questionnaire results for the profiling or descriptive questions are organized under the following headings:

- Academic background/training
- Type of work/team

¹ Quotes in inverted commas in this section correspond to text from the questionnaire questions.

- Frequency of direct interaction with the public
- Tools used for analysis or communications with others on urban forestry

Significance test were done for all the results but only significant results are reported so that no mention means that the result was not significant.

2.3.1. Academic Background / Training (Question 1.4)

As can be seen in Figure 32, the majority of London Tree Officers (LTOs) sampled have a background in arboriculture (83% of all LTOs). A much smaller proportion of respondents have Forestry (17%) and/or Urban Planning (9%) backgrounds. 5 respondents (9% of total) also specified a background in Horticulture, which was not one of the options offered in the Questionnaire.

Figure 32. Range of Academic Background/ Training – All Respondents

Note: Respondents could select multiple options, therefore percentages may add up to more than 100%.

Interestingly, the majority of respondents with a Forestry background (8 out of 9) work in Inner London boroughs (Figure 33).

Figure 33. Range of Academic Background / Training – Respondents from Inner Boroughs vs Outer Boroughs

NOTE: 2 respondents were not categorised as either INNER or OUTER and are not included in this analysis. Respondents could select multiple options, therefore percentages may add up to more than 100%. Total Respondents: 58

2.3.2. Type of work / team (Question 1.3)

As shown in Figure 34, the majority (76%) of LTOs sampled work with trees on public / council land. 20% of these also work on Private land. Only 18% of all LTOs sampled work only on Private Land. There were no significant differences in the breakdown across borough income or borough location groups.

Figure 34. Type of Work / team – All Respondents

Other responses: Development Management, Urban Design and Conservation

NOTE: Percentages add up to more than 100% as respondents could select multiple options. Total Respondents: 56

2.3.3. Frequency of direct interaction with the public (Question 2.3)

The majority of LTOs surveyed work directly with the public on a daily basis (54%), with only 14% working less than once a month with the public and all of the respondents having some working contact with the public. As can be seen in Figure 35, this effect is slightly less pronounced for LTOs working on public / council land, where 45% of those surveyed work with the public on a daily basis

Figure 35. Range of Responses Question 2.3 – All Respondents vs Respondents working on Council / Public land

Across groups, LTOs in High Income boroughs report having less frequent working interaction with the public than their counterparts in Low Income boroughs (see Figure 36 below).

2.3.4. Tools used for analysis or communications with others on urban forestry issues (Question 2.7)

As Figure 37 below shows, 53% of all respondents use Tree Management Software, whilst 37% use GIS or Mapping software, only 3% use modelling programs and no-one uses visualization programs. 13% of respondents don't use any tools for analysis or communication with others on urban forestry issues.

Figure 36. Frequency of interaction with the public – Respondents from High vs Low Income Boroughs

Figure 37. Tools used – All respondents.

Figure 38. Tools used – Respondents working on Public / Council land vs those who only work on Private Land

The differences between respondents working on Public / Council land and those working only on private land are significant. Tree management software is the most commonly used tool by those working on public / council land, while it is not used by any of the respondents working only on private land. LTOs on Private land use predominantly GIS or mapping software.

Across groups, there was no statistical significance in usage of tools (Figures 38 and 39)

Figure 39. Tools used – Respondents from High Income boroughs vs low income boroughs

Figure 40. Tools used – Inner vs Outer London respondents

2.4. Perceptions / Opinions

Questionnaire results for the perceptions or opinion questions are organized under the following headings:

- Activity time and dedication
- Challenges to the role
- Perception of public perceptions/communication
- Easy of communication to the public
- Perception of other groups' understanding of the importance of large mature trees for shading and cooling in a future with climate change

2.4.1. Activity time dedication (Question 2.1)

As can be seen in Figure 41 below, responses on Activity time dedication varied significantly across activities. On a scale of 1-5 (where 1 means no time at all and 5 means most of my time) the median response to 3 questions was a 2, to 1 question was a 3 and to the remaining 2 questions was a 4.

Figure 41. Time dedication to selected activities – All respondents

From these results, and using non-parametric test of significance (Wilcoxon Signed-Rank Paired Samples test), it was possible to build a ranking of activities by time dedication (Table 17 below).

Table 17. Activity Time dedication of all LTOs surveyed – Median and Ranking

Activity	Median	Rank
2.1 Tree maintenance	4	= 1
2.1 Dealing with public complaints (high hedges disputes, sap/leaves falling, damage on infrastructures by trees...)	4	= 1
2.1 Planting (new or replacement trees and species selection)	3	3
2.1 Management plans and strategies development	2	4
2.1 Pests and disease control	2	5
2.1 Public participation programs	2	6

This shows that tree maintenance and dealing with public complaints are the two activities that demanded the most time during the course of a LTOs' average year. Tree maintenance was scored more highly on average than dealing with public complaints, but the difference was not significant statistically. Third in terms of time dedication comes Planting, whereas Management Plans and Strategies development is fourth, Pests and Disease Control is fifth, and Public Participation Programs is last of the options provided (i.e. takes the least time out off a LTO's average year). Dealing with Tree Preservation Orders (TPOs) was specified under "other" by seven respondents, though it has not been included in the ranking or statistical analysis.

Across groups, scoring was generally aligned, with only one exception. “Dealing with public complaints (high hedges disputes, sap/leaves falling, damage on infrastructures by trees...)” was considered to take more time out of the normal year by Outer London respondents than Inner London respondents (Figure 42 below) and by respondents from Low Income boroughs than respondents from High Income boroughs (Figure 43 below)

Figure 42. Range of Responses to activity “Dealing with public complaints (high hedges disputes, sap/leaves falling, damage on infrastructures by trees...)” – Inner vs Outer London respondents

Figure 43. Range of Responses to activity “Dealing with public complaints (high hedges disputes, sap/leaves falling, damage on infrastructures by trees...)” – High vs Low Income borough respondents

2.4.2. Challenges to the role (Question 2.2)

As can be seen in Figure 43 below, the responses across the eleven challenges presented to respondents varied only gradually across the continuum of questions. It was therefore not possible to conclusively rank all eleven challenges according to the scale 1 (not a problem) to 5 (needs for more resources / time / research), as the non-parametric test of significance across challenges applied was most often not significant.

As can be seen above, Public Communication and Hazardous Trees received the highest scores in terms of needing more resources / time / research. Responses on Public Communications were statistically significantly higher than all challenges except Hazardous Trees. Hazardous Trees in turn was scored (significantly) more highly than all remaining

challenges except for Climate Change Consequences. At the other end of the range, Chalara / Ash dieback was scored (significantly) lower than all other challenges except for Community Engagement and Vandalism Prevention of urban trees, vegetation, greenspaces.

Across groups, three challenges were scored (statistically significantly) differently by respondents:

- Climate Change Consequences on urban tree species scored more highly by Inner London respondents than Outer London respondents (Figure 44 below).
- Massaria Diseases of Plane scored more highly by Inner London respondents than Outer London respondents (Figure 45 below).
- Hazardous Trees Assessment Procedures scored more highly by respondents from Low Income boroughs than respondents from High Income boroughs (Figure 46 below).

Figure 44. Range of Responses to question on Challenges of the role - All Respondents

Figure 45. Range of Responses to challenge "Climate Change Consequences on urban tree species" – Inner vs Outer London respondents

Figure 46. Range of Responses to challenge “Massaria Diseases of Plane” – Inner vs Outer London respondents

Figure 47. Range of Responses to challenge “Hazardous Trees Assessment Procedures” – High vs Low borough income respondents

2.4.3. Perception of public perceptions / communication (Question 2.4)

Figure 47 below shows the range of responses to the question on perception of public perceptions / communications, where respondents rated sentences based on their experience.

As can be seen respondents agreed most strongly with the statements “A better understanding of urban trees’ characteristics and the benefits they provide would make people more open to coping with minor inconveniences such as leaves/fruits/sap/honey-dew” and “People usually want trees to be planted in their neighbourhood but not in front of their houses”. While the former received a higher score on average than the latter, the difference was not statistically significant at a 5% confidence level. Both statements’ responses were significantly different from those of other statements.

Respondents disagreed most strongly with the statement “The public in general are very knowledgeable about urban trees and their phenology”. The difference in scores with other statements was highly significant statistically.

Across groups, there was only one statement which had significantly higher / lower scores: Outer London respondents agreed more with the statement “Street trees are less valued by people than trees in parks” than Inner London respondents (Figure XX)

Figure 48. Range of Responses Question 2.4 – All Respondents

Figure 49. Range of Responses to statement "Street trees are less valued by people than trees in parks" – Inner vs Outer London respondents

2.4.4. Ease of communication to the public (Question 2.5)

Figure 50 shows the range of responses regarding ease of communication to the public of various topics / messages.

Whilst all statements had a median response of 3 (on a scale of 1-5), 49% of respondents rated "Long term consequences of today's management decisions" as a 4 or a 5, whereas only 21% rated it as a 1 or a 2. Overall it was considered the hardest of the topics to communicate to the public, scoring statistically significantly higher than the other topics.

Figure 50. Range of Responses on Ease of Communication to the public – All Respondents

The need to fell diseased or structurally unstable trees, the importance of planting the right tree in the right place and the benefits of urban trees were considered the easiest topics to communicate to the public. The first two scored a slightly higher score in this respect, though the difference was not statistically significant.

Across groups, “Long term consequences of today’s management decisions” (Figure 51 below) was considered a harder topic to communicate to the public by Outer London LTOs than Inner London LTOs whilst “the benefits of urban trees” (Figure 51 below) was considered easier to communicate by Inner London LTOs than their Outer London counterparts.

Figure 51. Range of Responses to topic “Long term consequences of today’s management decisions” – Inner vs Outer London respondents

Figure 52. Range of Responses to topic “The benefits of urban trees” – Inner vs Outer London respondents

2.4.5. Perception of other groups' understanding of the importance of large mature trees for shading and cooling in a future with climate change (Question 2.6)

As can be seen in Figure 53 below, LTOs generally assigned some or poor understanding to the different types of people. Developers and the General Public were generally scored lowest in terms of understanding, with over 60% of respondents rating them as “poor” or “no” understanding and 7 respondents (20%) considering that developers have no understanding at all of this importance. Councillors/ Local politicians appear visually to have a better reputation than these two groups though the difference is not significant statistically at a 5% confidence level.

Other Borough staff were seen as the group with the highest understanding of the importance of large mature trees for SHADING and COOLING in a future with climate change. The difference with other groups was statistically significant at a 5% confidence level across all LTOs.

Across groups, the only statistically significant finding was that Outer London LTOs had a lower perception of the Public's understanding than Inner London LTOs (Figure 54 below).

Figure 53. Range of Responses to question on perception of the understanding of the importance of large mature trees for SHADING and COOLING by different types of people - All Respondents

Figure 54. Range of Responses on understanding of the importance of large mature trees for SHADING and COOLING by the General Public – Inner vs Outer London respondents

3. INTERVIEWS THEMATIC ANALYSIS RESULTS

In the following sections I present the results from the thematic analysis of the data collected via the semi-structured interviews. The Chapter is divided into two main sections, corresponding to the two parts of the interviews:

Part I:

Findings in this Section have been organized under 4 headings:

- Activities: what tree officers do and how much time they dedicate to the different tasks.
- Communication: how tree officers interact with other groups of people such as politicians, general public, developers and colleagues from other departments and how effective that communication is. Entries may have been included as an activity or a challenge at the same time.
- Challenges: problems and challenges related with urban tree management and planning, and how they affect their decisions and difficult their execution.
- Resources: the tools, personnel and budget tree officers have available.

Part II:

Findings identified across the data have been classified into five categories describing the opinions of tree officers about the integration of visualizations in urban forestry management and planning:

- Evaluation of visualizations as a tool
- Previous experiences with visualizations
- Applications
- Benefits
- Concerns and limitations

Quotes included in this document have been extracted directly from the interview transcripts and have only been altered when necessary to clarify its contents. Quotations are included where they help to convey typical or important results. The quotations selected do not represent a comprehensive list of all the relevant quotations for a given theme or category. To ensure confidentiality, names of people and boroughs had been omitted and numbers have been used to identify interviewees.

The tables included in each of the Sections are meant to offer an overview of the data and as a summary of the responses and patterns identified. Tables are not meant for statistical purposes, due to the reduced sample size frequently inherent to qualitative studies.

3.1. Interviewees demographics

A total of 17 tree officers were interviewed for this study. They worked for 12 different boroughs. Ten participants included in the study worked for inner London boroughs and seven for outer London boroughs. According to their income level there were 9 tree officers working for low income boroughs and 8 working for high income boroughs.

Majority of participants belonged to the public trees section where they manage all trees in the public realm. Five of them worked in the private trees section and one worked managing both public and private trees.

Tree officers were part of different departments along the different boroughs. The organizational structure and where the tree section was included varied hugely from one borough to another. Mainly, tree sections could be included inside the planning department (8 participants), the parks, leisure and culture department (2 participants) or the environment department (7 participants).

All tree officers interviewed were men and the most of them occupied senior positions (13 senior vs. 4 junior). It is important to notice that many positions were considered senior because the officer had a prolonged experience of more than 7 years and they were the only person in the team. All this data are summarized in Table 18.

Table 18. Main characteristics of interviewees.

Participants	Borough Location		Borough Income		Team			Department			Seniority	
	Inner	Outer	High	Low	Private trees	Public trees	Both	Environment	Planning	Parks/Leisure	Senior	Junior
Total	10	7	8	9	5	11	1	7	8	2	13	4
	(59 %)	(41 %)	(47 %)	(53 %)	(29 %)	(65 %)	(6 %)	(41 %)	(47 %)	(12 %)	(76 %)	(24 %)

Source: Own elaboration

3.2. Part I: Job description

The findings contained in this section try to answer Research Question 1 exploring the tasks tree officers perform, the challenges they have to face and how satisfactorily those challenges are addressed. This first section of results includes the interview responses in relation to: activities, communication, challenges and resources.

3.2.1. Activities

Tree officers perform very different tasks depending on the team they work in.

Those who manage public trees manage trees in streets, in parks, in schools and in council estates. They are in charge of the periodic inventory, they inspect works performed by the contractors and deal with public enquiries. They also attend occasionally public meetings and are contacted by councillors regarding public members' complaints. If the borough has a participatory program, they will be the ones meeting regularly with the volunteers, supervising their work and guiding and teaching them.

Planting schemes are also managed by tree officers working in the public trees section. They will have to replace trees where necessary and in cases where new trees are going to be

planted they will have to dig to find suitable tree pits and will select species and do public consultations if that is decided. Trees in areas with clay soil have to be managed closely and are usually under a very strict pollarding regime. Tree officers will also deal with insurance claims regarding damage to properties caused by trees on public land.

Those who work managing private trees deal mostly with planning application and tree protection orders (TPOs). They will recommend approval or refusal on landscape plans part of planning applications. They will attend pre-application meetings and then analyse planning application documents to determine the effect that the development would have on trees. They will provide comments to the planning department about tree protection and landscaping. They will recommend refusal entirely or impose conditions of consent that require tree protection, new landscaping, retention of existing trees or other mitigation strategies to ensure canopy cover is maintained even if some trees have to be felled. They will also evaluate periodically existing TPOs and relocate or modify when necessary and create new ones. They will deal also with public enquiries about trees in protected areas and protected trees.

There was one participant that worked in both sections. This can happen where the team is too small to be divided, the person is in a senior manager position that supervises both teams or where the planning department doesn't have anyone with expertise in trees and the team managing trees on public soil advises planners about tree related issues.

3.2.2. Communication

The team in which tree officers work defines the activities they perform and also who they interact with and in which role. Those in a private trees section are receptors of information in the form of planning applications from individual public members or from developers. Their role is to judge those documents and make an assessment on the viability of the project and its possible impacts on existing trees and how to mitigate or compensate those impacts. They communicate via meetings (pre-application meetings) or via the reports they write to the planning department about specific projects. This communication is mainly with developers but also takes place with colleagues from the planning department, less frequently with the Public and doesn't tend to happen with councillors.

Tree officers managing public trees have to deal with enquiries from the public both directly or via the councillors. They need to communicate with colleagues from other departments and with schools' managers and state housing managers if they also manage trees in schools and in council houses. They receive public enquiries by email, letter or the phone and will answer the same way. Sometimes a face to face meeting to inspect the tree on site will be necessary. Once or twice a year they are called to attend public meetings. They also interact with the public via participatory programs if the borough has any of those established. Communication tends to be mainly with the Public and councillors, also takes place with colleagues from the highways department, but doesn't tend to happen with developers. Forms of communication are typically email, phone, public meetings and public participation programs.

The responses regarding communication are included below under the following headings:

- communication with residents
- participatory programs
- communications with councillors
- communication with developers
- communications with colleagues from other departments.

1) Communication with residents

The team they work, whether it is in the private trees or in the public trees, will influence the way tree officers are contacted by residents and the issues that are discussed.

The following sections include the responses of tree officers about the way they interact with residents and the reasons why they are contacted.

a) How interacting with residents happens

Tree officers working in the private trees section communicate with residents only via planning pre-application meetings and via the application for works on protected trees or on trees in protected areas. Some also inform residents inside protected areas about the requirements regarding trees.

(1) It depends, we have sort of planning committee meetings where planning projects are discussed and the public can have an input. But mostly it has to do with applications for works on trees that are protected, such as TPO within Conservation Areas. Also development applications, landscape plans. Mostly that sort of things.

(15) We issue leaflets to inform residents in the conservation areas about the restrictions regarding trees. There is a lot of resentment when it comes to protected trees. Sometimes we get people thanking us when we make a new preservation order and it is very refreshing.

Those working in the public trees section are contacted directly by the residents via telephone, email or letter. Answering public enquiries occupies an important part of tree officers daily work load as they have 10 days to reply which requires to phone/email back, a possible on-site inspection and an email or call with the response.

(7) We have a lot of customer service. The work load of officers is based on enquiries from the public. People will phone or use the web to make a complaint about a tree issue and the officer has 10 days to resolve those enquiries. That takes up a lot of our time. By phone, email in person. Usually one to one. Before we act on an enquiry we have to visit the place. Tree officers employ half the day making visits.

(10) This year we got approximately 200-250 enquiries per month. Sometimes we have to say no but we always get back.

(12) Pretty much all my time (90%) I deal with residents' enquiries.

About 20% of the people who contact them do not have internet so they either have to phone back or send a letter. Some tree officers also preferred to meet face to face whenever possible.

(8) We try and go and talk face to face with residents; that accomplishes a lot of things when done right.

(17) I prefer the phone. We work for a local authority, I prefer to hear someone's voice. People are more receptive when you speak directly with them.

Sometimes they would also go to public meetings with the residents, but that does not happen very often.

(2) Ward councillors do regular public meetings where members of the public ask questions. If the people are particularly concerned about trees, he goes to the meeting. Not very often, 1 or 2 a year. Although trees might be an issue usually larger more pressing things come up like large traffic schemes, larger environmental schemes and trees are put off.

(6) We do [go to meetings] and we are quite keen on doing that. Best thing is to go early when they are not happy. Face to face, listen to them, people calm down and understand. We do that with subsidence because it is a big tree and even the people that are suffering it might like the tree and they don't want the neighbours to be upset. We usually go there and help explain and people understand.

When a tree needs to be removed they inform residents in the area by putting a sign on the tree and, in some boroughs they would also send a notification or even set up a meeting if it's many trees or a big tree that needs to be removed.

(2) We put out minimal information and for the trees that they ask [about], then we provide extra information. [We don't have] resources to provide a lot of information for every tree we remove; we remove a lot.

(3) [There are] no really public meetings. We inform always. If [it's] an emergency, we might cut and then inform. Even if it is obvious we inform because people might call to ask later.

Tree officers' opinion on public consultation was very polarized. Some of them did consultation periodically, primarily about planting schemes while other thought that consultations were only a source of unhappy residents because due to the many different responses they will get it would be impossible to satisfy them all.

(3) We do inform but we don't consult because we get a lot of different opinions. Even with more resources we wouldn't consult. If you ask ten people what we should do about the trees you get ten different opinions. If they call, we listen.

(8) Sometime we have to take the bull by the horn if it is a busy road and [there are] environmental reasons and we plant the trees without the consultation. On residential roads we try to consult. With the consultation process I have been using for years if someone says no, we won't plant a tree there. What has happened is that that property stands out like a sore thumb and then they go back and ask for a tree.

(11) First we scan the ground. Then we do the consultation. Last time we got the councillors to consult.

(17) I try to minimize public participation because if you ask about species they all will have different opinion. I try to keep their involvement to a minimum until the trees are in.

b) What communications are about

All tree officers have said that the typical letter they receive says “I love trees but...” not my neighbour’s, not the one in front on front of my house...

(15) Even with all the evidence that says how beneficial they are for the urban environment, often the people that live in those environments have completely the opposite view. They are very negative towards trees and would like to see most trees cut down, or only the one that affects them. They say “I love trees but I want that one gone” and you go to the neighbour and he says the same.

(17) The thing about this borough is that everybody loves trees in their neighbour’s garden.

People contact tree officers for very different issues such as complaining about trees shading their garden, damaging their property, being home for insects and birds that are bothering them and ask for those trees to be removed. The main reasons why they contact them are summarized in Table 19.

All tree officers were unanimous in saying that trees are not cut for being a nuisance but that trees damaging properties are carefully monitored and supervised (see Section 4.2.3. Challenges: Subsidence).

(3) Either the tree in a highway or in front of their house, the tree near them, or the tree on their neighbour’s garden, which we deal with if it is a council housing. About it being dangerous, dead, too big, blocking light, anything, you name it. People who complain about trees are the people that complain about everything.

(5) Sometimes they plant a lot of Tiliacs and you have problems with honey dew and people complain to the borough. Or insects going to the tree and infecting their children! People look at things with tunnel vision.

(6) People complain about general things such as a tree blocking light, touching their house, obscuring street lights at night, branches [being too] low... And sometimes they ask for trees to be cut for very bizarre reasons like trees scaring them or people hiding behind trees.

(10) Often we are asked to remove the trees but we have a policy that if the tree is healthy in a highway, we can prune it but not remove it.

(11) If someone calls saying the tree is shading their garden I believe them but it is not reason enough for me to remove the tree. Tree work is quite cheap, so even with budget cuts we would still be able to prune trees if needed.

(15) Trees improve air quality, urban heat island, etc. but in the end people see trees as a nuisance: leaves falling, bird lives on them and they mess their car, they don’t see the roots and think that they are damaging their houses.

Table 19. Main reasons why residents contact tree officers.

Reasons why public enquires about trees	Interviewees																	Total	%
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
To report a dangerous tree, dead tree, with broken branches			1	1	1										1			4	(24 %)
To report basal growth											1		1					2	(12 %)
To report low branches that need pruning						1	1					1	1					4	(24 %)
A tree is damaging their property (root damage)						1				1	1		1		1			5	(29 %)
A tree is shading their property			1	1	1		1		1	1	1	1	1	1	1		1	12	(70 %)
To ask for new trees to be planted						1			1									2	(12 %)
To complain about birds living in tree creating mess					1						1		1		1		1	5	(29 %)
To complain about honey dew					1								1					2	(12 %)
To complain about insects living in tree					1					1								2	(12 %)
To complain about their neighbour's tree blocking light/blocking view/overhanging braches			1		1				1									3	(18 %)
To complain about over pruning		1										1						2	(12 %)
To complain about tree removals		1	1			1						1						4	(24 %)
Blocking street lights						1												1	(6 %)
To complain about leaves/fruits falling										1	1				1		1	4	(24 %)
To report a neighbour had cut a tree																	1	1	(6 %)

Source: Own elaboration

One of the most mentioned reasons for public complaints is trees shading their gardens. People would contact the borough to ask for the tree next to their house to be pruned or even removed because it is shading their garden. It is usually a season related complaint. Tree officers know that shade trees wisely planted around property can be very beneficial but it is a message that has not been yet internalized by residents.

(3) They are opposed to new tree plantings because of blocking light. Light is precious in this country where the sun is limited.

(4) I get lots of complaints about shade. People don't understand the value of shade, they will in 2050. We haven't reached that position yet.

(6) The moment is amenity, particulates and birds, etc. Shading is the future, people don't yet care about it. Also, we prune in a 3-year cycle and sometimes we used to prune in early spring but now we are moving to prune only in the winter to maintain wildlife and amenity value. We will have to deal with complaints about shade. Also the law is on our side and we do not need to prune to provide light. We have to look at the bigger picture, not about one person only.

(15) Shade could be dressed up either way. As a benefit or as a problem.

(15) In terms of shading hopefully it will become a more prominent element in design but now doesn't form part of any decisions. It will certainly help my job because I get a lot of complaints about shade so I would be able to say that it is something important. With climate change, as we start to get more sun, people will start to see how important shade trees are.

Sometimes people also provide useful information such as informing that the tree outside their property is dead or dangerous.

(4) The public usually helps alerting if trees are dying because [we don't have] enough personnel.

(8) Our residents are very vocal in communicating any problem. That means a lot of work but also means that [when there is an] issue we can deal with it very quickly.

Over-pruning and tree removals are often the most controversial issues due to the harsh aesthetic impact that they have and because people get emotionally attached to trees.

(2) Any tree removals [in the borough], and probably in London, are very emotive. They are not always but generally mistrusting of the reasons why you are taking trees away. Either they are not confident in your technical ability or they think there is a general sort of feeling that the Council doesn't know what it is doing. Once I explain it to them it usually resolves the problem.

(3) We always plant where there is a vacant [tree pit] because people mind, residents do mind when we have to cut one down.

(7) We have a lot of trees on clay soil². Those are on a 3 year pruning cycle which is very intense. Costs 80,000 pounds a year and we get complaints because it looks quite brutal but needs to be done. Especially if we prune in summer, when trees are flowering and bees are there. We agree it is not ideal.

² See subsidence section in the Literature Review Chapter

Those boroughs that have a detailed tree strategy find it very useful when answering public complaints.

(16) We follow our tree management strategy and it is like our Bible. We explain it to the residents and clarify but then it is not my opinion, I don't have anything against you, I just follow the procedure that has been approved by the councillors. It makes things easier because it's not my personal opinion. It clarifies the process and helps also people understand.

They also contact tree officers to ask for trees to be planted, which unfortunately is not always possible.

(6) People also call a lot asking for trees. We plant in autumn / winter. It is nice but we can't plant all the trees people wants. We always try to replace when we remove a tree, unless [there is] subsidence that we have to re-evaluate. Then we also check data and look at the gaps because in rich areas of the borough people might ask more and it wouldn't be fair.

(10) We have a lot of requests for replacement and for new trees. Since we started this ward based management plan the number of nuisance calls has been reduced dramatically. From thousands of calls we dropped to 2,000 a year. They have started to see trees as an asset, not a nuisance, and they want more of them.

The results suggest certain patterns in the relationships between rich and poor areas and the kinds of complaints received:

(4) In rough terms, the west part of the borough is richer, which is the areas where there are more volunteers. Poor people don't have the time, don't have the knowledge and the rich ones know that they have rights, that they are entitled.

(5) I think it depends on cultural and demographic backgrounds. Also people with more money are happier to get an expert and they are happy to have trees around while people that have less money, they complain about the trees' leaves falling and blocking their gutters. They have more pressing things. I think we have to listen to them and to their problems.

(9) Response to planting is generally positive. We did a consultation in 2010 and 90% of people wanted trees planted. But you always get a small number of people that don't want a tree in front of their house, they like trees and understand the importance but just not that one.

(11) Consultation depends a lot on the culture of the area. In a very established rich road, people would generally oppose. If you go to a poorer road people would welcome the improvement. I think it has to do with objecting because they know how to object. They might be management themselves and they are used to running the show and when you come with an idea they say no, I want it my way.

(12) No one knows what happens first, if the affluence or the greenery but there is definitely a direct correlation as far as I can see. The trees on this borough are in the posh parts. There are some variations to it but not much. The pressure I get for planting from people is for the posh areas of the borough where there is already some greenery

and people want to conserve the existing and to even get more. While the pressure for removals comes from poorer areas [where] I get more complaints about trees and requests for removing trees and to not replace them.

2) Participatory programs

Some tree officers were very happy with their tree warden programs whilst others have had to stop because it wasn't working

(11) We used to have a successful tree warden program. We had about 70. The problem is almost everyone was retired. We realized that they were not up to work but more up to excursions and similar things.

Many have friends groups that act at local level focused on a specific park. Most of them are retired people who are not strong enough to work and are very small in number.

(4) There are also friend groups, local friend groups. Some are interested in the environment of a specific park. They turn out once a month to do some work, about 5 people when the park is used by 100 people. So not many.

Some boroughs already have or are starting a program under different names (tree friends, tree champions or tree adoptions) in which residents volunteer to look after some trees in their street and they will monitor closely and report diseases and problems, water them when it's hot and in some cases also remove basal growth. This program has proven to be successful in increasing the rate of tree establishment on new plantings.

(8) We water the trees by a model we have developed. We do a simple yes/no survey to see if residents want trees in the street [where] they live. Then they sign up as tree carers, we give them a watering can and they water the trees when it is hot. They are my eyes and ears and tell us if a tree is not doing well. We lose less than 1% of the trees we plant. We also have contractors doing the work but this is working extremely well. More participation, more ownership. The watering can is a very small cost but the benefits we get are immense. I can only afford two visits a month for contractors and if there is a very hot period trees might have to be watered every day. We have installed a vessel that retains 20 litres of water and then permeates slowly. We put stickers and give them information. A huge spectrum of residents participate. It is only watering, if there are any issues they report them and we take care of them.

Also some planting campaigns are run with schools. These initiatives are seen as very positive and a reason for reduced vandalism.

(8) Vandalism is very minor compared to other boroughs and I think it has a lot to do with the work we have done with schools.

(11) Last year we did a planting campaign in a small woodland and it was one of my best days at work with all the kids there. Imagining when they grow, they would not let anyone damage those trees.

(17) Once people take ownership, they will look after that tree.

3) Communication with councillors

Sometimes people do not contact the borough directly and instead contact their ward councillor. If the enquiry is related to trees, then the councillor will contact the tree officers and try to solve the problem. Sometimes the problem affects several areas and the councillors can contact and coordinate the different departments.

(2) [I am] frequently in touch with councillors. Ward councillors act as a link between people and the officers. Some problems are complex and involve several departments, councillors coordinate.

(10) [There is] lots of interaction with councillors, some positive, some not so positive. They represent the residents of their ward, some councillors sit on various committees. If we feel that a work is going to be controversial we talk to them.

The answer is the same no matter how the enquiry gets to them, but when it comes through the councillors it usually complicates the process.

(3) There is a great pressure from Councillors. Residents would email their councillor and then they call us.

Councillors don't have a great deal to say but they think that they can tell us what to do because they carry a lot of power. If I say no to a councillor asking they would go to my boss. Even if I give a reason they might say, I understand but even so I want you to do it. The problem is that all that takes time, more emails.

(15) Residents go to the councillors and then it goes to us. Nothing complex, simple enquiries. The answer is the same but it just goes through a long process.

In some cases there have been problems when political criteria had been made to prevail over technical criteria.

(6) Councillors intervene a lot. Trees are a very emotive thing. We are a very small group but we end up in the news very often. People have very strong opinions on trees. They either hate them and want them out, or love them. Generally politicians support us and tell us we are the experts. Sometimes we had to do what a politician told us and we said ok, but we make clear it is not what we recommend so we do it and we put it on record, it is your responsibility. They are the elected charges and they manage the budget so we have to do what they tell us ultimately.

Politicians are sometimes more worried about increasing the number of new trees planted and not on maintaining them.

(3) Sometimes you get, "put 200 more!" And I ask where, you can't just plant them anywhere, you have to think carefully.

(4) Some might come to me asking for more trees but also they need votes and another might come saying that tree is bothering a neighbour, blocking light.

4) Communication with developers

Interaction with developers usually starts with a pre-application meeting that is followed by a planning application.

(15) I go to pre-application meetings where developers can come in, they pay for it, and discuss and get councillors' reactions and we discuss which would be the potential problems, how to solve them. So by the time the application comes in it all should be solved. Not always, as sometimes they do not think that what the council says is right. If we say no, it goes to appeal and the appeal inspector is from central government and might have a different opinion.

(15) Bigger developers are more professional and they adjust and know how the system works. But they can be a little bullying.

Trees are usually not a main element in the proposals. Landscaping is usually left for the end of the project when in many cases budget is very tight and that causes the executed project to be far from the initial plan presented in the proposal.

(14) How do developers see trees? [This borough] has very little space for development. It's pretty much acknowledged that trees are a constraint. Some applications do not acknowledge trees and try to get away with it but it doesn't happen. Most developers are very good. They usually speak the right language. Our planning officers are very good. They are pretty much tree focused. I don't feel it is a battle we are losing with developers.

(15) This is typically what you get from developers with really nice trees and then the reality is completely different because they run out of money.

Tree officers were concerned that the teams preparing proposals for developers did not include people with knowledge about tree species and maintenance requirements, and they mostly focused on the design and the aesthetics.

(15) Sometimes we get planning applications where landscaping has been taken care of by architects and they don't know about what species to choose. Having to deal with non-professionals is hard, even if they think they are professionals.

Some tree officers are trying to get the message across to developers that trees could be very beneficial for them by for example increasing house prices in leafy streets or saving energy by shading glass facades.

(14) When talking to developers I try to sell the trees to developers during retention or selling them replacements. I use the benefits to try to convince them. Also the view is important when you look out of the window, also from high floors when you see the green canopies.

5) Communication with other departments

Street trees are important elements of highways' infrastructure but they are also the only ones that are alive and change size over time which can cause some friction with the highways engineers section.

(8) We have been doing this all the time. Especially with our engineering schemes because we are re-modelling the trees, lamps, etc. This way we make sure that we

don't put trees next to light columns. That is a common problem with trees and street lighting.

(12) [I'm] not very happy with highway engineers. [There is a] constant battle with them about tripping hazards [like roots overgrowth].

Other departments often ask for advice from tree officers for new design schemes. They will suggest suitable species for the available spaces.

(10) In the town centre there is a lot of new planting but site, location, etc., it's done by the design team. We discuss issues of future maintenance, and species. Sometimes they put trees too close to buildings and that increases the maintenance costs a lot.

(11) If there is going to be a new park, the planning department would do the design and they would ask for comments from us on species. We also get that a lot for new developments for council houses. Landscape architects choose the same species all the time, it seems they only learnt 10 species at university.

Often, the collaboration is much more beneficial when tree officers are involved in the early stages of the design or even part of the design team.

(3) I think they got the space for the trees because tree officers were consulted when the building and pavement was re-modelled. Which is great, at planning stage the tree officers asked for the spaces and the engineers found the spaces. That is good communication. We are getting better at it.

(8) Being in the highways section means that when they remodel the areas the green infrastructure are part of the design. When I first started I was the odd tree guy causing trouble but now that has ingrained in what they do and now we are even designing very innovative highways schemes integrating trees in them. I have been based in several departments with other local authorities and if you want to make a difference you have to be based in the highways section. Now the light engineers sit next to me.

3.2.3. Challenges

This section includes the findings from the tree officers' responses related to the challenges they encounter when performing their job.

The main challenges identified that will be explained in detailed in the following sections are:

- Climate change
- Pressure for development
- Underground services
- Subsidence
- Structural organization of London in 33 boroughs

1) Climate change

Most of the tree officers mentioned climate change when talking about species selection for new planting schemes or for replacements.

(2) The ultimate decision for species selection was based on pollution removal and shade. These concepts are being incorporated in species selection.

(5) We have to look for species that can cope with drought, reflective heat from pavement and buildings, etc. And it is climate change but also urban environment. We had had acid rain problems that means death to the root system. Basically [all we] have is London plane and Callery pear!

(9) We do try to mix a lot because monocultures with climate change will be at risk of pests and disease attacks. Most of the trees we have are planes so we try to mix. It is important because if we were to lose them we would have lost our reservoir of mature trees.

(16) Species selection is based on tree size, the bigger the better depending on the site but not too big that it needs pruning; that costs money and is bad for the tree. My idea is to try to plant a tree that doesn't need to be touched in 100 years. The problem is that there is not a lot of information on climate change. If you try to plant something from the South of Europe, then you don't find them in the nurseries. And we don't really know how the climate is going to be.

Some are more eager to experiment to try new species that will work for the new climatic conditions while others are more conservative.

(4) We don't have a recommended list of species, we need a full palette especially with climate change. [There are] very different contexts in urban environments: park, narrow street, wide avenues... And climate change predictions are not simple, we might be getting hotter conditions but very damp spring. It's not just getting a Mediterranean plant. We need the broadest range of possibilities, we have to work out, to have the potential to try different things. And it is going to take a long time, because trees take a long time to grow.

(8) We have a great huge variety of species in this borough. We monitor how they grow with climate change. I try not to put all eggs in one basket and having different species helps us be more resilient to climate change and also make things more interesting.

(9) We have tried some different species to see how they worked and we are monitoring. We have to be aware of that because the tree I plant now is going to be there for 50 years and climate change is more than temperature variation. Floods are going to be an important problem.

(12) We don't have many gambling opportunities, we don't have the luxury of experimentation. People looks at a dead sapling as a failure, and it is very upsetting.

Also, many concepts related to climate change came up during the interviews about criteria incorporated into urban tree management: such as canopy cover, closing the right tree for the right place, flood management, particulate capture, or carbon sequestration among others.

(2) But we know that the canopy cover is going down. It is going down because we are planting smaller trees. We can use that for insurance companies. For them that is good news. Not for the rest.

(5) I go for the right tree for the right place.

(6) We see climate change as a key threat, we have in mind to always go for as big a canopy cover as we can go.

(7) We want to increase canopy cover for climate change which links into carbon sequestration, flood management and other benefits.

(11) One of the things we have been pushing is particulate capture, and birch trees are very good on that.

Some have mentioned that the effects of climate change are already present.

(8) The climate is already changing. This year, for example, [there were] a lot more mosquitos, but having the fauna, birds and bats can control that. That is also why the trees are so important.

(14) We have started planting for climate change. The species selection is changing and we are planting bigger trees. The climate has already changed, 2 °C is a big change and it's happening faster in the centre of London.

Still, some tree officers have said that people are not yet aware of the role trees need to play in climate change and more action is demanded from authorities and other private sectors.

(5) Our Government has been rather quiet on climate change because it costs money. Even if not doing anything is more expensive. People are still awakening. With the crisis it has been pushed to the back of the list.

(6) The central government and local authorities should push for space for trees to confront climate change before it is too late.

(11) Floods are going to be one of the big issues and the insurance industry are going to have to push the role of trees there.

(12) The tree shade idea and urban heat island are not currently understood and heard about by the general public.

Perception of shade is very different for different countries and it is also very different for residential areas and transit areas where people look for shade, not complain about it.

(12) Transit areas are for visitors, like the arena here, people really look for the shade. It's different in residential areas. In Spain you can see how courtyards are designed to avoid sun. There is a cultural element. Like in the past getting a suntan was [a sign of the] low classes, then it was in fashion, now it's perhaps a sign that you don't understand about skin cancer.

(14) The concept of having a shade tree is not that big in England vs North America. In small London gardens people think they want direct sunlight into their gardens. Not because they want to sunbathe, because they don't. Maybe because they are gardens. And then when it's sunny they want shade. The English have a very weird relationship with sun.

(15) In America it is different because they have more land so trees do not affect property in the same way. Here there is no space for trees, only small trees and that means less benefits. The bigger the tree the bigger the benefits but people see the bigger the tree the bigger the problems.

(17) We have to change people's minds to make them understand that a tree next to your property can be a huge benefit.

(12) It is tricky because you are planting now to produce shade in 10 years. And you wouldn't know who will be living there in 10 years. We react to what people ask now.

(15) With climate change, as we start to get more sun, people will start to see how important shade trees are.

2) Pressure for development

Most tree officers have mentioned that the limited space available and the price that soil has for construction puts a great pressure on trees.

(4) When [there's a] new development, because of the price per metre, they leave very little space. If they need to cut, they compensate by giving money that will go to trees in public soil.

(5) They are only worried about "how much available area is there on my site?" Space for trees is wasted space.

(5) With the crisis it has been pushed to the back of the list. [It's] similar in new developments. First we come with this wonderful plan with impressive landscaping and at the end the budget and scope is reduced heavily because they used money on other things.

(15) Trees always come at the bottom of the list.

(17) People apply for permission to remove trees for construction mostly. Because of price of land in the borough trees are under great pressure.

Additionally, there are housing targets the boroughs have to comply with that come from central government legislation.

(15) There are many studies, especially with climate change but there is a lot of pressure for provision of housing. There are housing targets that we have to meet, from the central government.

The Economic crisis has made matters even worse, accentuating the problem when developers need to reduce costs.

(4) Trees are not a priority. I am afraid we are not making progress on green infrastructure. [It's] worse now with the crisis. [The] reason is money. Green stuff is left for the end of the project when already money is tight. No one checks if the planted trees are kept alive because within a development trees remain private.

Developments occurring in public soil also have a big impact on tree loss when highways need to be redesigned and street trees are cut in the process.

(4) The problem is that most urban infrastructure life span is 20 years. Every time they make a new scheme they remove all trees and plant new ones. We have to change the idea that trees can be removed. Trees should be the permanent elements in the urban landscape and the concrete, the buildings, the ephemera. That would be the only way to have mature big trees.

The private stock of large mature trees is also under serious threat for reasons related with new developments and construction of house extensions and basements of existing properties.

(5) We are losing big trees in back gardens for several reasons: cost of tree care; building extensions or back garden buildings, right where big trees are (away from the house), so they cut the trees or they cut most of the roots; and basements (not much in this borough but in others a lot).

Most private large trees are in back gardens and, unless they are inside a protected area or are protected by a TPO, they can be removed without needing permission from local authorities. Tree officers mentioned that they sometimes know about those constructions when nearby trees are being damaged by the tree roots. In most cases, even if the construction has been poorly built and the tree was there in the first place, big trees have to be removed. In the cases where the borough wants to preserve the tree and creates a TPO to protect it, the local authority becomes responsible for future expenses for the repair of tree induced damages to those properties.

(5) And these constructions (if not inside protected areas) don't need planning application so they go out of our radar. Then if that tree so near the buildings causes problems to the buildings the tree has to go. If the borough says no, and creates a TPO to protect it then we have to pay for all future damage that the tree causes. Many people [are] saying that tree protection orders are not effective because they don't have teeth.

3) Underground services

Most of the tree officers referred to the problems for finding suitable spaces for planting new trees because the space under the pavement is completely occupied by network pipes and cables of underground services. In some cases, even when the original plans were to plant trees, they have to be eliminated from the design. The problem is especially serious in inner London boroughs.

(2) We are consulted when there is a new design, usually new traffic design. But we are not involved all the time because there are a lot of problems with underground services. Many designs do not even include trees.

(3) Some roads we already know that we can't plant there for underground services. Sometimes you just put them down where you can.

(7) Location is very important. Sometimes we want big trees and we identify the place where we want them but then because of underground services it's very complicated.

(11) I walked all the road, 10 km, to scan the road. We had planned 20,000 tree pits and we came out with 120 possible sites in the end.

Many tree officers said that the limitation of space for planting due to underground services, also influences species selection and in many cases instead of big trees, that would require big soil volumes, they have to choose small trees, which is not ideal from an environmental point of view.

(2) Because of the space limitation, our species selection revolves more [around] whether they would fit in the street space rather than other services like shade etc. In housing and of course in parks we look for other features.

(6) [We are] always looking for opportunities to plant big trees. Here there is no space for trees and usually we have to get small trees so we look for any opportunity.

(14) The next thing is to try and get soil volumes correct. Because while we have large trees from the Victorians, now trees don't have space and we won't be able to grow big trees.

The information available on the location of underground services is only approximate and it is necessary to scan and dig to find suitable spaces which increases costs.

(6) Maps of underground services are just a rough guide; you don't know anything until you dig.

(11) Planting new trees in town centres is more expensive because you have to scan the ground.

Some also expressed the opinion that this situation should be regulated and changes should be introduced for new developments.

(11) The statutory companies can dig up the pavement as they want. We have given up our pavement space to them. They do as they like because if the local authority were to say "no", people with no phone or electricity would complain. I hope in new development it's getting organized. If it [were] standardized, we would be able to plant millions of new trees.

(15) We rarely get a clean space so it's difficult even in new developments. We are trying to adapt, policy change and trying to integrate these changes at a level where they have to be heard.

4) Subsidence

Subsidence was mentioned by many tree officers as one of the main issues influencing their management plans and strategies.

(5) Subsidence is a massive issue in this borough. We lose several trees a year. And we pollard on a 1-year rotation.

(6) Victorian houses don't have foundations and nearby trees can cause problems when they are on clay soil.

Those boroughs with Victorian residential areas on clay soils have adapted their pruning and inspection cycles to manage those trees very closely. Some even have tree officers dedicated exclusively to deal with insurance complaints.

(2) The borough's tree canopy has been reduced because of subsidence. We maintained them as pollards but sometimes we have to remove them and when replaced we plant something completely different. We have been changing species

because subsidence, still big trees where we can, but most of the borough is on clay soil.

(8) We have 2,500 pollards. London planes and limes [are] pollarded on a 3-year rotation. The existing trees we are trying to retain as much as possible. Always managed as pollards so we do what has always been done. In some areas, where there is no building conflict, we are trying to grow back the crown.

Sometimes one of those trees will have to be removed and it has a great impact on residents as they are usually old big trees.

(6) We do [set up meetings] and we are quite keen on doing that. Best thing is to go early when they are not happy. Face to face, listen to them, people calm down and understand. We do that with subsidence because it is a big tree and even the people that are suffering it might like the tree and they don't want the neighbours to be upset. We usually go there and help explain and people understand.

5) Structural organization of London in 33 boroughs

The administrative subdivision of the city of London in 33 boroughs was mentioned by many tree officers as a cause of concern. Trees are managed independently by each of the boroughs which do not share strategic goals, resources, or procedures. This situation results in an uneven distribution of the resources between the boroughs.

(2) The biggest problem is that we are broken into 33 boroughs [which] are different government bodies. [The] Greater London Authority has some strategic lines but each borough has their strategies.

(5) If you were to design from scratch a political organization you would do 4 or 5 divisions not 33, [it's] not very practical.

(9) Each borough is managing and projecting things their own ways so there is not a London scale climate change study. It depends on the resources of the boroughs. Those that do not have a lot of money work reactively and even if they are aware they cannot do much.

(12) Another important thing is that doing work in central London is much more expensive than on a sapling in outer London. So seeing the [different] budgets that boroughs have could be confusing to a lay person.

One tree officer mentioned that it also causes a dispersion of the messages that are not getting across with the same force as if they were all "speaking with the same voice" (17).

(17) London has 33 different kingdoms, not like in New York where there is one policy for trees. We would have more influence if we were speaking for the city of London, not for a little borough. Everyone is fighting in their own corner, which is not ideal.

Some mentioned the important role that the London Tree Officers Association (LTOA) has but commented that it acts merely as a forum where they put experiences in common. Some saw Treezilla as an opportunity to have a global idea for the first time of the total London tree stock.

(4) Treezilla, if that could talk to the other systems, and the data going in it can be validated properly, that is going to be a great tool. We have to go in that direction, to have all of London's trees there.

(5) [The] LTOA is the only way we put things in common.

(17) [The] LTOA is an umbrella group but not power and not money, more like a forum.

3.2.4. Resources and tools

In the following Section I include responses regarding resources (budget, personal) and tools (software they use) available to the tree departments.

Resources

In general, all tree officers mentioned that they did not have enough personal and economic resources to adequately plan their budget and have an annual planting plan and maintenance plan.

(5) We tree officers do love our jobs but we don't get paid very well. And we are not well resourced compared with other departments.

Cuts and economic crisis have reduced even more the resources of the tree departments along almost all of the boroughs from which I interviewed people.

(2) We used to have 9 people, now only 5 because of the financial crisis. [There is a] new range of cuts for the next 3 years.

(5) This particular borough [had] massive cuts.

(9) And it is going to get even worse because more cuts are coming. It's not that trees are going to come out specifically bad from them but our planting budget also comes from other departments. We can do what we can with what we have. [Our] priority is to keep our trees healthy and that they do not injury anybody. Health and safety is the priority.

Economic crisis has made decision makers change their priorities and unfortunately trees are not considered essential.

(2) We have to do a lot and money is tight and it's going to be more. When money is tight people don't see how important trees are and that money has to be invested in them. And it is something very long term.

(3) Trees are sometimes considered an extra, [despite the] requirements to manage for safety, especially on highways.

(5) With the crisis trees have been pushed to the back of the list.

And it is modifying pruning cycles and planning decisions that can result in the long term in problems with tree stock health and safety.

(12) Trees are in a pruning regime. Cycles used to cover most of the borough roads but now have been reduced to only trees with similar characteristics and streets with very varied species and sizes have been dropped from the plan. It was done because of the budget reduction; it hasn't been a planned decision.

Sometimes it forces tree officers to come up with creative solutions to save money like using volunteers for certain non-dangerous maintenance tasks.

(7) At the moment there are diminishing budgets. Now we don't have a budget for basal growth so we need volunteers.

Only two of the LTOs said that their department had not suffered a lot with the economic cuts.

(17) Economic cuts meant planting smaller trees but not too bad.

Tools

Practically all tree departments use some geographic information system (GIS) to store and geo-reference tree data which in most cases is a layer into the system that is shared along all departments of the borough.

About one third of them also have a specific tree management solution, with Easy Treeve the one used by all of those who participated in the interviews.

In addition to the software they have licensed in their departments, tree officers are also participating with two very relevant initiatives: i-Tree London and Treezilla.

i-Tree London inventory took place in the summer of 2015 (two months after the interviews had finished). Many of the tree officers around London took part in it reviewing the inventory and in volunteer training and were looking forward to the results of the study.

(11) I think following i-Tree it is going to be easier to communicate the benefits of trees. Once you put that pound value people will understand.

(15) I am interested to find out how much of our borough is covered in trees and if you can attach a financial value to them you can start to treat them as green infrastructure and people will start to listen.

Treezilla is a participatory-science web site with the objective to map all trees in the UK. It is open for individual citizens to up-load the trees from their garden or their street and also many boroughs were contributing to the initiative by uploading their complete inventories into the Treezilla cloud database. The system also calculates environmental benefits of individual trees such as carbon sequestration and energy savings and estimates a monetary valuation of the tree.

3.3. Part II: Visualizations

The findings included in this section seek to explore the role visualizations can have from an urban forestry perspective and what could be the main barriers and limitations for their implementation.

This first section of results includes the interview responses with regard to: previous experiences with the use of visualizations, proposed applications or uses of visualizations in urban forestry management and planning, benefits of the use of visualizations, concerns and limitations, and an overall evaluation of visualizations as a tool.

3.3.1. Previous experiences with visualizations

This section includes the responses related to the preconceptions, ideas and experiences of the tree officers using visualizations themselves or being presented with them.

Responses have been divided into those related to visualizations produced by the tree officers themselves and those related to visualizations produced by professional preparers of visualizations for Real Estate developers and presented to tree officers to evaluate as part of the documentation of a development application.

Table 20 summarizes the responses and the different types of visualizations that tree officers had done and received by developers.

Table 20. Different types of previous experiences with the use of visualizations by the interviewees.

Previous interaction with VIZs		Total	%
VIZs are presented to me		8	(47 %)
I produce/ask someone to produce VIZs	Hand drawn	2	(12 %)
	2D	3	(18 %)
	3D	1	(6 %)
Street View		12	(70 %)
No interaction with VIZs		3	(18 %)

Source: Own elaboration

Visualizations produced by them selves

A few of the interviewees mentioned that they had made hand-drawings or that they are still using that technique.

(2) I don't use these materials. We send drawings by hand or architectural CAD maps.

Two of them said how photographs used by other colleagues had been taken at different moments in time can show the long term impact of planting schemes (see Figure 55).

(3) Jim Smith from the Forestry Commission has these photographs from Kingsway. One from 60 years ago showing the new planted trees there and then the photo from 2011 where you can see all covered in green. We use those photos to explain that if you want to increase the canopy of London, you have to start planting now.

Figure 55. Photographs of Kingsway (London) circa 1959 and as it is today.

Source: London County Council and Jim Smith 2011.

Two tree officers have done 2D mock-ups using photomontage techniques in the past for specific projects.

(8) We used [2D mock-ups] on a planting project to actually demonstrate how it would look like. You can see the benefit instantaneously. It is a nice scheme where we put 6 semi mature planes and it was very leafy from the start. It was a big change. We used Photoshop though it would have been nice to have done it with something more fluid.
(11) We photoshopped sometimes. I did something similar, though not so advanced.

Only two have been able to move from 2D to produce 3D visual simulations for new planting schemes and to communicate the importance of planting the right tree for the right place.

(5) We have used visualizations when we want to plant new trees. You have now 4 trees and this is how it's going to look when you have 20.
(5) We present visualizations to public, councillors, [and] other officers, wherever we can to show how important it is that we get them. We use them to show: how a place is going to look with trees, how it would look after some time, even how they would look if they are not watered! The more stuff you can show people when you are talking to them to try to get them on-side, the better.
(5) We use visualization systems to show people how the small trees would look at eye level, at human level; rather [than how] the big trees are going to act as carbon sequestration, we show them how they could act to soften the street, how they act like a landscape feature. They are earning points in another way, even if not ticking all the boxes.

(8) We have an urban designer who has started doing visualizations because I think it is very important. Before I have done it by Photoshop I have used it with residents to show the potential for how their street is going to look like and they go “oh, that is amazing”. Now I usually say look at the neighbouring street with the visualizations [so] that they could recognize maybe their houses on them and that had an impact.

Those two tree officers that use 3D visualizations do not model them themselves but have one or more people in their department who are trained CAD modellers and know how to use the necessary software. Tree officers participate in the modelling process guiding the visualizations and offering input on the species selection.

(5) The visualizations are done by two of my colleagues who are landscape architects. They use CAD systems and Photoshop. I help them with species choices, and put this sort of thing together.

(8) Visualizations are a lot of work but for some situations it could be very beneficial. We have one engineer who is very good with CAD and she makes wonderful mock-ups that make [it] much more easy to [understand for] other members of the community and for councillors. Very good to explain them the new schemes.

(9) The council has a council centre design team of landscape architects, that is redesigning the city centre. They would do new designs and ask us for feedback on species choice and potential issues on later management.

The majority of the interviewed tree officers mentioned Street View and other similar platforms such as Bing Maps as essential tools that they use every day:

(6) I use Street View for things like when colleagues say the trees are too close, they are too close to a street lamp, close to an entrance, or the street furniture. Our tree records are pretty accurate but sometimes there is a problem and a resident calls and says the contractor did not do the job last year and I can have an idea.

(7) We use Google Earth and Street View.

(9) We use Google Earth a lot.

(10) We really use Street View quite a lot.

(12) I use Street View all the time. I couldn't do my job without it. Now if someone tells me you have to choose between Microsoft Word and Street View, I would get street view. I never write a letter now, everything is by email and phone.

(13) We use Google Maps and Street View every day.

Nothing substitutes for an on-site inspection, but these tools constitute an important first step that saves time and speeds up responses to public enquiries:

(5) Street View is always my first step. Prior to going to the site. It helps me understand what people are talking about.

(8) I use Street View and Google Earth to have a first impression on things.

(15) We use Street View and we combine with Bing Maps (you can look at an angle, usually in the winter so trees with no leaves). Really good remote vision tool to be able [to tell] if you need to make the visit or not.

Sometimes it is also used as part of the preliminary steps in the development of new schemes and designs:

(8) Depending on the scheme we do a consultation and a desktop initial inspection with Street View and then a site inspection until you go into more detailed planning looking at underground services. We can look not only at that street but also nearby streets to have an idea of what's going on.

(9) But relying on Google Street [View is not sufficient as it] is not updated. Images on site would be more reliable, 12 months is a very long period if a tree is under stress and decaying. It's a tool to highlight tree condition as part of a project.

(11) We also use Street View a lot. It's a hit and miss, I find. You can waste a lot of time, not very precise.

(16) Street View is not frequently enough updated to use it.

Nevertheless, it is also sometimes used as a tool to check the accuracy of the visualizations presented by the developers on planning applications:

(14) My usual impression is how accurate it is. I compare it with a tree survey with Google Street [View] or Bing maps just to see how realistic they are. Because a lot of the plans we receive are indicative, wishful thinking.

Also, Street View can be used to investigate if someone has committed an infraction, removing a tree in a protected area without getting the borough's approval first:

(17) Google Street View is a great tool in investigating if someone has removed a tree in a protected area.

Visualizations presented by developers as part of planning applications

Developers sometimes include, as part of the documentation accompanying planning applications, visual aid materials such as pictures from a similar development or visual simulations of the proposed project. The visualizations are not required and developers present them voluntarily to better illustrate the aesthetic impact and the integration of the development in the area.

(3) When the developers use it, it is good because it helps to illustrate what they are trying to say and put the point across more clearly of how they expect the site to develop with new trees.

(2) When involved in schemes we get this type of materials to understand the idea of the design.

(3) On the big schemes it happens quite often [that we get visualizations]. And it is usually prepared for the people working for the developers because they throw a lot of money to get the plan approved.

(5) We use visualizations a lot when looking at new development sites because it shows all the potential landscape. However, as I said before it doesn't necessarily materialize that way. But visualizations are good anyway, they show what I could have had.

Two have experience on the use of visualizations because they used to work for the private sector and had to model the simulations then.

(13) I know about SketchUp because I worked as a private consultant. Once or twice we mocked up the proposed 3D effect with shading showing the progressive growth of trees with real trees and we did that on Photoshop. It's a lot of work, it takes hours and hours. I remember doing one and it took one day. Too much time.

Ten tree officers mention the lack of accuracy of the visualizations presented by developers, which is addressed in more detail in Section 4.3.4. Concerns and limitations.

(5) Developers do the visualizations. It is part of the presentation. This is how they get us all excited. Visualizations are not based on real species or what's beneath the pavement. It is the idea. What they would like to do.

(12) I usually get similar materials. Showing very large trees where trees are not there. We can only determine or decide on materials that are put in front of us. If we don't have what we want, then we have to ask for it (we don't make the visualizations).

(13) This is similar to what you typically get from developers with really nice trees and then the reality is completely different because they run out of money.

3.3.2. Applications

This section includes the responses related to the uses and applications that visualizations can have in urban forestry management and planning.

Responses have been divided into those related to the visualizations presented to the tree officers in the presentation and those uses that they have proposed themselves after seeing the presentation.

1) Proposed visualizations from the presentation

This section includes those responses from tree officers related to the visualizations presented to them in sections 2 to 5 of the presentation. As described in the Methodology, section 1 only presented general visualizations of the area to elicit responses from tree officers about previous experiences with visualizations.

Sections 2 to 5 presented specific visualizations targeted to challenges and messages related to urban forestry management and planning. Those specific visualizations were:

- Tree condition
- Long term consequences of management
- Shade visualization
- Shade modelling as a technical analysis tool

Table 21 summarizes the responses of tree officers related to the visualizations presented in the presentation. Tree Officers' comments about the visualizations from the presentation

have been classified as positive (+), negative (-) or neutral (0) and are detailed in the following sections.

Table 21. Responses from tree officers evaluating the visualizations from the presentation.

Participants	Colour code dots			Colour code augmented reality			Long term			Shade			Shade technical tool		
	+	0	-	+	0	-	+	0	-	+	0	-	+	0	-
Total	4	4	3	9	0	3	11	4	2	10	2	1	6	0	0
	(23 %)	(25 %)	(18 %)	(53 %)	(0 %)	(18 %)	(68 %)	(24 %)	(12 %)	(59 %)	(12 %)	(6 %)	(35 %)	(0 %)	(0 %)

Source: Own elaboration

a) Tree condition visualizations

Two types of visualizations were presented representing graphically tree condition or phytosanitary tree assessment:

- Aerial view with trees represented by colour coded dots
- Street level augmented reality image where trees in a photograph are coloured representing their sanitary condition.

The aerial view with colour dots to represent trees and their sanitary condition was something most of the tree officers had already used in similar formats. Some reported how the management software they use represented trees that way or that they usually get CAD plans from developers with trees colour coded, though following the British Standards Code (in shades of grey, blues and reds).

(6) It is a bit like map info we have that can be linked to aerial view.

(11) Colour coding is nice, we can produce [dots] already with our data base

(14) For initial plans we use British Standard. We use colour coding in greys, blues and reds. It is trees in relation to design demolition and construction. With tree surveys, the most useful piece of information is the categorization in a/b/c.

(15) We look at plans all the time and British standards colour code trees according to their retention qualities: stem position plotted, crown extension, and colour blue, grey those that can be removed...

Aerial view was also considered more oriented for planners, while the augmented reality image was considered more appropriate for being presented to the public or councillors.

(1) Plan views [are] for planners, more familiar and more interested.

(4) They would be useful to send the councillors of all the wards what needs to be done. Maybe a way to educate them.

(7) The most useful [one] at the moment would be the [colour code] for the public.

(8) We've just undertaken a survey in one of our parks which is a natural reserve but also a historical site (one of the first arboretum cemeteries). I did a risk assessment and we colour coded it green, amber and red and people understand it very well. It is very simple, you can see it just like that.

The augmented reality image received positive responses as it was considered a simple but effective way to communicate with residents and politicians.

- (1) This is interesting. I have not seen anything like this before.*
- (5) I like it. I think we as an industry should be open to utilize new technology that can put our case across and make the management of trees more efficient.*
- (7) I like that one. Absolutely. It would be of use. It would help us certainly.*
- (8) That is useful.*
- (11) I quite like it. It is good.*
- (13) That is nice colour coding. I quite like this (augmented reality). If you go to a meeting with residents this could be very useful. It's very simple but it can be very useful.*
- (13) For my proposals I would use colour coding for meetings with residents.*

Those who did not find them useful referred to the amount of work they had and the lack of time and considered that these visualizations did not add any value to processes they were already following.

- (3) We wouldn't do this because we don't have the time. We have 50,000 trees and we have to look at all of them every two years. For special projects it could be useful, we would do it, but not for all of them. It is very detailed.*
- (4) From a day to day management [point of view] this is more than what we would need. To do this I would need someone sitting here to produce the volume of visualizations I would need.*
- (9) The tree condition, I would map that in the a/b/c colour coding and available space. Internally I would visualize without the colour coding.*
- (10) I don't think we would use this because we do on-site inspections and take detailed pictures that then we send by email. I think photos would give you much more information.*
- (16) I prefer to meet them on-site. I don't see how to use them. I prefer to see the tree directly. The only problem I can have is when the defect is internal so people cannot see it. I think [in that case, this could] help more.*

b) Long term visualizations

Most of the participants considered this type of visualizations of temporal sequences very useful and interesting:

- (1) This is the kind of thing that we do automatically, in our mind's eye, internally. But this could be very useful when trying to explain to other practitioners or professionals, planners.*
- (3) Particularly the long term ones would be useful. It would be interesting for certain roads to have images of how trees would look like 10 metres taller. It is certainly something that we would use. Not all the time but for specific places.*
- (4) I like this. That is the valuable one! I would use this all the time. First I would use it as a publicizing tool. I want to do this, look, I want to plant some trees now and this is how it's going to look in 20 years.*

They also thought and commented about the importance of communicating long term consequences of management decisions in urban forestry, which is something generally overlooked by developers, landscape architects and engineers.

(2) It is not something that we communicate to the public generally, the long term thinking, not sure why really, it's a good thought.

(3) Dealing with trees you can't have instant effect. You have to be patient, especially in regards to new trees.

(5) It is also useful when someone says "I love trees but I want this one out". We would be able to show them "look what happens if we cut one tree, it takes many years to recover".

(9) Temporal evolution (simulation) is a good tool if you can link it with root development and map what is supposed to be happening underground. To explain to planners and developers and focus their attention on how to improve tree health in the long term. The next step is to map roots.

(17) Landscape architects forget trees grow. Long term view is important. Continuity is important. There is nothing wrong with heavy planting as long as you plan to thin out in the future.

Most tree officers thought these visualizations could be used when interacting with the general public and residents as well as for planners and other departments:

(3) That would be very useful, for talking with residents. Because we spend a lot of time talking to them. The anti ones are often the loudest.

(13) That's quite good for the residents. Simple but effective.

(6) The growth one would be good for our planting programs to understand more how it would look like, for the planning process. You can use it to consult with other departments within the council or the councillors.

(8) We have been doing this all the time. Especially with our engineering schemes because we are remodelling the trees, lamps, etc. This way we make sure that we don't put trees next to light columns.

(9) That is a very good tool for both the public and from a planning perspective. It is very good from an arboricultural perspective to visualize how big crown is going to get and visualize the soil volume available. We would say to developers "so you want trees this big, that means we need this space of soil volume, can you provide them?"

(10) For the design team that would be interesting because sometimes developers tend to plan a design for something that looks good immediately but they don't think long term.

To be able to simulate tree growth and temporal evolution it is important to have the growth curves for accurate simulation. Officers recognized the lack of such curves for urban tree species in UK and the difficulty in producing them. The urban environment is very site dependent and the same species can grow at very different rates, even with trees right next to each other:

(5) That certainly would be very useful if you have the tool to visualize growth accurately.

(7) In terms of predicted growth you can only do your best with the information you have, but you say the range you are working with.

(14) Some tree officers have attempted to look at tree rings and try to correlate that to age and site conditions. But it is very difficult. I was working in [another borough], there was a Taxodium tree line and one was like double the size than the others. We did not know why and one day they dug up the road and we discovered there was a broken pipe.

The three tree officers that did not see the benefit in using long term visualizations mentioned that they wouldn't use them because their job was more oriented to daily management of the tree stock and they could be more useful for those working in planning and design.

(10) I think it is something that the planning department would be more interested in. We only deal with planting the trees, running them and replacing them. We do not have the resources but also I don't see the benefit.

c) Shade visualizations

59% of the interviewed tree officers commented very positively on the visualizations showing the projected shade by a line of trees and how it changes over the day:

(1) All this would be useful! The level of information on trees you get now is very limited. The more information, the more visualizations, the better.

(5) We use that a lot, we use that system ourselves.

(9) I like that. That is very interesting.

They thought they could be very useful when dealing with residents' enquiries or complaints about street trees shading their property and asking for the trees to be pruned or even removed.

(4) Some people complain about a tree to the North of their property and it is impossible. A tool that demonstrates to them that this is the shade of the tree would be useful. Now I do handwritings.

(6) Quite regularly people ask us to prune trees because of shading their houses. And we go there and the tree is in the North side and they insist "it might give us some light", but then they have a big building right there. This is useful.

(7) Interesting. It would be useful when people complain about shade to demonstrate that the tree is not really the problem. We never remove trees for shade or overhang.

(13) Often with large trees it is the neighbour two houses down, the one that's complaining. Always you have to consider the aspect and you have to tell them that pruning the tree is only going to benefit the neighbour two doors down and it will cost a lot of money. But they just want to see more light. That could be useful.

One even suggested the possibility to implement this as a separate software simple enough to be able to be used for daily management:

(4) A tool that you feed the height of the tree and a general shade and then run the program would be useful to talk with neighbours and for planners as well. Sometimes they put trees in the wrong place.

Sometimes, consultants also present these types of visualizations to argue for the removal or the pruning of specific street trees that are shading their clients' newly developed properties:

(5) Consultants also use them to show how the existing trees are shutting all the light from their clients' new buildings. They use them as a weapon.

One tree officer also considered the tool as useful for internal use to help on species selection for new planting, to evaluate the intensity and spread of the shaded area for different species:

(8) It would be fantastic to have those tools. I tend to use my head to think about the aspect, what would work as far as species selection as well as ultimate canopy shading. Because those sort of things have a big impact; if you are going to plant big canopy trees that are going to make the area completely dark, it is not going to be very inviting and I would be better choosing something with an interesting smaller leaf. I would love to be able to show how daylight affects things and shading. It would be very interesting but we do not have that here yet.

Those who did not comment positively on the shade visualizations also saw the application, though not suited for them:

(10) Again something more for the design team than for us.

One of the participants considered that the area chosen for the visualizations wasn't the most appropriate because it was a commercial area and problems with shading complaints happen mostly on residential areas:

(12) Most of the buildings in that area are office buildings so people do not complain about shade there, there are no residents.

d) Shade visualizations as a technical tool for modelling

The model developed using visualizations to calculate shaded area for different tree sizes, planting design and street orientations was considered by 12% to be an innovative and useful tool:

(14) I haven't seen this kind of materials.

Participants thought of different ways this model would be of use: to deal with complaints related with trees shading residents' properties, for backing up applications to the Mayor Re:leaf Program, for selecting new planting sites with climate change and urban heat island in mind:

(3) It would be interesting to have this data before planting. Even if the model showed up a potential site I would have to look and try to dig on-site. Water mains and electricity, etc. complicate things.

(7) I can see how that would be very useful. For the mayor's Re:leaf program one of the criteria is canopy cover, shading, water management, pollutant capture. This would be a good tool to identify the places in London where shade is most needed.

(9) From my point of view that is very important and if we can estimate the number of hours a property is getting shade we would be able to answer complaints. We would say you are complaining but you only get shade from 2 pm to 4 pm.

(9) Tree shade modelling is fantastic, for the shade of the building and also for plant health.

(16) The model would be useful for planning for heat island, reflectivity on hard surfaces.

The importance of having scientific studies and data to support their decisions and increase their credibility in front of the politicians and the public was also mentioned:

(6) We don't do anything as formal as this, having the science to back up our plans to plant more trees. Sometimes we are accused of being hippies and the data would be useful for that. Insurance companies just see us as tree huggers. Data is important.

2) New applications

The proposed visualizations not only provided examples to tree officers to evaluate but also established the arena for tree officers to consider new applications for visualizations.

Many applications were oriented to communicate with developers, residents, decision makers or colleagues from other departments.

(3) (We have a project where) the developers have not been very cooperative. Some of the trees had been taken down, and we did not mind. Now they plan to put birch trees in a very busy road. Birch trees don't do well with heavy traffic. They don't want to understand. I just hope the planners are strong with them. When we say that they wouldn't do well they say they will just replace them. That's not the point! (...) If their landscape architects would produce something like this it would have been plain sailing. If they were to do something like this and done by someone sensible they would understand.

(14) Also to sell tree sizes to developers showing them that big trees will shade a glass facade and save money on energy, reducing bills. Also the view is important when you look out of the window, also from high floors when you see the green canopies.

(4) They would be useful to send the councillors of all the wards what needs to be done. Maybe a way to educate them.

(6) Useful for public and politicians. Politicians are busy, long presentations and long documents of 10 pages, you have to use something simple an image and how much that cost, that would be enough.

(5) We use them to show: how a place is going to look with trees, how after some time and even how they would look if they are not watered!

Visualizations presented by the developers can be used by tree officers to compare the proposal with the final project execution.

(5) It gives you an overview. It also gives me a stick to bit them when the project is finished.

As described on Section 4.2.3 Challenges, underground services are a huge problem, especially in inner boroughs. Tree officers suggested the possibility of using visualizations to both help them select planting sites and explain residents the impossibility to plant new trees in their street by representing in a visualization the dense net of underground services.

(6) VIZs showing underground services to explain why we can't plant avenues and people do not understand.

(9) Do you have any software to model underground services? That would be very important for us. If someone can do a survey and put that into a software that would be amazing!

(13) What would be very useful is if you had a 3D model of underground services.

Another application of visualizations suggested by tree officers was to look at the impact new development would have on existing trees. That impact could be by reducing the numbers of sun hours they receive, how the new building materials reflect light and how the new structure interfere with that canopy changing pruning requirements which could have an impact on maintenance costs for the borough.

(9) That (visualizations) would be very interesting also from a planning point of view if you can also project what's going to happen in 10 years, if you prune, if you have different species. Also important to know if the trees are getting enough number of sun hours and if they are able to function and grow and develop properly.

(14) One very interesting thing would be to use this to look at the impact of new buildings on existing trees and how shading those trees is going to affect them. We have had some trees that have died when new glass buildings have been built next to them. They have been cooked. Changing the view, no how trees affect buildings about the opposite.

(14) Sometimes we get new buildings with balconies and how that is going to affect the maintenance cost that the council is going to have to assume. It would be good to calculate that impact.

3) Combined analysis

The results of the combined analysis of the comments of Tree Officers to the visualizations from the presentation and their own independent suggestions for the use of visualization in urban forestry management and planning are explained in this section.

A great majority of tree officers found that visualizations would be a very useful tool when used to communicate with residents, politicians and other colleagues. Messages that visualizations could help to convey better are those related to new schemes, works to be done to existing trees or the reasons, impact and following measures in case of tree removals. Tree

officers said the idea of introducing simulations showing time evolution was particularly useful.

As described in previous sections, shade complaints are one of the main reason people contact tree officers. They thought that visualizations could help to make people understand to what extent trees near their property are really shading their garden.

Some participants also suggested the convenience of using shade modelling data to select shade tolerance when needed for new planting sites or to evaluate the impact of new buildings in the number of sun hours existing trees would receive. That kind of information could also be useful for boroughs, shading being one of the criteria for new plantings in the Mayor of London's Planting Plan.

Those who are frequently presented with these visualizations from developers when considering planning applications insisted how important it would be for developers to incorporate accurate visualizations that considered trees and represented them correctly.

Table 22 summarizes all the responses, including both the responses to the visualizations from the presentation and their own independent suggestions.

3.3.3. Visualizations benefits cited by tree officers

Participants thought visualisations were very helpful in communicating things very effectively:

(8) The benefit is that visualizations are instant, just one picture speaks a thousand words. We have done it with residents and councillors.

We have sent plans to residents, if you give the same with a 2D perspective they grasp it much easily.

(15) A picture paints a thousand words, so it's easier to look at the picture than to read the description.

(17) I know about trees but I am very bad visualizing, I benefit a lot from visual materials.

They were seen as a powerful tool that convinces people, can add to the tree officers' skill set and level the playing field with other related professionals:

(4) It could be good to keep up with the materials planners are presenting. They present very nice images with nice lights and benches and they convince people even if we say that they are going to cut the trees. If we were able to also produce an image showing the impact maybe our message would get to more people.

(15) I can see how visualizations can go a long way to move people's opinions into approving or not whether something is going to be built or not.

Some tree officers commented that the visualizations were something that should be integrated soon as it will be demanded by the public. Additionally, more and more widely

available resources that include 3-dimensional information on the urban environment are also being developed very fast:

(3) Visualizations are being used more and more and could be very useful.

(8) Probably as time goes on everyone wants more and more information which is sometimes quite stifling on its own. It is something which would become more and more important as time goes on. And with canopy studies, carbon sequestration, visualizations of where heat islands are could be very useful tools. It would get to a point when that kind of information is going to be demanded.

(11) Would you see yourself doing something like this? Hopefully. In the future that is how things would be done.

(15) I think as time progresses and software [develops] and becomes more successful it will be more common. It will become more and more used and popular [versus] now [that] we only get elevation plans.

Table 22. Summary of the roles of visualizations in urban forestry extracted from tree officers' responses.

Visualization applications	Type of Visualizations	Total	%
To explain new plantings, tree removals or other works to the public, other departments and politicians	- Point of view: ground view - Level of detail: Semi-realistic 3D or realistic 2D photomontage - Content: colour code augmented reality, before and after and long term	13	(76 %)
To visualize tree growth and future problems with trees and buildings and other street infrastructure (street lamps, traffic lights, ...)	- Point of view: ground view - Level of detail: Semi-realistic 3D - 3D navigation important - Content: before and after and long term	3	(18 %)
To model tree growth	- Plan view with shaded area for potential growth - Integration with management software / GIS	1	(6 %)
To visualize tree shade to deal with public complaints	- Point of view: not specified - Level of detail: Semi-realistic 3D - Content: shade evolution along day and seasons	6	(35 %)
To model tree shade to deal with public complaints	Mathematical model of number of shade hours	2	(12 %)
As information for new planting sites on species selection and maximizing shading, etc.	Mathematical model of number of shade hours	5	(29 %)
To model how new buildings would shade existing trees	Mathematical model of number of shade hours	2	(12 %)
For local groups to present more effectively their proposals	Not specified	1	(6 %)
For planners to better explain their applications if the visualizations were based on facts	- More accurate representation of tree species - More accurate positioning of trees - Introduce long term simulations	6	(35 %)
Integration with management software /GIS	Integration with management software /GIS	3	(18 %)
To communicate benefits of urban trees and climate change, urban heat island.	Not specified	3	(18 %)
To simulate views from new or existing buildings (trees can screen providing privacy, block view or improve view)	Not specified	2	(12 %)

Source: Own elaboration

3.3.4. Concerns and barriers for implementation

This section includes the responses related to the concerns and limitations expressed by tree officers about the use of visualizations in urban forestry management and planning.

Responses have been divided into those related with the credibility of the visualizations (accuracy), those related with the adequate level of detail of the visualizations (realism) and those related to the main barriers or limitations for the introduction of visualizations.

1) Accuracy of the visualizations

Almost all the interviewees mentioned the lack of accuracy of the visualizations presented by developers accompanying planning applications. They mentioned the amounts of money involved and the developers' ability to do all that is necessary to get the plan approved.

(1) Visualizations have to be reliable, people have to be able to believe them. They are now very sceptical for a good reason: developers do very nice visualizations of how a development is going to look like and they are not even close. People see visualizations from developers. They don't know anything about trees or landscape and they expect to see that in 5 years' time. And when it is not built they do not blame developers, they blame the council.

(2) I have seen too many concept plans that have not worked. You have to start somewhere, so concept plans are for that but [they are] so far from what actually is done.

(3) It is more an artistic impression that what the tree would look like. You open a tree book and it gives you an image but trees won't look like that.

(4) I would be sceptical when presented with visualizations. I would ask how is this going to look in the future, are they going to be pruned because of the traffic and for being close to a building?

(5) Developers do the visualizations. It is part of the presentation. This is how they get us all excited. Visualizations are not based on real species or what's beneath the pavement. This is the idea. What we would like to do.

(14) My usual first step is to check how accurate it is, I compare it with a tree survey with Google Street [View] or Bing Maps just to see how realistic they are. Because a lot of the plans we receive are indicative, wishful thinking.

(14) I don't quite trust them, the mock-ups. They are quite ambitious. They are very optimistic: no traffic, lots of trees and sunny sky. The perfect aspect to see this building. Either existing trees, replaced by other beautiful species.

There are often different levels of accuracy in the same visualization:

(15) The building, yes it's accurate, materials, size, shape, colour. But typically they would put some trees around because they provide integration, they soften but they are just illustrative.

Sometimes, they discover that trees have been removed altogether from the visualizations presented by the developers:

(14) Very rarely are they accurate. When you see all identical trees and equally spaced on a tree line, they are not really there. Architects don't like trees obscuring their beautifully designed buildings. Often the focus is on the development rather than trees as well. Many times they say that trees have been removed for illustrative purposes only and you see mock-ups with no trees or with indicative trees.

They have not had credibility problems when presenting visualizations they have produced themselves:

(8) Our visualizations haven't been questioned, I don't think so. What we are trying to show is what it would look like. I try to explain that this is how it's going to look like in 20 years, in 50 years we might not be here and in a 100 years who knows.

They stressed the importance of having data backing up visualizations to increase their credibility and defensibility.

(1) Presenting visualizations with data modelling growth for example will increase credibility of the visualizations, as long as the variables are explained [as well as] the uncertainties

(3) If we had access to [visualizations] it would be good. Because this visualization is based on facts, it would be great, particularly for residential roads.

(6) That would be useful to show how the landscape would change. To do some visualizations with data, to support our proposals.

(7) To have that background information is probably vital because if we are questioned by a councillor he would ask "the image is nice but where is the data?" The data backing up is essential.

2) Realism of the visualizations

Some interviewees have expressed that they found the level of realism or simplification of the visualizations presented by the researcher as adequate for the intended purpose.

(7) It is very useful for the visualizations from the presentation if it is not cluttered so the trees are the focus. Still [it is important to show] some details like street furniture, which is essential for choosing planting location and reference.

(11) Real photographs are harder, 3D is neater with cars in the middle and bins. I think people are more receptive to false images. I think it looks very good, it's got style and it's very clean.

One of the tree officers would have liked more realistic visualizations, asking for more detailed tree models and more street furniture in the scene.

(1) The tree models are not very detailed; it could be several trees.

(1) Street clutter would be useful to include.

Another also explained that an interactive model, instead of images or a presentation with several image would have been more useful, especially for internal use.

(9) Being able to navigate is also important, like in Street View.

3) Limitations for implementation

The main barrier that almost all tree officers have mentioned is time. Producing visualizations can be a very time consuming process. Time is a very limited resource among tree officers, especially recently as most of the boroughs have suffered economic cuts resulting in loss of personnel.

The time limitation has been decisive in several cases, denying the possibility of attempting to introduce visualizations altogether. It is not only the time required to create the scenarios and the 3D modelling itself, but also the time required for training and learning new software:

(1) Of course [I would have liked to have had this kind of materials when I have had to present something to colleagues, public or politicians]. Internally we use the materials provided by the developers. We don't have the time or the ability to do this ourselves.

(4) To do this I would need someone sitting here to produce the volume of visualizations I would need. Limitations are resources, money and people.

(8) The main limitation is time. Resources. Our engineers here are working on our projects. If I had the time I would do visualizations for all that planting we have. At the end of the day it's about getting the trees in the ground so we can't expend several months with the consultation and planning process.

(9) We won't be able to integrate that on a daily basis and how [would we] justify buying the software, training [when] we would use that very rarely. If we were to start doing more consultation then yes, something like this would be useful but now we are doing minimal consultation. Now it takes too much time that I don't have.

(16) If it would be fast it would be useful. I would use it if it was fast and easy, to explain when I want to plant a tree or when one has to be removed. The more information the better.

(17) I think we would [use visualizations] but it depends on the contents. If it's a little property you could get to this detail, but is it really essential? For big strategic schemes, visualizations are necessary. For daily management visualizations are not necessary.

Nevertheless, technology advances very fast and the software industry moves very quickly, with a tendency to simplify the processes and make them more intuitive:

(7) It is like a glimpse into the future. Even Street View is so new!

(8) Soon you will be able to set a location and have the 3D model and be able to navigate around it. Now it's time and money to produce them.

(11) And in the future you might be able to do that for every road while now it requires a lot of time.

Many demanded that visualizations should be a feature integrated into their existing management software:

(1) If visualizations could be integrated into our GIS it would be really useful.

(7) The main benefit would be if this could be integrated in our GIS system which is feasible because it is very flexible. Recently they offered a phosphorescent imaging plugin. Street level visualizations and growth would be very useful.

(8) We have Easytreeve. And they are keen to keep developing it with inputs from tree officers and colour coding I think is very important because you can choose it straight away, this is how we should be working.

There is also the possibility of asking someone else or another department for help. Participants' quotes suggest how they are able to access someone trained in visualization techniques and with the necessary software available, depending on the department or section they work in:

(5) The visualizations are done by two of my colleagues who are landscape architects. They use CAD systems and Photoshop. I help them with species choices, and put this sort of thing together.

(7) (when asked about the possibility to ask someone from another department to do the visualizations) Yes there are two GIS people, only two for the council but they are interested in this.

(8) Visualizations are a lot of work but for some situations it could be very beneficial. We have one engineer who is very good with CAD and she makes wonderful mock-ups that make it much easier for other members of the community and for councillors.

They also commented that the usual preparers of visualizations are landscape architects, which as described in previous sections leads to lack of accuracy in the materials. In arboricultural training, landscape visualizations are not taught:

(8) Landscape architects are taught to use those tools; in arboriculture I don't think so, the emphasis is on information not on visual information.

Even if visualizations are a powerful tool to convince people they cannot be seen as infallible:

(5) I think people will look at the visualizations and utilise them as they feel. In ten years of being a tree officer I have never had somebody completely changing their mind no matter how much I tried, no matter how many visualizations, if they originally hated trees.

Another barrier would be the public's capacity to read this kind of materials, as many people that contact them don't have internet and are not familiar at all with technology:

(12) I think visualizations would be good for anyone involved in a planning process where they are used to reading this kind of materials, they will grasp them, interpret them just like that. If I go to an old lady's house and tell her "this is how your tree looks and how it's going to look in the future", she is not going to be able to interpret the picture or she is going to say, "I don't need a picture, I have lived here 30 years."

(12) I think the success of this is that computer power is growing and the new generation would use this every day. When I talk with someone older than 40 on the

phone and I tell them that I am watching their house on Street View, they don't understand. They look out their window to see if they can see me.

3.3.5. Overall evaluation of visualizations as a tool for urban forestry

To finish the section of the findings obtained from the interview analysis I include a general valuation of visualizations as a tool made by the tree officers interviewed. Table 23 summarizes the findings included in this section.

Table 23. Overall evaluation of visualizations as a tool in urban forestry and willingness and easiness to produce visualizations by the tree officers.

Participants	Previous experience with visualizations?			Visualizations similar to presentation useful for them?		Would they see themselves producing visualizations similar to those presented?		Possible to ask someone to produce the visualizations for them? (2)		
	Yes (1)		No	Yes	No	Yes	No	Yes		No
	Produced themselves	Presented to them						Easy	Difficult	
Total	4	5	8	11	6	8	9	4	4	3
	(24 %)	(29 %)	(47 %)	(65 %)	(35 %)	(47 %)	(53 %)	(24 %)	(24 %)	(18 %)
% Total	(53 %)		(47 %)	(65 %)	(35 %)	(47 %)	(53 %)	(48 %)		(18 %)

(1) Those who use Street View only are considered here as not using visualizations

(2) Boxes with "-" indicate no answer was given

Source: Own elaboration

All participants found visualizations a useful tool, if not directly for their role, for at least some fields inside urban forestry.

(1) I would find visualizations very useful not for me but for planners to analyse, also for highways designers [in planning] and for the public if they were openly accessible for local groups when they try to influence public policy to say this is how we want to see things progress

(1) I don't see myself doing this but certainly others from the department like the projects team that present to the public very often. They are already doing it but not to this level of detail.

(4) I think visualizations are more like a planners' tool. I am more of a practitioner. What I need to know is how this is going to last, how long till you come back with a new set of drawings.

About two thirds of the participants found visualisations useful directly for their job and half of them would be willing to attempt to produce the visualizations themselves or to ask someone from their department to produce the visualizations for them.

The reasons why about one third of the tree officers did not see the benefit of the use of visualizations for their job was that the specific duties they were carrying out did not include interaction with other stakeholders other than by telephone or in one to one meetings. Also,

on the occasions when they attended public meetings, they rarely had the opportunity to present support materials. They found that it wouldn't be worth the effort and time investment required to produce the visualizations.

(2) We are the ones who have to make things work. Working at the level that me and my people work, visualizations would not be useful for us.

(13) I don't really see myself doing [visualizations], because if I go to a meeting I usually sit down. Sometimes I have to do a presentation then yes, but that doesn't happen very often.

(13) This is more a planning tool than an operational tool and I am an operational officer. If the tree is dead I put a sign and if people phoned me I just tell them why we are doing so and that is enough.

(16) For the planning department or for landscape architects I see them using [visualizations] but not for me.

They also commented that the way they answered public complaints was already effective and simpler.

(16) I don't have the time and I don't see who would ask me for that kind of information. We don't have time to consult. We send an email explaining we are going to plant a tree, a link to see the colour of the leaves and everybody's happy. They don't demand more; they are happy that we put a tree.

Tree officers expressed their opinion that for those cases in which an email or a phone call were not enough, it was more effective to meet face to face with the concerned member of the public, and inspect in person the specific tree.

Some of the tree officers were already familiar with visualizations and used them frequently as part of their job. Three of them even had made them themselves or asked someone to produce them on a regular basis, as detailed on Section 4.3.1. All those who had used them previously would keep on using them and commented very positively on their applications and benefits.

4. SUMMARY

This Chapter has described the application of the methodology to the chosen case study. It started by describing the case study, offering an overview of the administrative organization of urban tree management and planning in the city of London. Next were described the study area chosen for the visualization and the process of applying the described methodology, the visual materials created and the presentation design. Finally, the results obtained in this study were included in two sections: results from the survey analysis, and results from the interview analysis.

In the next Chapter the results from the dissertation will be discussed in relation to one another and they will be compared with the existing literature.

CHAPTER 5

DISCUSSION

1. INTRODUCTION

The previous Chapter described the results obtained in this study that were included in two sections: results from the survey analysis, and results from the interview analysis.

In this Chapter the results from the study are discussed in relation to one another and they are compared with the existing literature. Given the exploratory character of this study, the research methodology chosen allowed urban forestry managers and planners interviewed to go beyond the research questions in their responses. LTOs brought up a series of issues during the interviews as well as implications of their work that are not covered by the research questions. It was considered important to include these findings too as part of the discussion of the thesis.

The Chapter starts with the description of the context for the use of visualizations in urban forestry management, the existing use of visualizations, and considerations about the level of realism and interactivity of the visualizations. Next, potential applications of visualizations to urban forestry management and planning are provided in Section three. The fourth and fifth sections cover the benefits of the use of visualizations and barriers for the use of visualizations by urban forestry managers and planners. The sixth Section translates those findings into recommendations to effectively integrate the use of visualizations in the field of urban forestry management and planning. Finally, this Chapter also acknowledges the limitations of the study and analyses the strengths of the research design, methodology and application of the proposed methodology.

2. CONTEXT FOR THE USE OF VISUALIZATIONS IN URBAN FORESTRY MANAGEMENT AND PLANNING

This Section offers an overview of the context for the use of visualizations in urban forestry before starting to describe specific application of the visualizations. The current existing use of visualizations is analysed and its consequences are discussed. Next general considerations about the level of realism and interactivity of visualizations that have come up during the questionnaire and interviews data analysis are provided.

2.1. Existing use of visualizations

As we have seen in previous sections, interviewed tree officers were aware of a number of benefits of the use of visualizations in urban forestry management and planning. In spite of this, it was surprising to discover in the questionnaire responses that none of the LTOs acknowledged using visualization tools when answering the multiple choice question (number 2.7 of the questionnaire) “Are there any tools that you currently use for analysis or communications with others on urban forestry issues?”. The choice “Visualization programs” was one of the six available choices, that also included “none” and “other” options.

The interviews conducted after the questionnaire allowed to look deeper into these results. Participants were asked whether they had ever used visualization software and whether anyone in their department used or produced visualizations. During the interviews, one of the Tree Officers explained that he had used visualizations on one occasion at some point in the past but hadn’t done so recently. Another participant declared he had used visualization in a previous position in the private sector, and two others explained that they currently did use them, but clarified that the visualizations were not produced by themselves, but rather by someone in their team / department with training in CAD software. These answers seem to contradict results from the questionnaire, which may reflect the low level of prominence that visualization holds in their day to day work.

The analysis of both questionnaire and interviews data let us explain this apparent contradiction. The wording of question 2.7 could have been interpreted as excluding those tree officers who use visualizations but do not produce them themselves, and those who have used them in the past but not currently. Therefore, a small number of tree officers who use visualizations by asking a third party to produce them, or who have produced visualizations themselves at some point previously, may have gone uncoded. Therefore, it can be concluded that despite coming from many different backgrounds such as arboriculture, forestry, horticulture or urban planning, none of them are currently users of visualization production software (0 out of 56), only 4 have made any attempt at producing visualizations or declared any previous experience with visualizations tools (4 out of 17) and only 2 (2 out of 17) are currently using visualizations and only because they have the possibility of asking someone with the necessary training to produce them for them.

Despite the implementation level of visualizations among tree officers in London being surprisingly low, it is worth mentioning that those that are currently using or had used visualizations had a high level of satisfaction and would keep on using them in the future.

Although only a small percentage of tree officers stated they were producers of visualizations, during the interviews all tree officers described themselves as recipients of visualizations, falling in one of two groups: those working in the planning department, which received them frequently as part of planning applications presented by developers; and those outside planning, who only received them occasionally, from colleagues such as engineers from the highways and planning departments, when their input on suitable species for the new plants was asked.

Planning applications from developers frequently include visualizations like renderings and photomontages of the new development. Tree officers have said that visualizations can help improve the acceptance of a proposed project and can provide them with a tool to check if the project is executed according to the projected specifications. In this last sense, Chenoweth (1991) argued that visualizations could be taken to be binding contracts between project applicant and regulators.

The main issue with the visualizations that are currently being provided by developers as part of the documentation accompanying development applications was that they were consistently evaluated as not accurate and misleading by all the tree officers interviewed. Consequences of this incorrect use and the lack of standards for visualizations are further discussed in the following sections. Additionally, those who have used or are using visualizations have used primarily photomontage techniques. Only the two respondents who could ask a third party to produce the visualizations for them were using 3D modelling techniques.

It is also worth mentioning that none of the visualizations, including those used by Tree Officers and those presented with planning applications, use available technologies like LIDAR data or simulate tree growth. These technologies can facilitate accurate tree model creation and visual simulations, and are currently being incorporated into landscape visualizations used in urban planning and forestry (Czyńska, 2015; Sheppard, 2000) and even in simulation of urban trees elsewhere (Omasa *et al.*, 2007; Rutzinger *et al.*, 2011; Tooke, Coops, and Voogt, 2009).

This data suggest that the implementation of visualizations among tree officers is not only very low, but that the few who are attempting to produce them are not using currently available technologies that can increase visualizations' accuracy and defensibility.

2.2. Considerations about the level of realism and interactivity of visualizations in urban forestry

The renderings from the presentation provided as examples of different applications of visualizations in urban forestry management and planning were semi-realistic. The degree of abstraction in the images was determined by the selection of the software used for the 3D modelling and rendering of the images. The decision prioritized ease of use over realism of the images, in order to present visualizations that the tree officers would be able to produce themselves with little training (see Limitations Section for more details on this).

Surprisingly, few of the LTOs interviewed expressed a positive or negative opinion regarding the level of realism of the proposed visualizations. Only three made positive comments regarding the level of abstraction chosen and only one demanded a higher level of realism. Generally, lay-people demand realistic visualizations, usually confusing realism with accuracy or with quality of the visualizations (Sheppard, 2000). It was therefore surprising that so few expressed concerns about the lack of realism of the visualizations from the presentation.

The literature does not provide a simple answer as to what is the necessary level of realism for landscape visualizations. It is suggested that when aesthetic characteristics are evaluated, the higher the realism of the visualizations the closer the responses for evaluating the images would be to the responses in real life (Zube *et al.* 1987, Bishop and Rohrmann 2003). However, Winn (1997) pointed out that realism and detail may be even counterproductive for cognition, where more abstract renderings can help simplify and explain complex associations in landscapes. Additionally, other authors have expressed their concerns about how a focus on realism can distract viewers from the inaccuracy of the visualizations (e.g. Orland and Uusitalo, 2001; Sheppard, 2001).

One interviewee explained that an interactive model, instead of images or a presentation with several images, would have been more useful, especially for internal use. As explained in the previous sections, one of the main purposes of visualizations used for internal modelling was to explore spatial relation between trees and other street elements such as buildings or street lights. Being able to observe the model from different perspectives would be essential for that purpose.

This kind of human-computer interaction was defined by Heim (1998) as the ability of the user to change his position and perspective. MacEachren *et al.* (1999) extended on this definition through the addition of different kinds of interaction that permit users to manipulate the visualization. Danahy (2001: 126) took cognitive science into account, arguing that the human visual system “requires a combination of the peripheral vision, movement, motion parallax and binocular vision to fully decipher the spatial qualities of a landscape.” Warren-Kretzschmar (2007) concludes that this interactivity will become a more important factor in communication with citizens than having higher levels of realism.

In the case of this study, where spatial relationships were the main objective, the most important characteristic to simulate is volumes. A high level of realism is not needed for this type of interactive visualizations, in fact, as pointed out by Sheppard (1989), abstraction can enhance understanding of some characteristics, such as spatial arrangement.

3. SPECIFIC APPLICATIONS OF VISUALIZATIONS TO TREE OFFICER’S CHALLENGES

Specific applications of visualizations to urban forestry management and planning are provided, based on the comments from LTOs on the visualizations presented to them during the interviews, the applications of visualizations proposed by the tree officers themselves, and on the challenges mentioned by tree officers and how visualizations can help resolve those challenges that existing tools and processes cannot effectively solve.

The applications of visualizations that are going to be described in the following sections are:

- Visualizations as a communication tool: Visualizing aesthetic impact of management operations and new schemes.
- Visualizations as a tool for capacity building: The importance of the fourth dimension and visualizing the invisible.

- Participatory programs and the use of visualizations.
- Visualizations as an internal modelling tool for analysis and design.

3.1. Visualizations as a communication tool: Visualizing aesthetic impact of management operations and new schemes.

Visualizations can be a useful tool for communicating the aesthetic impact of urban forestry management plans and new schemes as they reflect in image form how a project is going to look. This is typically how visualizations are used in fields like urban planning, highway design and architecture, by modelling CAD plans into 3D images or photomontages of the proposed plans that are presented to clients or to the involved stakeholders for evaluation, at different stages of the project.

Communication with the public is arguably the biggest issue faced by LTOs. According to the results from the questionnaire and the interviews, it is one of the two tasks that take the most time out of LTOs' average year (together with hazardous tree assessment). About half of tree officers work with the public on a daily basis and whilst tree maintenance was scored more highly on average than dealing with public complaints in the questionnaire, the difference was not significant statistically. This means that, whilst LTOs already dedicate a lot of time to communication with the public, it is still considered as one of the two most relevant ongoing challenges not satisfactorily tackled by existing tools and processes.

The results pointing to communication as one of the main challenges are consistent with the literature that considers communication between all stakeholders involved in urban forestry as crucial and as an area that requires deeper understanding and research (e.g. (Herzele *et al.*, 2004; Janse and Konijnendijk, 2007; Konijnendijk, 2000; Ronge, 1998).

The fact that urban forestry operates in highly populated areas under constant scrutiny from a variety of stakeholders that want to have a say in urban forestry management, planning and policy-making, is mainly what separates urban forestry from traditional forestry (Konijnendijk, 2000). Cities are becoming larger and urban dwellers are becoming more and more disconnected from natural processes. Normal occurrences such as leaves falling in the autumn, or birds living in the trees become a nuisance for people who flood tree officers with complaints.

Many strategies have been suggested by different authors to improve communication in urban forestry (Johnston 1985, 1989, Rongue 1989, Kennedy *et al.* 1998, Konijnendijk 2000). Konijnendijk (2000) even suggested getting public relations and other agents involved in order to facilitate communication in urban forestry.

Visualizations can help make more fluent the communication with the public and between urban forestry practitioners and politicians, by creating illustrative documents that can be used in advance of carrying out a contentious operation on site, to explain the reasons and expected impact of the projected operations (e.g. pollarding, tree cuts) and thus, reducing the number of complaints.

This is the kind of thing that we do automatically, in your mind's eye, internally. But this could be very useful when trying to explain to other practitioners or professionals, planners.

The power of visualizations as communication instruments follows from the importance of people's perceptions or mental images of a project in shaping their decisions about it (Sheppard 1989). Images are more powerful than verbal descriptions or text because they can cut across differences in knowledge and culture (Lewis and Sheppard, 2006).

I can see how VIZs can go a long way to move people opinions into approving or not whether something is going to be build or not.

Visualizations are more effective than maps or GIS digital elevation models alone, because the higher level of realism makes them easier to interpret (Lewis, Sheppard, and Sutherland, 2004). Also, the ability of visualizations to convey personal, cultural or emotional qualities associated by the public with the landscape exceeds that of cartographic formats, and can assist in predicting the reaction of the community to proposed projects (Lewis *et al.*, 2004).

3.2. Visualizations as a capacity building tool

As was outlined in the Results Chapter, questionnaire respondents agreed most strongly with the statements "A better understanding of urban trees' characteristics and the benefits they provide would make people more open to coping with minor inconveniences such as leaves/fruits/sap/honey-dew" and "People usually want trees to be planted in their neighbourhood but not in front of their houses". All of these statements are tied to people's poor understanding of the urban trees also suggested by the literature as one of the main challenges identified by urban foresters (Ely, 2009; Escobedo *et al.*, 2011; Driscoll, Ries, Tilt and Ganio, 2015)

Through engagement and education of people about urban trees, the benefits they provide and the reasons for and long-term objectives of management decisions, it is possible to reduce the number of complaints. Rongue (Ronge, 1998) (1998) suggested that, due to the public exposure of urban forestry, urban foresters should communicate values, norms, interests and objectives to the public to prevent conflicts arising from urban forestry management.

The management of urban green space including planning, design and resource management requires the collaborative working of many disciplines at different spatial scales (James *et al.*, 2009). This study investigated this collaboration through the perception of LTOs of the understanding of various other stakeholders, on the importance of large mature trees for shading and cooling in a future with climate change. While LTOs believe that other borough staff and councillors or other local politicians have some understanding of this, they feel that developers and the general public have only a poor understanding.

Visualization can help making complex concepts, such as long term consequences, easily understandable to lay people; therefore, they are increasingly being used in decision-support

and capacity-building roles to attempt to bridge the gap between expert knowledge and public understanding (Sheppard and Salter 2004).

3.2.1. The importance of the fourth dimension: visualizing tree growth and long term management consequences

The questionnaire sought to identify which topics were considered to be the hardest or easiest to communicate to the public, with long term consequences of today's management decisions considered the hardest of the topics to communicate to the public. On a scale of 1-5, where 1 was "easiest" and 5 was "hardest", 49% of respondents rated "Long term consequences of today's management decisions" as a 4 or a 5, whereas only 21% rated it as a 1 or a 2.

Street trees are the only element of street infrastructure (green infrastructure) that is alive and that grows / changes size over time. This inherent characteristic of all trees is often the source of conflict with architects and highway engineers who do not take into account tree dimensions at maturity when placing trees in their designs and other street furniture around them.

That is a common problem with trees and street lighting. Now the light engineers sit next to me. I would go and plant trees and then the engineer would come and put a light right next to it and ask me well they are like that and I would say, no, its a tree, they grow!

Landscape architects forget trees grow. Long term view is important. Continuity is important. There is nothing wrong with heavy planting as long as you plan to thin out in the future.

The issue here is to recognise not only the three-dimensional nature of trees above and below ground, but also the fourth dimension in that trees, as living entities, grow and their requirements change over time (Anom. 2007). The fact that long term impacts of tree management decisions are measured in periods of tens of years, often periods that extend past a person's lifespan, makes them very difficult to understand and evaluate by non-experts. Visualizations have been used in forestry to communicate long-term impact of forestry management to different stakeholders (refs here!)

The experimental proposed visualizations, simulating tree growth and aesthetic impact over time due to the replacement of a dying tree in an existing tree line, were the type of visualization that received the highest number of positive comments from interviewed tree officers, supporting the important and unique potential of visualizations in revealing future consequences. The power of visualizations is that they allow "time travel", showing not only present but also future conditions (Sheppard 2012).

One way of visualizing this type of long-term tree growth using L-systems, an empirical tree growth model, was shown by Rudnick *et al.* (2007). They defined 20 time steps per annum over a period of 40 years and applied branch production rules to individual branch segments

on the basis of their biological response to competition for light and space, in order to generate relatively accurate and life-like growth for the different species for display in computer visualizations. This continuous visualization of tree growth, though possible, is not yet technically easy to achieve and might not be accessible to urban forestry practitioners. The visualizations produced for the present research showed tree growth and long-term evolution of management impacts, not in a continuous simulation but modelled as a series of 5 snap-shots or images showing the trees at different “key moments”, which appeared to be well received being the visualizations that got the highest number of positive comments.

3.2.2. Visualizing the invisible

Visualizations can be used to translate into images processes that are not visible to our eyes, because they are hidden (such as in tree root visualization), because what we are trying to transform into images are abstract concepts (like tree condition), or because they are natural phenomena that can be measured but not seen (like temperature). In this way visualizations can be used as educational as well as capacity building tools.

Silva (2012) proposed a methodology to visualize the invisible image of cities by translating into images city dynamics captured by a participatory network of sensors.

In urban forestry management and planning, there are a number of phenomena or hidden objects that could be visualized. Below follows a discussion for each of the following proposed phenomena / hidden objects:

- Tree condition visualization: colour coding
- Visualization of the environmental benefits of urban trees
- Roots and underground services visualization

1) Tree condition visualization: colour coding

Tree condition can be visualized using augmented reality by colour coding trees in a photograph following an intuitive green-amber-red code to represent three possible conditions of street trees (healthy, average and critical). This proposed technique to visualize tree health condition have been tested by recording LTOs responses to this type of visualization, 75% of which were positive comments, establishing this example as one of the three better valued visualizations. Colour coding is a common tool used in graphs and data visualization. LTOs frequently used a colour code of blues and greys to represent trees according to the British Standard 5837 Trees in Relation to Design, Demolition and Construction.

Colour employed in augmented reality images should be chosen carefully. Salter (2005) colour coded different tree species in landscape visualizations, being careful not to choose a set of colours that had a cultural link to wrong or bad, while, in the proposed tree condition visualizations, a meaning loaded code made the information more intuitive and easy to grasp.

2) Visualization of the environmental benefits of urban trees

The benefits of urban trees were considered to be one of the three topics that were the easiest to communicate to the public. The benefits of urban trees were considered easier to communicate by Inner London LTOs than their Outer London counterparts. This is perhaps to be expected as the residents living in inner London live in more urbanized environment where trees are a scarcer and more valued natural element. Stakeholders with whom the Inner London LTOs communicate live in a more urbanised environment with lower density of urban trees.

However, it was agreed by most of the tree officers that a better understanding of the benefits of urban trees was needed, particularly for street trees that were less valued than trees in parks, especially in outer London boroughs.

Visualizations can help communicate environmental benefits of urban trees, in particular there are two messages that were considered of special relevance: the importance of shade trees in a future with climate change, and the importance of retaining big mature trees.

a) Importance of shade trees in a future with climate change

Without any doubt the benefit of urban trees that was least understood and least valued by Londoners was shade. Shade was the reason for complaints pointed out most often by interviewed tree officers. Traditionally in the UK, trees causing heavy shade on buildings, gardens and public spaces have always been viewed as being detrimental (Anom. 2010).

It is interesting to compare attitudes toward trees and shade in London with other places with warmer climates where shade from trees is appreciated. There is an extensive body of research about environmental benefits associated with shade trees coming from the USA, Mediterranean countries, China, South Africa (e.g. Spronken-Smith and Oke 1998, Laforzezza *et al.* 2009).

LTOs pointed out that people are not yet aware of the role trees need to play in climate change and more action is demanded from authorities and other private sectors. Urban trees are fundamental elements in cities adaptation to climate change (e.g. Huang *et al.* 1997, Gill *et al.* 2007). A better understanding of street tree benefits and how important they are going to be in a future with climate change might make people cope better with inconveniences caused by trees, such as trees shading their houses.

British people love the sun but they might want shade in a warmer world, for example to slow down the expected increase in need for or use of air conditioning. The expected impacts of climate change in the UK, particularly in urban areas, will mean that trees that provide a dense shade will become a valuable asset (Gill *et al.* 2007, Greater London Authority 2008). Their attitudes to having shade trees near residential buildings might change if they understood how much that specific tree was benefiting them and would benefit them in a warmer world by helping them save energy.

The presented visualizations showing a perspective of the area shaded by street trees in Buckingham Palace Road, at different hours of the day, were the type of visualizations receiving the second highest number of positive comments, and were considered of interest

by 10 out of 17 of the interviewed tree officers. They were seen as being able to demonstrate to people the hours of shade provided by the specific tree that they were complaining about for shading their property. They said that on numerous occasions the tree that people were complaining about did not really shade their house.

Interesting. It would be useful when people complain about shade to demonstrate that the tree is not really the problem. In any case, we never remove trees for shade or overhang.

One even suggested the possibility to implement this as a separate software package, simple enough to be used for daily management:

A tool that you feed the height of the tree and a general shade and then run the program would be useful to talk with neighbours and for planners as well. Sometimes they put trees in the wrong place.

b) Importance of big mature trees

The loss of mature trees was a focus of concern for a third of the interviewed tree officers and explained the several reasons why mature trees are being felled and substituted by smaller species.

Mature private trees are being cut because of construction of back gardens and the elevated costs of tree care and legal responsibilities of tree owners if trees or their roots damage neighbours' properties.

We are losing big trees in back gardens for several reasons: cost of tree care; building extensions or back garden buildings, right where big trees are (away from the house), so they cut the trees or they cut most of the roots; and basements (not much on this borough but in others a lot).

At the same time, mature street trees on clay soils are also being cut due to subsidence. In some cases, they are being replaced but only with smaller species.

The borough's tree canopy has been reduced because of subsidence. We maintain them as pollards but sometimes we have to remove them and when replaced we plant something completely different. We have been changing species because subsidence, still big trees where we can but most of the borough is on clay soil.

Developers are keen to use all available space on new developments for construction and existing trees are cut and replaced with new young trees. Some boroughs use the criteria of replacing mature trees with the necessary number of small trees to reach similar canopy cover, but often new trees are planted on private land so there is no borough control whether they live or die, they are often neglected, and landscaping is usually left until the end of the project when developers have frequently run out of money. Projected landscaping consequently often doesn't get carried out.

Trees are not a priority. I am afraid we are not making progress on green infrastructure. Worst now with the crisis. Reason is money. Green stuff is left for the end of the project when already money is tight. No one check if the planted trees are kept alive because within a development trees remain private.

This felling of big mature trees is important as new big trees planted will never have the same underground space for root development that big trees had in Victorian times. That limits their lifespan and will limit the size they reach at maturity.

Additionally, development cycles have become shorter in urban areas, particularly in non residential and commercial sites where they are often less than 30 years (Anom. 2010). This means that trees are increasingly subject to similar considerations to those applied to the rest of developments in that trees that are planted are not allowed to reach maturity due to being removed as part of the subsequent development cycle.

The problem is that most urban infrastructure life span is 20 years. Every time they make a new scheme they remove all trees and plant new ones. We have to change the idea that trees can be removed. Trees should be the permanent elements in the urban landscape and the concrete, the buildings the ephemera. That would be the only way to have mature big trees.

Sustainable planting of long term structural trees intended to survive each development cycle should be a priority. This shrinking canopy, which takes place one parcel at a time, is often not generally noticeable to the public. Visualizations could be used to show this effect over time as a cumulative damage / loss of cover and draw attention to this creeping but huge issue.

High oblique and low oblique visualizations showing how big landscape trees have been substituted with smaller species, and how those new trees would look over time would emphasize how urban landscapes are changing. Growth simulation should include factors such as different species size at maturity and also how current underground restrictions affecting root development and harsh urban environment conditions influence tree survival rates.

Additionally, borough scale maps or aerial photographs showing colour coded symbols for big mature trees vs younger and/or smaller species could help people understand how this phenomenon is extending all over London.

Initiatives like Treezilla which are aiming to obtain UK scale urban trees inventories that include both public and private trees would help to get real data about the magnitude of the problem and would offer an excellent data base to be used for visualizations.

3.2.3. Roots and underground services visualization

Trees can be a nuisance and can be a threat to people's most precious possession: their house That is why tree officers agreed with the sentence "people want trees in their neighbourhood

but not in front of their houses”, and in the interviews mentioned that people often say in their letters “I love trees but not the one in front of my house/my neighbour’s”.

Subsidence has had a great impact in the media and tree officers pointed out the influence of a media campaign about the subject and the rise in the number of complaints related to subsidence and root damage. Nevertheless, removing trees sometimes can exacerbate the problem in clay soils when the tree is older than the house and that is something people are not aware of. Subsidence is a subject that is perceived as alarming and not very well known by the public. Visualizations can help visualize tree root development to help people better understand the phenomenon. Also, as described in previous sections a better understanding of the benefits associated with having trees near houses can help people cope better with minor cracks or similar damages when they are only an aesthetic problem.

The fight for space in London between development and trees is not only above the ground. A common complaint of interviewees was that service companies had occupied ground without any control or regulation of underground public space, making it almost impossible in many areas to find spaces for trees.

Location is very important. Sometimes we want big trees and we identify the place where we want them but then because of underground services its very complicated.

The statutory companies can dig up the pavement as they want. We have given up our pavement space to them. They do as they like because if the local authority were to say “no”, people with no phone or electricity would complain. I hope in new development its getting organized. If it would be standardized, we would be able to plant millions of new trees.

The Trees and Design Action Group, pointed out in their report No Trees, No Future (2007) that underground services should, wherever possible, be routed in shared service ducts, which allow for ease of both maintenance and upgrading access, and which avoid sterilising the availability of large underground areas for planting and root growth. This requires well-managed and early- stage co-ordination between diverse organisations and service providers. New or renewed services should be designed and constructed to accommodate or withstand potential tree root growth and subsoil movement. New trees to be planted near existing services may require special considerations regarding species selection, tree pit design and precise location.

If cities want to increase canopy cover they will have to consider not only available space on the surface but also underground space. Available spaces are often very reduced which means only small to medium trees can be planted. Big trees, which are the ones that provide the most environmental benefits (McPherson *et al.* 1997, Maco and McPherson 2003), require big soil volumes to establish and grow in the already harsh urban environment.

The lack of accurate plans of underground services also increases planting costs, as the council need to dig to look for adequate space. Tree officers asked for accurate 3D maps of the existing underground infrastructures and services, which would be immensely useful to facilitate tree planting locations.

Visualizations of root balls can be used to explain developers' underground space requirements of trees, to make them aware of taking this into account in early stages of the design. One of the interviewees suggested the potential use of temporal evolution simulations, linking them with root development for underground services location. It would help to explain to planners and developers, and focus their attention on how to improve tree health in the long term.

Temporal evolution (simulation) is a good tool if you can link it with root development and map what is supposed to be happening underground. To explain to planners and developers and focus their attention on how to improve tree health in the long term. The next step is to map roots.

Simroot is a geometric simulation model of plant root systems (Lynch *et al.* 1997) that allows a continuous viewing of the root system during growth. Methods for non-destructive visualization and quantification of roots have been described using computed tomography (CT) (Perret *et al.* 2007) or using impulse Ground Penetrating Radar (GPR) (Wielopolsky *et al.* 2000)

Additionally, visualizations of underground services would also be very useful to explain to the public why it is not possible to plant trees in certain streets, as people are not aware of the dense net of services that occupy London's underground space and how much land is precluded by these utilities.

3.3. Public participation and visualizations

Beckley *et al.* (2006) define public participation tools as various techniques and mechanisms of public participation, ranging from workshops and focus groups to websites. Going into the study, the author was expecting public participation programs to be one of the key issues / challenges of LTOs. However, in the questionnaire, LTOs indicated that participation programs were the task that they dedicated the least time to of all. The interviews were used to further test this area with varying findings.

Not all participatory programs have proved to be effective. Friend Groups and Tree Wardens differ in usefulness to tree officers. Demographics of the areas around parks and green areas and borough demographics in general can have an influence. Effective participatory programs increase the number of public inquiries that report useful information to tree officers, as referred by 25% of the participants in the interviews.

Street tree adoption campaigns on the other hand have been proven to be very effective in tackling the bigger problem with the public of street trees. People who take ownership feel involved and that changes their attitudes. Also they increase the rate of tree establishment on new plantings (Bentley-Walls 2005) and save money to the borough, both by taking care of the trees and alerting of possible problems fast and effectively but also reducing the number of new trees to be replaced. LTOs' opinions on public consultation were very

polarized. While a small number of them (12%) did consultations periodically, most of them avoid it, at least until after the trees had been planted.

Public involvement can not only reduce the cost and pressure on local governments (Kobori and Primack 2003) and enhance the effectiveness of management programs (Donaldson-Selby *et al.* 2007), but also produce citizens' greater satisfaction with outcomes resulting from their efforts (Sommer *et al.* 1994, Kobori and Primack 2003). Participation in decision-making could provide citizens with a valuable opportunity to express their views and needs, thus enabling relevant decisions better adapted to their diverse needs. More importantly, through such participation, citizens could gain a sense of empowerment and control and further promote good use of and better care for urban parks (Kaplan 1980, Kobori and Primack 2003).

Visualizations have been used in participatory planning and public consultation in landscape planning and forestry for different reasons. First, visualizations can facilitate public consultation and participatory planning processes effectiveness by engaging non-experts in land-use planning processes (Al-Kodmany, 2000; Campbell and Salter, 2004; Sheppard, 1989; Sheppard 2012). Also, relatively few people can look at a map and visualize the landscape that it represents. Pictures ultimately say a great deal more than an abstract, often confusing, assortment of points, lines, and polygons (Lewis *et al.*, 2004). Visualizations can translate complex technical documents into easy to understand materials (Sheppard and Salter 2004), facilitating the dialogue between experts and non-experts.

Human responses to visual stimuli such as landscape visualizations can be broadly classified according to the following categories: engagement (level of interest and attention); cognition (related to knowledge, awareness and understanding); affect (related to feelings, perceptions, and emotions); and behaviour (related to changes in behaviour of the viewer) (Appleyard 1973, Zube *et al.* 1982). Visualizations can make explanations from urban tree managers easier to understand and more interesting and engaging helping to increase people's awareness about urban trees benefits. This new knowledge can change people perceptions and attitudes toward urban trees, making them more tolerant to tree related nuisances (e.g. leaves falling, fruits falling) and can increase their appreciation towards trees, even those situated near their houses, therefore reducing the number of tree related complaints. The new interest and the new appreciation towards urban trees would make people also more prone to participate in volunteer campaigns, friend groups or tree wardens groups, among others.

3.4. Internal modelling tool for analysis and design

LTOs referred to many of the visualizations in the presentation as "what they already do in [their] heads". This ability to simulate several alternative present and future scenarios constitutes a powerful tool to assist with planning and management decisions.

Visualizations can help decision making when different alternatives are being considered by providing a visual view of the impact of different management plan proposals on aesthetics and trees.

One very interesting thing would be to use this to look at the impact of new buildings on existing trees and how shading those trees is going to affect them. We have had some trees that have died when new glass buildings have been built next to them. They have been cooked. [Changing the point of view, don't think about] how trees affect buildings but the opposite.

Additionally, as an internal modelling tool, visualizations can let tree officers experiment with different species, planting designs and planting locations evaluating the spatial relations between trees and other infrastructures before the trees are planted. Moreover, by introducing growth simulation for future scenarios, it is possible to study possible future spatial conflicts and shade footprint evolution, helping management, species selection, planting site selection and studying the effect of future buildings on existing trees.

[visualizations] would be very interesting also from a planning point of view if you can also project what's going to happen in 10 years, if you prune, if you have different species. Also important to know if the trees are getting enough number of sun hours and if they are able to function and grow and develop properly.

One tree officer also considered shade visualization modelling as useful for internal use to help on species selection for new planting, to evaluate the intensity and spread of the shaded area for different species:

It would be fantastic to have those tools. I tend to use my head to think about the aspect, what would work as far as species selection as well as ultimate canopy shading. Because those sort of things have a big impact; if you are going to plant big canopy trees that are going to make the area completely dark, it is not going to be very inviting and I would be better choosing something with an interesting smaller leaf.

Planting criteria for species selection is based on LTOs' expertise but sometimes they feel they don't have much room for experimentation, as a young tree dying is considered a "failure" and something bad if seen by the public. Virtual experimentation using visualization tools with different species would let urban forestry practitioners evaluate and incorporate new tree species, decreasing the risks. Visualizations have the ability to present alternative futures side-by-side and pose 'what-if' questions (Ervin 1998).

The proposed application of visualizations as a technical tool for analysis was a model from an ongoing research project that identified street tree planting locations to maximize shaded area by the trees, taking into account tree size, planting frame and design, and street characteristics such as street orientation, street width and height of the surrounding buildings (Macias 2014). Visualizations were the instrument used to calculate shaded area by the trees, isolating it from the shade provided by the buildings. The idea of having a model to calculate shaded area by the trees and surrounding buildings was considered interesting by six of the interviewed LTOs.

4. BENEFITS

Visualizations are a tool that provides multiple benefits for the field of urban forestry management and planning. Many have been mentioned along the dissertation and have also been mentioned by the tree officers in the questionnaires and interviews.

LTOs expressed a number of potential applications and benefits of visualizations in urban forestry management and planning. The first benefit expressed by interviewees was the effectiveness of visualizations as a communication tool, allowing them to get their messages across clearly, effectively and fast.

By using visualizations urban tree managers and planners would be able to translate complex technical proposals and management plans into images that would be able to be easily understood at the same time by colleagues from different departments, politics and the lay public. Visualizations have proved to be more effective than maps or GIS digital elevation models alone, because the higher level of realism makes them easier to interpret (Lewis *et al.*, 2004).

Moreover, visualizations can be used to educate and change the public's attitudes toward urban trees. By translating into images invisible processes such as tree root development or abstract concepts like tree condition or the benefits of urban trees, they could be transformed into easy to comprehend documents that will increase people's understanding of urban trees. This new awareness can change the way people see trees and change their attitudes towards them.

Visualizations are more and more being used in decision-support and capacity-building roles to assist in bridging the gap between expert knowledge and public understanding, as they can help make complex concepts, such as the impact in the long term of a change today, easily understandable by lay people (Sheppard and Salter 2004).

Visualizations can increase community involvement and facilitate participatory planning. 3D geographical visualization can assist in collaborative planning processes, both in urban and rural contexts (Bishop *et al.* 2005, Pettit *et al.* 2004) (Isenberg *et al.*, 2011).

The ability to simulate several alternative present and future scenarios constitutes a powerful tool to assist with planning and management decisions. Visualizations have the benefit of letting urban forestry practitioners plan better spatial relations between trees and other infrastructures and experiment with different species and planting design, before the trees are planted.

Additionally, by using visualizations, urban forestry managers and planners would be using similar tools as urban planners, architects and landscape architects, that would help them integrate better in multidisciplinary teams by demonstrating similar technical capabilities.

Finally, visualizations presented to urban tree managers as part of planning applications have the advantage of providing a way to verify the project once the development has been finished, by comparing the result with the visualization of proposed conditions.

5. BARRIERS

This Section will describe and analyse the barriers that can difficult the use of visualizations as a tool for urban trees management and planning. There are mainly two: first, the lack of standards for the correct use of visualizations, which is allowing an incorrect and misleading use of this tool; second, the difficulties associated with the technical complexity of the visualization software itself that makes adequate training time consuming.

The reasons that can explain the limited use of visualization among tree officers and that are described below are:

- Lack of standards for visualizations.
- Lack of training.
- Lack of time and resources.
- Lack of access to someone trained in visualization production techniques.
- Lack of adapted tools.
- Lack of data sources and models.

Recommendations on how to overcome the mentioned barriers are provided in Section 6 of this Chapter.

5.1 Lack of standards for visualizations

One of the main problems of visualizations that are currently being provided by developers as part of the documentation accompanying development applications is that they have been consistently evaluated as not accurate and misleading by the tree officers interviewed.

Terms such as “not accurate”, “wishful thinking”, “ambitious” or “very optimistic” have been repeatedly used to describe the visualizations which suggests a pattern of misleading too optimistic visualizations. Developers try to influence the approval of their planning applications by providing visualizations that present their project under ideal conditions altering illumination of the scene, including or eliminating vegetation or other elements of the scene and selecting the most convenient viewpoints.

I don't quite trust them; the mock-ups are very optimistic: no traffic, lots of trees and sunny sky. The perfect aspect to see this building. (...) Existing trees are erased or replaced by others of beautiful species.

Visualizations are not part of the compulsory list of documents to include for planning applications because the same rules apply for big developers and for private residents applying for permission for a home extension, and it is considered too onerous for a private resident to be required to produce a visualization. Developers frequently include them voluntarily, knowing the persuasive effect this type of material can have. Nevertheless, and even when visualizations are not part of the compulsory list of documents to include for

planning applications, but are included voluntarily, they should be subject to the same controls of precision and reliability in place for the rest of the documentation (including other graphic documentation such as CAD plans).

Furthermore, LTOs pointed out that, since trees are usually not one of the main elements in the proposals, landscaping is usually left for the end of the project when in many cases budget is very tight and that causes the executed project to be far from the initial plan presented in the proposal.

This lack of importance attributed to trees often is reflected in presented visualizations that can present different levels of accuracy in the same image for the buildings and for the trees. Sometimes trees are not even considered, and are eliminated from the visualizations “for illustrative purposes” so they do not block the view of the proposed building. In other cases, when they are included, trees are represented with a lower level of accuracy compared with the other elements: when trees are modelled realistically, the species represented do not correspond with those specified in the proposal or with species that are adequate for London’s climate; in most cases though, trees are represented by random non-realistic models that could be any species; additionally trees are scattered along the model with the only objective of improving the look of the new building and subsequently they are in occasion located over basements or in other locations where trees cannot be planted.

*Visualizations are not based on real species or what’s beneath the pavement.
[They show] very large trees where trees are not there.*

[We] typically get [visualizations] from developers with really nice trees and then the reality is completely different because they run out of money.

This lack of standards for visualizations and the current incorrect use of visualizations is affecting the credibility of the borough as people identify the local authority as responsible for the images and the fact that the project execution doesn’t reach the expected results.

People see visualizations from developers. They don’t know anything about trees or landscape and they expect to see that in 5 years’ time. And when it is not built they do not blame developers, they blame the council.

The potential consequences of such an incorrect use of visualizations have been pointed out by Sheppard (1989). There is a risk that they will lead to poor decisions in planning, with unworthy projects given planning approval. Incorrect visualizations lead to the use of misleading information and can create distrust of other potentially accurate visualizations by association.

5.2. Lack of training

Though many Tree Officers used GIS or CAD plans they were not familiar with the creation and modification of such materials. This lack of familiarity will difficult a possible training on

other visualizations techniques such as 3D modelling even if focussing on easy to learn software like SketchUp.

Landscape architects are taught to use those tools. In arboriculture? I don't think so. The emphasis is on information not on visual information.

The lack of training on GIS, CAD and 3D modelling would limit the production of visualizations to photo-alteration techniques using software like Photoshop therefore reducing the potential use and available possibilities (e.g. unlimited view-points, atmospheric conditions manipulation, creation of sections)

5.3. Lack of time or resources

The main barrier pointed out by all interviewed tree officers is time. Current visualization production techniques require a lot of time which is a very scarce resource among LTOs, especially after the latest round of budget cuts which resulted in personnel loss.

It is also important to consider the time that would be needed for training in the use of the visualization software. Given that tree officers do not currently use CAD and are not familiar with any kind of visualizations software, training time could be considerable.

5.4. Lack of access to someone trained in visualizations production techniques

A way to overcome the lack of training in the production of visualizations and the lack of time and personnel would be to have easy access to someone trained in visualizations production techniques.

Only one fourth of interviewed tree officers mentioned that they would be able to ask someone from the planning department to do the visualizations for them, though half of those pointed out that it would be difficult due to the amount of work those able to produce the visualizations already have.

It was observed that the departmental organization of the boroughs and the department in which the tree section is located influenced urban forestry management and planning and the use of visualizations in several ways. Firstly, the degree of integration of tree officers and trees in general in the planning decision process had impact on the degree of integration of trees in the design, level of management of trees and the level of conflicts between street trees and other street infrastructure like street lights, traffic signs and traffic lights. Second, it also affected the level of access to personnel from the planning section such as designers and other people with CAD training that could help with the occasional visualization for those tree sections that otherwise could not have justified the time and money investment required to train someone inside the tree section and the cost of purchasing the software.

5.5. Lack of adapted tools

Visualization software has evolved to adapt to the demands of their most frequent users. Visualizations are mainly produced by architects and landscape architects in urban environments and recently landscape visualizations have been incorporated into forestry management. Therefore, many computer programs use similar concepts to the ones from CAD software, which are the tools most frequently used by architects.

On the other hand, foresters use GIS based software for their management operations and visualization software developed for forestry management is based on that technology.

Urban forestry management software has evolved to adapt to the requirements of the sector to use a detailed database, linked to georeferenced position of the trees and with the inclusion of modules for inspections forms. Existing visualization tools are not compatible with the software used by tree officers that would need to learn a completely new technology.

During the interviews, tree officers thought the best way for them to facilitate visualization production would be the integration with their management software or GIS.

The main benefit would be if this could be integrated in our GIS system which is feasible because it is very flexible. Recently they offered a phosphorescent imaging plugin. Street level visualizations and growth would be very useful.

We have Easytreeve. And they are keen to keep developing it with inputs from tree officers and colour coding I think is very important because you can choose it straight away. This is how we should be working.

Schmoldt (1992) defended that technology should adapt to natural resource managers and not managers adapt to existing technology. Therefore, if research and urban forestry managers and planners say visualizations are useful for urban forestry, software companies should consequently develop adequate tools.

The objectivity of visualizations could also be improved by referencing geographic data or including technologies like LIDAR data bases (Lange 1999). Additional benefits could be obtained from greater interactivity as it would provide users with greater control over the process. An example of this could be permitting users to select different perspectives from which to view the visualization (Schroth 2008).

5.6. Lack of data sources and models

To be able to produce accurate visualizations libraries of urban tree models would need to be developed because street space restrictions and traffic requirements force to prune street trees in a very different way to trees located in parks or other open spaces.

[Trees in visualizations are] more an artistic impression than what the tree would look like. You open a tree book and it gives you an image but trees won't look like that.

The lack of growth curves for the majority of geographic areas and urban tree species has important consequences for the accuracy of 4D visualizations. To be able to simulate tree growth and temporal evolution accurately it is important to have the growth curves. Unfortunately, not many growth curves have been modelled for urban species.

Having to model a multitude of management options over long time scales on tree sites subject to changing dynamics, makes forecasting urban tree growth challenging (Reineking *et al.* 2004). Empirical urban tree growth models, like i-Tree Eco or L-system (Prusinkewicz and Lindenmayer 1990), have been developed for North American species (Nowak 1994; Nowak *et al.* 2008; Brasch *et al.* 2007)), South Africa (Stoffberg *et al.* 2008) or Italy (Peper *et al.* 2001) but no similar work has been performed in the UK.

Accurate data may be crucial to credibility of the visualizations, especially if the data-gathering process and processing in the visualization can be explained to potential sceptical observers. Technologies such as LIDAR data, due to their self-verifying visual nature can be an advantage (Sheppard, 2000).

6. RECOMMENDATIONS FOR PRACTICE/POLICY

A set of recommendations are made below in order to overcome the barriers and facilitate visualizations use and the effective implementation of the use of visualizations in urban forestry management and planning and to ensure those visualizations are produced and used correctly.

Recommendations should cover two important areas:

- How to encourage and enable LTOs to use visualizations: overcoming the barriers
- How to regulate the use of visualizations so that they are used consistently and correctly: defining a common set of standards

6.1. Encouraging and enabling the use of visualizations in urban forestry management and planning: overcoming the barriers

To overcome the barriers described in the previous section and to facilitate the implementation of visualizations as a tool for urban tree management and planning, the following recommendations are provided:

- Regular training/upgrade on communication skills including the use of visualizations to urban tree managers and planners.
- Adapt technology to the demands of urban tree managers and planners.
- Restructure departmental organization of the boroughs.

6.1.1. Regular training/upgrade on communication skills including the use of visualizations to urban tree managers and planners

Urban tree managers and planners should have a regular training on communication skills that include the use of visualization.

Current visualization tools require a significant investment of time to learn to use the software. Whilst this investment would save them time in the long term, it is unrealistic to ask LTOs to dedicate the time required unless policy is adapted and time for training in visualizations is allocated.

It is recommended that the foundation training on visualization techniques and other communication skills is provided at universities as part of the arboriculture or urban forestry curriculum which would facilitate that urban foresters were already familiar with visualizations when they initiate their professional life. This initial basic training would reduce annual training times that would be limited to upgrading and improving their skills. Furthermore, a basic training would make them approach visualizations with a different mind-set and could stop them being viewed as a tool exclusively for architects and landscape architects.

Even if they were to ask a third party to produce the visualizations for them, they would need to be familiar with the potential sources of error and distortion to specify the visualizations they needed and review draft visualizations. The Standards for the Use and Production of Visualizations in Urban Forestry proposed in following sections would also be of help and can be used as guidelines when the visualization production is outsourced.

Sheppard *et al.* (2004) suggested three different options for implementing the use of landscape visualizations for First Nation and small rural communities in Canada: Third-Party Implementation, Basic Implementation, and Advanced Implementation. They suggested the choice should be based on community resources, skill base and their land management goals.

A similar approach could be followed in urban forestry adapting the level of implementation and therefore, the investment in training and resources, depending on the Urban Forestry Management Goals established in the Tree Strategy, the department and Local Authority available resources and the existing level of GIS, CAD or other visualization skills among urban tree managers and planners or other departments open for collaboration.

6.1.2. Adapt technology to the demands of urban tree managers and planners

Effort should be put into adapting technology and visualization software to suit the needs of urban forestry.

As mentioned in Section 5.2.4 of the analysis of the results, most Tree Officers use a GIS system to store tree inventory data and position and about a third of them use an additional separate software specific for urban tree management.

Urban tree management software has evolved rapidly to adapt to technology changes and to be compatible with GIS and CAD programs. The literature suggests that future tree management software will be cloud-based and open source (Maastikuarhitektid 2012). The

next step would be to integrate visualization tools with existing urban tree management tools and software, even if all they can offer are basic semi-realistic visualizations; there is no need for photorealistic renders to start with. New emerging technologies like existing 3D city models and technologies that are more available every day like LIDAR databases will facilitate this integration that is already happening in other fields such as urban planning (Czynska 2015).

To be able to simulate tree growth and to simulate accurate visualizations, growth curves specific for urban trees and libraries of urban tree models would need to be developed.

6.1.3. Restructure departmental organization

As we saw from the questionnaire and interviews results, how boroughs are organized and the department in which the tree section is located can influence a number of things. Simple changes can improve the organizational effectiveness of tree officers and improve their ability to produce visualizations. The proposed changes are:

- a) Integrate tree officers and the tree section in the planning decision process, as this will result in better integration of trees in the design, better management of trees and will reduce conflicts between street trees and other street infrastructure like street lights, traffic signs and traffic lights.
- b) Sit tree officers in close proximity to other borough staff trained in the use of visualizations, so that the teams can support one another to produce more complex and detailed visualizations when needed, even potentially leveraging the skills of personnel from the planning section such as designers and other people with CAD training that can help with the occasional visualization.
- c) Allocate time and budget for consultation on and production of visualizations as a priority for key uses in urban forest situations, especially where contentious issues or big decisions are to be made.

Moreover, visualizations are often done by architects and landscape architects with only a limited knowledge of trees and street trees management and planning, which results in inadequate species choice, inadequate placement and, ultimately, inaccurate visualizations. In order to avoid this, any teams / firms preparing visualizations for public planning / communication should consult an urban forester (or an equivalent expert) on species selection and placement or, alternatively involve an urban forester trained in the use of visualizations as a part of the team producing the designs and the visualizations from the beginning.

6.2. Regulating the use of visualizations so that they are used consistently and correctly: defining a common set of standards

To regulate the use of visualizations so they are correctly and consistently used and produce, the following recommendations are provided:

- Develop and apply a code of conduct for visualizations: Standards for the Use and Production of Visualizations in Urban Forestry

- Consider how to review and/or regulate the production and use of visualizations in public communications

6.2.1. Develop and apply a code of conduct for visualizations: Standards for the Use and Production of Visualizations in Urban Forestry

A code of standards for the use of visualizations in urban forestry management and planning should be developed and followed as a guidance for all parties involved:

- Trained experts preparing visualizations involving urban trees.
- Urban forestry practitioners asking others to produce the visualizations for them.
- Practitioners receptors of the visualizations that should review and judge them as part of the documentation of a project proposal or a planning application.

The code of standards specific for urban forestry should include the procedures, requirements and guidelines and should cover the following aspects:

- Visualization design: defining purpose and scope of the visualizations.
- Visualization process detailing the steps to produce the visualizations and when in the project the visualizations should be produced.
- Types of content that visualizations should include.
- Criteria for the evaluation of the visualizations.
- Resources requirements.

The Code of Ethics for Landscape Visualization (Sheppard 2001) and the following criteria for visualization evaluation should serve as guidance for its elaboration (based on Sheppard 2001, Sheppard *et al.* 2004, Sheppard and Cizek 2009 and Sheppard 2012):

a) Accuracy

Visualizations should simulate the actual and expected appearance of the site after the development project has been completed, without distortion and at an appropriate level of abstraction/realism for the intended purpose.

Visualizations should include all elements included in the project such as built infrastructure and landscaping and be represented accurately, according to the specifications stated in the project plan. Existing trees not affected by the project, adjacent buildings and other significant elements should be included in the visualizations. If existing elements of the scene blocked the view of the proposed development, an additional set of visualizations could be produced stating clearly which elements have been removed.

b) Representativeness

Visualizations should represent the typical or important range of views, conditions and time frames which would be experienced with the proposed project.

Additionally, visualizations should represent more than one representative viewpoint and atmospheric conditions.

c) Comprehensibility

The details, components, and overall content of the visualization should be clearly communicated.

The interpreter should be able to obtain enough information from the image to make a clear and reliable judgement of the project shown in the visualization.

d) Interest

Visualizations should engage and hold the interest of the audience, without seeking to distract or impress the audience

e) Legitimacy

Visualizations should be defensible throughout by making the simulation process and assumptions transparent to the viewer, and by clearly describing the expected level of accuracy and uncertainty.

The assumptions made about tree species, tree management and future climate conditions should be stated. The inventory data, growth curves or any other data used to produce the imagery should be described, its accuracy stated and even provided if considered necessary.

f) Access to visual information

Visualizations which are consistent with the above principles should be made readily accessible to the public and other interested parties.

g) Framing and presentation

Important contextual and other relevant information should be presented along with the visualization imagery and in a clear, neutral fashion.

Dependent on how visualizations are going to be presented, the labelling, accompanying documents or explanations provided by the presenter should be carefully considered.

6.2.2. Consider how to review and/or regulate the production and use of visualizations in public communications

To advise on visualizations preparation and use, and to ensure that the Code of Standards for the Preparation and Use of Visualizations in Urban Forestry is known and followed, a review body or task force could be established.

7. OTHER FINDINGS

Due to the exploratory character of the research and the qualitative semi-structured interview method used for part of the thesis, there are a number of findings that are not directly related to the research questions.

Those findings are mostly related to urban forestry management in general and to specific characteristics of London's urban tree management administrative organization. These findings can be summarized as:

- Tree strategies as tools to improve communication
- London's administrative subdivision into 33 boroughs

Tree strategies as tools to improve communication

In terms of communication and answering public complaints, an interesting finding from the interviews was the perception that having a tree strategy was useful when responding to public complaints, particularly where the tree strategy specified in which specific cases trees were to be pruned, crown thinned, pollarded or removed.

We follow our tree management strategy and it is like our Bible. (...) It makes things easier because it's not my personal opinion. It clarifies the process and helps also people understand.

Trees in Towns II (Britt and Johnston, 2008) highlights the importance of local authorities having a comprehensive tree strategy that covers all the tree and woodland resource held on both public and private land.

It would appear that people have a higher acceptance of written policy than of expert-based judgment by tree officers. This is particularly the case when the explanations about a tree's removal were given after the tree or even the stump had been removed.

London's administrative subdivision into 33 boroughs

There was a demand among tree officers for having some London scale inventory and strategy to plan London's tree stock as one body, even if each borough had their own particularities that could be dealt with at borough scale.

A database containing all the street trees in London (including their location, type and dimensions) was created for the Mayor's scheme, in 2008 but unfortunately it has not been updated

Having a global vision of London's urban forest and developing a global strategy could also help balance budgetary and social inequalities between the boroughs. An example of budgetary differences is how maintenance budgets per tree vary across boroughs, ranging from 55 to 1 pound (London Assembly 2011).

Additionally, the fact that messages about urban trees are coming from 33 different authorities instead of one body speaking for all of London contributes to the dispersion of the message and reduces its impact.

8. LIMITATIONS

This Section will acknowledge the limitations encountered during the research and how the author tried to minimise those limitations. It will cover the following subsections:

- Scope of the research
- Bias and self-selections

- Generalizability
- Other limitations

Scope of the research

The research has contributed both to theory building in the potential roles of visualizations in urban forestry and to offering recommendations for practice for an effective implementation of visualizations tools for urban forestry practitioners.

Cost-benefit issues are not included in this research as they will be covered by the software industry and the market when these tools are needed (Sheppard 2005).

The study population chosen for this thesis were urban forestry managers and planners working for Local Authorities in the city of London (UK). Urban forestry managers and planners are referred locally as tree officers and the Local Authorities that manage trees in London are the 33 boroughs. Transport for London was also included in the study because they manage street trees in highways across the city. That meant that study population was limited to 152 tree officers which is a fairly small population. The possibility to extend the study to other cities in South East UK was considered but finally rejected due to the singularity of London compared with the other much smaller cities.

The limited number of responses for the questionnaire made the statistical analysis more challenging particularly the statistical significance analysis among groups. This was especially relevant with respondents among the group of tree officers managing only private trees. The reduced population (N=152) made it harder to get a lot of responses, even when the response rate was comparable to similar studies (Britt and Johnston, 2008; Johnston and Rushton, 1999).

The limited number of interviews conducted is another weakness of the research. In depth interviews provide invaluable insight and understanding but their time consuming nature (both for interviewer and interviewees) limits the number that are achievable within the time constraints of a project.

Bias and self-selection

The questionnaire and the interview responses are constrained by the problem of self-selection (Bamberger, Rugh, and Church, 2004). Those tree officers that voluntarily chose to participate would very likely be those more interested in communicating their views and opinions and more interested in exploring new tools and new technology to assist them in their work.

To try to avoid only those interested in visualizations participating in the study, the questionnaire did not include many questions about visualizations. Visualizations only appeared as one of the options when asking tree officers about the software they used. The wording of the invitation to participate in a personal interview and the wording in the letter

to participants about the interview were also carefully chosen to provide honest information but avoiding mentioning visualizations as the main objective of the research project.

It is possible that in the interviews which spent more time on the role of visualization, that some participants were influenced to provide positive responses about visualization due to the perceived interest of the researcher. However, the results suggest that there was a variety of views about the visualizations, and in fact not many overly positive responses

Generalizability

The results from the questionnaire and the interviews can be considered as representative for the population of LTOs but generalization to other groups of tree officers would have to be considered with caution.

The generalization of the findings and recommendations for practice to other populations of tree officers should be considered as guidance for further research on those other groups. Nonetheless, those findings of the study linked with particular characteristics of the city of London, like the administrative subdivision in 33 boroughs, are specific to the study area. The findings associated with the perception of shade as a nuisance could potentially be generalized to other city centre locations in the UK (Trees and Design Action Group 2008), but not to other countries where the perception of shade has more positive connotations and shade is considered a benefit derived from trees (REFS!!!).

Other limitations

Though the visualizations techniques chosen tried to be as simple as possible, 3D modelling is not generally accessible to the average tree officer. The author presumed that Tree Officers would frequently use CAD software and GIS, so the next step to 3D visualization software would not be too difficult, whereas it was found that they do not typically use these tools.

The limitation of the case study site also needs to be considered. The rationale for the selection of the study site for visualizations was to find a place that was easily recognizable, and that was representative of intensely urban, densely populated street tree corridors as found in both inner London and urban centres in outer London boroughs. Though the chosen site met the selected criteria it was also a small area, with few trees. Additionally, it is not necessarily applicable to other urban fabrics and tree densities.

9. STRENGTHS

The two main strengths of the dissertation and covered in the following subsections are:

- Research design and research methods
- Originality of the research subject and approach

Research design and research methods

Despite the existence of limitations of the research, the research design also has important strengths. The multiple method approach provided a useful strategy for investigating a complex real world phenomenon (Creswell, 2009). The use of both a quantitative survey in addition to semi-structured interviews to explore urban forestry managers and planners' perspectives on the use of visualizations in urban forestry added to the robustness of the research.

Additionally, the semi-structured interviews provided very rich information. The prompting in the semi-structured interviews allowed for the elicitation of information that would not have been possible with a survey.

The developed set of visualizations was based on careful analysis of the potential applications of visualizations to urban forestry management and planning and served a multiple purpose. First, it offered LTOs a range of visualizations and applications they hadn't encountered before. Second, it helped tree officers to come up with new applications of visualizations. Last, it helped to elicit responses about concepts such as the credibility or the defensibility of the visualizations that would have been more difficult to talk about without the help of the proposed set of visualizations as examples that contrasted with the visualizations they were used to receiving on planning applications from developers.

Originality of the research subject and approach

The originality of the study is another important strength as no other precedents for this kind of study are known. Research on the use of visualizations for urban forestry management and planning is very limited and literature is mostly reduced to describing the advantages of visualizing tree growth as part of the design process allowing to choose adequate species for the space (Auclair, 2002; Alinat, 2002) and the use of GIS systems integrated with 3D visualizations and LIDAR technology (Haala and Brenner, 1999; Toutin, 2004).

Literature on the use of visualizations in other areas of urban forestry or greenspace planning is mainly focussed on technical developments (Brasch *et al.*, 2009; Hayek, Halatsch, Kunze, Schmitt, and Gret-Regamey, 2010; Landes *et al.*, 2015; Neuenschwander *et al.*, 2014; Omasa *et al.*, 2007; Rutzinger *et al.*, 2011), in the use of visualizations to understand public preferences in urban forestry (Laing, Davies, and Scott, 2003; Lange, Hehl-Lange, and Brewer, 2008; Schroeder and Orland, 1994), or in collaborative urban greenspace planning (Tyrvalinen, Gustavsson, Konijnendijk, and Ode, 2006; Wang *et al.*, 2015; Warren-Kretzschmar and Tiedtke, 2010; West, Halley, O'Neil-Dunne, Gordon, and Pless, 2013).

The literature on studies looking into practitioners' perspectives on the use of visualizations is very reduced and only focused on urban and greenspace planning (Donaldson-Selby, 2007; Groulx, 2010). No other study had looked before into urban forestry managers and planners' views on the use of visualizations.

10. SUMMARY

This Chapter contained the results from the study discussed in relation to one another and compared with the existing literature. It also included recommendations to effectively integrate the use of visualizations in the field of urban forestry management and planning.

Finally, in this Chapter the limitations of the study were acknowledged and the strengths of the research design, methodology and application of the proposed methodology were analysed.

Next will be the final Chapter of the dissertation that will include the main findings of the study and suggestions for future research.

CHAPTER 6

CONCLUSIONS

1. INTRODUCTION

The previous Chapter included the discussion of the results, how they relate with existing literature and how those findings have been translated into contributions to the field of urban forestry. It also acknowledged the limitations of the study and analysed the strengths of the research design, methodology and application of the proposed methodology.

The following pages contain a summary of the main findings of the study, other findings not related to the research questions and offer direction for future research.

2. MAIN FINDINGS OF THE STUDY

The main findings of the dissertation in relation to the research questions are provided in the following sections.

Research question 1: What are the actual and potential roles of visualizations in the context of urban forestry management and planning?

Actual use of visualizations among LTOs

- There was practically no production of visualizations:
 - None of the 56 LTOs surveyed currently use visualization production software.
 - From the 17 interviewed LTOs, only 2 are currently producing visualizations by asking a third party to produce them, and only another 2 declared they had made any attempt at producing visualizations in the past or declared any previous knowledge about visualizations tool.
- High level of satisfaction: Despite the surprisingly low level of usage, those who had used visualizations had a high level of satisfaction and a desire to use them again in the future.
- Frequent receptors of visualizations: Almost all tree officers interviewed were frequent receptors of visualizations.

Potential role of visualizations in urban forestry

The potential main applications of visualizations in urban forestry management and planning are:

- Visualizations as a communication tool: Visualizing aesthetic impact of management operations and new schemes
- Visualizations as a tool for capacity building:
 - The importance of the fourth dimension: tree growth and long term management consequences visualization
 - Visualizing the invisible: tree condition visualization, environmental benefits visualization, roots and underground services visualization
- Participatory programs and the use of visualizations
- Visualizations as an internal modelling tool for analysis and design

Research question 2: What are the potential benefits and barriers for the implementation of visualizations in urban forestry management and planning?

Benefits

Visualizations provide multiple potential benefits for urban forestry management and planning:

- Effectiveness as a communication tool: it allows LTOs to get their messages across clearly, effectively and fast. It allows to translate complex proposals into simple images that can be easily understood by the different stakeholders.
- Ability to educate and change public attitude to urban trees: By helping people understand the importance of trees in general and the benefits of trees near houses, visualizations would help people cope better with inconveniences caused by trees like leaves or fruits falling and the risk of trees damaging their houses. The ability to translate into images, invisible processes such as tree root development or abstract concepts such as tree condition or the benefits of urban trees can change people's attitudes towards them.
- Pre-empting public complaints: Better informing residents of the works to be done, planting, pruning campaigns, etc. and the long term objectives of the actions, would reduce public complaints. Visualizations would be a useful tool for this.
- Ability to increase community involvement and participatory planning: collaborative planning processes are facilitated by 3D geographical visualization

- Ability to simulate scenarios: Visualizations are a powerful tool for presenting several alternative present and future scenarios and plan better spatial relations between trees and other infrastructures before the trees are planted.
- Ability to integrate in multidisciplinary teams: Visualizations are already used by urban planners, architects and landscape architects with whom urban forestry managers and planners often need to work as part of a team.
- Ability to verify projects and developments post-completion: verification would be simplified, by comparing the result with the ex-ante visualization of proposed conditions.

Barriers

There are multiple barriers to the use of visualizations as a tool for urban trees management and planning:

- Lack of standards for visualizations: incorrect / inaccurate development of visualizations can lead to a higher risk of poor decisions being made as a result of misleading information being presented to decision makers and the public and can lead to a distrust of potentially good visualizations in the future.
- Lack of adapted tools: tools have not been adapted to urban forestry requirements, making them complex to use and not offering a solution that covers all the needs of urban forestry managers and planners
- Lack of training: often due to a lack of time and resources, managers and planners do not have access to training in the use of what are generally technically complex tools
- Lack of access to someone trained in visualizations productions techniques: whilst people trained in the relevant techniques often exist in the boroughs, they are usually in separate departments and the managers and planners do not have access to them.
- Lack of data sources and models: Correct urban tree libraries and urban tree growth curves do not exist for many of the required species, so practitioners must either use incorrect representations or make incorrect growth assumptions.

3. OTHER FINDINGS

A number of other findings of the study were not related to the research questions but came out of the exploratory character of the research and the qualitative semi-structured interviews methods used:

- Lack of public awareness of the benefits of trees: A poignant example of this was the number of complaints linked to shade trees, which in a future with climate change are going to be highly beneficial. Better communication of this is important.
- Importance of a tree strategy: A tree strategy that can be referred to helps tree officers to improve communications with public
- Pressure from underground services: Trees in urban environments compete with underground services, particularly in developments. Greater regulation would help.
- Departmental organization: Locating Tree Officers inside or closer to the Planning Departments improves the integration of trees in planning decisions and avoids future spatial conflicts.
- London-wide inventory and strategy: There was a demand among tree officers for having some London scale inventory and strategy to plan London's tree stock as one body, even if each of the 33 boroughs had their own particularities that could be dealt with at borough scale

4. DIRECTIONS FOR FUTURE RESEARCH

There are still a lot of uncertainties in the field of visualizations applied to urban forestry, but priorities emerging directly from the present research include:

- Develop a Code of Standards for the Use and Production of Visualizations in urban Forestry
- Extend the study to the perspectives of other groups involved in the urban forestry sector, such as arborists from the private sector or charity members, to study how their priorities and views on visualizations differ or converge with those from tree officers.
- Evaluate the visualizations that are currently being produced by local authorities, private developers and other interest groups to research the motivations behind the visualizations production, and how accurate they are in relation to urban trees and urban vegetation
- Explore the alternatives for the visualization of roots and underground services
- Explore shade complaints to determine whether the complaint relates to shade or rather light and how it varies between residential and commercial areas.

5. SUMMARY

Chapter 6 has been the final chapter of this dissertation and has included a summary of the main findings of the study. The findings were divided into those related to the research questions and those that emerged during the study but were not linked to the objectives that guided the thesis. The chapter finished offering ideas and topics to be explored in future research.

The next pages contain the thesis bibliographic references and the appendices.

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APPENDICES

1. EMAIL FOR PARTICIPANTS

EMAIL 1: LTOA

Dear Ms Porter,

My name is Ana Macias and I am a PhD candidate from the Forestry School of the Universidad Politecnica de Madrid (Spain). I am working in collaboration with Kieron Doick, from Forest Research (Land Regeneration and Urban Greenspace Research Group) in a qualitative research project on urban forestry.

The objective of my doctoral thesis is to study the use of innovative tools to facilitate decision-making and public communication in urban forestry

For that purpose, we would like to conduct a two steps research plan, consisting in:

- **A short 10 minute questionnaire**, to understand urban forestry managers' priorities, and how efficiently and satisfactorily they feel these are tackled
- **A follow-up 1 hour semi-structured interview**, to further discuss the use of computer generated media in urban forestry

In your role as Executive Officer for the London Tree Officers Association, I was wondering if you could help me on how best to pass along the questionnaire to the relevant urban forestry managers across London Boroughs. Would you be able to assist in establishing this contact?

I provide further details about the study in the attached file along with the questionnaire to pass along. Feedback on it will be more than welcomed.

Please do not hesitate to contact me with any questions you might have.

Thanking you in advance,

Ana Macias

Link to the on-line survey: <http://www.smartsurvey.co.uk/s/107297USJDF>

Find word document attached, if you rather fill it off-line. Please send complete forms to ana.macias@upm.es

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www.ecsen.es

EMAIL 2: TREE OFFICERS

Dear Mr. xxx,

Are you interested in learning more about the use of innovative tools to facilitate decision-making and public communication in urban forestry?

We are asking urban tree managers working in London to take a 10 minute questionnaire, for which you will be entered into a free prize draw to win a bottle of Champagne.

There is still time for you or someone from your team to complete the questionnaire and ensure Islington is part of the study.

Your answers will help us understand urban forestry managers' priorities, and how efficiently and satisfactorily you feel these are tackled.

Those interested will also be able to take part in a 1 hour semi-structured interview to further discuss the use of computer generated media in urban forestry.

We have carried out several interviews already with your peers from other boroughs, who felt that the discussion was "interesting and useful".

Of course, your input will be kept confidential and I will be happy to share the results of the research once it is published.

Link to the on-line survey: <http://www.smartsurvey.co.uk/s/117935QSJEW>

Find word document attached, if you rather fill it off-line. Please send complete forms to ana.macias@upm.es

Thank you,
Ana Macias

Ana Macias
Forestry Engineer

Economics for a Sustainable Environment Research Group
Economy and Forestry Management Department
Forestry School
Universidad Politecnica de Madrid
www.ecsen.es

2. QUESTIONNAIRE

URBAN FORESTRY PRACTITIONERS' PERSPECTIVES

Are you interested in learning more about the use of innovative tools to facilitate decision-making and public communication in urban forestry?

We are asking urban tree managers and planners working in London to take a 10 minute questionnaire, for which you will be entered into a free prize draw to win a bottle of Champagne.

Your answers will help us understand urban forestry practitioners' priorities, and how efficiently and satisfactorily you feel these are being tackled.

Those interested will also be able to take part in a 1 hour semi-structured interview to further discuss the use of computer generated media in urban forestry.

Link to the on-line survey: <http://www.smartsurvey.co.uk/s/117935QSJEW>

Find word document attached, if you rather fill it off-line. Please send complete forms to ana.macias@upm.es

QUESTIONNAIRE “URBAN FORESTRY PRACTITIONERS’ PERSPECTIVES”							
Thank you for taking the time to complete this survey. It should only take 10 minutes to finish. All responses will be pooled together so that individual respondents cannot be identified.							
1	PERSONAL DATA						
	Please give your name (only used to avoid duplicates)						
	Which London borough do you work for?						
	What team do you work in?						
	☐ Trees on council owned / other public land						
	☐ Trees on private land						
	☐ Other (please, specify):						
	What is your academic background/training?						
	☐ Forestry						
	☐ Arboriculture						
	☐ Urban planning						
	☐ Other (please, specify):						
2	QUESTIONS						
Q1	How much time do you dedicate in the average year to the following issues? Please rate each from (1) no time at all to (5) most of my time.						
		1	2	3	4	5	I don't know
	Pests and disease control	☐	☐	☐	☐	☐	☐
	Planting (new or replacement trees and species selection)	☐	☐	☐	☐	☐	☐
	Tree maintenance	☐	☐	☐	☐	☐	☐
	Dealing with public complaints (high hedges disputes, sap/leaves falling, damage on infrastructures by trees...)	☐	☐	☐	☐	☐	☐
	Public participation programs	☐	☐	☐	☐	☐	☐
	Management plans and strategies development	☐	☐	☐	☐	☐	☐
	Other (please specify):	☐	☐	☐	☐	☐	☐
Q2	To what extent do each of the following subjects present an ongoing challenge to your role? Please rate from (1) not a problem, to (5) needs a lot more resources/time/research to address the problem.						
		1	2	3	4	5	I don't know
	Climate change consequences on urban tree species	☐	☐	☐	☐	☐	☐
	Urban heat island mitigation by urban vegetation	☐	☐	☐	☐	☐	☐
	Water storm management	☐	☐	☐	☐	☐	☐
	Drought and sustainable water management	☐	☐	☐	☐	☐	☐
	Massaria diseases of plane	☐	☐	☐	☐	☐	☐
	Oak Processionary moth	☐	☐	☐	☐	☐	☐
	Chalara /Ash dieback	☐	☐	☐	☐	☐	☐
	Hazardous trees assessment procedures	☐	☐	☐	☐	☐	☐
	Community engagement	☐	☐	☐	☐	☐	☐
	Vandalism prevention of urban trees, vegetation, greenspaces	☐	☐	☐	☐	☐	☐
	Public communication	☐	☐	☐	☐	☐	☐
	Other (please specify):	☐	☐	☐	☐	☐	☐
Q3	How often do you work directly with the public? Please, choose ONE						
	☐ Never						
	☐ Rarely (less than once a month)						
	☐ Every month						
	☐ Every week						
	☐ Every day						

Q4	Based on YOUR experience, please rate the following sentences from (1) strongly disagree to (5) strongly agree						
		1	2	3	4	5	I don't know
	Communicating with the public is easy	☐	☐	☐	☐	☐	☐
	The public in general are very knowledgeable about urban trees and their phenology	☐	☐	☐	☐	☐	☐
	It is difficult to make people understand trees needs to be managed even when they look healthy	☐	☐	☐	☐	☐	☐
	People usually want trees to be planted in their neighborhood but not in front of their houses	☐	☐	☐	☐	☐	☐
	Street trees are less valued by people than trees in parks	☐	☐	☐	☐	☐	☐
	A better understanding of urban trees' characteristics and the benefits they provide would make people more open to coping with minor inconveniences such as leaves/fruits/sap/honey-dew	☐	☐	☐	☐	☐	☐
	The community is motivated and eager to participate	☐	☐	☐	☐	☐	☐
	Other (please specify):	☐	☐	☐	☐	☐	☐
Q5	Please rate the following messages with regard to ease of communication to the public.						
	Please rate from (1) very easy to (5) very difficult to explain						
		1	2	3	4	5	I don't know
	Long term consequences of today's management decisions	☐	☐	☐	☐	☐	☐
	The benefits of urban trees	☐	☐	☐	☐	☐	☐
	The importance of planting the right tree in the right place	☐	☐	☐	☐	☐	☐
	The need to fell diseased or structurally unstable trees	☐	☐	☐	☐	☐	☐
	The benefits of community engagement	☐	☐	☐	☐	☐	☐
	Other (please specify):	☐	☐	☐	☐	☐	☐
Q6	Based on your interaction with them, how well do the following groups understand the importance of large mature trees for SHADING and COOLING in a future with climate change?						
	Please rate as (1) good understanding, (2) some understanding, (3) poor understanding or (4) no understanding.						
		1	2	3	4	I don't know	
	General public	☐	☐	☐	☐	☐	
	Councillors/ local politicians	☐	☐	☐	☐	☐	
	Other borough staff	☐	☐	☐	☐	☐	
	Developers	☐	☐	☐	☐	☐	
	Other (please specify):	☐	☐	☐	☐	☐	
Q7	Are there any tools that you currently use for analysis or communications with others on urban forestry issues?						
	Please, tick all that apply						
	☐ None						
	☐ GIS or mapping						
	☐ Visualization programs						
	☐ Modelling programs						
	☐ Tree management software						
	☐ Other (please specify):						
3	FEEDBACK						
	Is there anything you would like to add? Your feedback on the survey is very welcomed.						
	Would you be interested in participating in a semi-structured interview to further discuss the use of technology tools and computer generated media to improve decision-making and public communication in urban forestry?						
	☐ No						
	☐ YES, please, include your email and other contact details						
Thank you very much for your time! Please send complete forms to: ana.macias@upm.es							

3. INTERVIEW INFORMATION SHEET

Project title
URBAN FORESTRY MANAGERS' PERSPECTIVES:
A QUALITATIVE RESEARCH STUDY

Principal researcher: Ana Macias, Forestry School, Universidad Politecnica de Madrid
Research supervisors: Kieron Doick (Forestry Commission, Alice Holt)
Antonio Prieto Rodriguez (Universidad Politecnica de Madrid), Stephen R.J. Sheppard (University of British Columbia)

INFORMED CONSENT FORM FOR RESEARCH PARTICIPANTS

Part I: Information Sheet

Purpose of the study. The objective of this research is to study the use of innovative tools to facilitate decision-making and public communication in urban forestry. Your answers will help us understand urban forestry managers' priorities, and how efficiently and satisfactorily **you** feel these are tackled.

What will the study involve? The study involves a ca. one hour one-to-one semi-structured interview.

Participant selection. You have been selected to take part in this study because you are a professional working in urban forestry management.

Participation is voluntary. Participation in this study is completely voluntary. You have the option of withdrawing before the study commences (even if you have agreed to participate) or discontinuing after data collection has started.

Confidentiality. No clues of participants' identities will appear in the thesis. Any extracts from what you say that are quoted in the thesis will be entirely anonymous.

What will happen to the information you give? Interviews will be recorded. The data will be kept confidential for the duration of the study. On completion of the research, recordings will be retained for a further six months and then destroyed.

What will happen to the results? The results will be presented in a PhD thesis. The study may be published in research journals or other academic publications.

What are the possible disadvantages of taking part? I don't envisage any negative consequences for you in taking part. No sensitive personal questions will be asked.

Any further queries? If you need any further information, you can contact me: ana.macias@upm.es

Part II: Consent Form

I agree to participate in the project “Urban forestry manager’s perspectives: a qualitative research study”.

The purpose and nature of the study has been explained to me in writing.

I am participating voluntarily.

I give permission for my interview to be recorded.

I understand that I can withdraw from the study, without repercussions, at any time, whether before it starts or while I am participating.

I understand that I can withdraw permission to use the data within two weeks of the interview, in which case the material will be deleted.

I understand that anonymity will be ensured in the write-up by disguising my identity.

Print name.....

Signed.....

Date.....

4. INTERVIEW PROTOCOL

INTERVIEW PROTOCOL (ONLY FOR RESEARCHERS!)

Interview CODE: _____

Introduction

I want to **thank you** for taking the time to meet with me today.

My name is Ana Macias and I would like to talk to you about your work as an urban forestry manager and some possible tools to assist you in your work.

I am going to ask you questions about your views on these materials. The questions deal with your own personal opinion. There is no wrong or right answer, and all comments, whether positive or negative will be helpful.

I will be **taping** the session because I don't want to miss any of your comments. Although I will be taking some notes also during the session, I can't possibly write fast enough to get it all down.

All responses will be kept **confidential**. This means that your interview responses will only be shared with research team members and we will ensure that any information we include in our report does not identify you as the respondent.

The interview should take an **hour** but we may **end** the interview at any time.

Are there any **questions** about what I have just explained?

- ☐ Interviewee has consented (signed)
- ☐ Recording is on

Probing:

- Would you give me an example?
- Can you elaborate on that idea?
- Would you explain that further?
- I'm not sure I understand what you're saying...
- Is there anything else?

First part

Let's get started. I have some quick questions about your job and your department.

1. Can you tell me for the record your job title and description and the department you work in?
2. How many people are there in your department? What roles do they have?
3. Do you use any specific **software** for your job? Mapping tool?
4. I get from your questionnaire that you mainly do xxx, right?
5. what messages do you find more difficult to help people understand? why??
6. why do think urban heat island management needs more resources?

((questions 4, 5 and 6 are designed to go into more detail on the responses from the questionnaire) (they will be personalized based on the different questionnaire responses))

Second part

((VIZs are going to be presented in two ways:

- Trough a lap-top to run a power-point presentation
- 2-3 VIZs selected among those contained in the presentation will be printed in A4 to let the interviews to go over them, sort them, and talk about them))

A. Presentation

I am going to show you a presentation that contains different types of visualizations based in the Victoria BID area, in Buckingham Palace Road.

The presentation is divided in four chapters

1) Google earth etc

2) VIZ tree condition

3) VIZ tree evol

4) VIZ shade

((Describe each of them briefly before playing each video/part of the presentation))

((After each of them, ask questions 7-8 and hand the printed A4 images corresponding to each part of the presentation))

7. **Have you already used similar materials?**

8. **What are your first impressions on them?**

B. Printed images

((Using as a reference the printed A4 images with the selected VIZs from the presentation, ask the following questions, letting the interviewees sort and look at the prints))

9. Do you see your self or anybody in your team **producing any of them?**

a. Would you ask an expert to produce something similar?

10. Which ones would be more **useful** for your job?

11. Which ones would you use for?

b. In **personal analysis**

c. **Public meetings**

d. **Presentations to decision makers**

12. Are there any **situations** where you think **VIZs** could be particularly **useful**?

13. What do you think are the most **effective** ones?

14. Which are the most **compelling** images?

15. Which ones do you find more...?

e. **accurate**

f. **clear**

16. How **plausible/credible** do you think the visualizations are?
17. Do you think any of the images/videos could be considered as **misleading**?
18. Would you have any **concerns** about using visualizations?
19. These VIZs have a modeling work behind and have a **scientific background** to support them,
 - g. do you think that would make a **difference when presented to the public**?
 - h. would that make **you feel more confident** when using them?
 - i. In terms of credibility, **how important it is to present the images together with the data** to support them?

And to summarize, one last question

20. What do you think are the **potential benefits** or
 - j. **limitations** of using VIZs in urban forestry?
21. Do you have any other thoughts about the videos or the images that we haven't covered yet?

Closing

Is there anything else that you'd like to add, in general?

Would you be willing to have a brief follow-up phone conversations or email if you (or we) want to clarify anything?

Thank you very much for your time!

5. QUESTIONNAIRE ANALYSIS RESULTS

1. Question 1.3: What team do you work in?

1.1. Range of Responses

Table 1: Range of Responses Question 1.3 – All Respondents

1.3	What team do you work in?		
		Response percent	Response total
	1 - Trees on council owned / other public land	76%	44
	2 - Trees on private land	33%	19
	3 - Other (please, specify):	7%	4

Other responses: Development Management, Urban Design and Conservation

NOTE: Respondents could select multiple options, therefore percentages may add up to more than 100%. Total Respondents: 58

Table 2: Range of Responses Question 1.3 – Respondents working on Council / Public land

1.3	What team do you work in?		
		Response percent	Response total
	1 - Trees on council owned / other public land	100%	44
	2 - Trees on private land	20%	9
	3 - Other (please, specify):	2%	1

NOTE: Respondents could select multiple options, therefore percentages may add up to more than 100%. Respondents: 44

Figure 1: Range of Responses Question 1.3 – All Respondents vs Respondents working on Council / Public land

1.2. Inter-group comparison: Inner vs Outer

Table 3: Range of Responses Question 1.3 – Respondents from Inner Boroughs vs Outer Boroughs

1.3	What team do you work in?		
		INNER	OUTER
	1 - Trees on council owned / other public land	21	21
	2 - Trees on private land	10	9
	3 - Other (please, specify):	2	2

NOTE: 2 respondents were not categorised as either INNER or OUTER and are not included in this analysis

Figure 2: Range of Responses Question 1.3 – Respondents from Inner Boroughs vs Outer Boroughs

NOTE: 2 respondents were not categorised as either INNER or OUTER and are not included in this analysis

1.3. Inter-group comparison: High vs Low Income Boroughs

Table 4: Range of Responses Question 1.3 – Respondents from High vs Low Income Boroughs

1.3	What team do you work in?		
		HIGH	LOW
	1 - Trees on council owned / other public land	22	20
	2 - Trees on private land	11	8
	3 - Other (please, specify):	1	3

NOTE: 2 respondents were not categorised as either HIGH or LOW and are not included in this analysis

Figure 3: Range of Responses Question 1.3 – Respondents from High vs Low Income Boroughs

2. Question 1.4: What is your academic background/training?

2.1. Range of Responses

Table 5: Range of Responses Question 1.4 – All Respondents

1.4	What is your academic background/training?	Response percent	Response total
	1 - Forestry	17%	10
	2 - Arboriculture	83%	48
	3 - Urban planning	9%	5
	4 - Other (please, specify):	14%	8

Other responses: Architecture, Urban Design and Building Conservation, Ecology, Horticulture, Landscape architecture, General Office Administration.

NOTE: Respondents could select multiple options, therefore percentages may add up to more than 100%. Total Respondents: 58

Table 6: Range of Responses Question 1.4 – Respondents working on Council / Public land

1.4	What is your academic background/training?	Response percent	Response total
	1 - Forestry	20%	9
	2 - Arboriculture	89%	39
	3 - Urban planning	2%	1
	4 - Other (please, specify):	11%	5

NOTE: Respondents could select multiple options, therefore percentages may add up to more than 100%. Total Respondents: 44

Figure 4: Range of Responses Question 1.4 - All Respondents vs Respondents working on Council / Public land

2.2. Inter-group comparison: Inner vs Outer

Table 7: Range of Responses Question 1.4 – Respondents from Inner Boroughs vs Outer Boroughs

1.4	What is your academic background/training?		
		INNER	OUTER
	1 - Forestry	8	1
	2 - Arboriculture	19	27
	3 - Urban planning	3	2
	4 - Other (please, specify):	6	2

NOTE: 2 respondents were not categorised as either INNER or OUTER and are not included in this analysis

Figure 5: Range of Responses Question 1.4 – Respondents from Inner Boroughs vs Outer Boroughs

NOTE: 2 respondents were not categorised as either INNER or OUTER and are not included in this analysis. Respondents could select multiple options, therefore percentages may add up to more than 100%.

2.3. Inter-group comparison: High vs Low Income Boroughs

Table 8: Range of Responses Question 1.4 – Respondents from High vs Low Income Boroughs

1.4	What is your academic background/training?		
		HIGH	LOW
	1 - Forestry	5	4
	2 - Arboriculture	20	26
	3 - Urban planning	3	2
	4 - Other (please, specify):	3	5

NOTE: 2 respondents were not categorised as either HIGH or LOW and are not included in this analysis

Figure 6: Range of Responses Question 1.4 – Respondents from High vs Low Income Boroughs

3. Question 2.1: How much time do you dedicate in the average year to the following issues? Please rate each from (1) no time at all to (5) most of my time

3.1. Descriptive Statistics

Table 9: Descriptive Statistics for Question 2.1 – All Respondents

	<i>2.1 Pests and disease control</i>	<i>2.1 Planting (new or replacement trees and species selection)</i>	<i>2.1 Tree maintenance</i>	<i>2.1 Dealing with public complaints (high hedges disputes, sap/leaves)</i>	<i>2.1 Public participation programs</i>	<i>2.1 Management plans and strategies development</i>
Mean	2.02	2.91	3.70	3.59	1.84	2.34
Standard Error	0.11	0.13	0.15	0.17	0.12	0.14
Median	2	3	4	4	2	2
Mode	2	3	4	4	2	2
Standard Deviation	0.83	0.96	1.11	1.25	0.91	1.08
Sample Variance	0.68	0.92	1.23	1.56	0.83	1.17
Kurtosis	0.50	-0.10	0.07	-0.69	2.25	-0.26
Skewness	0.78	0.44	-0.77	-0.56	1.38	0.61
Range	3	4	4	4	4	4
Maximum	4	5	5	5	5	5
Minimum	1	1	1	1	1	1
Sum	111	163	207	201	103	131
Count	55	56	56	56	56	56
Geometric Mean	1.86	2.75	3.47	3.31	1.65	2.09
Harmonic Mean	1.70	2.58	3.15	2.93	1.50	1.86
AAD	0.54	0.72	0.89	1.06	0.66	0.89
MAD	0	1	1	1	1	1
IQR	0.5	1	1.25	2	1	1
Shapiro-Wilk Test						
W	8.1E-01	8.9E-01	8.7E-01	8.8E-01	7.7E-01	8.8E-01
p-value	7.3E-07	7.8E-05	2.2E-05	3.7E-05	6.1E-08	5.3E-05
alpha	0.05	0.05	0.05	0.05	0.05	0.05
normal	no	no	no	no	no	no

Figure 7: Means and Standard Error for Question 2.1 – All respondents

3.2. Range of Responses

Table 10: Range of Responses Question 2.1 – All Respondents

2.1.	How much time do you dedicate in the average year to the following issues?							
	Please rate each from (1) no time at all to (5) most of my time.							
		1 - No time	2	3	4	5 - Most of my time	I don't know	Response total
	Pests and disease control	14	30	7	4	0	1	56
	Planting (new or replacement trees and species selection)	2	18	23	9	4	0	56
	Tree maintenance	3	5	12	22	14	0	56
	Dealing with public complaints (high hedges disputes, sap/leaves falling, damage on infrastructures by trees...)	4	8	11	17	16	0	56
	Public participation programs	22	26	4	3	1	0	56
	Management plans and strategies development	13	22	12	7	2	0	56
	Other (please specify):	3	1	7	6	6	1	24

Other responses (grouped): Tree Preservation Orders (TPOs), Planning and Planning Applications, Team management and other office tasks, Customer Enquiries, dealing with S211 notices, dealing with subsidence claims.

Table 11: Range of Responses Question 2.1 – Respondents working on Council / Public land

2.1.	How much time do you dedicate in the average year to the following issues?							
	Please rate each from (1) no time at all to (5) most of my time.							
		1 - No time	2	3	4	5 - Most of my time	I don't know	Response total
	Pests and disease control	6	27	6	4	0	1	44
	Planting (new or replacement trees and species selection)	0	13	20	8	3	0	44
	Tree maintenance	1	0	11	20	12	0	44
	Dealing with public complaints (high hedges disputes, sap/leaves falling, damage on infrastructures by trees...)	0	7	9	14	14	0	44
	Public participation programs	14	24	2	3	1	0	44
	Management plans and strategies development	9	18	10	5	2	0	44
	Other (please specify):	1	0	6	3	2	1	13

Figure 8: Range of Responses Question 2.1 – All respondents

Figure 9: Range of Responses Question 2.1 – Respondents working on Council / Public land

Table 12: Wilcoxon Signed-Rank Test for Paired Samples for Range of Responses Question 2.1 – All Respondents

	2.1 Tree maintenance		2.1 Dealing with public complaints (high hedges disputes, sap/leaves)		2.1 Tree maintenance		2.1 Planting (new or replacement trees and species selection)		2.1 Dealing with public complaints (high hedges disputes, sap/leaves)		2.1 Planting (new or replacement trees and species selection)		2.1 Management plans and strategies development		2.1 Management plans and strategies development		2.1 Pests and disease control		2.1 Pests and disease control		2.1 Public participation programs	
median	4	4	4	3	4	3	3	2	2	2	2	2	2	2	2	2	2	2	2			
count	55		55		55		55		54		54		54		54		54		54			
# unequal	34		37		41		41		25		25		25		25		25		25			
T+	260.5		63		184.5		220		83		110.5		83		110.5		83		110.5			
T-	334.5		640		676.5		641		242		214.5		242		214.5		242		214.5			
T	260.5		63		184.5		220		83		110.5		83		110.5		83		110.5			
	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail		
alpha	0.05		0.05		0.05		0.05		0.05		0.05		0.05		0.05		0.05		0.05			
mean	297.5		351.5		430.5		430.5		162.5		162.5		162.5		162.5		162.5		162.5			
std dev	56.40	ties	64.04	ties	75.7	ties	75.74	ties	29.13	ties	28.06	ties	29.13	ties	28.06	ties	29.13	ties	28.06	ties		
z-score	0.65		4.50		3.243		2.77		2.71		1.835		2.71		1.835		2.71		1.835			
effect r	0.06		0.43		0.309		0.26		0.26		0.177		0.26		0.177		0.26		0.177			
T-crit	204.2	186.5	245.7	225.5	305.5	281.6	305.4	281.6	114.1	104.9	115.8	107	114.1	104.9	115.8	107	114.1	104.9	115.8	107		
p-value	0.26	0.52	0.00	0.00	6E-04	0.001	0.00	0.01	0.00	0.01	0.033	0.066	0.00	0.01	0.033	0.066	0.00	0.01	0.033	0.066		
sig (norm)	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	no		
T-crit	200	182	241	221	302	279	302	279	100	89	100	89	100	89	100	89	100	89	100	89		
sig (table)	no	no	yes	yes	yes	yes	yes	yes	yes	yes	no	no	yes	yes	yes	yes	yes	yes	yes	no		

3.3. Inter-group comparison: Inner vs Outer

Table 13: Range of Responses Question 2.1 – Respondents from Inner Boroughs vs Outer Boroughs

2.1.	How much time do you dedicate in the average year to the following issues?	Please rate each from (1) no time at all to (5) most of my time.													
		INNER							OUTER						
		1 - No time	2	3	4	5 - Most of my time	I don't know	Response total	1 - No time	2	3	4	5 - Most of my time	I don't know	Response total
	Pests and disease control	7	14	1	3	0	0	25	7	15	5	1	0	1	29
	Planting (new or replacement trees and species selection)	1	9	7	7	1	0	25	1	8	15	2	3	0	29
	Tree maintenance	1	2	5	10	7	0	25	2	3	6	11	7	0	29
	Dealing with public complaints (high hedges disputes, sap/leaves falling, damage on infrastructures by trees...)	2	6	7	8	2	0	25	2	2	4	8	13	0	29
	Public participation programs	8	13	1	3	0	0	25	13	12	3	0	1	0	29
	Management plans and strategies development	6	8	5	6	0	0	25	7	13	6	1	2	0	29

Figure 10: Range of Responses Question 2.1 – Respondents from Inner Boroughs vs Outer Boroughs

Table 14: Wilcoxon Rank-Sum test for INNER / OUTER boroughs for Question 2.1

Wilcoxon Rank Sum test	2.1 Pests and disease control	2.1 Planting (new or replacement trees and species selection)	2.1 Tree maintenance	2.1 Dealing with public complaints (high hedges disputes, sap/leaves falling, damage on infrastructures by trees...)	2.1 Public participation programs	2.1 Management plans and strategies development
<u>OUTER</u>						
Count	28	29	29	29	29	29
Median	2.0	3.0	4.0	4.0	2.0	2.0
Rank Sum	772	797	769	957	751	757
<u>INNER</u>						
Count	25	25	25	25	25	25
Median	2.0	3.0	4.0	3.0	2.0	2.0
Rank Sum	660	689	717	528	735	728
<u>TEST (Normal Dist)</u>						
alpha	0.05	0.05	0.05	0.05	0.05	0.05
Mean	756	798	798	798	798	798
Variance	3,150	3,323	3,323	3,323	3,323	3,323
Std Dev	56.1	57.6	57.6	57.6	57.6	57.6
p-value (1-tail)	0.39	0.51	0.69	0.00	0.79	0.76
significant?	No	No	No	Yes	No	No
p-value (2-tails)	0.78	0.99	0.61	0.01	0.41	0.48
significant?	No	No	No	Yes	No	No

3.4. Inter-group comparison: High vs Low Income Boroughs

Table 15: Range of Responses Question 2.1 – Respondents from High Income vs Low Income Boroughs

2.1.	How much time do you dedicate in the average year to the following issues?														
	Please rate each from (1) no time at all to (5) most of my time.														
		HIGH							LOW						
		1 - No time	2	3	4	5 - Most of my time	I don't know	Response total	1 - No time	2	3	4	5 - Most of my time	I don't know	Response total
	Pests and disease control	7	14	4	1	0	0	26	7	15	2	3	0	1	28
	Planting (new or replacement trees and species selection)	1	9	10	4	2	0	26	1	8	12	5	2	0	28
	Tree maintenance	1	1	9	11	4	0	26	2	4	2	10	10	0	28
	Dealing with public complaints (high hedges disputes, sap/leaves falling, damage on infrastructures by trees...)	1	5	9	8	3	0	26	3	3	2	8	12	0	28
	Public participation programs	11	13	1	1	0	0	26	10	12	3	2	1	0	28
	Management plans and strategies development	7	8	6	4	1	0	26	6	13	5	3	1	0	28

Figure 11: Range of Responses Question 2.1 – Respondents from High Income vs Low Income Boroughs

Table 16: Wilcoxon Rank-Sum test for High Income / Low Income boroughs for Question 2.1

	2.1 Pests and disease control	2.1 Planting (new or replacement trees and species selection)	2.1 Tree maintenance	2.1 Dealing with public complaints (high hedges disputes, sap/leaves falling, damage on infrastructures by trees...)	2.1 Public participation programs	2.1 Management plans and strategies development
<u>LOW</u>						
Count	27	28	28	28	28	28
Median	2.0	3.0	4.0	4.0	2.0	2.0
Rank Sum	735	791	831	885	822	755
<u>HIGH</u>						
Count	26	26	26	26	26	26
Median	2.0	3.0	4.0	3.0	2.0	2.0
Rank Sum	696	695	654	600	664	731
<u>TEST (Normal Dist)</u>						
alpha	0.05	0.05	0.05	0.05	0.05	0.05
Mean	729	770	770	770	770	770
Variance	3,159	3,337	3,337	3,337	3,337	3,337
Std Dev	56.2	57.8	57.8	57.8	57.8	57.8
p-value (1-tail)	0.46	0.36	0.15	0.02	0.19	0.61
significant?	No	No	No	Yes	No	No
p-value (2-tails)	0.91	0.72	0.29	0.05	0.37	0.79
significant?	No	No	No	Yes	No	No

4. Question 2.2: To what extent do each of the following subjects present an ongoing challenge to your role? Please rate each from (1) not a problem to (5) needs a lot more resources/time/research to address the problem.

4.1. Descriptive Statistics

Table 17: Descriptive Statistics for Question 2.

	2.2 Climate change consequences on urban tree species	2.2 Urban heat island mitigation by urban vegetation	2.2 Water storm management	2.2 Drought and sustainable water management	2.2 Massaria diseases of plane	2.2 Oak Processionary moth	2.2 Chalara /Ash dieback	2.2 Hazardous trees assessment procedures	2.2 Community engagement	2.2 Vandalism prevention of urban trees, vegetation,	2.2 Public communication
Mean	2.91	2.64	2.40	2.58	2.41	2.44	2.00	3.26	2.38	2.27	3.36
Standard Error	0.18	0.18	0.19	0.18	0.17	0.18	0.18	0.16	0.18	0.18	0.15
Median	3	2.5	2	2	2	2	2	3	2	2	3
Mode	4	2	2	2	1	3	1	4	1	2	3
Standard Deviation	1.22	1.22	1.25	1.23	1.18	1.22	1.19	1.06	1.21	1.18	1.03
Sample Variance	1.49	1.49	1.56	1.52	1.40	1.48	1.41	1.13	1.47	1.38	1.06
Kurtosis	-1.07	-0.92	-0.41	-0.92	-0.79	-0.65	0.12	-0.42	-0.89	-0.35	-0.68
Skewness	0.02	0.27	0.71	0.34	0.38	0.41	1.02	-0.44	0.34	0.77	-0.05
Range	4	4	4	4	4	4	4	4	4	4	4
Maximum	5	5	5	5	5	5	5	5	5	5	5
Minimum	1	1	1	1	1	1	1	1	1	1	1
Sum	131	116	108	116	111	110	90	150	107	102	158
Count	45	44	45	45	46	45	45	46	45	45	47
Geometric Mean	2.62	2.33	2.09	2.27	2.11	2.13	1.71	3.04	2.06	1.99	3.19
Harmonic Mean	2.30	2.03	1.82	1.97	1.83	1.84	1.49	2.77	1.76	1.74	2.99
AAD	1.04	1.05	1.03	1.06	1.01	1.03	0.93	0.88	1.05	0.95	0.87
MAD	1	0.5	1	1	1	1	1	1	1	1	1
IQR	2	2	2	2	2	2	2	1	2	2	1
Shapiro-Wilk Test											
W	9.0E-01	9.0E-01	8.7E-01	9.0E-01	8.9E-01	8.8E-01	8.0E-01	9.0E-01	8.7E-01	8.5E-01	9.1E-01
p-value	1.3E-03	1.4E-03	9.7E-05	6.9E-04	3.8E-04	3.3E-04	2.4E-06	6.4E-04	1.4E-04	3.3E-05	1.2E-03
alpha	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
normal	no	no	no	no	no	no	no	no	no	no	no

Figure 12: Means and Standard Error for Question 2.2

4.2. Range of Responses

Table 18: Range of Responses Question 2.2 – All Respondents

2.2.	To what extent do each of the following subjects present an ongoing challenge to your role?							
	Please rate from (1) not a problem, to (5) needs a lot more resources/time/research to address the problem.							
		1 - under control	2	3	4	5 - needs more	I don't know	Response total
	Climate change consequences on urban tree species	6	13	9	13	4	3	48
	Urban heat island mitigation by urban vegetation	9	13	10	9	3	4	48
	Water management storm	12	16	8	5	4	3	48
	Drought and sustainable water management	10	14	9	9	3	3	48
	Massaria diseases of plane	13	12	12	7	2	2	48
	Oak Processionary moth	13	10	14	5	3	3	48
	Chalara /Ash dieback	21	11	7	4	2	3	48
	Hazardous trees assessment procedures	3	8	13	18	4	2	48
	Community engagement	15	8	14	6	2	2	47
	Vandalism prevention of urban trees, vegetation, greenspaces	13	18	5	7	2	3	48
	Public communication	1	9	16	14	7	1	48
	Other (please specify):	2	0	1	0	3	2	8

Other Responses: Cultural and Political Change, Urban Development, the planning process, woodland regeneration.

Total Respondents: 48

Table 19: Range of Responses Question 2.2 – Respondents working on Council / Public land

2.2.	To what extent do each of the following subjects present an ongoing challenge to your role?							
	Please rate from (1) not a problem, to (5) needs a lot more resources/time/research to address the problem.							
		1 - under control	2	3	4	5 - needs more	I don't know	Response total
	Climate change consequences on urban tree species	4	8	6	12	4	3	37
	Urban heat island mitigation by urban vegetation	6	12	5	7	3	4	37
	Water storm management	9	12	5	4	4	3	37
	Drought and sustainable water management	7	10	7	7	3	3	37
	Massaria diseases of plane	7	9	11	7	2	1	37
	Oak Processionary moth	7	9	12	4	3	2	37
	Chalara /Ash dieback	13	10	6	4	2	2	37
	Hazardous trees assessment procedures	2	8	7	15	4	1	37
	Community engagement	10	7	11	5	1	2	36
	Vandalism prevention of urban trees, vegetation, greenspaces	6	17	4	7	1	2	37
	Public communication	0	6	13	12	5	1	37
	Other (please specify):	1	0	1	0	2	1	5

Total Respondents: 37

Figure 13: Range of Responses Question 2.2 – All Respondents

Figure 14: Range of Responses Question 2.2 – Respondents working on Council / Public land

Table 20: Wilcoxon Signed-Rank Paired Samples test for 2.2 Public Communications against next highest Median statements

	2.2 Public communication 2.2 Hazardous trees assessment procedures		2.2 Public communication 2.2 Climate change consequences on urban tree species		2.2 Public communication 2.2 Urban heat island mitigation by urban vegetation	
median	3	3	3	3	3	2
count	45		44		43	
#						
unequal	26		28		27	
T+	154.5		114		70	
T-	196.5		292		308	
T	154.5		114		70	
	one	two	one	two	one	two
	tail	tail	tail	tail	tail	tail
alpha	0.05		0.05		0.05	
mean	175.5		203		189	
std dev	37.034	ties	42.604	ties	40.19	ties
z-score	0.5535		2.0773		2.948	
effect r	0.0583		0.2214		0.318	
T-crit	114.08	102.42	132.42	118.997	122.4	109.723
p-value	0.2899	0.5799	0.0189	0.03778	0.002	0.0032
sig						
(norm)	no	no	yes	yes	yes	yes
T-crit	110	98	130	116	119	107
sig						
(table)	no	no	yes	yes	yes	yes

Table 21: Wilcoxon Signed-Rank Paired Samples test for 2.2 Hazardous Trees Assessment Procedures against next highest Median statements

	2.2 Hazardous trees assessment procedures	2.2 Climate change consequences on urban tree species	2.2 Hazardous trees assessment procedures	2.2 Urban heat island mitigation by urban vegetation
median	3	3	3	2.5
count #	43		43	
unequal	32		31	
T+	195.5		124.5	
T-	332.5		371.5	
T	195.5		124.5	
	one tail	two tail	one tail	two tail
alpha	0.05		0.05	
mean	264		248	
std dev	52.8914	ties	50.32147	ties
z-score	1.285653		2.444285	
effect r	0.138636		0.263574	
T-crit	176.5014	159.8348	164.7286	148.8717
p-value	0.099282	0.198564	0.007257	0.014514
sig (norm)	no	no	yes	yes
T-crit sig (table)	175 no	159 no	163 yes	147 yes

Table 22: Wilcoxon Signed-Rank Paired Samples test for 2.2 Chalara / Ash dieback against next lowest Median statements

	2.2 Massaria diseases of plane		2.2 Chalara /Ash dieback		2.2 Community engagement		2.2 Chalara /Ash dieback		2.2 Vandalism prevention of urban trees, vegetation, greenspaces		2.2 Chalara /Ash dieback	
median	2		2		2		2		2		2	
count #	45				43				43			
unequal	17				28				22			
T+	25.5				142.5				87			
T-	127.5				263.5				166			
T	25.5				142.5				87			
	one tail		two tail		one tail		two tail		one tail		two tail	
alpha	0.05				0.05				0.05			
mean	76.5				203				126.5			
std dev	21.52215		ties		42.87628		ties		27.3313		ties	
z-score	2.346419				1.399375				1.426935			
effect r	0.247334				0.150899				0.15387			
T-crit	40.59921		33.81735		131.9748		118.464		81.04401		72.43163	
p-value	0.009477		0.018955		0.08085		0.1617		0.076799		0.153599	
sig (norm)	yes		yes		no		no		no		no	
T-crit	41		34		130		116		75		65	
sig (table)	yes		yes		no		no		no		no	

4.3. Inter-group comparison: Inner vs Outer

Table 23: Range of Responses Question 2.2 – Respondents from Inner Boroughs vs Outer Boroughs

2.2.	To what extent do each of the following subjects present an ongoing challenge to your role?														
	Please rate from (1) not a problem, to (5) needs a lot more resources/time/research to address the problem.														
		INNER							OUTER						
		1 - under control	2	3	4	5 - needs more	I don't know	Response total	1 – Under Control	2	3	4	5 – needs more	I don't know	Response total
	Climate change consequences on urban tree species	1	4	5	8	2	1	21	5	8	4	4	2	2	25
	Urban heat island mitigation by urban vegetation	3	5	4	6	1	2	21	6	8	4	3	2	2	25
	Water storm management	3	8	3	4	1	2	21	9	7	4	1	3	1	25
	Drought and sustainable water management	2	9	1	6	1	2	21	8	5	6	3	2	1	25
	Massaria diseases of plane	2	3	7	6	1	2	21	11	9	4	0	1	0	25
	Oak Processionary moth	5	3	4	5	1	3	21	8	7	8	0	2	0	25
	Chalara /Ash dieback	8	4	1	4	1	3	21	13	6	5	0	1	0	25
	Hazardous trees assessment procedures	1	4	5	7	2	2	21	2	2	8	11	2	0	25
	Community engagement	5	4	5	4	1	2	21	9	4	8	2	1	0	24
	Vandalism prevention of urban trees, vegetation, greenspaces	5	7	3	4	0	2	21	8	10	2	2	2	1	25
	Public communication	0	3	6	7	4	1	21	1	5	9	7	3	0	25
	Other (please specify):	1	0	1	0	2	1	5	1	0	0	0	1	1	3

Figure 15: Range of Responses Question 2.2 – Respondents from Inner Boroughs vs Outer Boroughs

Table 24: Wilcoxon Rank-Sum test for INNER / OUTER boroughs for Question 2.2

Wilcoxon Rank-Sum test	Rank	2.2 Climate change consequences on urban tree species	2.2 Urban heat island mitigation by urban vegetation	2.2 Water storm management	2.2 Drought and sustainable water management	2.2 Massaria diseases of plane	2.2 Oak Processionary moth	2.2 Chalara /Ash dieback	2.2 Hazardous trees assessment procedures	2.2 Community engagement	2.2 Vandalism prevention of urban trees, vegetation, greenspaces	2.2 Public communication
<u>OUTER</u>												
Count	23	23	24	24	25	25	25	25	25	24	24	25
Median	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0	4.0	2.0	2.0	3.0
Rank Sum	427	451	484	492	420	506	517	577	493	493	504	528
<u>INNER</u>												
Count	20	19	19	19	19	18	18	19	19	19	19	20
Median	3.5	3.0	2.0	2.0	3.0	3.0	2.0	3.0	3.0	3.0	2.0	4.0
Rank Sum	520	452	462	455	570	441	429	414	453	453	442	507
<u>TEST (Normal Dist)</u>												
alpha	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Mean	506	495	528	528	563	550	550	563	528	528	528	575
Variance	1,687	1,566	1,672	1,672	1,781	1,650	1,650	1,781	1,672	1,672	1,672	1,917
Std Dev	41.1	39.6	40.9	40.9	42.2	40.6	40.6	42.2	40.9	40.9	40.9	43.8
p-value (1-tail)	0.03	0.14	0.86	0.81	0.00	0.86	0.79	0.37	0.80	0.72	0.72	0.86
significant?	Yes	No	No	No	Yes	No	No	No	No	No	No	No
p-value (2-tails)	0.05	0.27	0.28	0.37	0.00	0.27	0.42	0.74	0.39	0.56	0.56	0.28
significant?	No	No	No	No	Yes	No	No	No	No	No	No	No

4.4. Inter-group comparison: High vs Low Income Boroughs

Table 25: Range of Responses Question 2.2 – Respondents from High Income vs Low Income Boroughs

2.2.	To what extent do each of the following subjects present an ongoing challenge to your role?														
	Please rate from (1) not a problem, to (5) needs a lot more resources/time/research to address the problem.														
		HIGH							LOW						
		1 - under control	2	3	4	5 - needs more	I don't know	Response total	1 - under control	2	3	4	5 - needs more	I don't know	Response total
	Climate change consequences on urban tree species	1	6	6	8	1	1	23	5	6	3	4	3	2	23
	Urban heat island mitigation by urban vegetation	3	8	4	5	1	2	23	6	5	4	4	2	2	23
	Water storm management	5	10	2	2	2	2	23	7	5	5	3	2	1	23
	Drought and sustainable water management	4	8	3	5	1	2	23	6	6	4	4	2	1	23
	Massaria diseases of plane	5	5	8	3	0	2	23	8	7	3	3	2	0	23
	Oak Processionary moth	7	4	5	4	1	2	23	6	6	7	1	2	1	23
	Chalara /Ash dieback	10	5	4	2	0	2	23	11	5	2	2	2	1	23
	Hazardous trees assessment procedures	2	5	6	7	1	2	23	1	1	7	11	3	0	23
	Community engagement	6	3	8	2	2	2	23	8	5	5	4	0	0	22
	Vandalism prevention of urban trees, vegetation, greenspaces	6	9	3	2	1	2	23	7	8	2	4	1	1	23
	Public communication	0	5	7	8	2	1	23	1	3	8	6	5	0	23
	Other (please specify):	1	0	1	0	2	1	5	1	0	0	0	1	1	3

Figure 16: Range of Responses Question 2.2 – Respondents from High Income vs Low Income Boroughs

Table 26: Wilcoxon Rank-Sum test for High Income / Low Income boroughs for Question 2.2

Wilcoxon Rank Sum test	2.2 Climate change consequences on urban tree species	2.2 Urban heat island mitigation by urban vegetation	2.2 Water storm management	2.2 Drought and sustainable water management	2.2 Massaria diseases of plane	2.2 Oak Processionary moth	2.2 Chalara /Ash dieback	2.2 Hazardous trees assessment procedures	2.2 Community engagement	2.2 Vandalism prevention of urban trees, vegetation, greenspaces	2.2 Public communication
<u>LOW</u>											
Count	21	21	22	22	23	22	22	23	22	22	23
Median	2.0	2.0	2.0	2.0	2.0	2.0	1.5	4.0	2.0	2.0	3.0
Rank Sum	420	438	495	478	491	482	487	595	452	488	553
<u>HIGH</u>											
Count	22	21	21	21	21	21	21	21	21	21	22
Median	3.0	2.0	2.0	2.0	3.0	2.0	2.0	3.0	3.0	2.0	3.0
Rank Sum	526	465	452	468	499	465	460	396	495	459	483
<u>TEST (Normal Dist)</u>											
alpha	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Mean	462	452	484	484	518	484	484	518	484	484	529
Variance	1,694	1,580	1,694	1,694	1,811	1,694	1,694	1,811	1,694	1,694	1,940
Std Dev	41.2	39.8	41.2	41.2	42.6	41.2	41.2	42.6	41.2	41.2	44.0
p-value (1-tail)	0.15	0.37	0.40	0.56	0.27	0.52	0.48	0.04	0.21	0.47	0.30
significant?	No	No	No	No	No	No	No	Yes	No	No	No
p-value (2-tails)	0.31	0.73	0.80	0.88	0.53	0.95	0.95	0.07	0.43	0.93	0.59
significant?	No	No	No	No	No	No	No	No	No	No	No

5. Question 2.3: How often do you work directly with the public?

5.1. Range of Responses

Table 27: Range of Responses Question 2.3 – All Respondents

2.3.	How often do you work directly with the public?		
	Please, choose ONE		
		Response percent	Response total
	1 - Never	0%	0
	2 - Rarely (less than once a month)	14%	8
	3 - Every month	14%	8
	4 - Every week	18%	10
	5 - Every day	54%	30

Note: respondents: 56

Table 28: Range of Responses Question 2.3 - Respondents working on Council / Public land

2.3.	How often do you work directly with the public?		
	Please, choose ONE		
		Response percent	Response total
	1 - Never	0%	0
	2 - Rarely (less than once a month)	18%	8
	3 - Every month	18%	8
	4 - Every week	18%	8
	5 - Every day	45%	20

Figure 17: Range of Responses Question 2.3 – All Respondents vs Respondents working on Council / Public land

5.2. Inter-group comparison: Inner vs Outer

Table 29: Range of Responses Question 2.3 – Respondents from Inner Boroughs vs Outer Boroughs

2.3.	How often do you work directly with the public?		
	Please, choose ONE		
		INNER	OUTER
	1 - Never	0	0
	2 - Rarely (less than once a month)	4	4
	3 - Every month	3	4
	4 - Every week	4	5
	5 - Every day	14	16

Figure 18: Range of Responses Question 2.3 – Respondents from Inner Boroughs vs Outer Boroughs

NOTE: 2 respondents were not categorised as either INNER or OUTER and are not included in this analysis

5.3. Inter-group comparison: High vs Low Income Boroughs

Table 30: Range of Responses Question 2.3 – Respondents from High vs Low Income Boroughs

2.3.	How often do you work directly with the public?		
	Please, choose ONE		
		HIGH	LOW
	1 - Never	0	0
	2 - Rarely (less than once a month)	6	2
	3 - Every month	4	3
	4 - Every week	3	6
	5 - Every day	13	17

Figure 19: Range of Responses Question 2.3 – Respondents from High vs Low Income Boroughs

6. Question 2.4: Based on YOUR experience, please rate the following sentences from (1) strongly disagree to (5) strongly agree

6.1. Descriptive Statistics

Table 31: Descriptive Statistics for Question 2.4

	<i>2.4 Communicating with the public is easy</i>	<i>2.4 The public in general are very knowledgeable about urban trees and their phenology</i>	<i>2.4 It is difficult to make people understand trees needs to be managed even when they look</i>	<i>2.4 People usually want trees to be planted in their neighborhood but not in front of their houses</i>	<i>2.4 Street trees are less valued by people than trees in parks</i>	<i>2.4 A better understanding of urban trees' characteristics and the benefits they provide would make people more open to coping with minor inconveniences such</i>	<i>2.4 The community is motivated and eager to participate</i>
Mean	3.25	2.13	3.33	3.73	3.13	3.96	2.89
Standard Error	0.13	0.14	0.17	0.14	0.16	0.15	0.12
Median	3	2	3	4	3	4	3
Mode	3	2	3	4	3	5	3
Standard Deviation	0.99	1.04	1.24	1.03	1.16	1.14	0.86
Sample Variance	0.97	1.08	1.55	1.05	1.35	1.29	0.74
Kurtosis	-0.49	1.44	-1.12	-0.39	-0.48	-0.50	0.21
Skewness	0.18	1.18	-0.06	-0.49	-0.19	-0.79	0.22
Range	4	4	4	4	4	4	4
Maximum	5	5	5	5	5	5	5
Minimum	1	1	1	1	1	1	1
Sum	179	117	180	205	166	218	156
Count	55	55	54	55	53	55	54
Geometric Mean	3.10	1.91	3.07	3.56	2.87	3.76	2.75
Harmonic Mean	2.92	1.71	2.77	3.34	2.54	3.48	2.59
AAD	0.80	0.74	1.07	0.85	0.89	0.92	0.63
MAD	1	1	1	1	1	1	1
IQR	1	1.5	2	1.5	1	2	1
Shapiro-Wilk Test							
W	9.0E-01	8.2E-01	8.9E-01	8.8E-01	9.1E-01	8.2E-01	8.8E-01
p-value	1.9E-04	8.3E-07	1.8E-04	7.4E-05	5.3E-04	1.0E-06	8.0E-05
alpha	0.05	0.05	0.05	0.05	0.05	0.05	0.05
normal	no	no	no	no	no	no	no

Figure 20: Means and Standard Error for Question 2.4

6.2. Range of Responses

Table 32: Range of Responses Question 2.4 – All Respondents

2.4.	Based on YOUR experience, please rate the following sentences from (1) strongly disagree to (5) strongly agree							
		1 - strongly disagree	2	3	4	5 - strongly agree	I don't know	Response total
	Communicating with the public is easy	1	11	23	13	7	0	55
	The public in general are very knowledgeable about urban trees and their phenology	15	26	9	2	3	0	55
	It is difficult to make people understand trees needs to be managed even when they look healthy	3	13	14	11	13	1	55
	People usually want trees to be planted in their neighborhood but not in front of their houses	1	6	14	20	14	0	55
	Street trees are less valued by people than trees in parks	6	7	21	12	7	2	55
	A better understanding of urban trees' characteristics and the benefits they provide would make people more open to coping with minor inconveniences such as leaves/fruits/sap/honey-dew	1	7	9	14	24	0	55
	The community is motivated and eager to participate	2	15	26	9	2	1	55
	Other (please specify):	1	0	0	0	0	1	2

Other Responses: None specified

Respondents: 55

Table 33: Range of Responses Question 2.4 – Respondents working on Council / Public land

2.4.	Based on YOUR experience, please rate the following sentences from (1) strongly disagree to (5) strongly agree							
		1 - strongly disagree	2	3	4	5 - strongly agree	I don't know	Response total
	Communicating with the public is easy	1	9	21	8	5	0	44
	The public in general are very knowledgeable about urban trees and their phenology	11	23	6	2	2	0	44
	It is difficult to make people understand trees needs to be managed even when they look healthy	2	11	11	9	10	1	44
	People usually want trees to be planted in their neighborhood but not in front of their houses	0	6	10	16	12	0	44
	Street trees are less valued by people than trees in parks	6	6	16	11	5	0	44
	A better understanding of urban trees' characteristics and the benefits they provide would make people more open to coping with minor inconveniences such as leaves/fruits/sap/honey-dew	1	5	9	12	17	0	44
	The community is motivated and eager to participate	2	13	23	4	1	1	44
	Other (please specify):	1	0	0	0	0	0	1

Respondents: 44

Figure 21: Range of Responses Question 2.4 – All Respondents

Figure 22: Range of Responses Question 2.4 – Respondents working on Council / Public land

Table 34: Wilcoxon Signed- Rank test for various statements in Question 2.4

	2.4 A better understanding of urban trees' characteristics and the benefits they provide would make people more open to 2.4 People usually want trees to be planted in their neighborhood but not in front of their houses		2.4 People usually want trees to be planted in their neighborhood but not in front of their houses 2.4 It is difficult to make people understand trees needs to be managed even when they look healthy		2.4 It is difficult to make people understand trees needs to be managed even when they look healthy 2.4 Street trees are less valued by people than trees in parks		2.4 Street trees are less valued by people than trees in parks 2.4 The community is motivated and eager to participate		2.4 The community is motivated and eager to participate 2.4 The public in general are very knowledgeable about urban trees and their phenology	
median	4	4	4	3	3	3	3	3	3	2
count	55		54		52		52		54	
# unequal	38		38		39		41		39	
T+	310.5		244.5		300		367		102	
T-	430.5		496.5		480		494		678	
T	310.5		244.5		300		367		102	
alpha	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail
mean	0.05		0.05		0.05		0.05		0.05	
std dev	370.5		370.5		390		430.5		390	
z-score	67.772598	ties	67.76799	ties	70.76987	ties	76.41253	ties	69.21795	ties
effect r	0.877936		1.851907		1.264662		0.824472		4.153547	
effect r	0.0837079		0.1782		0.12401		0.080846		0.399675	
T-crit	258.524	237.1681	258.5316	237.1772	273.0939	250.7936	304.3126	280.2342	275.6466	253.8353
p-value	0.1899892	0.379978	0.03202	0.064039	0.102996	0.205992	0.204836	0.409671	1.64E-05	3.27E-05
sig (norm)	no	no	yes	no	no	no	no	no	yes	yes
T-crit	256	235	256	235	271	249	302	279	271	249
sig (table)	no	no	yes	no	no	no	no	no	yes	yes

6.3. Inter-group comparison: Inner vs Outer

Table 35: Range of Responses Question 2.4 – Respondents from Inner Boroughs vs Outer Boroughs

2.4.	Based on YOUR experience, please rate the following sentences from (1) strongly disagree to (5) strongly agree														
		INNER							OUTER						
		1 - strongly disagree	2	3	4	5 - strongly agree	I don't know	Response total	1 - strongly disagree	2	3	4	5 - strongly agree	I don't know	Response total
	Communicating with the public is easy	0	5	10	6	4	0	25	1	6	12	7	2	0	28
	The public in general are very knowledgeable about urban trees and their phenology	5	13	6	0	1	0	25	9	12	3	2	2	0	28
	It is difficult to make people understand trees needs to be managed even when they look healthy	0	7	5	6	7	0	25	3	5	9	5	5	1	28
	People usually want trees to be planted in their neighborhood but not in front of their houses	1	4	6	10	4	0	25	0	2	7	9	10	0	28
	Street trees are less valued by people than trees in parks	6	3	9	4	2	1	25	0	4	11	7	5	1	28
	A better understanding of urban trees' characteristics and the benefits they provide would make people more open to coping with minor inconveniences such as leaves/fruits/sap/honey-dew	0	3	4	7	11	0	25	1	3	5	7	12	0	28
	The community is motivated and eager to participate	0	8	11	5	1	0	25	2	6	14	4	1	1	28
	Other (please specify):	0	0	0	0	0	0	0	1	0	0	0	0	1	2

Figure 23: Range of Responses Question 2.4 – Respondents from Inner Boroughs vs Outer Boroughs

Table 36: Wilcoxon Rank-Sum test for INNER / OUTER boroughs for Question 2.4

Wilcoxon Rank-Sum test	Rank						
		2.4 Communicating with the public is easy	2.4 The public in general are very knowledgeable about urban trees and their phenology	2.4 It is difficult to make people understand trees needs to be managed even when they look healthy	2.4 People usually want trees to be planted in their neighborhood but not in front of their houses	2.4 Street trees are less valued by people than trees in parks	2.4 A better understanding of urban trees' characteristics and the benefits they provide would make people more open to coping with minor
		2.4 The community is motivated and eager to participate					
<u>OUTER</u>							
Count	28	28	27	28	27	28	27
Median	3.0	2.0	3.0	4.0	3.0	4.0	3.0
Rank Sum	713	727	664	842	812	743	702
<u>INNER</u>							
Count	25	25	25	25	24	25	25
Median	3.0	2.0	4.0	4.0	3.0	4.0	3.0
Rank Sum	718	705	715	589	515	688	677
<u>TEST (Normal Dist)</u>							
alpha	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Mean	756	756	716	756	702	756	716
Variance	3,150	3,150	2,981	3,150	2,808	3,150	2,981
Std Dev	56.1	56.1	54.6	56.1	53.0	56.1	54.6
p-value (1-tail)	0.22	0.70	0.17	0.06	0.02	0.59	0.60
significant?	No	No	No	No	Yes	No	No
p-value (2-tails)	0.44	0.60	0.34	0.13	0.04	0.82	0.80
significant?	No	No	No	No	Yes	No	No

6.4. Inter-group comparison: High vs Low Income Boroughs

Table 37: Range of Responses Question 2.4 – Respondents from High Income vs Low Income Boroughs

2.4.	Based on YOUR experience, please rate the following sentences from (1) strongly disagree to (5) strongly agree														
		HIGH							LOW						
		1 - strongly disagree	2	3	4	5 - strongly agree	I don't know	Response total	1 - strongly disagree	2	3	4	5 - strongly agree	I don't know	Response total
	Communicating with the public is easy	1	6	9	7	3	0	26	0	5	13	6	3	0	27
	The public in general are very knowledgeable about urban trees and their phenology	5	14	4	2	1	0	26	9	11	5	0	2	0	27
	It is difficult to make people understand trees needs to be managed even when they look healthy	1	5	7	6	6	1	26	2	7	7	5	6	0	27
	People usually want trees to be planted in their neighborhood but not in front of their houses	1	2	7	8	8	0	26	0	4	6	11	6	0	27
	Street trees are less valued by people than trees in parks	4	2	12	5	2	1	26	2	5	8	6	5	1	27
	A better understanding of urban trees' characteristics and the benefits they provide would make people more open to coping with minor inconveniences such as leaves/fruits/sap/honey-dew	0	2	4	10	10	0	26	1	4	5	4	13	0	27
	The community is motivated and eager to participate	0	9	12	5	0	0	26	2	5	13	4	2	1	27
	Other (please specify):	0	0	0	0	0	0	0	1	0	0	0	0	1	2

Figure 24: Range of Responses Question 2.4 – Respondents from High Income vs Low Income Boroughs

Table 38: Wilcoxon Rank-Sum test for High Income / Low Income boroughs for Question 2.4

Wilcoxon Sum test	Rank	2.4 Communicating with the public is easy	2.4 The public in general are very knowledgeable about urban trees and their phenology	2.4 It is difficult to make people understand trees needs to be managed even when they look	2.4 People usually want trees to be planted in their neighborhood but not in front of their houses	2.4 Street trees are less valued by people than trees in parks	2.4 A better understanding of urban trees' characteristics and the benefits they provide would make people	2.4 The community is motivated and eager to participate
<u>LOW</u>								
Count	27	27	27	27	26	27	26	
Median	3.0	2.0	3.0	4.0	3.0	4.0	3.0	
Rank Sum	738	689	682	711	719	719	715	
<u>HIGH</u>								
Count	26	26	25	26	25	26	26	
Median	3.0	2.0	3.0	4.0	3.0	4.0	3.0	
Rank Sum	693	743	696	720	607	712	664	
<u>TEST (Normal Dist)</u>								
alpha	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
Mean	729	729	716	729	676	729	689	
Variance	3,159	3,159	2,981	3,159	2,817	3,159	2,986	
Std Dev	56.2	56.2	54.6	56.2	53.1	56.2	54.6	
p-value (1-tail)	0.44	0.24	0.27	0.37	0.21	0.57	0.32	
significant?	No	No	No	No	No	No	No	
p-value (2-tails)	0.87	0.47	0.54	0.75	0.42	0.86	0.64	
significant?	No	No	No	No	No	No	No	

7. Question 2.5: Please rate the following messages with regard to ease of communication to the public. Please rate from (1) very easy to (5) very difficult to explain

7.1. Descriptive Statistics

Table 39: Descriptive Statistics for Question 2.5

	<i>2.5 Long term consequences of today's management decisions</i>	<i>2.5 The benefits of urban trees</i>	<i>2.5 The importance of planting the right tree in the right place</i>	<i>2.5 The need to fell diseased or structurally unstable trees</i>	<i>2.5 The benefits of community engagement</i>
Mean	3.42	2.83	2.70	2.70	3.08
Standard Error	0.15	0.13	0.15	0.17	0.11
Median	3	3	3	2.5	3
Mode	4	2	2	2	3
Standard Deviation	1.08	0.95	1.11	1.27	0.83
Sample Variance	1.17	0.90	1.23	1.61	0.69
Kurtosis	-0.61	-0.78	-1.09	-1.16	0.03
Skewness	-0.25	0.07	-0.07	0.18	0.07
Range	4	4	4	4	4
Maximum	5	5	5	5	5
Minimum	1	1	1	1	1
Sum	181	153	146	146	163
Count	53	54	54	54	53
Geometric Mean	3.21	2.66	2.44	2.38	2.96
Harmonic Mean	2.96	2.47	2.15	2.05	2.82
AAD	0.91	0.79	0.96	1.11	0.60
MAD	1	1	1	1.5	1
IQR	1	2	2	2	1
Shapiro-Wilk Test					
W	9.1E-01	8.9E-01	8.9E-01	8.9E-01	8.8E-01
p-value	6.3E-04	9.7E-05	1.3E-04	1.5E-04	7.2E-05
alpha	0.05	1.05	2.05	3.05	4.05
normal	no	no	no	no	no

Figure 25: Means and Standard Error for Question 2.5

7.2. Range of Responses

Table 40: Range of Responses Question 2.5 – All Respondents

2.5.	Please rate the following messages with regard to ease of communication to the public.							
	Please rate from (1) very easy to (5) very difficult to explain							
		1 - Very easy	2	3	4	5 - Very difficult	I don't know	Response total
	Long term consequences of today's management decisions	2	9	16	17	9	2	55
	The benefits of urban trees	3	19	17	14	1	1	55
	The importance of planting the right tree in the right place	9	15	14	15	1	1	55
	The need to fell diseased or structurally unstable trees	11	16	9	14	4	1	55
	The benefits of community engagement	1	11	26	13	2	2	55
	Other (please specify):	2	0	0	0	0	0	2

Other Responses: "comment - it's easy but needs time in many cases; peoples understanding is a test of good policy strategy, web information, contact centre knowledge etc"

Respondents: 55

Table 41: Range of Responses Question 2.5 – Respondents working on Council / Public land

2.5.	Please rate the following messages with regard to ease of communication to the public.							
	Please rate from (1) very easy to (5) very difficult to explain							
		1 - Very easy	2	3	4	5 - Very difficult	I don't know	Response total
	Long term consequences of today's management decisions	2	8	13	14	5	2	44
	The benefits of urban trees	2	16	14	10	1	1	44
	The importance of planting the right tree in the right place	6	11	11	14	1	1	44
	The need to fell diseased or structurally unstable trees	10	8	8	14	3	1	44
	The benefits of community engagement	1	7	23	9	2	2	44
	Other (please specify):	2	0	0	0	0	0	2

Respondents: 44

Figure 26: Range of Responses Question 2.5 – All Respondents

Figure 27: Range of Responses Question 2.5 – Respondents working on Council / Public land

Table 42: Wilcoxon Signed-Rank Test for Paired Samples for Question 2.5

	2.5 Long term consequences of today's management decisions		2.5 The benefits of community engagement		2.5 The benefits of community engagement		2.5 The benefits of urban trees		2.5 The benefits of community engagement		2.5 The need to fell diseased or structurally unstable trees		2.5 The benefits of community engagement		2.5 The importance of planting the right tree in the right place	
median	3	3	3	3	3	2.5	3	3	3	3	3	3	3	3	3	3
count	52		53		53		53		53		53		53		53	
# unequal	37		32		37		37		35		37		35		37	
T+	215		190.5		229.5		192.5		229.5		192.5		229.5		192.5	
T-	488		337.5		473.5		437.5		473.5		437.5		473.5		437.5	
T	215		190.5		229.5		192.5		229.5		192.5		229.5		192.5	
	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail
alpha	0.05		0.05		0.05		0.05		0.05		0.05		0.05		0.05	
mean	351.5		264		351.5		315		351.5		315		351.5		315	
std dev	64.35934	ties	50.7383	ties	65.21311	ties	59.08257	ties	65.21311	ties	59.08257	ties	65.21311	ties	59.08257	ties
z-score	2.113135		1.438755		1.863122		2.064907		1.863122		2.064907		1.863122		2.064907	
effect r	0.20721		0.139744		0.180962		0.200561		0.180962		0.200561		0.180962		0.200561	
T-crit	245.1383	224.858	180.0429	164.0548	243.734	223.1846	217.3178	198.7003	243.734	223.1846	217.3178	198.7003	243.734	223.1846	217.3178	198.7003
p-value	0.017295	0.034589	0.07511	0.15022	0.031223	0.062445	0.019466	0.038932	0.031223	0.062445	0.019466	0.038932	0.031223	0.062445	0.019466	0.038932
sig (norm)	yes	yes	no	no	yes	no	yes	yes	yes	no	yes	yes	yes	no	yes	yes
T-crit	241	221	175	159	241	221	213	195	241	221	213	195	241	221	213	195
sig (table)	yes	yes	no	no	yes	no	yes	yes	yes	no	yes	yes	yes	no	yes	yes

7.3. Inter-group comparison: Inner vs Outer

Table 43: Range of Responses Question 2.5 – Respondents from Inner Boroughs vs Outer Boroughs

2.5.	Please rate the following messages with regard to ease of communication to the public.														
	Please rate from (1) very easy to (5) very difficult to explain														
		INNER							OUTER						
		1 - Very easy	2	3	4	5 - Very difficult	I don't know	Response total	1 - Very easy	2	3	4	5 - Very difficult	I don't know	Response total
	Long term consequences of today's management decisions	1	6	7	9	0	2	25	1	2	9	8	8	0	28
	The benefits of urban trees	1	13	8	1	1	1	25	2	5	8	13	0	0	28
	The importance of planting the right tree in the right place	4	10	4	6	0	1	25	5	4	10	8	1	0	28
	The need to fell diseased or structurally unstable trees	2	10	3	6	3	1	25	9	6	5	7	1	0	28
	The benefits of community engagement	0	6	10	6	1	2	25	1	5	14	7	1	0	28
	Other (please specify):	0	0	0	0	0	0	0	2	0	0	0	0	0	2

Figure 28: Range of Responses Question 2.5 – Respondents from Inner Boroughs vs Outer Boroughs

Table 44: Wilcoxon Rank-Sum test for INNER / OUTER boroughs for Question 2.5

Wilcoxon Rank Sum test	2.5 Long term consequences of today's management decisions	2.5 The benefits of urban trees	2.5 The importance of planting the right tree in the right place	2.5 The need to fell diseased or structurally unstable trees	2.5 The benefits of community engagement
<u>OUTER</u>					
Count	28	28	28	28	28
Median	4.0	3.0	3.0	2.0	3.0
Rank Sum	841	881	804	673	731
<u>INNER</u>					
Count	23	24	24	24	23
Median	3.0	2.0	2.0	2.5	3.0
Rank Sum	485	497	574	705	596
<u>TEST (Normal Dist)</u>					
alpha	0.05	0.05	0.05	0.05	0.05
Mean	728	742	742	742	728
Variance	2,791	2,968	2,968	2,968	2,791
Std Dev	52.8	54.5	54.5	54.5	52.8
p-value (1-tail)	0.02	0.01	0.13	0.10	0.48
significant?	Yes	Yes	No	No	No
p-value (2-tails)	0.03	0.01	0.26	0.21	0.96
significant?	Yes	Yes	No	No	No

7.4. Inter-group comparison: High vs Low Income Boroughs

Table 45: Range of Responses Question 2.5 – Respondents from High Income vs Low Income Boroughs

2.5.	Please rate the following messages with regard to ease of communication to the public.														
	Please rate from (1) very easy to (5) very difficult to explain														
		HIGH							LOW						
		1 - Very easy	2	3	4	5 - Very difficult	I don't know	Response total	1 - Very easy	2	3	4	5 - Very difficult	I don't know	Response total
	Long term consequences of today's management decisions	1	4	10	8	1	2	26	1	4	6	9	7	0	27
	The benefits of urban trees	2	10	8	4	1	1	26	1	8	8	10	0	0	27
	The importance of planting the right tree in the right place	4	8	5	7	1	1	26	5	6	9	7	0	0	27
	The need to fell diseased or structurally unstable trees	4	7	5	8	1	1	26	7	9	3	5	3	0	27
	The benefits of community engagement	1	3	10	9	1	2	26	0	8	14	4	1	0	27
	Other (please specify):	1	0	0	0	0	0	1	1	0	0	0	0	0	1

Figure 29: Range of Responses Question 2.5 – Respondents from High Income vs Low Income Boroughs

Table 46: Wilcoxon Rank-Sum test for High Income / Low Income boroughs for Question 2.5

Wilcoxon Rank Sum test	2.5 Long term consequences of today's management decisions	2.5 The benefits of urban trees	2.5 The importance of planting the right tree in the right place	2.5 The need to fell diseased or structurally unstable trees	2.5 The benefits of community engagement
<u>LOW</u>					
Count	27	27	27	27	27
Median	4.0	3.0	3.0	2.0	3.0
Rank Sum	786	783	710	673.5	621.5
<u>HIGH</u>					
Count	24	25	25	25	24
Median	3.0	3.0	3.0	3.0	3.0
Rank Sum	540	595	668	704.5	704.5
<u>TEST (Normal Dist)</u>					
alpha	0.05	0.05	0.05	0.05	0.05
Mean	702	716	716	716	702
Variance	2,808	2,981	2,981	2,981	2,808
Std Dev	53.0	54.6	54.6	54.6	53.0
p-value (1-tail)	0.06	0.11	0.54	0.22	0.06
significant?	No	No	No	No	No
p-value (2-tails)	0.11	0.22	0.92	0.44	0.13
significant?	No	No	No	No	No

8. Question 2.6: Based on your interaction with them, how well do the following groups understand the importance of large mature trees for SHADING and COOLING in a future with climate change? Please rate as (1) good understanding, (2) some understanding, (3) poor understanding or (4) no understanding.

8.1. Descriptive Statistics

Table 47: Descriptive Statistics for Question 2.6

	<i>2.6 General public</i>	<i>2.6 Councillors/ local politicians</i>	<i>2.6 Other borough staff</i>	<i>2.6 Developers</i>
Mean	2.71	2.46	2.18	2.80
Standard Error	0.11	0.12	0.11	0.13
Median	3	2	2	3
Mode	3	2	2	3
Standard Deviation	0.65	0.73	0.69	0.80
Sample Variance	0.43	0.53	0.48	0.64
Kurtosis	-0.65	-0.04	1.28	-0.68
Skewness	0.37	0.37	0.77	0.01
Range	2	3	3	3
Maximum	4	4	4	4
Minimum	2	1	1	1
Sum	103	91	83	98
Count	38	37	38	35
Geometric Mean	2.63	2.35	2.08	2.68
Harmonic Mean	2.56	2.23	1.97	2.55
AAD	0.56	0.63	0.49	0.65
MAD	0.5	0	0	1
IQR	1	1	0	1
Shapiro-Wilk Test				
W	7.8E-01	8.3E-01	7.7E-01	8.5E-01
p-value	3.4E-06	5.3E-05	3.2E-06	2.8E-04
alpha	0.05	1.05	2.05	3.05
normal	no	no	no	no

Figure 30: Means and Standard Error for Question 2.6

8.2. Range of Responses

Table 48: Range of Responses Question 2.6 – All Respondents

2.6	Based on your interaction with them, how well do the following groups understand the importance of large mature trees for SHADING and COOLING in a future with climate change?						
	Please rate as (1) good understanding, (2) some understanding, (3) poor understanding or (4) no understanding.						
		1 - Good Understanding	2 - Some Understanding	3 - Poor Understanding	4 - No understanding	I don't know	Response total
	General public	0	15	19	4	0	38
	Councillors/ local politicians	2	19	13	3	1	38
	Other borough staff	4	25	7	2	0	38
	Developers	1	12	15	7	3	38
	Other (please specify):	1	0	0	0	0	1

Other Responses: Tree Officers
Respondents: 38

Table 49: Range of Responses Question 2.6 – Respondents working on Council / Public land

2.6	Based on your interaction with them, how well do the following groups understand the importance of large mature trees for SHADING and COOLING in a future with climate change?						
	Please rate as (1) good understanding, (2) some understanding, (3) poor understanding or (4) no understanding.						
		1 - Good Understanding	2 - Some Understanding	3 - Poor Understanding	4 - No understanding	I don't know	Response total
	General public	0	12	14	2	0	28
	Councillors/ local politicians	2	15	9	1	1	28
	Other borough staff	3	19	6	0	0	28
	Developers	1	7	11	6	3	28
	Other (please specify):	1	0	0	0	0	1

Respondents: 28

Figure 31: Range of Responses Question 2.6 – All Respondents

Figure 32: Range of Responses Question 2.6 – Respondents working on Council / Public land

Table 50: Wilcoxon Signed Rank Test for Paired Samples for Question 2.6

	2.6 Developers		2.6 General public		2.6 Developers 2.6 Other borough staff		2.6 Developers 2.6 Councillors/ local politicians		2.6 General public 2.6 Other borough staff		2.6 Councillors/ local politicians 2.6 Other borough staff	
median	3	3	3	2	3	2	3	2	3	2	2	2
count	35		35		35		38		37			
# unequal	21		24		22		19		20			
T+	100.5		43.5		77.5		8.5		52.5			
T-	130.5		256.5		175.5		181.5		157.5			
T	100.5		43.5		77.5		8.5		52.5			
	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail	one tail	two tail
alpha	0.05		0.05		0.05		0.05		0.05			
mean	115.5		150		126.5		95		105			
std dev	27.072	ties	32.799	ties	29.37	ties	20.112	ties	23.302	ties		
z-score	0.5356		3.2318		1.6513		4.276		2.2315			
effect r	0.064		0.3863		0.1974		0.4905		0.2594			
T-crit	70.471	61.941	95.551	85.216	77.69	68.435	61.418	55.081	66.171	58.828		
p-value	0.2961	0.5922	0.0006	0.0012	0.0493	0.0987	1E-05	2E-05	0.0128	0.0256		
sig (norm)	no	no	yes	yes	yes	no	yes	yes	yes	yes		
T-crit	67	58	91	81	75	65	53	46	60	52		
sig (table)	no	no	yes	yes	no	no	yes	yes	yes	no		
p-value	0.3046	0.6091	0.0008	0.0016	0.0603	0.1207	5E-05	1E-04	0.0242	0.0484		
sig (exact)	no	no	yes	yes	no	no	yes	yes	yes	yes		

8.3. Inter-group comparison: Inner vs Outer

Table 51: Range of Responses Question 2.6 – Respondents from Inner Boroughs vs Outer Boroughs

2. 6	Based on your interaction with them, how well do the following groups understand the importance of large mature trees for SHADING and COOLING in a future with climate change?												
	Please rate as (1) good understanding, (2) some understanding, (3) poor understanding or (4) no understanding.												
		INNER						OUTER					
		1 - Good Understanding	2 - Some Understanding	3 - Poor Understanding	4 - No understanding	I don't know	Response total	1 - Good Understanding	2 - Some Understanding	3 - Poor Understanding	4 - No understanding	I don't know	Response total
	General public	0	11	7	0	0	18	0	4	11	4	0	19
	Councillors/ local politicians	1	11	6	0	0	18	1	8	6	3	1	19
	Other borough staff	3	12	3	0	0	18	1	12	4	2	0	19
	Developers	1	6	8	2	1	18	0	6	7	4	2	19
	Other (please specify):	1	0	0	0	0	1	0	0	0	0	0	0

Figure 33: Range of Responses Question 2.6 – Respondents from Inner Boroughs vs Outer Boroughs

Table 52: Wilcoxon Rank-Sum test for INNER / OUTER boroughs for Question 2.6

Wilcoxon Rank Sum test	2.6 General public	2.6 Councillors/ local politicians	2.6 Other borough staff	2.6 Developers
<u>OUTER</u>				
Count	19	18	19	17
Median	3.0	2.5	2.0	3.0
Rank Sum	444	368	402	318
<u>INNER</u>				
Count	18	18	18	17
Median	2.0	2.0	2.0	3.0
Rank Sum	260	299	302	277
<u>TEST (Normal Dist)</u>				
alpha	0.05	0.05	0.05	0.05
W	259.5	298.5	301.5	277.0
W-crit (1-tail)	287.0	280.0	287.0	249.0
P-value (1-tail)	0.02	0.17	0.22	0.26
significant?	Yes	No	No	No
W-crit (2-tails)	277.0	270.0	277.0	240.0
P-value (2-tails)	0.04	0.34	0.45	0.53
significant?	Yes	No	No	No

8.4. Inter-group comparison: High vs Low Income Boroughs

Table 53: Range of Responses Question 2.6 – Respondents from High Income vs Low Income Boroughs

2.6	Based on your interaction with them, how well do the following groups understand the importance of large mature trees for SHADING and COOLING in a future with climate change?														
	Please rate as (1) good understanding, (2) some understanding, (3) poor understanding or (4) no understanding.														
		HIGH							LOW						
		1 - Good Understanding	2 - Some Understanding	3 - Poor Understanding	4 - No understanding		I don't know	Response total	1 - Good Understanding	2 - Some Understanding	3 - Poor Understanding	4 - No understanding		I don't know	Response total
	General public	0	8	10	1	▲	0	19	0	7	8	3	▲	0	18
	Councillors/ local politicians	1	10	7	0		1	19	1	9	5	3		0	18
	Other borough staff	1	14	4	0		0	19	3	10	3	2		0	18
	Developers	0	4	10	3		2	19	1	8	5	3		1	18
	Other (please specify):	1	0	0	0		0	1	0	0	0	0		0	0

Figure 34: Range of Responses Question 2.6 – Respondents from High Income vs Low Income Boroughs

Table 54: Wilcoxon Rank-Sum test for High Income / Low Income boroughs for Question 2.6

Wilcoxon Rank Sum test	2.6 General public	2.6 Councillors/ local politicians	2.6 Other borough staff	2.6 Developers
<u>LOW</u>				
Count	18	18	18	17
Median	3.0	2.0	2.0	2.0
Rank Sum	358.5	352	341.5	260.5
<u>HIGH</u>				
Count	19	18	19	17
Median	3.0	2.0	2.0	3.0
Rank Sum	344.5	314	361.5	334.5
<u>TEST (W tables)</u>				
alpha	0.05	0.05	0.05	0.05
W	325.5	314.0	341.5	260.5
W-crit (1-tail)	287.0	280.0	287.0	249.0
P-value (1-tail)	0.31	0.27	0.49	0.10
significant?	No	No	No	No
W-crit (2-tails)	277.0	270.0	277.0	240.0
P-value (2-tails)	0.62	0.55	0.99	0.20
significant?	No	No	No	No

9. Question 2.7: Are there any tools that you currently use for analysis or communications with others on urban forestry issues?

9.1. Range of Responses

Table 55: Range of Responses Question 2.7 – All Respondents

2.7	Are there any tools that you currently use for analysis or communications with others on urban forestry issues?		
	Please, tick all that apply		
		Response percent	Response total
	1 - None	13%	5
	2 - GIS or mapping	37%	14
	3 - Visualization programs	0%	0
	4 - Modelling programs	3%	1
	5 - Tree management software	53%	20
	6 - Other (please specify):	5%	2

Other Responses: Excel, PICUS reports

NOTE: Respondents could select multiple options, therefore percentages may add up to more than 100%

Total respondents: 38

Table 56: Range of Responses Question 2.7 – Respondents working on Council / Public land

2.7	Are there any tools that you currently use for analysis or communications with others on urban forestry issues?		
	Please, tick all that apply		
		Response percent	Response total
	1 - None	8%	3
	2 - GIS or mapping	16%	6
	3 - Visualization programs	0%	0
	4 - Modelling programs	3%	1
	5 - Tree management software	53%	20
	6 - Other (please specify):	3%	1

Figure 35: Range of Responses Question 2.7 – All Respondents vs Respondents working on council / public land

9.2. Inter-group comparison: Inner vs Outer

Table 57: Range of Responses Question 2.7 – Respondents from Inner Boroughs vs Outer Boroughs

2.7	Are there any tools that you currently use for analysis or communications with others on urban forestry issues?		
	Please, tick all that apply		
		INNER	OUTER
	1 - None	0	4
	2 - GIS or mapping	7	7
	3 - Visualization programs	0	0
	4 - Modelling programs	1	0
	5 - Tree management software	11	9
	6 - Other (please specify):	0	2

Figure 36: Range of Responses Question 2.7 – Respondents from Inner Boroughs vs Outer Boroughs

NOTE: 2 respondents were not categorised as either INNER or OUTER and are not included in this analysis

9.3. Inter-group comparison: High vs Low Income Boroughs

Table 58: Range of Responses Question 2.7 – Respondents from High vs Low Income Boroughs

2.7	Are there any tools that you currently use for analysis or communications with others on urban forestry issues?		
	Please, tick all that apply		
		HIGH	LOW
	1 - None	1	3
	2 - GIS or mapping	6	8
	3 - Visualization programs	0	0
	4 - Modelling programs	1	0
	5 - Tree management software	11	9
	6 - Other (please specify):	0	2

Figure 37: Range of Responses Question 2.7 – Respondents from High vs Low Income Boroughs

6. INTERVIEWS THEMATIC ANALYSIS RESULTS

DETAILED TABLES AND DATA FROM THE INTERVIEWS THEMATIC ANALYSIS

Table 59. Main characteristics of interviewees.

Participant s	Borough Location		Borough Income		Team			Department			Seniority	
	Inne r	Oute r	Hig h	Lo w	Privat e trees	Publi c trees	Bot h	Environmen t	Plannin g	Parks/Leissur e	Senio r	Junio r
1	1			1	1			1				1
2	1		1			1			1		1	
3	1		1				1			1	1	
4		1	1			1			1		1	
5		1			1				1		1	
6	1		1			1		1				1
7		1		1		1			1		1	
8	1			1		1		1			1	
9	1		1			1		1				1
10		1		1		1			1		1	
11		1	1			1			1		1	
12		1		1		1				1	1	
13	1			1		1			1		1	
14	1		1		1			1			1	
15		1		1	1			1			1	
16	1			1		1			1		1	
17	1		1		1			1				1
Total	10	7	8	9	5	11	1	7	8	2	13	4
	(59 %)	(41 %)	(47 %)	(53 %)	(29 %)	(65 %)	(6 %)	(41 %)	(47 %)	(12 %)	(76 %)	(24 %)

Source: Own elaboration

Table 60. Different types of previous experiences with the use of visualizations by the interviewees.

Previous interaction with VIZs		Interviewees																	Total	%
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
VIZs are presented to me		1	1	1		1			1						1	1		1	8	(47 %)
I produce/ask someone to produce VIZs	Hand drawn		1						1										2	(12 %)
	2D					1			1			1							3	(18 %)
	3D					1													1	(6 %)
Street View						1	1	1	1	1	1	1	1	1	1	1		1	12	(70 %)
No interaction with VIZs					1						1						1		3	(18 %)

Source: Own elaboration

Table 61. Responses from tree officers evaluating the visualizations from the presentation.

Participants	Colour code dots			Colour code augmented reality			Long term			Shade			Shade technical tool		
	+	0	-	+	0	-	+	0	-	+	0	-	+	0	-
1	1			1			1			1					
2								1							
3				1			1						1		
4			1	1			1			1					
5	1			1						1					
6		1					1			1			1		
7				1			1			1			1		
8	1			1			1			1					
9			1			1	1			1			1		
10						1		1			1				
11	1			1			1			1					
12								1							
13				1			1					1			
14		1						1		1			1		
15		1						1			1				
16			1			1	1		1						
17		1		1			1			1			1		
Total	4	4	3	9	0	3	11	4	2	10	2	1	6	0	0
	(23 %)	(25 %)	(18 %)	(53 %)	(0 %)	(18 %)	(68 %)	(24 %)	(12 %)	(59 %)	(12 %)	(6 %)	(35 %)	(0 %)	(0 %)

Source: Own elaboration

Table 62. Summary of the roles of visualizations in urban forestry extracted from tree officers' responses.

VIZs applications	Type of VIZs	Interviewees																	Total	%
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
To explain new plantings, tree removals or other works to public, other departments and politicians	- Point of view: ground view - Level of detail: Semirealistic 3D or realistic 2D photomontage - Content: colour code augmented reality, before and after and long term	1	1	1	1	1	1	1	1	1		1	1	1				1	13	(76 %)
To visualize tree growth and future problems with trees and buildings and other street infrastructure (street lamps, traffic lights, ...)	- Point of view: ground view - Level of detail: Semirealistic 3D - 3D navigation important - Content: before and after and long term				1	1									1				3	(18 %)
To model tree growth	- Plan view with shaded area for potential growth - Integration with management software / GIS	1																	1	(6 %)
To visualize tree shade to deal with public complaints	- Point of view: not specified - Level of detail: Semirealistic 3D - Content: shade evolution along day and seasons				1	1	1	1		1					1				6	(35 %)
To model tree shade to deal with public complains	Mathematical model of number shade hours				1					1									2	(12 %)
As information for new planting sites on species selection and maximizing shading, etc.	Mathematical model of number shade hours			1			1		1	1							1		5	(29 %)
To model how new buildings would shade existing trees	Mathematical model of number shade hours									1					1				2	(12 %)
For local groups to present more effectively their proposals	Not specified	1																	1	(6 %)
For planners to better explain their applications if the VIZs were based on facts	- More accurate representation of tree species - More accurate positioning of trees - Introduce long term simulations			1						1	1		1				1	1	6	(35 %)
Integration with management software /GIS	Integration with management software /GIS	1						1	1										3	(18 %)
To communicate benefits of urban trees and climate change, urban heat island.	Not specified		1						1						1				3	(18 %)
To simulate views from new or existing buildings (trees can screen providing privacy, block view or improve view)	Not specified														1	1			2	(12 %)

Source: Own elaboration

Table 63. Overall evaluation of visualizations as a tool in urban forestry and willingness and easiness to produce visualizations by the tree officers.

Participants	VIZs before?			VIZs similar to presentation useful for them?		Would they see themselves producing VIZs similar to the presented?		Possible to ask someone to do the VIZs? (2)		
	Yes (1)		No	Yes	No	Yes	No	Yes		No
	Produced themselves	Presented to them						Easy	Difficult	
1		1		1		1			1	
2	1				1		1			1
3		1		1		1		-	-	-
4			1	1		1				1
5	1			1		1		1		
6			1	1		1			1	
7			1	1		1			1	
8	1			1		1		1		
9			1		1		1		1	
10			1		1		1			1
11	1			1		1		-	-	-
12			1		1		1	1		
13			1		1		1	-	-	-
14		1		1			1	-	-	-
15		1		1			1	1		
16			1		1		1	-	-	-
17		1		1			1	-	-	-
Total	4	5	8	11	6	8	9	4	4	3
	(24 %)	(29 %)	(47 %)	(65 %)	(35 %)	(47 %)	(53 %)	(24 %)	(24 %)	(18 %)
% Total	(53 %)		(47 %)	(65 %)	(35 %)	(47 %)	(53 %)	(48 %)		(18 %)

(1) Those who use Street View only are considered here as not using visualizations

(2) Boxes with "-" indicate no answer was given

Source: Own elaboration