



Collaborative City Co-design PlatfOrm

Deliverable D2.1 (version 03)

State of the art

Revision 01

Project	ITEA 2 Call 8 13016 C ³ PO <i>Collaborative City Co-design PlatfOrm</i>		
Deliverable	D2.1 State of the art		
Version	v03	Status	FINAL
Revision	Yes: rev01	Date	08/02/2017
Dissemination level	PU - Public		
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File Identifier	C ³ PO-WP2-D2_1-PU-v03-rev01-FINAL-SOTA		

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Executive summary

According to City Metric three million people move to cities from rural areas every week and it is estimated that cities will be home to 70% of the world population by 2050 (UN-habitat, 2013). Such intensive growth in combination with global migration crisis **requires upgrading existing infrastructure and developing new ones** (urbanisation challenge). Cities alone will have to spend \$350 trillion or seven times the current global GDP in the next 30 years on urban infrastructure (Accenture, 2011). Better planning, integrating a new ecological context and mediating a range of self-interested stakeholders (citizens, leaders in cities, architects, etc.) engaged in the urban development are needed **to address the urbanisation challenge**, to optimize the costs and allow continuous value creation for city developers and citizens.

Information and communications technologies (ICT) and its rapid development in the urban planning could become a recipe in solving the urbanisation challenge: cloud computing, big data, Web technologies, mobile connectivity, Internet of Things are providing opportunities at affordable cost for cities (Accenture, 2011). Moreover, ICT can provide cities with new ways of interacting and collaborating with different stakeholders. Some cities are now measuring the ICT potential by promoting technology-driven innovations within cities like **open data initiatives** (a.k.a. Open APIs, see for instance <http://www.amsterdamopendata.nl/>). By providing access to valuable city data, cities enable the creation of new applications and services, and, in turn, create better ways of living and working. Moreover, involving citizens and other stakeholders into city development opens an opportunity for collaborative city development allowing building sustainable smart cities with user-and environment-friendly infrastructure.

The opportunity of a **smart support of the urban development** that exists today has never been greater. In this context, C³PO aims at providing a **Cloud collaborative and semantic platform for city co-design**. The uniqueness of the C³PO platform lies in covering the whole urban project development process where cities empower, engage and guide different stakeholders (citizens, decision makers, architects, etc.) to develop an urban project together. C³PO **does not intend to replace or modify existing applications** offering unique but partial solutions of city co-design (simulation tool, open API, 3D modelling and visualization, gaming tool, etc.). C³PO should be seen as an **open and generic intermediary** that enables the interaction between **existing** applications through a **unique multi-dimensional semantic repository** (covering the different types of information in city co-design like GIS, BIM, electricity grids, traffic, etc.). As such, C³PO **enables the capitalization of existing applications and data sources by enabling their integration as services, or by enabling them to exploit the C³PO Open API.**

This document presents the state of the art in the field of collaborative city design. It describes methodologies, tools, technologies and trends related to the C³PO project innovation domain. We describe the technological state of the art of the project partners, and how their technological competences contribute C³PO. We continue with discussing methodologies, tools and applications of collaborative city design and with particular focus on stakeholders of this proposed collaborative city design. We follow with the technological state of the art in the domains associated with the C³PO platform, look at the data sources and link C³PO to the closely related projects. We also explore the business opportunities for C³PO platform, its potential market, customers and competitors, analyse the options of potential business models relevant for such a solution as C³PO platform.

1 Introduction

This document is the third and final iteration of the C³PO project related state of the art. It covers both methodological and technological aspects of city co-design, current trends and related projects upon which C³PO is built as well as future business opportunities for C³PO.

1.1 C³PO Project in brief

C³PO aims at providing a cloud Collaborative and semantic City Co-design PlatfOrm. The C³PO platform is unique in that it covers the whole urban project development process where cities empower, encourage and guide different stakeholders (citizens, decision makers, architects, etc.) to develop an urban project together. C³PO does not intend to replace or modify the existing applications offering unique but partial solutions of city co-design (simulation tool, open API, 3D modelling and visualisation, gaming tool, etc.) but can be seen as an open and generic intermediary that enables the interaction between existing applications through a unique multi-dimensional semantic repository (covering the different types of information in city codesign like GIS, BIM, electricity grids, traffic, etc.). As such, C³PO enables the capitalisation of existing applications and data sources by enabling their integration as services, or by enabling them to exploit the C³PO Open API (ITEA Portal, 2017).

C³PO project consortium includes 21 partner from 3 countries - Belgium, Finland and Turkey. Five partners represent cities for C³PO platform pilots - Brussels and Kortrijk (Belgium), Kouvola and Oulu (Finland), Pendik Municipality (Turkey). Read more about the project from ITEA portal (<https://itea3.org/project/c3po.html>) or project website (<https://c3poprojectblog.wordpress.com/>). Each of the project partners and its related developments are described in more detail in the section 2 of this deliverable.

C³PO Project in brief



1.2 Relation to other deliverables

This subsection highlights the principal relationships between this deliverable (D2.1, version 03) and other deliverables.

This deliverable serves as a basis and starting point for all the other deliverables of the project. It describes the existing concepts, competences of project partners, existing techniques, processes, regulations and methodologies. Moreover, it provides a brief overview of the related projects and initiatives currently running as well as current vision of C³PO business model.

1.3 Background

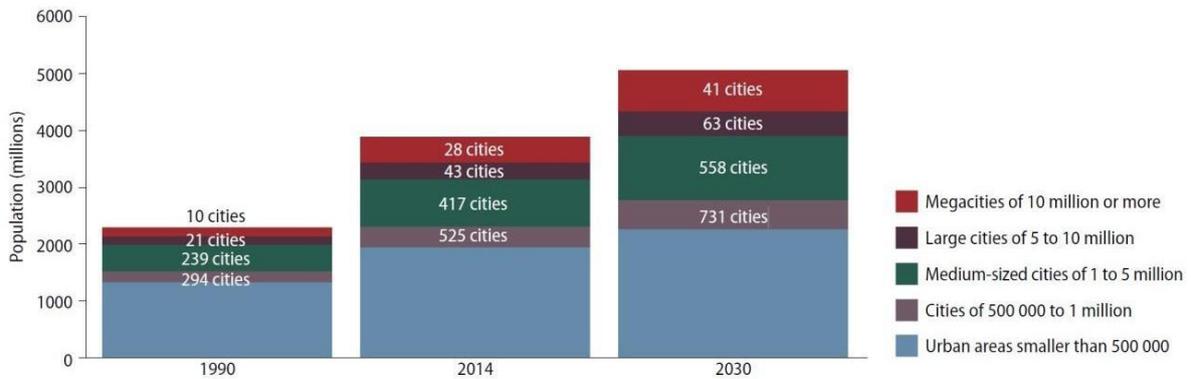
According to World Urbanization Forecast (United Nations, 2014) cities are growing rapidly. This growth is also supported by immigration flows and will continue in the future (see figure below). As a consequence, the pressure in terms of different challenges on urbanization: ecological, infrastructural and economical in respect to growing costs of the city maintenance and development, will continue to increase.

Urbanization manifests itself in two ways: **expansion of existing cities and creation of new ones**. For example, in terms of city's population growth just in Europe, there are fast-growing cities like Istanbul, London, Paris ranked respectively 14th, 20th and 25th in a worldwide study conducted by McKinsey Global Institute in 2012. As existing cities continue to expand, new ones are being created. Urbanization in developing countries like Turkey or North African ones has been characterized by the emergence of new cities. For instance, the new Bosphorus channel in Turkey will be accompanied with the creation of two middle-sized cities¹.

The idea of **smart cities** has become a globally recognized proposition and a value creator. The European Initiative on Smart Cities for 2010-2020 promotes systemic approaches and organisational innovation, encompassing energy efficiency, low carbon technologies and the smart management of supply and demand, requesting innovative solutions for water, energy and transport planning and sustainable development (<http://setis.ec.europa.eu/implementation/technology-roadmap/european-initiative-on-smart-cities>). It is followed by a number of supportive initiatives as for instance global Open Cities (<http://www.opencitiesproject.org/>) and European project Open Cities (<http://www.opencities.net/>) aiming at making the urban planning data more open. European Charter on Participatory Democracy in Spatial Planning Processes has been approved at European Council of Spatial Planners (ECTP -CEU) in October 2015. Planners and governments of EU countries are invited to sign it (Brussel Region Prime Minister already signed the charter in April 2016) (LinkedIn, 2016). This indicates the movement on smart cities initiatives at EU level.

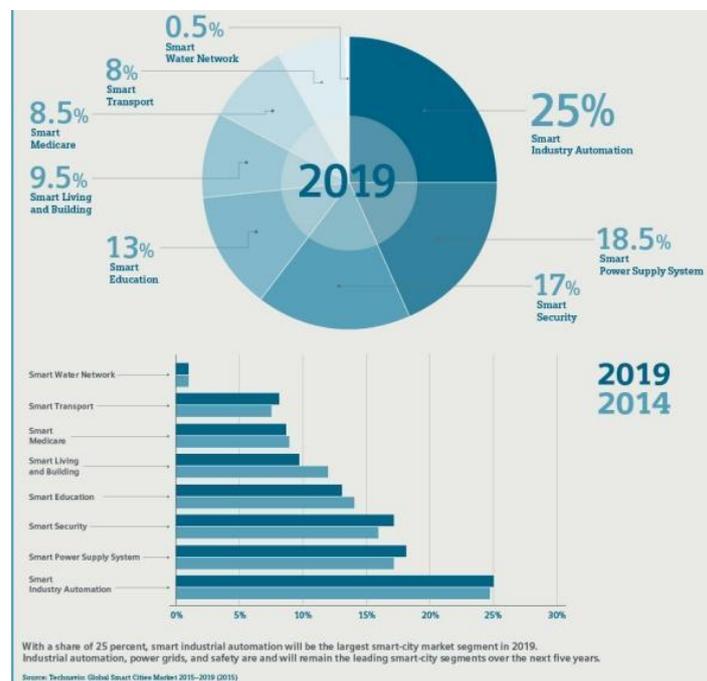
¹ Following the criteria applied by EU medium-sized cities are those with between 500,000 and 1,000,000 inhabitants (Manville et al., 2014)

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World urbanization forecast (United Nations, 2014)

The concept of smart city gave a birth for the entire market of smart city solutions, where many companies are nowadays operating (IBM, Oracle, Google, General Electric, Cisco and many others). It is forecasted that in the next 10 years, over \$100 billion will be spent on core technologies to support smart city development worldwide. The smart city market is expected to be worth \$1,5 trillion by 2020, opening tremendous opportunities for business (Frost & Sullivan, 2014).



Smart city market: structure and growth (Rohling, 2015)

According to the Smarter Cities for Smarter Growth Report (IBM, 2012) cities will need to continue building on other core services agendas such as energy, water and environmental sustainability, urban planning and architecture. They will also cultivate a systems level view of the entire city that allows them to capture the most value from their investments,

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optimizing improvements across different parts of the city (Smarter Cities for Smarter Growth, IBM, 2012).

The C³PO project aims at research and development of an open platform for urban co-design. Thus, it is addressing a niche of smart-city market. The platform relies on three main building blocks:

1. Urban co-design semantic description of multi-dimensional information (ontologies),
2. Scalable computing platform and
3. Cooperative urban design process.

These three building blocks will offer the efficient multi-dimensional information access and the orchestration of different applications (visualization, simulation, data acquisition and participation). Thus, the research and development is related to several topics, including cooperative urban design process, urban ontology and 3D visualization.

1.3.1 Cooperative urban design process

The key elements of cooperative participation in urban planning are:

- inclusiveness (who is allowed to participate?),
- stakeholders and their representativeness (what kind of groups are represented in the process and by whom?),
- expertise (who possesses information and what kind of information is seen relevant and valuable?),
- knowledge and understanding about the planning process, interest in or motivation to be involved in the planning process (Bäcklund, 2007; Häikiö, 2005; Laine and Peltonen, 2003; Leino, 2006).

All these elements must be included in the cooperative urban planning and design processes. According to Fu & Lin (2014) the urban co-design process includes five main stages: exploration (including stakeholder analysis); integration (including participatory research for city challenges); ideation (to generate concept based on analysed data and built models); implementation (including framing service ecosystem and project pilots); evaluation (evaluation and testing with public). The co-design platform should communicate and visualize clearly, what is the exact process and in which phases different stakeholders can participate. The technical solutions should support people's own aims and motivation to be involved. Multiple different applications and platforms already exist to support these processes. They are reviewed in the Chapters 3 and 4 of this document.

1.3.2 Standards and initiatives in urban information

There exist several XML-based **standard protocols** for exchange of urban information. Each protocol describes a **specific dimension** of urban information (e.g., OGC - geospatial and location standards by the Open GIS Consortium; aecXML - BIM information which uses Industry Foundation Classes (IFCs), LandXML - a data structure widely used in infrastructure planning which the IFC does not yet cover, etc.). Tentative **ontologies** have also been developed in areas related to GIS/BIM applications. This is the core theme of Chapter 5 of

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this document.

1.3.3 Visualization and transmission of 3D scenes

Some commercial products already exist for mobile augmented reality architectural visualization. However, they typically suffer from problems with accuracy and stability (being based on just compass and GPS), poor rendering quality (visualization not adapted to real world lighting conditions, not accounting for reflections etc.) and incorrect occlusions (foreground objects hidden by virtual objects). Improved performance can be obtained by applying computer vision (for tracking), image analysis (for rendering) and 3D reconstruction (for occlusions). Further research problems are presented with handling complex 3D models in real time on consumer level mobile devices. Making possible the effective transmission and sharing of complex 3D scenes on various terminals and under different bandwidth constraints, while fully ensuring the necessary quality of services, requires the deployment of effective compression technologies (Li et al, 2001). The requirements to be fulfilled are: (1) scalable/progressive transmission; (2) high speed decoding, in order to make it possible the deployment of such solutions on mobile devices; (3) support of arbitrary topologies and geometries. However, the majority of the existing techniques fail from supporting the whole set of the above-mentioned requirements (Siew et al, 2012). In particular, they are dedicated to manifold structures and thus inappropriate for more generic topologies such as those encountered in practice. It is discussed more in detail in Chapter 5 of this document.

1.3.4 Related trends

Open data-driven smart cities

The global interest in open data is growing rapidly. The Europe Open Data catalogues (<http://lod2.okfn.org/eu-data-catalogues/>) illustrate the growing European interest in open data. Many cities (e.g. London - <http://data.london.gov.uk/datastore>, Amsterdam - <http://www.amsterdamopendata.nl/>, Seattle - <https://data.seattle.gov/>) and other data providers (e.g. utility providers or transportation companies) provide access to their data through interfaces designed for external third party developers called Open APIs. The benefits of Open Data initiatives include: increased transparency in city planning and development, empowered citizens, fostered innovation and contribution to reforming public services. In terms of the direct economic benefits from open data in 2014 in the European Union it was valued around Euro 40 billion and over Euro 140 billion annually across the whole EU27 economy (Ojo et al., 2015). For instance, London has seen a multitude of new applications built upon government data. The **London Datastore** created competition in the information product market, with several different applications competing for similar space. Citizens receive greater choice and the private sector grew as a result. For instance, UK-based public transport data aggregation firm, Placr, achieved a £120,000 turnover within 18 months and several other companies are now following (Accenture, 2011)

The report on open data maturity by European Data Portal (2016) addressed significant development of national activities on the use of open data. The majority of EU countries successfully developed an approach to promote open data. As a result the presence of an open data policy, the use of open data and its impact have been increased in most of the EU countries. Among the top leading countries, who have implemented an advanced open data policy with extensive portal features and national coordination mechanisms, are Spain and France.

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EU highlights public open data as one of the priorities for further development. In respect to this, the Connecting Europe Facility (CEF) in Telecom is an EU programme aimed at facilitating cross-border interaction between public sector, citizens and businesses. Particularly, the programme supports projects aimed to promote interconnection and interoperability of national, regional and local networks as well as to enable access to such networks supporting the development of a Digital Single Market. (European Commission, 2016a) In 2016 3,5 million EUR has been allocated to projects on public open Data under CEF Telecom (European Commission, 2016b).

At the same time there are certain drawbacks with city open data, since *'smartness is not equal to open access for everybody'* (Meijer & Bolívar, 2015, p. 11). Governments should promote open data usage and needs to open the city data, but it should be done very carefully in terms of ethical issues, IPRs, privacy and security (Walravens, 2012; Batty et al., 2012).

Urban planning and simulation tools

Urban design tools are specific techniques that can be applied at appropriate stages in the design or project planning process. These tools can help in understanding the urban context, encouraging community involvement, increasing the understanding of urban design issues, describing intended design outcomes, establishing design processes, and organizing people and resources. A classification of urban design tools is given in the urban design toolkit (Urban Design Protocol Ministry of the Environment, New-Zealand, 2006).

Segments of this market are dominated by **major players** like:

The *BIM (Building Information Modeling) market (dominated by players like Revit, Autodesk, Bentley, Trimble, Nemetschek, Catia, Hitachi etc.)*, is in charge with modeling the water and energy systems, security-related support, facility maintenance, lighting and air conditioning at a building level. Steps towards the use of CAD products at city level are already accomplished. The analyst Kathleen Maher notes that "today, the CAD industry is more dynamic than ever. It is involved in every aspect of design, building, constructing and manufacturing. Increasingly, CAD is becoming part of a visually connected world that can be understood and better managed. There are opportunities in new platforms, new technologies, and new customers in emerging economies. It's a very good time for the industry." (Jon Peddie Research, 2012).

Autodesk, Esri, Bentley, InterGraph, MapInfo, etc. act in the *GIS market*, where the cartography technology is extended to support the inclusion of new city infrastructures elements, to test and validate their pertinence.

Virtual environments such Second Life that simulates the life in a city, or city building simulation games as SimCity or CitiesXL have a good impact to public, and their example should be exploited in the real business.

Very few city simulator tools, such as AnyLogic, are destined for urban planners to understand how cities are likely to evolve in response to various policy decisions. City simulators are generally agent-based simulations with explicit representations for land use and transportation. UrbanSim and LEAM are examples of large-scale urban simulation models that are used by metropolitan planning agencies and military bases for land use and transportation planning. Many other sectors of the smart cities are still waiting for being modelled and exploited in such approaches.

Virtual and augmented reality

Various novel visualization technologies have emerged at the market and matured up to commercial application level in the past few years:

- **Augmented Reality (AR).** With Augmented Reality, different stakeholders can immediately verify the effects of new city plans in previously existing urban environment, compare between plans and designs etc. Mobile AR enables the plans to be viewed from any chosen location on-site, while photo based methods are available for design evaluations at office or home.
- **3D Screens.** Novel public screen solutions enable crowds of people to compare and interact with urban planning designs at hot spot locations around the city. The related technologies include auto stereoscopic screens, multi-touch interaction, virtual 3D as well as Augmented Reality presentations.
- **Data glasses.** A whole new generation of data glasses (e.g. wide angle optical see through), is currently entering the market, even with reasonable pricing for consumer use. Compared to hand-held or screen based solutions, data glasses offer completely new forms of interaction (e.g. gesture based) and immersive visualization.

Open and User Innovation in smart city development: civic open innovation

Overall, open innovation has received a particular emphasis in the context of smart city development in the recent years all over Europe and globally. More specifically, it is reflected in three trends. First, increased interest of citizens towards getting access to administrative data and involvement in administrative decision-making (user-involvement). Second, open data has spread all over Europe and citizens have become widely recognized as stakeholders of the city. Third, crowdsourcing and participation tools also using mobile devices are continuously elaborated to make city co-development go beyond traditional forms of public petitions and civic protests. One of the basic conditions for implementing open innovation in the context of urban development, which implies city administration involvement, is establishing of culture of openness to insure open-mindedness and transparency in the entire process. That is why it is so important to develop a platform, which connects different stakeholders and facilitate their collaborative work. Support of such a platform by public administration is essential to ensure open collaboration (Barthel, 2013).

Already for many years, management research has been pinpointing the attention to the concepts of collaborative value creation, democratising innovation processes, and user involvement. This logic enabled the emergence of user innovation theory and open civic innovation (Almirall et al., 2014). If city design is considered as an innovation of a kind, then these two theories allow explaining the need and role of the users (here - stakeholders) in this process. Both open and user innovation theories tell, that stakeholder involvement is necessary and inevitable in modern innovation processes (Piller and West, 2014). There is hardly any entity, which could reach long term success without assessing customer needs, desires, satisfaction etc. (Piller and Ihl, 2009). A number of empirical studies show that most successful new products and services have been initiated by information about user needs, often referred to as *need pull* (Baker et al., 1967; Utterback, 1971; Robertson, 1973). In many cases, technical improvements were realized during the diffusion phase by user

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feedback or re-invention by users (Rogers, 1995). Ornetzeder and Rohrache's (2006) studies of user innovations show how the users can be involved in the design and dissemination of technologies at different levels of intensity. For example, early users can start completely new technologies and designs new products. They can find and test new applications of a product as well as can appropriate unconventional building technologies and design solutions in the course of collective planning processes. However, as the analysis of literature reveals, the role of users in innovation processes is much broader than simple direct user participation. Even without active user engagement, designers are still able to represent the needs and expectations of future users and match it with the design of a product through imagination about future uses and users or through the experiences of designers or producers as users. Users may also try to change or re-design technologies, or block their usage (Ornetzeder and Rohrache, 2006). There is a number of opportunities for users to participate in product/service development. Different kinds of contributions by users have been identified, for instance quality improvement, customization of existing products, refinements and niche-targeted variety, or breakthrough innovative ideas. Some of the authors believe that users do not play a part in the initial generation of new product ideas; users are only contacted after the company has developed a new solution to evaluate it, e.g. focus groups (McQuarrie & McIntyre, 1986). However, von Hippel has stated that users can be perceived as sources of new ideas or inventions (von Hippel, 1977, 1978, 1988).

A dimension of user involvement in open innovation relates to the nature of involvement. Jespersen (2008) defines five possible user roles that differ in terms of interaction control as well as task/social orientation:

- User as a resource (unstructured interaction and task oriented)
- User as a co-creator (structured interaction and task oriented)
- User as a product (unstructured interaction and socially oriented)
- User as a buyer (structured interaction and socially oriented)
- User as a 'user' (in the middle of both dimensions)

On a theoretical level, these concepts and understanding of collaborative process allows us speaking of collaborative city design - co-design, where user is a citizen.

Emergence of co-design trends

“Co-design (...) is a product, service, or organization development process where design professionals empower, encourage, and guide users to develop solutions for themselves. Co-design encourages the blurring of the role between user and designer, focusing on the process by which the design objective is created. This process assumes that by encouraging the trained designer and the user to create solutions together, the final result will be more appropriate and acceptable to the user. It is generally recognized that the quality of design increases if the stakeholders' interests are considered in the design process.

The citizen involvement in the city planning process has changed dramatically throughout the years. First, the communities grew or emerged with little intentional or longer term plans - only the biggest public buildings were the monuments of establishment. When the modern cities started to grow the governance drew the plans with minimum involvement from other stakeholders. In the era of representative governing bodies, first the estates, later the elected city councils have had their say on the city planning. It may be called

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representative participation. Later, as the demand for more direct involvement rose, more direct hearing and participation of different stakeholders started to become more common. During the computer and internet era, the methods and means of general participation have been evolving rapidly. Interaction between experts, planners, companies and decision makers has increased and taken new forms.

The methods and tools have progressed accordingly. Plans on the papers with technical calculations and symbols were merely for the experts. Early computers with clumsy interaction methods made the interaction even more complicated. The development of visualisation and simulation tools during the last 20 years has made the representation of plans more intelligible and comprehensive. The internet has provided city planning with a potentially unforeseen democratic publication and communication media. The extent to which it is used to actually encourage participation is a matter of cultural and political change. Currently both the opening of public (and sometimes private) data, fast and easy-to-use simulation tools enables all the stakeholders to see and handle the designed environment in different planning scenes. C³PO's objective is to integrate all the relevant data in one platform and use the demonstrating tools with co-design methods to achieve better planning process.

Internet of things (IoT) for smart cities

IoT implies '*global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies*' (ITU, 2012). Such global and complex infrastructure is required to enable continuous data gathering and processing (transforming the physical objects characteristics into digital data by using sensors, software and network connectivity). Urban IoTs are designed to support smart city concept through optimizing the city costs (value for city administration) and continuous interaction between all the stakeholders and their devices (value for all the stakeholders including citizens). Zanella & Vangellista (2014) describing the case of Italian Padova and its development under the smart city concept define nine types of services forming IoTs for smart cities. Among them are:

- Structural health of buildings (meaning automotive monitoring and control of state of especially historical buildings)
- Waste management (opening up economical and ecological advantages)
- Air quality (monitoring and control of air quality collecting also a feedback from joggers)
- Noise monitoring (building a noise map, recognizing the noises, linking them with emergency services)
- Traffic congestion (monitoring and optimizing traffic by using sensors and gps)
- City energy consumption (public lighting, transportation, heating and cooling systems control)
- Smart lighting (adjusting lighting to weather conditions, presence of people, etc.)
- Automation and salubrity of public buildings (controlling the parameters inside public buildings to optimize the consumption and costs)

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In order to ensure sustainability, the described IoT infrastructure lacks a set of services for city co-design, which C³PO fills. However, the complexity and need of embeddedness of all the listed services has to be acknowledged. It is evident that there are huge urban planning market needs augmented further to the European initiatives and to the accelerated expansion of urban areas. Currently, multiple mature business markets reside mostly separately. They are focused on various domains and start to collaborate in the domain of urban planning. These factors support the need for the development of an integrative platform enabling collaboration via applying systematic approach as currently such a platform is not yet available.

1.4 Main concepts and terms

3D Scene (Adminotech and Playsign)	Is a description of a 3D space with links to scripts as well as 3D assets, such as materials, textures, UI elements, etc. Meshmoon platform uses TXML format and 3D content is published on the web.
Augmented reality	AR is a live direct or indirect view of a physical, real-world environment whose elements are <i>augmented</i> (or supplemented) by computer-generated sensory input. Sensory input can be sound, video, graphics, GPS data or other acquisitions of sensors i.e. heat, temperature, pressure, etc. Recent technologies have begun to benefit from 3D data, panoramic images, CAD designs and maps, which play a major role either as input or as output data. For instance, 3D visualisations of buildings can be shown to users in order to enhance the current perception of reality.
Augmented Virtuality	Refers to augmenting of predominantly virtual worlds with real world content. An example of augmented virtuality is using photos and videos of real people to furnish virtual buildings and city models.
Big data	Big data is an evolving term that describes any voluminous amount of structured, semi-structured and unstructured data that has the potential to be mined for information. It is often described by 4 Vs: <ul style="list-style-type: none"> ● Volume - huge amount of data ● Variety - different types/sources of data ● Velocity - fast generation and processing of data ● Veracity - uncertainty of data
Bootstrap	The bootstrap is a computer-intensive tool for answering inferential questions. The underlying idea of the bootstrap is based on the substitution and simulation principles. If the experiment cannot be rerun, the already acquired data can be used and new data can be created create to come up with an estimate within an acceptable confidence interval. The “new” data is obtained through random sampling from the original data.
Co-design	Co-Design is a well-established approach to creative practice,

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<p>including participation</p>	<p>especially in the public sector. It is often used as an umbrella term for participatory, co-creation and open design processes.</p> <p>In this project the definition used by both the UK Design Council and The European Design Leadership Board in their report 'Design for Growth and Prosperity' is used. They both define co-design as <i>a community centred methodology that designers use to enable people who will be served by a design outcome to participate in designing solutions to their problems.</i> (Koskinen & Thomson, 2012)</p>
<p>Core ontology</p>	<p>Core ontology is a basic and minimal ontology consisting only of the minimal concepts required to understand the other concepts (W3C).</p> <p>Different layers of C³PO information (GIS, traffic, BIM, etc.) necessitate different ontologies so as to appropriately define the various objects and relations relevant to their specific domains. Core ontology for C³PO is aimed to provide a basis from which to build ontologies for any information layer (domain-specific extensions).</p>
<p>Design research</p>	<p>Design research should be regarded as a separate activity from design practice. It grew out of the need to formally address the increasing complexity of systems designers were being asked to create. The increasing complexity of products such as cars, airplanes and urban areas created a need for new design methods that were more predictable and more collaborative. The design methods movement grew out of this need, and generated the first cohort of design researchers focusing on the development of knowledge instead of artifacts for consumption.</p>
<p>Geographical information system</p>	<p>A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. GIS can show many different kinds of data on one map. This enables people to more easily see, analyze, and understand patterns and relationships.</p> <p>With GIS technology, people can compare the locations of different things in order to discover how they relate to each other. For example, using GIS, the same map could include sites that produce pollution, such as gas stations, and sites that are sensitive to pollution, such as wetlands. Such a map would help people determine which wetlands are most at risk.</p> <p>GIS can use any information that includes location. The location can be expressed in many different ways, such as latitude and longitude, address, or ZIP code. Many different types of information can be compared and contrasted using GIS. The system can include data about people, such as population, income, or education level. It can include information about the land, such as the location of streams, different kinds of vegetation, and different kinds of soil. It can include information about the sites of factories, farms, and schools, or storm drains, roads, and electric power lines. (National</p>

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	Geographic, 2015)
Head Mounted Displays	HMD worn on the head or as part of a helmet, that has a small display optic in front of one (monocular HMD) or each eye (binocular HMD). Two main categories of HMD are optical see through (OST), and video see through (VST) displays.
Infrastructure as a Service (IaaS)	Infrastructure as a service (IaaS) is one of the service models of cloud computing. IaaS provides access to computing resource in a virtualized environment. Computing resources include CPU cores, RAM, hard disk or storage space and network components. Consumers don't manage or control underlying cloud physical infrastructure but has control over operating systems, storage, deployed applications and possibly limited control of select network components.
Linked data	<p>Linked data describes a method of publishing structured data so that it can be interlinked and become more useful through semantic queries.</p> <p>Linked Data refers to data published on the Web in such a way that it is machine-readable, its meaning is explicitly defined, it is linked to other external data sets, and can in turn be linked to from external data sets (Bizer et al, 2009).</p> <p>Berners-Lee (2006) outlined a set of 'rules' for publishing data on the Web in a way that all published data becomes part of a single global data space:</p> <ol style="list-style-type: none"> 1. Use URIs (Uniform Resource Identifiers) as names for things 2. Use HTTP (Hypertext Transfer Protocol) URIs so that people can look up those names 3. When someone looks up a URI, provide useful information, using the standards (RDF (Resource Description Framework), SPARQL (RDF query language)) 4. Include links to other URIs, so that they can discover more things
Mixed Reality (MR)	MR or hybrid reality encompasses both augmented reality and augmented virtuality, which are merged to obtain a fusion of real and virtual worlds. In mixed reality, new environments and visualisations including physical and digital objects interact in real time. MR does not take place only in the physical world or the virtual world, but as a mix of reality and virtual reality, encompassing augmented reality (AR) and augmented virtuality.
Ontology	An ontology is an explicit specification of a conceptualization (Gruber, 2010). An ontology describes a set of entities (concrete and/or abstract) and the relationships they can have with each other (Guarino, 1998).

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	<p>Ontologies are considered one of the pillars of the Semantic Web. OWL is the W3C ontology language.</p>
Open data	<p><i>Open data is data that can be freely used, reused and redistributed by anyone - subject only, at most, to the requirement to attribute and sharelike (Open Data Handbook)</i></p> <p>It means:</p> <ul style="list-style-type: none"> • Availability and Access: the data must be available as a whole and at no more than a reasonable reproduction cost, preferably by downloading over the internet. The data must also be available in a convenient and modifiable form. • Reuse and Redistribution: the data must be provided under terms that permit reuse and redistribution including the intermixing with other datasets. • Universal Participation: everyone must be able to use, reuse and redistribute - there should be no discrimination against fields of endeavour or against persons or groups. For example, ‘non-commercial’ restrictions that would prevent ‘commercial’ use, or restrictions of use for certain purposes (e.g. only in education), are not allowed.
Linked data platform	<p>Linked Data specification defining a set of application integration patterns for building RESTful HTTP services that handle RDF documents. A W3C Working Group operated from June 2012 to June 2014 to publish a specification which is currently a Candidate Recommendation (http://www.w3.org/TR/ldp/)</p>
Platform as a Service (PaaS)	<p>Platform as a service (PaaS) is another service model of cloud computing. In this model, a cloud provider delivers hardware and software tools. A PaaS provider hosts the hardware and software on its own infrastructure. Application developers can develop and run their software solutions on a cloud platform without the cost and complexity of buying and managing the underlying hardware and software layers. With some PaaS providers like Microsoft Azure and Google App Engine, the underlying computer and storage resources scale automatically to match application demand so that the cloud user does not have to allocate resources manually.</p>
Scene recognition (BAH)	<p>Scene recognition in the field of computer vision is defined as the task of understanding the components of an environment and their layout captured in images. This task requires analyzing indoor and outdoor scene images that may be captured by various types of cameras to detect the objects, places in the camera view and label them according to a pre-defined classification dictionary.</p>
Semantic repository	<p>Semantic repositories are engines similar to database management systems. They allow for storage, querying, and management of structured data. The major differences with the DBMS: they use</p>

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	<p>ontologies (allowing automated reasoning about data) and they are more flexible (possibility to interpret and adopt “on the fly” new ontologies. The main standards for storing and querying semantic repository are RDF(S) and OWL. Sesame is one of the most popular semantic repositories that supports RDF(S) and all the major syntaxes and query languages related to it. GraphD is another semantic repository, packaged as a storage and inference layer (SAIL) for Sesame -</p>
Semantic Workflow	<p>Semantic workflows are scientific workflows enriched by using semantic annotations based on semantic expression languages (OWL, RDF, SPARQL) to describe the workflow elements (data, computations, results etc). The semantic extension of scientific workflows allows a number of benefits related to the possibility to apply reasoning engines (e.g. FACT++) capable of deriving implicit knowledge from a set of explicit statements. Expressive representations of workflows based on ontologies, together with reasoning algorithms for workflow composition (supported by interactive assistance), workflow validation, automated completion, metadata propagation, and retrieval, enable users that are part of the co-design process to easily associate meaning to what the workflow represents and exploit this meaning to facilitate the overall design process.</p>
Simulation	<p>Is the imitation of the operation of a real-world process or system over time. (Banks et al, 2001). Simulation in C³PO covers the population growth simulation in urban planning as described in local planning process, and also rendering of 3D scenes with elevated buildings, functional areas (parks, trade centers etc.) streets and people in a time line.</p>
Software as a Service (SaaS)	<p>Software as a Service (SaaS) is a software delivery method that provides access to software and its functions remotely as a web based service. The applications are hosted in the cloud and can be used for a wide range of tasks for both individuals and organizations. SaaS is sometimes referred to as “on-demand software” and is usually priced on a pay-per-use basis or using a subscription fee.</p> <p>In the SaaS model, cloud providers install and operate application software in the cloud and cloud users access the software from cloud clients. Cloud users do not manage the cloud infrastructure and platform where the application runs. This eliminates the need to install and run the application on the cloud user’s own computers, which simplifies maintenance and support. The pricing model for SaaS applications is typically a monthly or yearly flat fee per user, so price is scalable and adjustable if users are added or removed at any point.</p>
Stakeholders	<p>There are many definitions of stakeholders. Two important definitions are: one for Stakeholder as a term commonly used in</p>

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	<p>planning and public policy, and one in public projects theory.</p> <p>(1) A stakeholder is defined as someone with a “stake”, or interest, in the issues being addressed. In practice, this means anyone could be a stakeholder because a resident, taxpayer, and concerned citizen could all have an interest. Because the distinction between the public and stakeholder can be confusing, it is important to consider WHY stakeholders should be involved and how they should be selected. People who convene a collaborative planning effort need to plan this step carefully. (Planning and Urban Design Standards, American planning association)</p> <p>(2) For projects, stakeholders are often defined as ‘all the people who are affected by the project, who have influence or power over it, or have an interest in its successful or unsuccessful conclusion’ Stakeholders may be both organizations and people.</p>
Structured and unstructured data	<p>Data sources can provide structured or unstructured data. Structured data refer to information that either does have a pre-defined data model or is organized in a pre-defined manner.</p> <p>Examples of unstructured data include images, files and unstructured text.</p> <p>Examples of structured data are openGIS, etc.</p>
Urban interaction design	<p>Urban Interaction Design is an emergent field composed of three main elements: technology, society and art. It addresses the question of how human, as a physical being, interacts with the technologically augmented, data-rich urban environments that increasingly characterize cities. Urban Interaction Design (UrbanIXD) draws upon knowledge and approaches from a range of disciplines involved in the design of urban spaces, connecting them and establishing their interactions as a principle.</p>
Virtual Reality (not covered in the project but usually confused with AR)	<p>Virtual Reality (VR), sometimes referred to as immersive multimedia, is a virtual computer simulation environment immersively simulating the real environment or totally imagined worlds, by re-creating sensory experiences, such as virtual taste, sight, smell, sound, and touch. As contrary to augmented reality, virtual reality replaces the real world with a simulated one.</p>
Visualisation	<p>Visualisation is generally any technique for creating images, diagrams, or animations to communicate a message. In the C³PO context, visualisation refers more specifically to displaying (“rendering”) of buildings and plans by means of 3D computer graphics.</p>
Web rendering	<p>In Meshmoon means Web Tundra client (WebRocket) implemented with Javascript, which can render and run scripts in TXML format.</p>

2 Consortium cumulative state of the art in each partner's domain

ASSAR ARCHITECTS (Belgium)

ASSAR ARCHITECTS has over 120 architects applying their expertise to a large range of disciplines, which ranks it among the largest Belgian architect firms. ASSAR ARCHITECTS is therefore able to take on large scale projects in different sectors (urban planning, office, housing, security facilities, laboratories, care homes, hospitals and mixed projects). Since 1985 ASSAR has been pioneer in using 3D modelling and visualization software, being one of the earlier adopters of Revit and BIM in Belgium.

Main contributions by ASSAR ARCHITECTS to the state-of-the art developments of C³PO project include:

- Definition of co-design process: phases, necessary data, main activities, best practices.
- Stakeholder's classification and interactions.
- Guidelines for architectural and urban planning visualization.

In C³PO project ASSAR ARCHITECTS has shared its expertise in the domain of urban planning and co-design accompanying other companies in the development of relevant solutions for the smart city market. Assar has also defined and developed the Brussels case study, proposing a whole co-design process "proof-of-concept" where each tool of the consortium reveals its added value according to the phase of development of an urban project and the stakeholders that participate.

Bahçesehir University (BAH, Turkey)

Bahçeşehir University (BAU) is a private educational institution in Turkey, located at the European side of Istanbul. BAH has been developing advanced tools and utilizing them in the C³PO project:

- Indoor Augmented Reality Software Tool: BAH has developed an indoor AR application for Android Tablets and demonstrated in Dolmabahçe Palace Museum. This tool is developed in an abstract way which can be easily adapted to different scenes and contents if data is provided in sufficient amount and quality by the data owner.
- Motion and Crowd Analysis Software: This tool can extract flow data, including the type of objects either vehicle, person, or else, from street cameras.
- ARKINECT: BAH has developed an AR tool that can utilize a Kinect Sensor. ARKINECT can be used for body therapy especially for people with diseases like Parkinson, etc.
- 3D Visualization Tool: BAH develop a 3D visualization tool that can operate fast enough even in conditions with low computation and storage power. This tool has been experimented in historical sites, like Dolmabahçe Palace, on touch screen devices.

Barco N.V. (Belgium)

Barco, a global technology company, designs and develops networked visualization products for the Entertainment, Enterprise and Healthcare markets. Barco has its own facilities for Sales & Marketing, Customer Support, R&D and Manufacturing in Europe, North America and APAC. Barco is active in more than 90 countries with 3,300 employees worldwide. Barco posted sales of 1.029 billion euro in 2015. The two examples of state-of-the-art developments by Barco include:

- **Small deployable immersive space:** All current solutions of immersive 3D visualization are both costly and aimed towards the high-level market, or are not adequate for the intended use. VR and immersive environments combine advanced technology with social interaction to analyze complex problems with the help of huge datasets, and to take quick and accurate decisions. Very powerful, their applications range from large-scale 3D collaborative viewing rooms to fully immersive spaces completely surrounding the interpreters with their data. These large-screen visual display systems show large amounts of data - typically 2.5 to over 4 Mega pixels - on large flat or curved screens at the same time. They allow multi-disciplinary teams of up to 20 viewers to effectively visualize and evaluate data. Most systems are tailored to meet specific needs with the screen size, the depth of the system, and number and type of projectors customized to provide the optimum display solution. These large presentation environments usually carry a high price tag, as a dedicated building is often used to host them. A CAVE display is a multi-sided immersive environment that offers great levels of immersion. Cave displays can have any number of sides, ranging from two to six, in any size you want. A CAVE is typically a large cube-like construction sited within a larger room. The walls of a CAVE are typically made up of rear-projection screens, however flat panel displays are becoming more common. The floor can be a downward-projection screen, a bottom projected screen or a flat panel display. The projection systems are very high-resolution due to the near distance viewing which requires very small pixel sizes to retain the illusion of reality. People using the CAVE can see objects in the air (with 3D glasses), and can walk around them, getting a proper view of what they would look like in reality. CAVE solutions are used in high-end markets such as Oil&Gas exploration, Automotive (R&D) and research institutes.
- **Displays and projectors:** large arrays of displays and projectors in all sizes are available on the market. However, solutions that reach the quality needed to build a small immersive space as foreseen in this project are targeted to high-end markets and as such have the same setbacks (such as high cost, large size, etc.). Furthermore these solutions are in most cases custom made to fit a limited purpose. General purpose commodity displays that are readily available at low(er) cost are also not useable due to the fact that they are e.g. not seamless, are square or disconnected. General purpose commodity projectors as are available for e.g. meeting rooms, do not reach the necessary image quality needed and as such can also not be used.



Createlli N.V. (Belgium)

Createlli's expertise is in creative collaboration processes and collaboration technology. Examples of C³PO-related developments by Createlli include:

- co.createlli.com web app organizes collaboration in and between teams of collaborating organizations and stakeholder groups. It facilitates collaboration on many different ways (objectives, calendars, meetings, tasks, work plans, documents, files, discussions, voting, polls).
- The company has high expertise in group creativity and creative collaboration processes. It facilitates groups from different organizations or communities to get aligned on projects and work out solutions, despite barriers.

ERARGE (Turkey)

ERARGE, with its 70 employees, is an SME which has been operating in ICT, security and defense, energy, construction, oil, manufacturing and mining sectors since 1975. ERARGE R&D Branch employs experienced researchers spin off from TUBITAK (Turkey's largest R&D Organization) and with the contributions of Bahçeşehir University. The research team has 3 PHDs, 2 academicians, 5 experienced and 5 junior researchers working on information technologies, cryptography, chaos theory, machine learning, smart cards, hardware security modules, augmented/virtual reality, 2D/3D image processing and computer vision, embedded design, simulation technologies, trusted electronics, automation solutions, biometrics and privacy preservation. ERARGE core research team has contributed its crypto-devices to literature and market including very fast key generators (over 500 Mbit/s), true random number generators, mobile security solutions, digital signatures, and PKI. ERARGE has applied sophisticated theories like chaos and non-linear systems to security domain and published R&D results in top journals, received PCT patents and awarded with best papers.

ERARGE is competent in the following research topics and has developed software tools that can be integrated with other applications within C³PO:

- Chaos™: ERARGE has been active in chaotic ising-like dynamics. The tools in line with nonlinear dynamics have been applied to model probabilistic behaviours of time-varying events. In C³PO, ERARGE adapts its chaotic Ising-like model-based tool (Chaos™) on vehicle and pedestrian behaviour in Pendik. This model has been realised by chaotic billiard dynamics that arises naturally from non-chaotic elements. A foremost study reported by Suzuki et.al (2013) applied ising-like Dynamics on Kyoto City traffic data in Japan
- Bootstrapping Tool: This tool is based on the substitution and simulation principle using the already acquired data and create "new" data and recalculate an estimate (Zoubir and Iskander, 2004). This tool works on any kind of numerical data, like traffic flow or energy consumption, to approximate measures of an estimator such as its distribution function.

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- 3D Modelling and Reconstruction Software: ERARGE has a set of utility tools that can acquire 3D point cloud, extract mesh data and enable image wrapping by using Leica's 3D Acquisition Hardware.
- Augmented/Virtual Reality: ERARGE, has a set of utility codes that can convert CAD drawings to 3D mesh data, pose estimation and visualization tools for Android platforms. ERARGE has competences in markerless and marker based AR as well as VR technologies that can be improved or adapted for the project.

FCG City Portal Ltd (Finland)

FCG City Portal Ltd is a joint venture of FCG Finnish Consulting Group and Adminotech Ltd, providing smart city portal services for public and private clients. Its service product is the MAPGETS 3D application platform for professional 3rd party smart city applications and services.

FCG Design and Engineering Ltd (Finland)

FCG (Finnish Consulting Group) is a multi-industry consulting company operating worldwide. The FCG' services focus on:

- Infrastructure, environmental and community planning
- Urban and strategic planning, GIS
- Training and capacity building services
- Public sector services development and
- Management consulting services

FCG has numerous ongoing city planning and design projects. These range from strategic planning projects to detailed city architecture and design assignments. Customers include both cities and other public authorities, who generally buy the preparation work of their land use plans from private consultants, and private companies in diverse sectors from retail, real estate and construction to energy and other industries. FCG is owned by the Association of Finnish Municipal and Regional Authorities.

Lappeenranta University of Technology (LUT, Finland)

Lappeenranta University of Technology (<http://www.lut.fi/en/>) - (established in 1969) is a Finnish national university of technology and economics strongly focusing on sustainable solutions of the future. The LUT team from the department of Innovation and Software involved in C³PO project supports the consortium from the methodological standpoint as well as assist Finnish city trials and their validation. LUT's expertise is related to methodologies of business model development and user involvement in innovation process

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as well as collaborative innovation (e.g. such approaches as user innovation, lead users, beta testers, online communities, motivation in online communities, open innovation). Among the recent projects of LUT C³PO team in this domain are:

- Open Innovation Academic Network (OI-Net, 542203-LLP-1-2013-1-FI-ERASMUS-ENW see www.oi-net.eu) developed a European curriculum on open innovation and has been promoting cooperation on open innovation topics.
- Accelerate project (ITEA Project, 12014 ACCELERATE). The project has developed services based on technological innovation, advanced processes and new software technologies that enable massive adoption of acceleration knowhow in the European technological industry.
- INSPIRE project (Horizon 2020 research and innovation programme under grant agreement No 691440 - INSPIRE). NSPIRE seeks to pool knowledge, expertise and interest around Open Innovation in SMEs, with a view to providing its target audience (in particular SMEs) with inspirational good practice cases, tools and methodologies to implement effective processes to use external knowledge and strategic collaborations in order to innovate.

In C³PO project LUT has been analyzing the business opportunities for C³PO platform as well as risks linked to each of the potential strategic options and developing the business model for C³PO platform as a future business.

Mantis (Turkey)

Mantis is a software company that has expertise in Data Mining, Social Media Analysis, Semantic Web, Search and Information Retrieval, Speech Synthesis and Recognition and Image Processing. It has serious know-how, experience and products from its previous projects and ongoing works:

- Sakuwassa (The God All-Seeing in Hittite language) is a tool to collect and analyze relative content and news wanted to monitor on the Web.
- Sosyal Göz (Social Eye) is a tool to monitor and analyze social networks.
- Mansad (Virtual Detective) is a tool to regularly monitor and detect web pages which have objectionable content and providing to inform the system user about the activities on these web pages.
- Mantam is a general purpose search engine which can be used to perform vertical as well as ontology based searches.
- Manres is a tool to discover illegal use of copyrighted photos and pictures.
- DICOMA is a Pan-European project supported by the ITEA2 initiative within the framework of the Eureka program of the European Commission, devoted to provide disaster recovery agencies with tools aimed at improving efficiency in decision making processes.
- BİHAP is a national information mapping project realized for Ministry of Development in Turkey.

Netcad (Turkey)

Netcad was founded in 1989 with 100% nationally-financed capital to develop software for use in the engineering and project implementation fields such as Geographical Information Systems (GIS), Mapping, Urban Planning, Civil, Agricultural and Geological Engineering, Mining and Forestry.

Market share of Netcad Technologies in Turkey has grown to 85% by its solutions in the scope of Public Enterprises, Municipalities and Private Sector.

Netcad, which has close to 30 GIS and CAD applications for the desktop, web, mobile and cloud spaces, all of which comply with international standards, develops localized software in Turkish, English and Russian. Netcad has 20,000 licenses and 100,000 licensed users in Turkey and abroad.

Some of the C³PO related products are as follows:

- **Netcad GIS.** Main Netcad module with capabilities of data read/write, database access, CAD and GIS operations, raster data read/write options and many other features. <http://portal.netcad.com.tr/display/EN/NETCAD+GIS>
- **Planet.** Planning solution prepared for carrying out drawings, plan revisions or amendments of zoning plans used in cities and Regional Planning disciplinary applications. Planet provides city planners with fast and accurate plan generation, plan verification with control accounts, keeping the plan alive and sustainable with smart objects, visual quality increase with new drawings and output tools, tracking development of the city by simulating it with 3D modeling based on plan conditions. Scenario simulations can be carried out via Netcad Architect, where many operators and workflows can be freely designed and run over the same data.
- **Analist.** Netcad application in which basic and advanced surface analyses, raster (image) analyses, basic and advanced spatial analyses can be performed. GIS, CAD, RS analyses are performed together interactively. Precision impact maps are produced for natural hazards by performing and evaluating together environmental, topographical and hydro topographical analyses as well as basic surface analyses through digital terrain model (SAM). **Surface Analyses, Image Processing and Remote Sensing Analyses, Spatial Analyses can be performed with ready operators and workflows. Users can also code their own algorithms and integrate into Netcad Architect.**
- **Netigma, Netgis Server.** Database independent (MS SQL Server, Oracle, PostgreSQL, PostGIS, IBM DB2) web solutions with the following capabilities: standard document archiving; log management; user and authorization management; process management; business intelligence; dynamic form, report, and map production; multi-language support; spatial data support; tariff manager; self-documenting capability; self-testing and performance measurement capability; integrated version management; integration with e-government services; web browser independent; visual theme support and basic web portal capabilities.

NOESIS Solutions N.V. (Belgium)

Noesis is a market leader provider of process integration, design optimization and uncertainty management engineering software tools. The main tool, Optimus, is a tool used in engineering to automate the design processes in automotive, aerospace and a number of other industries. Core expertise thus resides in the following:

- **Process Integration:** a company has a large experience in scientific workflows and how these can be deployed and used in engineering contexts to automate the product development process (PDP) from conceptual design down to detailed design and up again to validation and verification of the overall system or product. This process automation mainly relates to formalization of the design process and automatization of the computational layer (simulation, models, predictive tools etc.) on small to large computational infrastructures (HPCs, Clouds etc). As such the company has also a large expertise on computational architectures, service oriented architectures and virtualization infrastructures (e.g. cloud and hybrid clouds, etc). Based on this experience, Noesis has been developing semantic workflows to be used in C³PO.
- **Design Optimization:** Noesis knows very well that any product design process is iterative in nature and, step by step, aims at improving and optimizing the performances of the product or of the system. For this reason, Noesis has accumulated a large expertise in numerical optimization algorithms that automatically and iteratively find the optimal solutions of the design problem at hand. Based on the process integration layer, the company has many analysis methods and algorithms that can find the optimal solution to the co-design problem and respect all the problem constraints. Noesis has been exploiting this experience to support and improve the iterative co-design problem towards optimal solutions.
- **Uncertainty management:** the product design process is based on simulation models that are always an abstraction of the real world. As such, they are perfectly reproducible (i.e. deterministic) despite the real world is not. In real situations, the performance of a system is affected by a number of uncertain parameters that cannot be determined (or kept) exact and constant, even in the best situations possible. As such, the performance predicted by the numerical models will always be affected by some errors. The management of the uncertainty that affects the numerical models is a key aspect in engineering disciplines and is also called robustness or reliability, depending on the associated risk level. Noesis has a lot of experience in managing uncertainties in engineering and has been exploiting this experience to properly manage statistical models that are typically part of city co-design processes.

Playsign Oy (Finland)

Playsign is a small 3D application development studio in Oulu, Finland. The product by the same name is a cloud service for publishing plans for built environments as interactive functional applications. The offering covers the whole span of urban development projects with a family of 3 tools: Playsign Create, Experience and Live. Playsign product was first published in 2016 and is under intensive development during 2017.

Examples of the state of the art developments done linked to project by Playsign include:

- Playsign has been used for City Co-Design in Oulu, with City of Oulu (a C³PO pilot city)
- Playsign is being integrated with Createlli backends for joint offering of these C³PO partners

IN C³PO Playsign has participated in the requirements and design work for city co-design tools. The team has developed the game-like user experiences and tools for urban planning which are tested in some of the pilots and available for use now.

SIRRIS (Belgium)

Sirris is a research collective center. Sirris has an expertise in data integration and semantic data. Sirris is also a member of W3C and is an active member of the Spatial data WG of W3C/OGC.

Studio Dott (Belgium)

Studio Dott is a creative agency active in the design, development and realisation of human driven products, environments and services. Core expertise is human centered design: putting stakeholders first throughout the design process. Depending on the type of project and the stage in the design process focus adapts dynamically;

- **Analysis:** gathering insights about, and building empathy with the intended stakeholder group(s). The analysis phase is a solid foundation for further design.
- **Conceptualisation:** constructing (sometimes “extreme”) concepts using creative techniques. These concepts are evaluated with relevant stakeholders, eliciting reactions and insights.
- **Deployment / engineering & testing:** making sure that core elements relevant for the interaction design are implemented in the intended way.
- **Optimisation:** looking at a given product or concept to optimise its user experience.

An important part of company’s expertise lies in the identification and involvement of stakeholders. Users and stakeholders are involved in every stage of this process, through interviews, observations, workshops and co-creative sessions. From these activities

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qualitative user/stakeholder data is gathered, translate them into ‘rich user insights’ and workable requirements that inform the design and development of solutions. Managing this co-creative process with different stakeholder groups, by choosing the right methods and approaches, is a key expertise of Studio Dott that are beneficial in the C³PO process.

Trimble Solutions Corporation (Former Tekla, Finland)

The company is part of Trimble Navigation Ltd and its name has changed on 1.1.2016 from Tekla to Trimble Solutions Corporation. The company provides model-based software for customers in construction, infrastructure and energy industries worldwide.

Trimble’s solution for local government is a productized set of modular software applications and services for managing built environment data and carrying out planning and building process tasks from land use planning to building supervision, asset management and customer service.

Process tasks and customer service activities are supported by modular industry applications which address each process and user group-specific need. Supported activities cover: land use planning, mapping, property management, cadastral services, building control, environmental control, street and park management.

The advanced data management enables modelling and managing of all information related to natural and built environment and needed in the local government building process tasks. Company’s technology has enabled the integration of data contents in basic registers in the same technical platform, which has created an excellent basis for building process support for local government and enabled sharing of information between different applications and processes. Geospatial data and functionalities are utilized throughout the business processes.

Modern customer service can be achieved with ready-made eService tools which can easily be customized for each customer organization.

VTT Technical Research Centre of Finland Ltd. (Finland)

VTT is a multi-technological contract research organisation providing high-end technology solutions and innovation services. From its wide knowledge base, VTT can combine different technologies, create new innovations and a wide range of world-class technologies and applied research services, thus improving its clients’ competitiveness and competence. Through its international scientific and technology networks, VTT can produce information, upgrade technology knowledge, and create business intelligence and value added for its stakeholders.

In order to allow VTT to carry out the high-risk strategic research necessary to generate the knowledge and know-how required for fulfilling its public mandate, it receives substantial funding directly from the Finnish government. This funding amounts to approximately one third of VTT’s total income. By virtue of its status as a government

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organisation, its public mandate, its substantial research programmes with dedicated public funding, VTT Group is the largest public applied research activity in Finland with a staff of 2600 and turnover 280 M€ .In the past 20 years, VTT has participated in more than 1000 European R&D Framework Programme projects, within various thematic programmes.

VTT is one of the world's leading developers of Augmented Reality (AR) technology and solutions. Among various application fields, VTT's special research focus is on mobile outdoor AR visualisation of buildings and city plans. Throughout years, VTT has produced world first implementations of mobile AR on PDA (2003), locationing based on Google Earth maps and GPS (2007), applying mobile AR at construction site with 4D BIM (2010), taking mobile AR to decision making process in city planning (2012), and most recently, providing mobile AR as tool for citizens to evaluate alternative city plans (2014).

VTT's AROnSite application relies on feature based 3D tracking which provides superior accuracy compared to alternative solutions (most typically based on GPS and compass). Two tracking methods are available according to the situation: fully automatic solution (based on point clouds, requiring a pre-processing step), and an interactive version (simple initialisation step performed by the user, but no pre-processing required). In both cases the tracking performance is very fast, accurate and robust, being tolerant against occlusions, shadows etc. VTT also provides photorealistic visualization methods, for example to adjust AR rendering with real world lighting conditions.

VTT's tracking technology is packaged as ALVAR SDK (A Library for Virtual and Augmented Reality). Marker-based version of ALVAR is open sourced and has been adopted by thousands of users worldwide. The feature based tracking methods are commercially available as ALVAR Mobile and ALVAR Tracker modules. VTT's point cloud based tracking technology is internationally distributed with the AR-Media product family by Inglobe Technologies (Italy).

3 Collaborative city design

3.1 Description of city design process

The **planning process** varies from one project to another depending on country, region, and type of project. There are different amounts of stages in certain timescale. Co-innovation and co-development with the citizens and stakeholders have increased during the past years. The challenge in outlining (even in theory) planning involvement, is that the nature of involvement, whom to involve, what methods to use, duration of involvement and the authority of the participants vary in different stages of the process.

Archon Fung (2004, as cited by Lindenau & Böhler-Baedeker, 2014) has identified three key questions that are intended to help when analysing the level of participation:

- **Who** should be involved?
- **What is the method** of communication and decision-making?
- **How much influence** and authority do citizens and stakeholders have?

The concept of Sustainable Urban Mobility Planning, which is promoted by the European Commission, established the principle that the public should be involved from the very beginning of the (transport) planning process and not only when the plans are largely completed and only minor amendments can be carried out. (Lindenau & Böhler-Baedeker, 2014)

Who. Participation reflects the overall integration of citizens and groups in planning processes and policy decision-making and consequently the share of power. A term commonly referred to in participation research is “stakeholder” which may be an individual, group or organisation affected by a proposed plan or project, or who can affect a project and its implementation. Groups with economic interests such as retailers, shop owners or local industry can be considered as stakeholders just like groups representing mobility-related or public interests including mobility, environmental or resident associations. Also cultural and educational institutions such as schools and kindergartens usually have a stake in mobility and often call for involvement (Krause, 2014).

It is crucial to involve all different types of stakeholders throughout the planning process, addressing their specific requirements. This especially concerns groups with less ability to articulate their concerns or requirements and prevail in comparison to other more powerful groups. Examples of hard to reach groups are ethnic minorities, impaired people, young people and the elderly, people with low literacy and apathetic groups. Depending on the purpose of the participation it may be appropriate to target the involvement of specific groups, e.g. people with mobility difficulties in a given instance. Thinking about the justification for giving particular influence to a few members of the population or a few groups the question of influence can be difficult as well. (Lindenau & Böhler-Baedeker, 2014).

Method. Many European cities exploit new information technology to support their innovations and new forms of participation in developing the smart city need to be generated from new forms of ICT. (Batty, M., 2012) In addition, many traditional types of engagement are and will be used, especially face-to-face meetings and workshops.

In the literature several different approaches to involve citizen and other stakeholders are

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determined:

- Referendum, initiative and recall (Buss, T.F. et al., 2006)
- Public hearings (Buss, T.F. et al., 2006)
- Advocacy and public interest groups (Buss, T.F. et al., 2006)
- Portals and other access points to useful information about any aspect of routine living and working in cities (Batty, M., 2012)
- Surveys and focus groups, used increasingly, either by telephone, mail, e-mail, group distribution or in person (Buss, T.F. et al., 2006). Focus groups can be widened on larger groups defined as mega focus groups (MFG) allowing all sections of society to be represented in the participation process. (Ibeas, A. et al., 2011)
- Workshops, retreats and conferences, increasingly popular in government decision making (Buss, T.F. et al., 2006)
- Citizens engaging with crowd-sourced systems in which they are responding to queries and uploading information (Batty, M., 2012)
- Web-based participation, online tools it is possible to reach a large amount of users quickly and cost-efficiently. Online tools enable more easy and effective participation due to the fact that the users can participate from the place they want and at the time suitable for them (Näkki and Antikainen, 2008). This is also seen as largely passive method if there is not any interactivity implemented. (Batty, M., 2012)
- The world is more digitally connected than ever before which makes it possible to utilize smartphones and information technology in applications. Gamification can be used to encourage citizen to solve problems and increase awareness to change behaviour. (Burdett, et al., 2015)
- Mapping practices. Approaching urban information from a citizen's viewpoint. Builds on ethnographic-based participatory design. Personal interview and a timeline exercise in mapping practices. (Laakso et al., 2014)
- Citizen advisory boards and partnership (Buss, T.F. et al., 2006)
- Group facilitation (Buss, T.F. et al., 2006)
- Time Planning: planning focused on the time schedules and spatio-temporal organization of people's actions (Horelli, L., 2013)
- E-Planning: the use of ICTs in urban planning to foster citizens participation, including also participation in design and use of digital tools and media content. Socio-cultural, ethical and political practices are recognized in the planning and decision making cycle by using digital and non-digital tools. (Horelli, L., 2013)
- The 'creative corner' combined of three distinct co-creative 'tools' (creative artifacts, the innovation tree, the pin-board) to encourage the locals in formalising, sharing and articulating their ideas. (Mitts, C., 2013)

The figure below gives one possibility about suitable involvement instruments in relation in

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different stages of the planning process and with different stakeholders.

	1 Letters	2 Posters, notices and signs	3 Leaflets and brochures	4 Fact sheets	5 Newsletters	6 Technical reports	7 Telephone techniques	8 Radio shows & TV shows	9 Internet techniques	10 Web-based forums	11 Questionnaire surveys	12 Key person interviews	13 Exhibitions	14 Information centres	15 Information sessions/briefings	16 Public meetings	17 Topical events	18 Community visits	19 Focus groups	20 Workshops	21 Citizen juries	22 Technical working parties	23 Stakeholder conferences	24 Transport visioning events	25 Weekend events	26 Planning for Real®	27 Open-space events
Classifications ● generally applicable ○ partially applicable																											
Who to engage																											
Wider audience	○	●	●	○	●	●	●	○	●	●	●	●	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○
Targeted audience	●	○	●	●	○	●	●	○	●	●	●	●	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○
When to engage																											
Problem definition	●	●	●	●	●	●	●	●	●	●	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Option generation	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Option assessment	○	●	●	●	●	●	●	●	●	●	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Formal decision making	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Implementation plan	○	●	●	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Monitoring and evaluation	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Type of project																											
Strategy	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Scheme	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Duration of engagement																											
Restricted	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Continuous	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Overview of engagement techniques in mobility planning (Guidemaps, 2004)

For the purposes of this project, two approaches describing the city design and co-design processes, which are mentioned in the literature, will be presented.

3.1.1 City design process cycle

The Figure below demonstrates different phases of city design process as summarised from Batty et al (2012). Batty et al mainly made their observations in the UK.



City design process cycle - based on Batty et al (2012)

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According to Batty, the process of city design goes through six stages, starting with **project context definition**, which involves two parallel activities:

- **Goal formulation:** process of defining the goals, which justify the decision of developing a new urban project. These requirements constitute the “problem” that the co-design process has to solve. In the architectural world, it also receives the name of “program”. Nowadays these goals are usually formulated as: (1) qualitative objectives and general descriptions, e.g. ‘a green and sustainable district...’, ‘the development of a new economical pole...’; ‘the creation of more green spaces for the residents...’ and (2) quantitative objectives, usually in terms of construction surfaces by land use. For example, ‘the construction of 200 new housing units’, ‘2000 m² of sport equipment’.
- **Process planning:** Every urban project is unique. A project management strategy should be settled in order to identify decision makers in the project; foresee constraints: temporal scope, financial resources, and required skills; settle a series of rules, phases, deliverables, and actions to be followed by the different participants in the whole process. The most common strategies, which are currently in use: public markets, idea competitions, direct contract, participatory budget.

After defining the project context, **data collection** phase starts, where accurate information about the city is gathered to propose pertinent solutions for the identified problem. Relevant data concerns the physical location (if known) and/or the kind of activities that need to be developed. The following list with examples is a basic classification of the most common data used in city design nowadays.

- Physical Reality:
 - Situation: Distance to the city center or other activity poles; presence of transport connections; presence of water or vegetation.
 - Tissue type: scale of the existing built environment (volumes, heights, proportions, public spaces.)
 - Aesthetics: valuable views, perspectives, materials.
- Legal constraints: There is a hierarchy of planning tools corresponding to the administrative structure of each country that go from national, to regional, municipal, district even parcel levels. Every new project is supposed to follow all of these prescriptions. In general, these are important constraints in terms of permitted land use, environmental protections, possible volumetry, position of the buildings, servitudes to respect, and technical performance specifications
- Quantitative Data: statistics and quantitative surveys are an objective source of information about how the city is working and it is a basis for comparison. Quantitative data can be re-elaborated to create new indicators and evaluate decisions. Some examples: market studies, market prices; socio-economic level of the population, educational level of the population, density rates, criminality rates, energy consumption ratios.

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- Living experience: information about how a place is being used is very important in city design, but it is difficult to ensure that an accurate and global view is correctly integrated in the solution. There are no accessible and systematized sources of information for living experience data. Designers approach is usually based on a short and personal on-site perception or fragments of information from secondary sources. Some examples: identity of the place for the citizens, history / traditions and events related to it, type of commerce or activities being developed, evolution of uses in time, daylife vs. nightlife, use of public space, conflicts and demands from users, rejected projects in the past, counter projects taking place, stakeholders which could be affected by the project.

At the **analysis** phase, requirements definition and data collection lead to a stage of analysis where the project context is successively defined and redefined, objectives are prioritized, guidelines are established, and new stakeholders are considered. Intuitive insights and idea exchanges are gradually integrated in a 'diagnosis' as the problem becomes better understood. There is no standard tool for this phase, but SWOT analysis (Strengths - Weakness - Opportunities - Threats) may be taken as example.

Phase 4 is time for **generation of alternative solutions**. A succession of drafts in increasing level of definition and constraints integration is produced. This exercise requires the expertise of multidisciplinary professionals (architects, engineers, landscape designers or other professionals).

One of the key activities for the success of the process is **communication** (Phase 5). Solutions in city design are formally visual and the most effective way of communicating such ideas is visual too (Batty, 2000). Visualization of urban design ideas takes places at every stage of the project. The level of definition follows the timeline of the project and has to be adapted to the receiver of the information (professional, client, general public).

At the Phase 6 **evaluation** takes place - alternative solutions are compared with the program and goals set at the beginning of the project and redefined in analysis phases. The state-of-the-art about evaluation of urban projects varies depending on the criteria:

- Qualitative evaluation, based on a global perception of the project. In practice, proposals are mainly evaluated with qualitative criteria (general concept and aesthetics). This is one of the reasons, why communication and visualization is crucial for the success of a project. On the other hand, the eye-catching of a project is not a guarantee of social, economic or environmental efficiency.
- Quantitative evaluation: based on quantitative indicators that may have been established at the beginning of the project. Obviously, financial feasibility is the key verification for every project execution, and profit for those commercially oriented ones. Nevertheless, other indicators can help to evaluate a project, for example in terms of environmental criteria. This is how some certificates as BREEAM or LEED classify sustainable projects.
- Performance evaluation: based on simulations that may give a prospective view about how the project is going to be lived or how the environment is going to respond once it is in place. This kind of evaluation is rare. Impact studies are demanded by some public authorities in building permits for big scale projects, and specialized study offices work on simulations concerning traffic congestion or fire security.

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Nevertheless, there is a lack of information about buildings performance and use after construction. On the contrary, of the industrial sector, buildings are always first-prototypes.

The final stage is **Decision/Approval**:

Co-design is a complex creative process where many variables have an impact on others and interests of different stakeholders may be contradictory. Solutions ameliorate after several rounds of analysis - proposal - evaluation and decision iterations. It is important to understand this from the process planning perspective, in order to establish decision gates at different levels that focus on the objectives of the project and guide it in order to respect the schedule and the financial feasibility.

In the stakeholders mapping, some have to be classified as decision makers. Nowadays, this power is usually in hands of public authorities or investors because they take the responsibility and the risk of the success or failure of the project.

3.1.2 Framework of city co-design process

Analysing urban co-design process and projects in Beijing Fu & Lin (2014) built a **framework of city co-design process** (see table below). The stages are defined slightly differently than the ones proposed by Batty et al. (2012), but in principle they draw a similar cycles: (1) exploration - defining the context, stakeholder and vision; (2) data collection and then (3) data analysis; (4) generation of solutions and building models; (5) running pilots and (6) evaluation, decision making and enabling sustainability. Communication is not mentioned by Fu & Lin (2014) as a separate stage, but it goes across the stages and is reflected in certain methods applied in urban co-design: interviews and workshops during exploration; user journey and storytelling at the integration stage; brainstorming, role plays and focus groups at ideation and data analysis stages; crowd iterative development at implementation stage; tracking and usability testing at evaluation stage.

Framework of city Co-design process (Fu & Lin, 2014)

Steps	Description	Main Methods
Exploration	Top design with sustainable and people-centered vision; Positioning the R&D territory in the macro-micro level. <ul style="list-style-type: none"> • Define the means of Smart City. • Analysis stakeholder group. • Co-create a specific Smart City vision. • Establish credible decision-making process. 	Road map Territory Mapping Interview Workshop
Integration	Participatory Research with big/open data; Deep research for the real challenges of the city. <ul style="list-style-type: none"> • Draw on the available resources and expertise. • Structure the approach to a Smart City. • Establish the policy framework. • Populate a roadmap that can deliver the vision. 	Storytelling Scenario User journey Frame opportunities Business plan
Ideation	Form the team through open activities and generate first prototype; Co-design with smart citizen based on lean startup model <ul style="list-style-type: none"> • Identify the target user groups and do user study. • Analyze the data and build user models. • Identify specific contexts for different models. • Concept generation. 	Brainstorming Role play Focus group Workshop
Implementation	Frame new service ecosystem with Physical/ Virtual ICT. <ul style="list-style-type: none"> • Refine design contexts and solutions. • Put the financing in place. • Run pilot project. 	Rapid prototype Iterative design Crowd development
Evaluation	Evaluation and testing with public; Summarize research approaches and solutions for future research. <ul style="list-style-type: none"> • Analyze the data for refining the user models and reframing the contexts. • Enable communities and engage with informality. • Make a self-sustaining process for citizen. 	Tracking Learning Usability Testing Guide / Report

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Top-down and bottom-up approaches

Two main tendencies can be noted within planning theory: top-down and bottom-up.

Top-down approach indicates a technical expert-driven process, with a '*tendency towards centralism and de-politicizing decision-making*' (Murray, 2009 in Pissourios, 2014, p84). Professional view is systematic and rational and focuses on priorities, efficiency, etc but they tend to overlook day-to-day life on the local scale.

On the other hand, bottom-up approach calls for a larger participation and democratic decision-making, including end-users, citizens and other stakeholders in the process. The discourse of the bottom level is multidimensional and interrelated urban scales. It is usually fragmented, and not well articulated, so hard to incorporate in urban planning. Pissourios (2014) analyses the difficulties for the implementation of bottom-up approaches. Among them are:

- The existence of a 'bottom level', or a community that is willing to participate in planning procedures in order to influence them.
- The process is limited by existing regulations.
- It is more time-consuming than top-down approach. "gathering of the various stakeholders of the community, the arrangement of the procedure in which the open-ended forms of discussions will be held, the arrival at agreement on conflicted and interrelated issues and the translation of these agreements into planning objectives require the amplexness of time". (Pissourios, 2014, p 11)
- "Their efficiency in planning is inversely proportional to the size of the community that is planned". When the population size increases, the process of urban intervention is slowed-down. In large communities "techniques of representative participation will be adopted, degenerating the nature of the bottom-up approach"(Pissourios, 2014, p 11).
- Such approach can be implemented only when planning deals with spatial issues related to local interest and consequences. Its scope is limited to the local planning of small settlements or the planning of districts in larger settlements.

Both tendencies have advantages as well as weaknesses that make them appropriate for application in certain planning scales:

- For regional and strategic urban planning, a top-down approach is inevitably the only available choice for planning practice.
- For local urban planning scale bottom-up approaches can be richer and get to a more pertinent result.

3.1.3 Context specific process steps in city design/city planning

As the city design steps are not general across different contexts, in first Table below a brief overview of different stages as per different country is given and in the following Table these stages are generalized:

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Comparison of different process stages

Assar (Belgium)	General process (UK Batty 2000, 2012)	FCG (Finland)	Juridical planning process in Finland	Planning Process in Turkey	General project / program management
	Project context definition	Need for change, definition of planning questions		Determining the planning region and the responsible party	Initiative
Data Compilation	Data Collection	Gathering of data	Planning initiative	Data collection	Feasibility - definition
Diagnosis	Analysis	Background studies (traffic, natural values etc.)		Analysis	
Proposition	Generation of alternative solutions	Ideas stage	Preliminary plan	Determining visions and missions	Feasibility - design
Co-design	Communication and evaluation	Collaboration with citizens, authorities, landowners and other stakeholder groups		Planning strategy, goals and missions	
Production	Decision	Finalizing stage	Finalized plan	Generation of plans and related reports	Feasibility - preparation
		Approval of plan, agreements on legal constraints,	Approval of plan	Approval and waiting for possible objections (from	

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Assar (Belgium)	General process (UK Batty 2000, 2012)	FCG (Finland)	Juridical planning process in Finland	Planning Process in Turkey	General project / program management
		cost division etc.		stakeholders)	
				Plan revisions (if necessary)	Realization
		Identification of revision needs, follow-up		Implementation and continuous revision (if necessary)	Management

Generalized city design process

Name	Description	Typical activities
Framing & Context definition	Key project team is defining the project, first list of stakeholders, high level constraints	<ul style="list-style-type: none"> Meetings with project initiator, owner, key project team Desktop research Stakeholder workshop to list the first draft of stakeholder needs, issues and initiatives Responsible party depends on the scale of the plan (Turkey)
Data gathering	Obtain available data on issues, needs, context: <ul style="list-style-type: none"> Open data from authorities Additional measurements through technology (IoT) Studies Interviews Existing background studies and data Sensor data Open citizen feedback 	<ul style="list-style-type: none"> Data gathering and processing Measuring Interviews Workshops Broader communication to identify further stakeholder, gather input & issues, Polls, ... Determining current land use
Analysis	<ul style="list-style-type: none"> Further analysing and fine- 	<ul style="list-style-type: none"> Population projections Predictions on the directions to

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Name	Description	Typical activities
	<p>tuning data gathered; checking assumptions</p> <ul style="list-style-type: none"> • Formalizing listing of legal constraints • Formalizing listing of objectives, needs • Formalizing stakeholder maps, relations, expectations, relations, synergies, conflicts of interest 	<p>which the city will expand</p> <ul style="list-style-type: none"> • Environmental and visual problems investigation • Analysis of historical and cultural values • Analysis of accessibility to hospitals, schools etc. • SWOT analysis regarding risks
<p>Ideas & alternative solutions</p>	<p>Experts (e.g. architects) develop solutions & alternatives</p> <p>Stakeholders can be involved to</p> <ul style="list-style-type: none"> • Create ideas for solutions • Evaluate & improve ideas for solutions • Input tacit knowledge on the site and the social and historical context • Input their specific needs and requirements for planning <p>Additional experts</p> <ul style="list-style-type: none"> • Input specific knowledge on their field or expertise, e.g. natural values, traffic requirements, urban structure etc. 	<ul style="list-style-type: none"> • Workshops, idea generation and idea improvement with stakeholders, • Virtual environments to help idea simulation • Quantification of cost and other performance indicators (for example number of new jobs, reduction in hours of traffic jam)
<p>Communication & Evaluation</p>	<ul style="list-style-type: none"> • Developed proposals are presented to stakeholders and public for: <ul style="list-style-type: none"> ○ Informing, engaging ○ Feedback ○ Suggestions • Feedback is evaluated, impact of proposed changes is assessed <ul style="list-style-type: none"> ○ Qualitative, Quantitative, Performance evaluation. 	<ul style="list-style-type: none"> • Distributing information and gathering feedback through different media • Social feedback on virtual environments with mockups • Interactive simulation and impact visualization • Workshops around specific issues to generate broad support for final solutions

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Name	Description	Typical activities
	<ul style="list-style-type: none"> Potential solutions and impact are iterated to come to a final proposal supported by a large representation of the stakeholders. 	
Finalizing & Agreements	Final solution is <ul style="list-style-type: none"> Selected Elaborated & engineered Submitted for approval authorities Contracted 	Collaboration in engineering, contracting
Realization & Construction	<ul style="list-style-type: none"> Preparation works (Phased) Construction works (Phased) commissioning and acceptance 	<ul style="list-style-type: none"> Issue, conflict, complaint management Solving issues arising with above tools
Management	<ul style="list-style-type: none"> Facilities management Traffic management 	<ul style="list-style-type: none"> Issue, conflict, complaint management Solving issues arising with above tools

Based on the knowledge gathered during the C³PO project, Assar Architects, Studio Dott and Createlli teams have jointly developed a consolidated city co-design process flow, which consists of the 8 key stages (see illustrative figure below): framing and context definition, data gathering, analysis, idea gathering and defining the alternative solutions, communication of the alternative solutions and evaluation of those, finalizing the agreements required for implementation, realization and construction and continuous project management.



Consolidated city co-design process flow (developed during the C³PO project by Assar Architects, Studio Dott and Createlli teams)

3.1.4 City planning and city co-design in the countries hosting C³PO pilots

City planning and city (co-)design in Belgium

Belgium, consisting of three regions (Wallonia, Brussels, Flanders), has a national territorial planning and urban development system, which has certain peculiarities in between the regions. A study done by Philippe Hanocq in 2011 gives a comprehensive overview of urban

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planning and development in the country on the national level as well as across the regions. Here a short summary of this study is provided.

Hanocq (2011) defines three general practical tools applied across Belgium:

- o **Strategic plans** (or “schemes”) - describing mainly long-term political intentions regarding territory development elaborated by regional or local authorities.
- o **Binding executive/destination plans** - a graphical and precise reflection of construction plans in certain area (sector, neighbourhood unit ,etc).
- o **Urbanistic rules** - legal written documents, which compliment strategic plans and binding executive plans. Urbanistic rules define a base for public control and intervention, including its structure, texture, organisation of both territorial development and urban design.

Hanocq (2011) also describe the legal documents applied for territory planning in each region (see figure N) and their modifications in the recent decades. When it comes to interaction between different territories the notable differences exist between Flemish region in comparison with practices applied in Brussels and Walloon region. Hanocq (2011) describes planning systems in Brussels and Walloon as "*models with a zoom effect*", since the process starts with *executive plans*, then goes through detalization of options in *strategic municipal plans* and finally *binding executive municipal plans* formalize the options and may even refine the regional executive plans. The Flemish system according to Hanocq is a "*patchwork model*", since public authorities of each level (regional / provincial / municipal) intervene, and each administrative level has an "autonomous" development policy for certain territory of its own jurisdiction taking a responsibility for its own policy and financing for its implementation. The actual *binding plans* are in force until new *executive plans* are not substituting them. Thus, Flemish territory is covered by a variety of planning documentation creating a kind of *patchwork* as per Hanocq.

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Territorial development and urban design in the Belgian federal state. General architecture of the system and main tools (Hanocq, 2011)

		Brussels Région	Walloon Région	Flemish Région
General legal framework (Codex)		Code bruxellois d'Aménagement du Territoire (OOPU 1991 / COBAT 2004)	Code wallon de l'Aménagement du Territoire, de l'Urbanisme, du Patrimoine et de l'Energie (CWATU 1984 / CWATUP 1991 / CWATUPE 2009)	Vlaamse Codex Ruimtelijke Ordening (Décret de base 1999 / VCRO 2009)
Régional level	Strategic plans	Plan régional de développement (PRD)	Schéma de développement de l'espace régional (SDER)	Ruimtelijk Structuurplan Vlaanderen (RSV)
	Executive plans	Plan régional d'affectation du sol (PRAS)	Plans de secteur (PS)	Geswestplannen / Gewestelijke ruimtelijke uitvoeringsplannen (RUPs)
	Urbanistic rules	Règlement régional d'urbanisme (RRU)	Règlements généraux d'urbanisme (RGU - RRU - RGB)	Gewestelijke stedenbouwkundige verordeningen (GSV)
Provincial level	Strategic plans			Provinciaal ruimtelijk Structuurplan (PRS)
	Executive plans			Provinciaal ruimtelijke uitvoeringsplannen (RUPs)
	Urbanistic rules			Provinciale stedenbouwkundige verordeningen (PSV)
Municipal level	Strategic plans	Plan communal de développement (PCD)	Schéma de structure communal (SSC)	Gemeentelijk ruimtelijk Structuurplan (GRS)
	Executive plans	Plan particulier d'affectation du sol (PPAS)	Plan communal d'aménagement (PCA)	Bijzondere Plannen van Aanleg (BPA's) / Gemeentelijke ruimtelijke uitvoeringsplannen (RUPs)
	Urbanistic rules	Règlement communal d'urbanisme (RCU)	Règlement communal d'urbanisme (RCU)	Gemeentelijke stedenbouwkundige verordeningen (GSV)

In the following subchapter the participation and co-design processes applied particularly in the Brussels Region are discussed more in detail.

Participation and co-design oriented processes in Belgian Urban Planning: the case of Brussels Region.

The official legislation integrates public participation and consultation in specific moments of the urban planning process. Depending on the administrative level of particular project three key procedures to be highlighted are:

- **Concertation commission:** the municipal level prepare “concertation commissions” before the adoption of a new binding/executive plan or new urbanistic rules, as well as the acceptance of some building or environmental permits with regional impact. This procedure is developed in two stages:
 - First, a public hearing where the author of the project explains it and all the stakeholders can express their advice (inhabitants, associations, representatives, regional authorities and technicians).
 - Second, representatives from the municipality, the Region and technicians from public institutions of mobility, urbanism, heritage, housing, economy held a private meeting where they write an official advice that will be taken into account by the Region decision makers who have the power to demand

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some modifications, accept or refuse the project.

- **Public surveys (call for statements):** when any building permit is submitted to the authorities, citizens have the right to consult the official documents during a limited period of time and express their objections. As a consequence, the author of the project may add some precisions and justify the choices made. At the end it is the public's authority responsibility to demand some modifications, accept or refuse the project.
- **Public hearings:** even if it is not compulsory in the legislation, some local authorities use to specifically invite inhabitants living near a new urban project of big impact to an informative session before the public survey period. During this meeting the authors of the project explain their choices and answer the questions from the citizens directly. Afterwards these have the right to express their objections to the project by the legal procedure.

In general, legislation includes public participation in a phase of the project where the ideas and the design have been defined. Participation is usually understood like the right of access to the information.

Nevertheless, in Brussels Region some examples of co-design procedures that integrate stakeholders in the phases of idea creation and decision making can be found. The two key examples are:

- **Director Scheme:** Brussels Region has developed a procedure for strategic regional projects that consist on co-designing the new masterplans between a group of stakeholders. Several workshops are organised with everybody around the table and an architect traduces the result of the agreements in a masterplan. Evaluations, negotiations and agreements are reached through several iterations. For the moment this process is restricted to stakeholders such as regional and municipal authorities, public technicians, investors, landowners, and managers from public equipments, but not citizens. Materials for communication are very traditional: maps and models, not technologically based.
- **Sustainable District contracts:** since 1994, Brussels Region, communes and inhabitants work together on the revitalisation of some neighbourhoods of the city. This collaboration is made through a 4 years plan, with a limited budget to invest on a perimeter. Decisions are taken by a District comission where different stakeholders are represented, also inhabitants. Their role is to decide in which projects (from some predefined categories: housing, public equipment, public space, socioeconomical actions, commertial spaces) the budget is spent. The projects can be proposed by different stakeholders through an organised process with phases and events where participation is enlarged to the public and local associations.

Bottom up initiatives

Besides the official legislation, there are several bottom up initiatives. As mentioned in section 3.1, these are usually very local groups focussing on local issues. Yet, these initiatives have shown to influence on a larger scale. This is in contrast to what is suggested in the literature mentioned in section 3.1. Two examples include:

- Ringland (<http://www.ringland.be/>): citizen & private companies initiated urban development project, aimed to provide an alternative to a government initiated proposal for the same area.

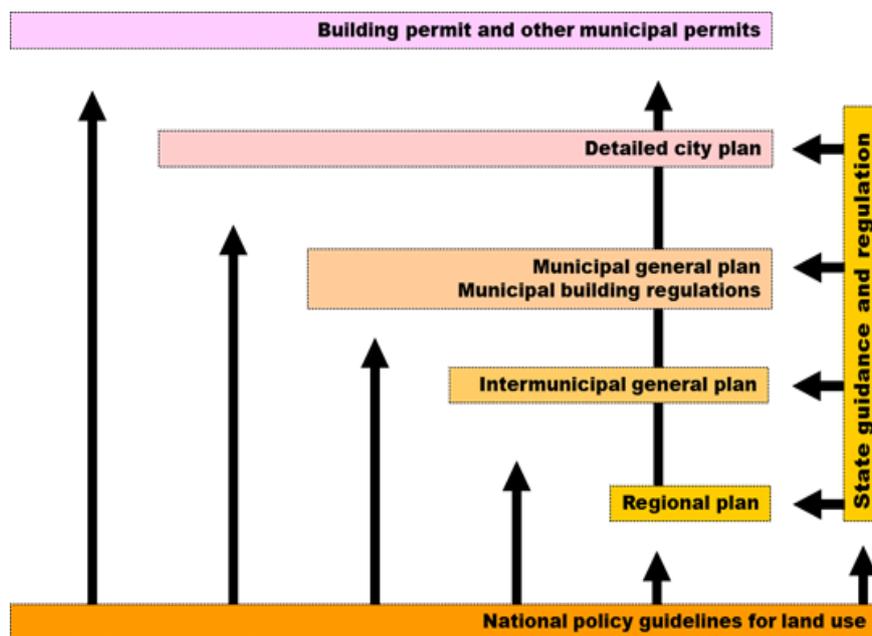
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- Oostnatie (<http://www.parkspooroost.be/>): a citizen powered bottom up initiative which has a constructive dialogue with the city.

The interplay between bottom up and top down initiatives is not to be overlooked in the Belgian context. There are several non-profit organisations that actively engage in urban participation, they thereby form a valuable communication channel to cities and municipalities. Unfortunately, these channels are rarely formalised in legislation.

City planning and city (co-)design in Finland

The Finnish land use planning system has three levels of land use plan with a clear division of labour between them: the regional land use plan, the local master plan and the local detailed plan. The land use planning system is hierarchical; higher level plans steer lower plans.



City planning in Finland (by Savisalo, 2008)

Finland's municipalities draft their own local land use plans, which must be approved by local municipal councils.

Municipalities produce local master plans and local detailed plans to control land use and building. The plans aim to ensure that living environments are favourable, community structures function well, vital services are available to everyone, and local natural and cultural heritage is safeguarded.

Municipal planning procedures are based on openness and public participation. Finland's Land Use and Building Act (2000) ensures that local residents have the right to receive information about plans under preparation, and a chance to influence them. The right to participate in planning procedures covers everyone affected by plans, including local

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residents, landowners, public authorities, enterprises and organizations (The Finnish Ministry of Environment, 2015a).

Participation and assessment schemes are drawn up at the start of the planning process, to define how citizens, organisations and other interest groups can contribute to the whole process. Such co-operation begins during the initial phase of the planning process, while alternatives are still open, to allow participants to genuinely influence the plans.

Public meetings are then organised for local residents and other interested parties at key stages of the planning process.

Planning objectives are set through detailed consultation with interest groups. During the drafting of planning proposals, interested parties can participate in impact assessments for alternative planning options, and express their opinions on planning proposals.

Draft planning proposals are exhibited in public places to allow all citizens and interest groups to examine them and officially submit any objections.

Typical moments and means of interaction in municipal planning are described below. In the regional plans, a regional authority does the preparation work at different stages. The process looks like this (methods of interaction are shown in **bold**):

- all municipalities must provide citizens with an **annual overview** of ongoing planning projects.
- introductory stage: an individual or a landowner can make a **written initiative** for a detailed plan or plan amendment to the municipal board.
- municipality must publish a formal **plan for public hearing and impact assessment** for each planning project in the beginning of the process. This plan is updated during the process.
- in case of the plans playing a significant role for the region, a **council of regional authorities** must be held in the introductory stage of the planning process.
- in preparatory stage, municipality or their consultant planner prepares a preliminary proposition for the plan for the **first public hearing**. The regional authorities, regional museums, etc. are also called to **file their statement** on the plan.
- Based on the collected feedback, municipality or their consultant planner then prepares the final plan proposition for a **second public hearing and call for statements**.
- After the finalized plan has been approved by the municipal council, stakeholders have the right to bring the plan process in court to appeal the eventual formal mistakes in the process (but not for substance questions in the plan, although this is often misunderstood) (The Finnish Ministry of Environment, 2015b).

A typical planning process can take from approximately 3 months (in case of small amendments in the detailed city plan) to several years (in case of a complicated municipal general plan).

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City planning and city (co-)design in Turkey

City planning process in Turkey consists of steps listed below.

1) Planning region is determined. The responsible party depends on the scale of the plan.

City design in Turkey: scale and responsible party

Scale	Name of the Plan	Responsible Party
1/100.000	Environmental Plan	Ministry of Environment and Urbanization
1/5000	Master Plan	Metropolitan Municipality
1/1000	Implementation Development Plan	District/County Municipality

2) Collecting information / feedback / opinion from other parties.

- o Demographic data from TUIK (Turkish Statistical Institute).
- o Information regarding natural structures data, geological maps, land classes, forest regions, earthquake maps, water resources etc. from Ministry of Food, Agriculture and Livestock.
- o Information regarding economy, unemployment ration, production, number of employed women etc. from Ministry of Economy and Ministry of Food, Agriculture and Livestock.
- o Information regarding cultural values, cultural history and traditions from Ministry of Culture and Tourism.
- o Information regarding current technical and social infrastructures in the planning region from the Ministry of Development.

3) Collecting information regarding how the land is currently being used in the city.

- o City is visited and housing and commercial regions are marked.
- o Structural quality of buildings is determined for urban transformation.
- o Opinion polls and surveys are conducted.
- o Depending on the scale of the plan, troublesome crossroads and junctions are determined, opinion polls are conducted for public transportation.
- o Planning region is photographed.

4) Analysis Process

- o Population projections are done for the upcoming years (probably decades).
- o Predictions about which directions will the city evolve are done.

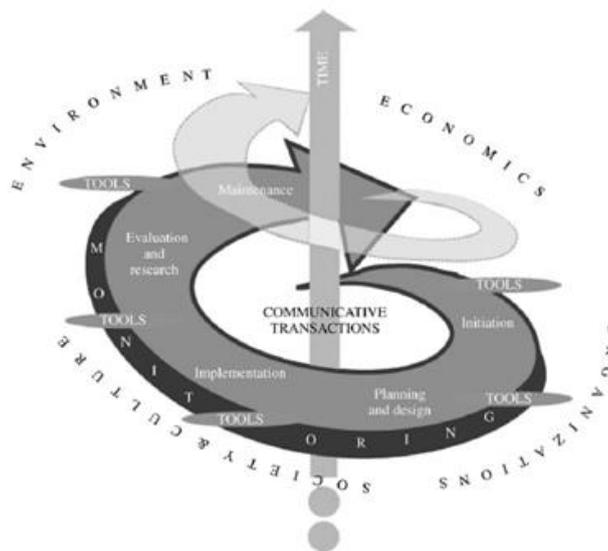
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- o Environmental and visual problems that might occur are investigated.
 - o Analysis of historical and cultural values is done.
 - o Analysis of accessibility to hospitals and schools is done.
- 5) SWOT analysis regarding risks.
- o Determining visions and missions.
 - o Planning strategy, determining goals and strategies to achieve those goals.
 - o Making decisions on plans based strategy plans.
 - o Generating plans and related reports.
 - o Submitting plans to city council for approval.
 - o After having approved, stall the plans for possible objections.
 - o Reviewing plans in case of objections. Making revisions if necessary.
 - o Submitting the plan to the parliament for approval.
 - o After approval, the plan is implemented.
 - o If necessary, continuous reviewing and revising the plan during the implementation.

3.2 Current state of collaborative city design

Collaborative city design has major differences from general city design: the communication component is not representing separate stage but rather constitutes the core of the process, around which all other phases are built.

When talking of city co-design, few main schools have to be mentioned: Kevin Lynch's (1981) and John Kaliski's (1999) understanding of city design built on idea of *collaboration*, which has been proposed as an alternative to *participation* by Innes and Booher (2004) and Miessen (2010).



Schema of participatory planning (Horelli and Kaaja, 2002)

Kevin Lynch, American urban theorist, suggested human-centered alternative for improving cities instead of the practiced project-orientated, top-down and expert driven approach to urban design and city planning. His description of concept dates back to 1981:

City design is the art of creating possibilities for the use, management, and form of settlements or their significant parts. It manipulates patterns in time and space and has as its justification the everyday human experience of those patterns. It does not deal solely with big things, but also with policies for small things - like seats and trees and sitting on front porches - wherever those features affect the performance of the settlement. City design concerns itself with objects, with human activity, with institutions of management, and with processes of change.

Miessen (2010) discusses the idealization of the idea of participation in politics and architecture. He considers it to be too often seen through '*romantic notions of negotiation, inclusion, and democratic decision-making*', however in reality it is messy and full of conflict. He questions the majority of existing participatory practices noting that it is often used as a way to pacify the masses, thus amounting to a form of pseudo-participation. He

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proposed that rather than use the term ‘participation’ the notion of ‘collaboration’, as discussed by Florian Schneider, might be a more helpful reference point (cited in Flood, 2015):

In contrast to cooperation, collaboration is driven by complex realities rather than romantic notions of a common ground or commonality. It is an ambivalent process constituted by a set of paradoxical relationships between co-producers who affect each other.

Innes and Booher (2004) also pointed to the limitations of participatory approaches as being one-way, when citizens provide input in a reactive manner only. In reaction to this dualist model, they also propose the idea of a collaborative approach which they describe as a *multi-dimensional model where communication, learning and action are joined together and where the polity, interests and citizenry co-evolve.*

When it comes to the practical side of organising urban participation, it becomes questionable what the role of technology should or can be. Technological tools have the potential to involve large groups of city stakeholders, yet technology can be a barrier for participation (In Ross Atkin’s ‘Manifesto for the Clever City’ (Atkin, 2015)). Although that the manifesto is written regarding city service design, the principles are applicable to urban collaboration. Two aspects that stick out are:

- “Use digital technology to solve problems experienced by citizen”: when using technology, the benefit for stakeholders should be made very clear.
- Collect as few data as are required to solve the problem for the citizens: by keeping things as simple as possible, stakeholders know what to expect and what they are contributing to.

3.2.1 Approaches for collaborative city design

Following the logic of stakeholder involvement to design process, the set of best practices (below) has been selected to illustrate different approaches to collaborative city design. These examples reflect a number of methods to involve citizens in city design. In addition to section 3.1, where methods for participation are listed based on the literature, the methods given here have been applied in concrete, recent urban development cases.

The methods used can be summarized by five types:

- **Sharing ideas or opinions**

These initiatives provide some sort of discussion board or pin-up board that gathers different opinions or ideas. The ideas can be triggered by answering questions, or they can be free. The ideas can usually be commented upon, or voted for. Other options include tagging or grouping the ideas, localizing ideas. *Examples: Place Pulse, Neighborland, Better Cities, My ideal city Bogotá, Christchurch Share an idea, Notice.City, Smartcity.Brussels, Better Reykjavik.*

- **Using visual models**

Visual models of how the city could look in the future can also be used to involve citizens. These models can be 2D or 3D. Participants either provide feedback on them, suggest changes, or build the models themselves (physically or digitally).

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Examples: District Builder, Hub2, Crowdmap Beijing problem areas, Block by block.

- **Playing games**

Using games or gamification techniques can serve two purposes: educating citizens about urban planning and its challenges, or collecting input. This input is usually less concrete than the previous methods. It mostly is information that city planners can interpret and use for their plans and decisions. *Examples: Community PlanIt, Future city game.*

- **Iterative collaboration** between designers and citizens - involving citizens in analysis as well as design phase. Feedback loops. *Examples: LA 2050, Rebuild by design, DreamHamar.*

- **Empowering people to take action / Experiment**

The method goes beyond information - it provokes action. Citizens are given the means to try out things in the city, experiment, make permanent changes and take part in decision making regarding city budget (participatory budgeting). In this way, they can actively shape their city. *Examples: Idées Paris, Kortrijk congé, People St, Fix my street, Krasimir, Safecity, CoDesign Studio.*

Above mentioned examples are described in more details in the following chapter. It should also be noted that one example might be a combination of features of different methods of citizen involvement.

Many projects combine different channels for collaboration. They use a mix of digital channels such as dedicated websites, videos, and social media. Often there is a physical aspect to the methods of collaboration as well as a digital. Bringing people together provides extra valuable interaction and information than staying purely digital. Gathering input from citizens can be done to achieve three goals: collecting needs of the citizen, gathering citizens ideas for changes in the city, or for gathering feedback on (first/intermediary/final) proposals made by experts. The most inclusive / collaborative projects combine methods and channels (online/offline) to reach all stakeholders.

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3.2.2 Examples of applications and tools for participation in city co-design

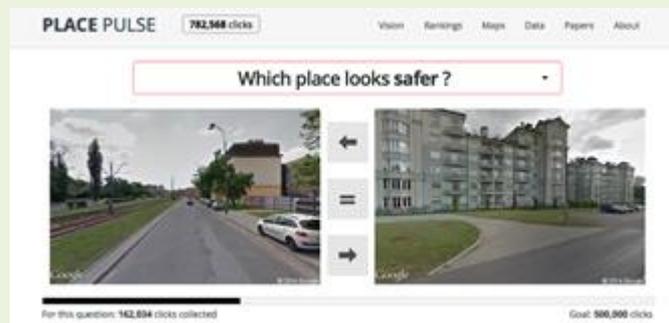
The selected illustrative examples are grouped according to five types of methods for citizen involvement in city design discussed in the previous section: sharing ideas or opinions, using visual models, playing games, iterative collaboration and empowering people to take action/experiment. The examples are given below and are accompanied by illustrative pictures, which follow the example description.

1. Sharing ideas or opinions

Place Pulse

→ <http://pulse.media.mit.edu/>

Cities are not just collections of demographics, but places that people experience. Urban environments trigger strong responses in people, and these responses can affect criminal and health behaviours. Place Pulse measures urban perception by crowdsourcing visual surveys to users around the globe. Its goal is to discover which areas of a city are perceived as wealthy, modern, safe, lively, active, unique, central, adaptable or family friendly. The data is then transformed to urban perception maps, which can be used for urban planning.



Neighborland:

→ <https://neighborland.com/>

Software that empowers civic leaders to collaborate with residents in an accessible, participatory, and enjoyable way following this process:

- Organizations start projects by asking a question
- Organizers engage people in public space and online.
- People discuss and prioritize ideas by voting



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- They propose moderation, clustering, and de-duplication tools for organizers to aggregate all of the data from residents.
- Reports make it easy for organizers to see trends in the data, make decisions, allocate resources, and keep participants involved in the fun part - making their neighborhoods better places.

Better Cities

→ <http://www.betterciti.es/about/>

→ <http://www.betterciti.es/projects/>

Better Cities is an initiative to focus on creative, collaborative and community-centered approaches to improve urban living and environment in Southeast Asian cities. It wants to achieve this through critical discourse, creative intervention, and participatory action. They want to empower citizens to take more ownership of the places where they belong. The urban campaign started in Kuala Lumpur in 2011 but today Singapore and George Town have joined.

The project tries to involve as many people as possible, -using different channels:

- People can tweet ideas for a better city using a special hashtag
- Co-creative workshops with different formats let citizens think about their city and how it's evolving (e.g. building a LEGO future city)
- Physical interventions in the city to involve people during their idle time
- Talks about ongoing projects to inform interested people

My ideal city Bogotá

→ <http://www.miciudadideal.com/en>

The city of Bogotá involves its citizens in its planning for the future by asking them to share ideas for certain challenges (e.g. What local resources should be better recycled and reused?). These questions are posed on a website, anyone can post an idea. "Free" ideas (not related to a challenge) are also possible. People can like and comment on the ideas.



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Christchurch Share an idea

<http://www.ccc.govt.nz/homeliving/civildefence/chcheearthquake/shareanidea.aspx>

<http://www.nvinteractive.co.nz/our-work/share-an-idea>

<http://www.strategy.co.nz/our-work/share-an-idea.aspx>

After a devastating earthquake that destroyed much of its central city, Christchurch needed to create an effective redevelopment plan that government would approve. To do this, the City Council needed wide public participation. “Share an Idea” was a way for the public to share their ideas about how the Central City should be redeveloped to be a great place again.

Consulting the public started from questions about their views for the new central city. These questions were posed to the public through a multitude of channels: the official website, a community expo in the city, Twitter, Facebook, radio stations going to malls and campuses to record ideas, viral Youtube videos, even tabloids and postcards delivered to citizens’ homes.



The campaign lasted for 6 weeks, and in that time span over 106,000 ideas were shared. These ideas were brought together to help inform the draft Central City Plan as a broadly agreed structure and direction for the Central City.

Smartcity.Brussels

→ <http://smartcity.brussels/>

This participation platform asks city inhabitants and stakeholders very bitesize questions in order to get insights into needs and problems in the city.

Two levels of engagement are offered:

- Projects: city stakeholders can propose their own projects. These projects can be voted on by a wider audience
- Questionnaires: very concise questions are asked which can be rapidly answered. Typically, these focus on more practical issues instead of major urban development projects.

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Notice.City

→ <http://notice.city/>

A conceptual proposal for urban participation within a city context. In comparison to apps on personal devices, Notice.city consists of a variety of devices placed in the public context.

“Notice is a family of three online electronic devices that provide an on street communication platform for planning applications and other city notices, replacing the text-heavy sheets of paper that currently reside on lamp posts throughout cities. It is linked to a mobile app and a website which allow the public to quickly and easily respond to planning applications a process that was once far more complex.”



Depending on the type of location, a different type of physical device can be placed on location throughout the city. These devices can be used to engage a wide variety of stakeholders, yet the focus is on citizens and visitors.

Better Reykjavik

→ <https://betrireykjavik.is/>

The city council of Reykjavik launched this idea platform, and managed to make it a success: over 60% of the citizens use the platform. Citizens can post ideas in different categories, add arguments for or against ideas of others and vote for or against them. Since Reykjavik implemented their city platform, they have spent €1.9 million on developing more than 200 projects based on ideas from citizens.

2. Using visual models

District Builder

→ <http://www.districtbuilder.org/>

DistrictBuilder is web-based, open source software for collaborative redistricting. It enables to:

- Create and edit district plans
- Use template plans to get started faster
- Import and merge plans from other systems
- Display demographics, election and other data
- Integrate with GoogleMaps, Esri ArcGIS Online, OpenStreetMap or Bing maps
- Show additional reference map layers, like school districts and administrative boundaries
- Automatically calculate contiguity, compactness and population statistics as you create your plan
- Customize demographic, geographic and election data statistics on-the-fly as you build your plan
- Find unassigned areas
- Draw communities of interest and evaluate a plan against them
- Evaluate how closely your proposed plan matches legal requirements
- Save and share your plans via a URL link
- Support public competitions, scoring and leaderboards

Block by block

→ <http://blockbyblock.org/>

"Block by Block" is an innovative partnership between the United Nations Human Settlements Programme (UN-Habitat), the UN agency promoting sustainable towns and cities, and Mojang, the makers of Minecraft. Block by Block involves young people in the planning of urban public spaces. Minecraft has turned out to be the perfect tool to facilitate this process. The process is as follows: a special team makes Minecraft maps of the current state of the public areas in focus. These maps are then used by young people to redesign the public space in Minecraft. This method was used to upgrade 300 public spaces by the end of 2016.

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Hub2

→

<http://engagementgamelab.org/projects/hub2/>

Hub2 is a project that uses a digital 3D environment (Second Life) to trigger reactions and ideas from citizens. In workshops, participants explore the digital environment.

They each have a character (e.g. old man in a wheelchair) that they can move around the space. They are asked to act out certain scenarios, such as walking to the library or parking their car and entering the garden. Participants can give reactions and suggest changes, by planting digital flags by an object or area. The flags are then voted on and turn red or green according to the votes. Players can also comment within flags, adding notes to certain areas.



LocalData:

→ <http://localdata.com/>

LocalData is a cloud-based mapping platform that helps cities and communities make data-driven decisions by capturing and visualizing street-level information in real time. It enables to:

- Collect and map street-level qualitative and quantitative data with mobile devices
- Design custom map-based surveys
- Manage data online
- Visualize geospatial data without a data expert

Target public: Public sector and non-profit professionals, Universities.

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Crowdmap Beijing problem areas

→ <http://www.psfk.com/2013/04/china-crowdmaps-pedestrian-and-cyclist-problem-areas-my-ideal-city.html#!bylaqM>

A crowdsourcing website in China in the making has asked pedestrians and cyclists to point out areas in need of repair or improvement in Beijing. This website should help transportation planners in the municipal government to know how roads and sidewalks are being used by the public, and where changes may be needed. Anyone can submit a mini report on issues related to quality of cycling and walking infrastructure that they discover, via web, smart phone app, SMS or social media. All user-generated reports are then mapped and visualized, available for others to view and comment on. Transport planners hope that the feedback from citizens on urban transport conditions help them in building safer and more accessible transportation solutions.



3. Playing games

Community PlanIt

→ <https://communityplanit.org/> and <http://engagementgamelab.org/games/community-planit/>

Community PlanIt is a game that wants to involve citizens in city planning, using gamification techniques like completing missions, earning awards and collecting coins. It is meant to involve people who do not have time or do not want to go to council meetings to be heard.

Citizens achieve three results with this game: they can give input for long term strategic planning, they can use their coins to donate to real-life causes, and they can meet new people in their community.



Future city game

→ http://creativecities.britishcouncil.org/urban_co-design_tools/future_city_game

Future city game is a game, played by city inhabitants from different professions, genders and generations, that aims to create a dialogue between the public sector and citizens.

Teams of players think about challenges related to globalisation, migration, climate change, urbanisation and social needs, and generate ideas. They design, test and present their ideas on how to improve the quality of life in the city. The games master gives players a set of tools to help them work together and develop ideas. At the end of the game, the ideas are presented to local stakeholders, professionals, residents, and each other. Everyone involved votes on the best ideas and thinks about how they can be realized once the game has ended.



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4. Iterative collaboration

LA 2050

→ <http://www.la2050.org/challenge/>

LA 2050 is an initiative to create a shared vision for the future of Los Angeles, and to realise and track progress of that vision. The city consulted citizens to make up a report of the current state of the city and developed a series of goals for LA in the year 2050.

The goals were finalised during #LAlistens a series of events led by local organizations to solicit feedback on the draft LA2050 Goals. Afterwards, the city asked its citizens how to turn these goals into action. People can submit ideas or vote for them. There is a public vote and a jury vote, the top projects from each receive funding.

Rebuild by design

→ <http://www.rebuildbydesign.org/>

Hurricane Sandy devastated a lot in the New York and New Jersey region. The US department of Housing and Urban Development (HUD) wanted to rebuild, but in a durable and resilient way.

Rebuild by design is a new take on the design competition model that would develop innovative, implementable solutions to respond to the region's most complex needs.

Collaborative design the teams developed and refined their selected ideas into implementable and fundable solutions. They worked with and formed coalitions of local stakeholders -including residents, nonprofit organizations, business owners, government and elected officials, and others - to achieve the level of specificity and detail needed to drive their ideas forward.

Five winning designs were chosen by a jury process, and implemented with public and private funding.

DreamHamar

→ <http://www.dreamhamar.org/>

DreamHamar is a participation and network design process led by Ecosistema Urbano to redesign the Stortorget Square in Hamar, Norway.

Hamar citizens were able to participate in a collective brainstorming process to determine Stortorget's new configuration. This process consisted of several aspects:

Preliminary urban design: Experts identified the needs expressed by Hamar and Hedmark's residents, and developed creative solutions for the construction of the square - an urban and architectural approach to Stortorget, analysing its main characteristics and suggesting the Hamar citizens principles and tools to think the future square.

Physical lab: A physical lab placed in Hamar, facing Stortorget square where workshops, lectures and exhibitions take place hosted by local and foreign creative guests to collect citizens' dreams, knowledge and ideas. It is also Ecosistema Urbano's pop up office during the participation process.

Urban actions: The urban actions created at Stortorget, aim to generate expectation and call citizens to action on the square. These actions serve as a way of experiencing possible uses and solutions for the future square, but it is also a way to directly change the urban environment in a short period of time with a reduced amount of resources.

Digital lab: Stortorget is a digital square by means of a large and international system of integrated communication and participation tools that open the project to a global network. The digital lab consisted of a web platform, social media channels, online workshops, mobile app (to add georeferenced ideas or dreams), video broadcasts

Academic network: Dreamhamar is engaging different European universities into this global participative brainstorming. Students with different backgrounds are working around Hamar's main public space as their course case study.

The cultural rucksack: Dreamhamar gives 1292 students from elementary and high schools at Hedmark county the possibility to contribute by sharing their ideas for Stortorget.

5. Empowering people to take action / Experiment

Kortrijk congé

→ <http://www.kortrijkconge.be/kor/>

Kortrijk Congé is a festival and temporary city. Anyone interested can become a citizen. In this city there is no money, people need to take care of themselves and their neighbours. The temporary city experiments with new or different methods to organize things within a city: from making strategic decisions in a city-hall-sauna and citizens voting laws directly, over learning through exchange of knowledge, to the communal organization of cooking and sport.



It is an investigation of how cities of the future might function, and an attempt to rethink the city as it is today.

Fix my street

→ <https://www.fixmystreet.com/> for the UK platform; there are platforms all over the world

“Fix my street” is a platform where citizens can report problems regarding the state of the public domain. Citizens locate the problem, describe it and attach a picture of the problem. The authorities provide feedback about the number of problems they fixed.



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Idées Paris

→ <https://idee.paris.fr/co-construisons-paris>

→ <http://www.participatorybudgeting.org/about-participatory-budgeting/what-is-pb/>

Under the title “Madame la maire, j’ai une idée”, citizens of Paris can post their ideas on this website. They can describe their idea, localize it and tag it with a theme. An idea is “under discussion” for three weeks, during which other people can comment on it or vote for it. Every person that posts an idea is invited to the open office hours of the town hall to discuss his idea and receive support. After three weeks the idea needs to be finalized by the author and is sent to the technical team of the city, where they investigate whether it can be implemented.



The current round of ideas is related to the spending of a participatory budget. This is a government method that enables the community members to directly decide how to spend a public budget. It enables taxpayers to work with government to make the budget decisions that affect their lives.

Krasimir

→ <http://krasimir.org/>

The webpage and mobile app to report on problems in the city within only 20 seconds. Currently available in Russian, English and Spanish languages. Uses Yandex.maps service. Citizens attach a photograph of a problem and once reported, the city has 30 working days to fix it.

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People St

→

<http://www.fastcodesign.com/3025927/la-offers-diy-urban-design-kits#9>

→ <http://peoplest.lacity.org/about/>

The LA department of Transportation launched People St, an initiative that helps communities in LA to transform underused streets into accessible public space, such as pedestrian plazas, mini parks, and bike parking. These projects are extremely hard to organize for community groups themselves because of the bureaucracy involved in city planning. People St offers DIY urban design kits to create these public spaces in what were formerly car-dominated areas. In addition, they streamline the process for getting a permit. Communities apply by submitting a project proposal. The department of transportation chooses some applications (based on a number of fixed criteria). When approved, the community pays for materials and installation, and agrees to maintain the projects.



Safecity

→ <http://safecity.in/main>

The website Safecity.in uses local citizen reporting to solve larger issues. Women can report different types of sexual harassment or abuse on a map. This service wants to help women fight sexual harassment and reduce the risk of rape, by encouraging them to 'pin the creeps'.



CoDesign Studio

→ <http://codesignstudio.com.au/>

CoDesign Studio is a social enterprise design consultancy aiming at inspiring people to participate in shaping neighborhood areas.

- Charles Street Parklet tested the concept of community engagement to see whether citizens support the idea of proposed urban changes.



Experiential Community Engagement

Build local participation
and support with effective,
place-based engagement.

3.2.3 Managing a co-design process

Managing the design process workflow

The concept of **workflow** from the most general point of view can be defined as a sequence of work activities where each of them follows the previous one without delay or gap in order to perform a specified target job. In this sense, workflows can be seen as an abstraction of or a view on any real work. **Workflow management systems** allow the users to define, modify, control and share workflows, i.e. the activities associated to a business process, simulation process or generic process (DiCaterino et al., 1997). Workflow management systems automate redundant and iterative tasks allowing a better, cheaper and faster management of the processes. Most of the workflow systems are useful in order to integrate other different systems used by an organization (document management systems, databases, production applications etc.) or software tools (as in case of simulation workflows).

Nowadays there exist plenty of workflow management systems that serve different purposes, provided with various features and based on several workflow languages. An instance of a workflow may involve a series of human tasks rather than tasks that can be executed by tools, machines or software codes. When considering the context of engineering disciplines, mainly two different workflow categories can be identified: **Business Process Workflows** and **Simulation or Computational Workflows**. Within the context of Computational workflows the most important features adopted to evaluate the soundness of a workflow system are:

- Existence of a neutral representation of the computational workflow
- Distributed computation capability
- Possibility to implement a set of control flow patterns like those described in (Russell et al., 2006)

Especially for Simulation Workflows, a big effort has been put in place in order to enable the interoperability and reusability of automated computational design workflows. In this view, the decoupling (or at least loose coupling) of the logic of the computational workflows from their implementation has become fundamental.

In general, a relevant feature for a workflow management system is the possibility to perform distributed computations. This offers many advantages such as cross-organization simulation collaboration (removing the need for machines hosting different simulation assets to be in the same location), execution time reduction, reuse of simulation assets etc. Distributed simulation addresses big challenges like: plug-and-play interoperability between heterogeneous and independent-developed simulation assets; synchronization of different simulation environment in the same simulation run; cross-enterprise collaboration in order to link simulation assets. Because of the several benefits that distributed computation provides many platforms that support web services such as Kepler (Altintas, 2004), (Altintas, 2004b) and Taverna (Missier, 2010), (Hull, 2006), (Oinn et al., 2006) were born. These tools, defined as Scientific Workflow Systems, are a specialized form of workflow management systems conceived specifically to design and execute a series of data manipulation or computational steps across a broad range of scientific and engineering disciplines (Wikipedia). By means of these systems it is possible to federate or integrate

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several different simulation environments speeding up the development and testing of new products. In this field Noesis Optimus (Noesis, 2012), for example, largely facilitates and supports the process integration phase and offers the possibility to perform repetitive tasks (as engineering design optimization or design of experiments) of the workflow built by the users.

All workflow management systems are based on a formalism or language that can support different features. A set of requirements that a workflow management system has to satisfy have been expressed in form of patterns that are often used to compare different workflow systems. Van der Aalst (Aalst, 2005) introduced YAWL, a new workflow language inspired by Petri nets that allow a direct and intuitive support of the patterns proposed in (Russell et al., 2006).

In summary, some key trends have emerged for workflow systems and represent the current state of the art. These trends are:

- Standardization of the workflow description, in this respect particular attention is given to the XML format
- Multi-level workflows that allow management of problem decomposition
- Deep integration of the distributed computation approaches described above (different from parallel computing)
- Support new smarter workflow operations such as: synchronization, cancellation and termination as well as multi-instances

However, despite the large advantages that the current workflow management systems offer, there are limitations that cannot be overcome when the interactions between the design actors increase in number and complexity. This typically happens in multidisciplinary, heterogeneous design environments where the meaning of the data and tools used is an important element of the design process.

Semantic workflows are scientific workflows enriched by using semantic annotations based on semantic expression languages (OWL, RDF, SPARQL) to describe the workflow elements (data, computations, results etc.). The semantic extension of scientific workflows allows a number of benefits related to the possibility to apply reasoning engines (e.g. FACT++) capable of deriving implicit knowledge from a set of explicit statements. Expressive representations of workflows based on ontologies, together with reasoning algorithms for workflow composition (supported by interactive assistance), workflow validation, automated completion, metadata propagation, and retrieval, enable users that are part of the co-design process to easily associate meaning to what the workflow represents and exploit this meaning to facilitate the overall design process.

The semantic workflows allow the expression of what the data means and how it can be used to derive information that is normally not explicitly described. This links directly to the ontological foundation of C³PO by semantically linking simulation tools, applications and data sources, guaranteeing automation and proper execution of the co-design activities.

A simple example of this can be seen in a typical co-design activity whenever two actors need to pass information from one to the other in order to accomplish their tasks. Whenever the first actor needs to perform a task and pass the result of this task to the second actor, it is 'implicit' that a data transfer needs to take place. However, if none of the actors makes this information explicit in the workflow of the tasks, a computer cannot derive this fact.

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In Semantic workflows, this fact can be derived because of the description that is done of the specific tasks and of their logical relation, thus the computer can ‘infer’ that data needs to be transferred and ‘derive’ the necessary transfer operation without need to ask the user. This relieves the burden of the actors to deal with specific low level transfer operations and leave the computer the choice of selecting the most suitable cloud based or other transfer approaches:

- Extend the ‘data transformation’ element of its workflow with semantic annotations that describe the original context where the analytical models have been created and determine their relevance for the design process at hand
- Extend its scientific workflow engine to support workflow ontologies so that relevant data can be related to the proper entities (e.g. train traffic to train stations, etc.) in a flexible way.

Time varying optimization under uncertainties

Most of the design optimization problems within the engineering field are performed based on specific engineering data and/or models that can be considered by the engineer to fit for the specific purpose. For example, a specific simulation model is considered good when the accuracy reached by that model is validated and verified against experimental or statistical data. These models, once available, can be used as representative of the real objects they are modelling and can be used for numerical optimization. In these cases, the solution of the optimization routine is not time dependent, unless updates of the model are performed as a result of the optimization or re-design processes. However, this is a special case of the design optimization class of problems - in fact the time independence implicitly assumed in such design optimization tasks is normally acceptable for the engineering cases. In co-design environments, this hypothesis is not necessarily valid anymore. In fact, most of the times the modification events are very frequent and require an optimization process to run continuously adapting the optimized solution according to the changed boundary conditions (changed models, changed constraints, improved data fidelity etc.). This is normally dependent on the trust level about the information available, the completeness of this information and the objectives that the designers set for the specific situation at hand (building, construction, feedback from citizens etc.). Since all these conditions are ‘uncertain’ (or, in other terms, not known completely), the optimization algorithm should also take into account a measure of this uncertainty and continuously optimize the solution. Such optimization algorithms thus need two new features that are not typical in engineering problems that are: time varying and uncertainty management. This class of algorithms has a huge value not only in co-design problems but can be applied successfully to actor based interactions like co-design or co-evolution of systems due to their interactions. This happens also in fields like manufacturing where the actual product delivery depends on the supply chain, the different actors, the uncertainties on the defects and on the production lines and many other elements that are either time dependent or uncertain or both. As such, time varying optimization algorithms under uncertainty are particularly suitable for co-design approaches and empower the capabilities of the C³PO platform with new intelligence.

Mining social media

Social networks, e.g. Twitter, Facebook and Instagram etc. have drastically increased online communication. Millions of people share opinions (reviews, ratings, recommendations etc.) on various topics. As a result, the Internet is full of public opinions, both expert and novice.

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Sentiment analysis, also called opinion mining, tries to make sense of these opinions. There are several sentiment analysis software or tools which extract opinions from a piece of text. Opinions are typically expressed as positive, negative or neutral and visualized by these tools (Tamatometer, 2015; MetaCritic, 2015). Expressing such opinions is very important for decision makers to understand what the current opinion of citizens towards a specific decision is.

Opinion mining tools are already being used by the local authorities to collect feedback from citizens and improve their services. Deployers of such tools typically sell some analytics services to their clients, namely municipalities in C³PO's case. However, opinion (or data) mining tools recently started to be an inherent part of smart city frameworks. The smart city case study, for instance, is relevant to the area of Santander in Spain which is implementing a large smart city project (Santander, 2015; Vakali, 2013). It provides a mobile application where users can select between the six primary emotions (anger, disgust, fear, joy, sadness and surprise) at the Santander area. Upon user's choice of a sentiment at the back end of the application the proposed methodology is applied and the sentiment analysis reveals the dispersion of tweets in the particular smart city area. The SmartSantander project envisions the deployment of 20,000 sensors in Belgrade, Guildford, Lübeck and Santander (12,000), exploiting a large variety of technologies. The INNPRONTA project CIUDAD 2020 aims to achieve a significant advanced in the areas of energy efficiency, internet of the future (IoF), internet of the things (IoT), human behaviour, environmental sustainability and mobility & transport in order to design the city of the future: sustainable, smart and efficient (Innpronta, 2015; Villena-Roman, 2014).

When a person expresses his/her opinion, the post typically comes with hidden location and time information. This information (or dimensions) can be considered while mining social media, as well. There are several examples of this sort of mining in the literature. Clusters identified by Foursquare check-ins help to describe the socio-dynamics of urban districts in different times of the day (Rösler, 2013). Check-ins (to Foursquare, Facebook, Twitter, etc.) is generally a good source of information to identify groups of people which are of different types, communities and interests, and how they use urban space (Sagl, 2102), (Silva, 2012), (Joseph 2012). Traditional municipal organizational units such as neighbourhoods are studied in the Livehoods project which shows that neighbourhoods' boundaries do not always reflect the character of life in them (Cranshaw, 2012). Tweets can be monitored to detect social behaviours (Villatoro, 2013) and events such as release parties, musicians in a park, or art exhibitions (Boettcher, 2012).

Municipalities can monitor the live social media platform posts. According to these live posts, municipalities can instantly act for citizens need. Also it is provided some statistics and analysis like sentiment analysis, total user post count, distribution of post amount by time. With geolocational analysis, citizens' needs will be determined for specific areas. This allow municipalities to interfere the necessary issues for right ares directly. Because of the format of social media post, citizens do not provide feedback like a product review. Generally citizens attempt to use them when they face a complaint or lacking about municipal services. With using search comparison ability, municipalities would observe the citizen post activity (sentimental), after fixing any lacking. Search comparison ability provides to compare search results which are belongs to two different time range.

Shortly, by mining social media, municipalities can harness feedback from residents even when the residents do not reach out directly to the municipality. Of course, there are challenges to this process. Citizens typically do not provide feedback like a product review.

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They mostly notice the municipal service when it is late or lacking. When it happens, the citizen should be encouraged to communicate via social media. Naturally, municipalities need to listen to these channels and respond to constructive feedback and improving their services.

3.2.4 Other (general) collaborative software: methodologies and typologies

This section focuses on other collaborative tools and platforms which are not directly linked to city co-design but might be adopted for its needs. Online tools enable easy and effective participation because the users can participate from the place they want and at the time suitable for them. By using online tools, it is possible to reach a large amount of users quickly and cost-efficiently.

The platforms are divided into five categories: 1) Data gathering platforms, 2) Collaborative platforms, 3) Idea Management platforms, 4) Crowdsourcing platforms and 5) Co-creation, User Involvement and Group Support Systems. Most of the platforms support more than one of the above mentioned purposes. Some examples are presented in corresponding subchapters 3.4.1-3.4.5.

Data gathering platforms

Every good design begins with understanding the users and their needs. Online platforms can be used to gather qualitative and quantitative data about the needs and preferences of users/stakeholders of a certain public space. These platforms can sometimes analyse data as well, thus lending support in stages 2 and 3 of the generalised city design process. Examples of such platforms are Liveminds, dscout, Revelation, Typeform, Polar. Also regular internet forums could take up the role of a data gathering platform, when it's used to manage discussions or conversations with users.

Common “data collection” features of these platforms are:

- Surveys in different forms: from standard, text-based questions to visual cues or choosing between two concepts
- Ethnography to collect rich data (photo, video, audio), often location-based
- Diaries or blogs
- Conversations or discussions: one-on-one, in focus groups or in communities

Common “analysis” features are:

- Location analysis: on which locations was input submitted?
- Basic statistic on given answers (spread of answers in community)
- User analysis (number of inputs of a user, his sentiment)
- Word count

Collaborative Platforms

Collaborative platforms enable exchange of information between large groups of people. The platforms enable the staff of a whole company to record and communicate high quality data about issues, ideas, hazards etc. with ease. With the collaborative features one can better get everyone on the same page with what is happening, make them part of the global

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culture and engage them in collaborative, constructive exchange of information and ideas. The focus of what data is exchanged most, depends on the industry, culture and focus of the programs run by the company management.

Generally, they use a series of features as:

- **Dashboards** - to organize projects, clients, members, teams, and tasks.
- **Member profile sharing** - to easily find colleagues, experts, etc.
- **File and document sharing** - files, images, videos, presentations.
- **Real-time discussions and broadcast messages**, communicating on what is happening at all time
- **Networks**, social networks; as private or internal networks.

The additional features that enhance the collaboration may include:

- **Planning features and due dates** for projects that have deadlines for delivering.
- **Voting, ranking and liking on proposals, ideas, exchanges, updates** to identify the group interest and preferences. The final goal is to achieve an agreement but also to get the engagement of all groups and identify the positive and useful issues that appear.
- **Notifications** if there is any change or modification, using mentions and labels for warning each participant about those changes.
- **Concurrent editing**: some platforms allow one and the same document or file to be edited by several users concurrently, increasing productivity when commonly creating a piece of content.
- **Multi-device support** (desktop, tablet, phone) allowing staying in sync while away from the desk.

Yammer, Appgree, Loomio, co.createlli and Ushahidi are examples of collaborative platforms.

Idea Management Platforms

Idea Management Platforms (Bright Idea, Cognistreamer, Hype, Innocentive, SAP Innovation Management, Spigit, Crowdcity, IdeasMine etc.) - are developed for ideation processes; ideas that are spontaneously brought forward, or ideas that are solicited by launching challenges or campaigns, asking people to propose ideas to a specific question. The main point is that the ideas go through a structured process of having interesting thoughts identified and improved with the help of experts and teams. After that, the experts select the ideas to be elaborated in the project proposals, having them approved for R&D and to be later on developed into products.

The main features may include:

- **Idea documentation and communication** - to support people in the organization, to interconnect high quality ideas in a powerful way;
- **Idea challenges or campaigns** - to solicit a large group of people into creating ideas to solve a specific question or aspect of the business;

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- **Voting, liking mechanisms** - to allow peers to support ideas and hence identify ideas that are valued;
- **Feedback and comment functions** to allow peers to improve an idea collaboratively;
- **Search functions** - to allow re-usage of old ideas or find similar ideas;
- **Member profiles showing people' expertise** - to easily involve experts into idea improvement process.

The additional features that enhance the idea management process:

- **Workflows to guide an idea through different stages (idea tracking)** like (1) drafting (2) self rating (3) publishing (4) peer review (5) expert review (6) others;
- **Clustering functions** to combine several similar ideas into one bigger;
- **Automated expert search** based on tags or words in the idea;
- **Several rating models** to support the evaluation and selection processes;
- **Management and governance functionality** to support managing and responding to large numbers of ideas;
- **Reporting functionality** to enable the management and governance;
- **Incentive management** to reward top contributors.

Citizenlab (citizenlab.co) is an idea management platform dedicated to citizen participation. Citizens can post ideas, or evaluate proposals of cities. Additionally the city can post polls and challenges. [Studio Dott]

Another example is **Loomio**, which uses the same features but acts as a tool for bottom-up idea management and decision making. Instead of being governed by experts, the community decides on actions to take and divides tasks. [Studio Dott]

Crowdsourcing

Crowdsourcing (Chaordics, Topcoder, Wazoku, 99designs etc.) - is about addressing the right question to the right network of people or experts. **Crowdsourcing platforms** help a company or institution to take a function typically performed by employees (solving a problem, finding a solution to a question, writing a good slogan etc.) and outsource it to an undefined network of people in the form of an open call. The concept is that one selects the best proposals and pays for the solution, not for the work. Crowdsourcing software allows to create **targeted challenge** to separate subsections of participants (much like idea management software above). Once one has a short list of the top ideas, crowdsourcing software allows creation of a **closed review groups** (peer review, review board) to further analyse the viability of an idea. Some crowdsourcing platforms are close to idea management software. Some others though are more targeted to source one specific type of expertise or service from a large external network.

Some crowdsourcing platforms have extended **community building functionality** to allow a company gathering and animating a group of for example customers who are interested in a certain product group. This community is then an ideal network to start crowdsourcing challenges in their area of interest. Crowdsourcing **external** and **internal**. In external

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crowdsourcing, everyone can be involved in the crowdsourcing process: employees, partners or any other stakeholder.

The BBC's iCreate platform is an example of internal crowdsourcing. The aims of that platform are to put employees at the very centre of future programming. By that, BBC wants to enable more cross-genre programming through bringing together more than 4,200 people across the Television division. The initiative has been deployed to 4200 members across the BBC and it now has 2500 active users, who have submitted 909 programme ideas. Also Lego uses crowdsourcing in their product development (<https://ideas.lego.com/>)

The company can gather a lot of different ideas and points of view, resulting in faster time to market and deeper insight into customer needs (as crowdsourcing is often used for gathering ideas or solutions about what customers need). The concept of wisdom of the crowds is that a large group of diverse people can make better decisions. That diversity is what makes brainstorming and innovation in crowdsourcing more efficient. A company can rely on a crowd to expand the size of its talent and thus can gain deeper insight into what customers really want.

Co-creation, user involvement and group support systems

Co-creation platforms

Co-creation platforms (Cage, OpenIdeo, Quirky etc.) - are more targeted to improving an idea or getting ideas to improve an already existing product or a first design. While crowdsourcing is simply people creating a great idea for you, co-creation is about people working with you to improve that good idea into a better defined solution or even into a product. A co-creation platform enables an active, creative and social process, orchestrating collaboration between producers and users throughout different stages of the product definition, design and testing. It is initiated by the enterprise to develop faster products that generate more value for customers.

They do not start with a specific idea. For example, when a car industry company wants to improve its last version of a car, they create a virtual meeting place (platform) where people share their ideas about cars and related topics. Participants are asked to evaluate new concepts by sharing their own ideas, so they can play an integral part in designing new products and services. They become **co-creators of value**, thus users feel more engaged as they shift from mere customers to developers.

Main functions are that people post **challenges** to designers or creative users, people who "create" something or play the role of "creative user". Community members respond to the challenge posting their **own idea or proposal**, and then peers or groups discuss it. There is often a **voting process** to agree, disagree or abstain. In co-creation tools utilize **reward system** based on recognition and virtual points, the users can participate in the decision making process.

In some platforms, incentives are in the form of participating in the product's success. If the creation is successful on the market, the participant can receive a remuneration linked to a percentage of sales as a winning prize.

An example of instrument for co-creation and user-involvement tool is living lab Owela developed in 2007 by VTT. Since 2007 Owela has been utilized in several projects to involve different users (consumers, end-users, co-operation partners, citizens, other stakeholders). Owela is designed for user centric studies and consists of different types of tools that can

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be widely used in the development process. The tools include e.g. user diaries, chats, polls and voting. Owela suits well for co-innovation and co-development in all different phases of an innovation process. Owela can be utilized in:

- Developing new innovations based on consumers' needs
- Testing early service concepts and developing them further with users
- Testing and developing prototypes
- Evaluating existing services
- Marketing and consumer research

During the recent years several similar tools have become to market. The advantage of these online tools is that they can be utilized globally, but it also increase the competition in the innovation market. Some examples of the companies (from Finland and Sweden) that offer similar co-innovation tools; InterQuest Oy, Adage Oy, Doberman Group AB, Ziggy Creative Colony AB.

Group support systems

Decision making with vast amount of stakeholders, especially at different hierarchy levels is very challenging. To facilitate it, a practical process to support decision making was implemented in **group support system (GSS)** or **group decision support system (GDSS)** software. It is often used in the early phases of a individual company's innovation process, including brainstorming of new product ideas and business concepts and can be migrated to city decision making as well. The process is based on electronic brainstorming. A group support system (GSS) is a group work tool for managing the idea generation and evaluation. The objective of the GSS is to increase the effectiveness and efficiency of many types of group work and group processes by supporting communication and facilitating meetings (Elfvengren, et al. 2009). The GSS can be viewed broadly as computer-supported interaction between two or more people, which can take place in any of four environments: same/different time and same/different place.

GDSS have been used already in early 80s by such companies as Boeing, IBM, P&G, Intel to make the organizational decision-making more effective (Hayen et al., 2007). In compare to last generation of GDSS solutions that required all the participants to be on one room, nowadays there is a variety of solutions supporting distant group decision-making. Hewlett-Packard (HP) became one of the pioneers in applying such systems, since the engineers of this global company working across the world required frequent technical meetings to make the decisions on product development (Nikoi, 2013). Examples of providers of such group decision support systems are GroupSystems (www.groupsystems.com), Facilitate.com (www.facilitate.com), Spilter (www.spilter.nl), Meeting Sphere (<https://www.meetingsphere.com/>) and others. Software developers nowadays offer browser-based GSS/GDSS solutions, which allow remote participation in group brainstorming also from mobile device.

GSS is superior to a conventional meeting in the following possibilities it offers for supporting a group in promoting cooperation and effectiveness (e.g. Jessup and Valacich, 1993; Power, 2002):

- Enables parallel communication between the participants

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- Offers equal and anonymous opportunity to contribute ideas and opinions
- Prevents domination of the meeting by domineering people
- Identifies common and divergent viewpoints quickly
- Helps to manage the schedule and agenda of the meeting
- Provides effective automatic documentation capabilities

The GSS is an instrument for better group work, it is not a toolbox for gaining the best results automatically; all results depend on the group. Limitations of the GSS, which must be considered before a meeting, are (Aiken et al., 1994):

- The system only assists and supports the group work process
- The task and group size must be considered
- The communication speed per person is lower (when typing)
- The reduced media richness hinders subtle communication
- The same-time-and-place requirement (only in room-based GSS)

3.3 Visualization of city co-design process

Visually communicating urban concepts and designs is a time consuming activity and it has to be planned in order to offer the right level of representation according to the phase of the project and the kind of interaction and feedback that is expected from the other stakeholders.

It is not the same to prepare an image to be printed, than to be published online A 3D model will not have the same definition if it is used for rendering or for 3D printing. Even if the project is the same, it will be necessary to highlight the elements that need to be the object of discussion and avoid other details that may disturb a productive reflexion.

The type of representation or visualization methods used in the co-design process will be adequate if they facilitate an ideas exchange adapted to the development phase where this interaction occurs. On the contrary, it will be inadequate when it gets to continuous deviation of the subject of discussion or it produces useless input (not relevant to improve our living environment).

The following steps can be used in order to ensure that the choice of the type of visualization used in the co-design process is appropriate:



Project context

Each project is unique, and it has its own timing, procedures and participants. Some questions that should be clear before initiating any idea gathering or visualization are:

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- Which are the objectives of the urban project?
- Where is the project located?
- Who is concerned? Who is promoting the project? Who will decide about the project?
- How much time is available for the development of the project?
- How will the different stakeholders participate?
- Are there any procedures to follow in order to participate in the project?

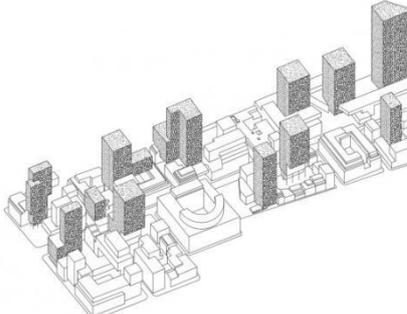
For example, participation in the public competition does not provide total freedom in choosing the visualization methods. A procedure establishes the unified rules for all the participants and the methods used should be adopted to that rules. In the last years, the most common demand was to produce a limited number of exposition panels or a brochure with printed images of 2D plans, and 3D views. When a public exposition is also planned a physical model might need to be produced.

Perimeter

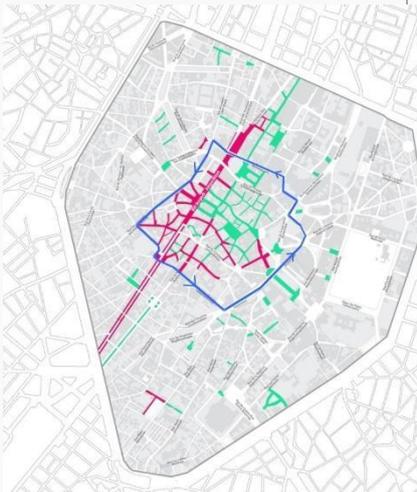
Every project has defined limits of intervention. It may depend on administration issues, physical barriers, land ownership, or the specific subject treated on the project (all the green spaces or urban vacuums or protected buildings of an area for example).

The system used for visualization should express the limits of the area object of discussion. In the following table there are some options of how the perimeter can be indicated:

Options for indicating the perimeter

Technique	2D Example	3D example
Representing the area alone (without context)	 <p data-bbox="582 1675 965 1758"><i>Masterplan for Brussels International airport – Jasper Eyers. Source: http://www.jaspers-eyers.be/</i></p>	 <p data-bbox="1013 1668 1388 1803"><i>Masterplan for Rue de la Loi (Brussels) – Portzamparc. Source: http://projectivecities.aaschool.ac.uk/portfolio/brussels-capital-of-europe/</i></p>

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Technique	2D Example	3D example
<p>With a perimeter line which separates the project area from the context</p>	 <p><i>Biestebroek area in Brussels Canal.</i> Source : http://www.dhnet.be/regions/bruxelles/biestebroeck-tire-son-masterplan-533605be35708f17bb2f5849</p>	
<p>A different treatment between the project area (always more detailed or eye-catching) and the context.</p> <p>For example, a colored an/or textured project in a uniform neutral context.</p>	 <p><i>Brussels walkable city center project.</i> Source: http://www.lavenir.net/cnt/dmf20140131_00425958</p>	 <p><i>Masterplan for Rue de la Loi (Brussels) - Portzamparc.</i> Source: http://www.portzamparc.com/fr/projects/la-rue-de-la-loi/</p>

This helps to focus the exchanges with other stakeholders. In general, the context around needs to be expressed in the way the project is connected to the rest of the city. The distance to be represented around the project will depend on its scale.

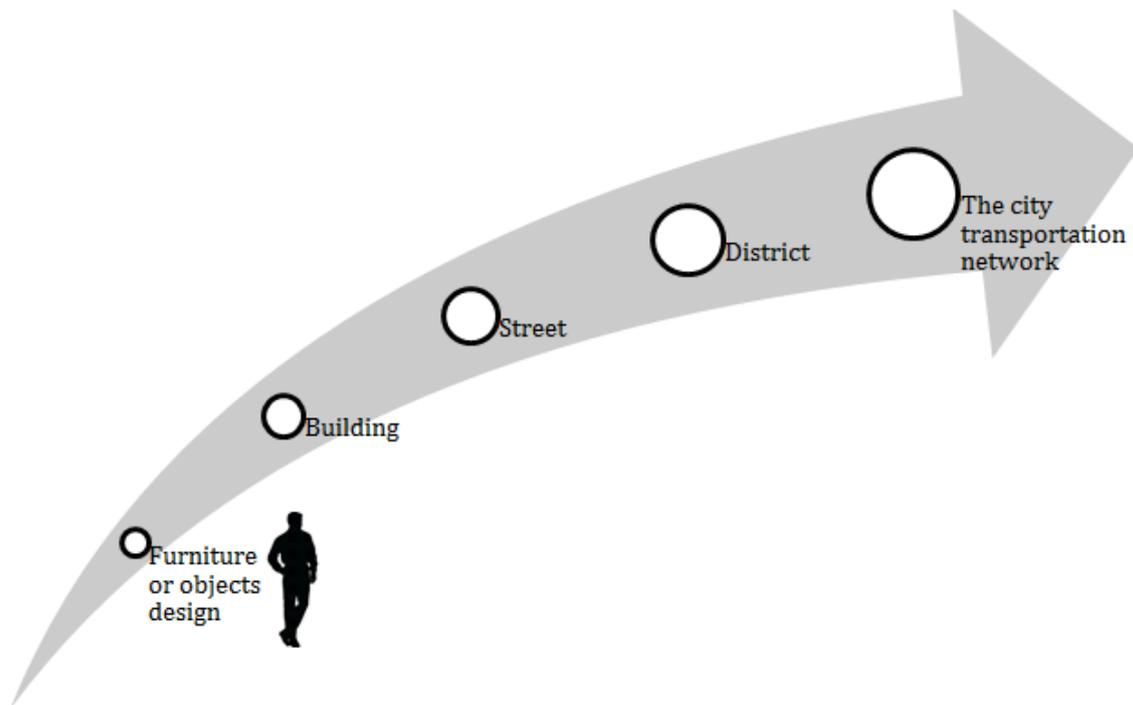
Scale

The next criterion to take into account is the scale of the project. This means, the size of the object of discussion when compared to its environment. Taking into account large scale

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projects the perimeter is in relation to a whole city or a large part of it. On the contrary, small scale projects are nearer to human size.

In the following image there are examples of possible objects of discussion classified from a smaller to a larger scale.



Examples of possible objects

This factor has an important impact in the level of detail and the characteristics of the representation for visualisation.

Phase

This chapter is about some guidelines that can help to adapt the visualization tools to the phase of the project where the interaction with other stakeholders occurs. In general, the level and quality of information available will increase in the evolution of the project and determine the kind of proposals or decisions to be made.

In the following tables the information with some examples or characteristics of representation that can be useful to choose visualization systems for each phase of the project is represented.

In order to gather first impressions or ideas of which are the problems or what happens in a location it is enough to work with maps of the existing situation. Wikimaps can be a good tool for participation. They enable stakeholders to point out locations and post a comment on them. Their input can be the report of a problem or the suggestion of a new location for a solution (for example new bike parking spots.) This can be a starting point for further spatial and content analysis.

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Framing and context definition phase

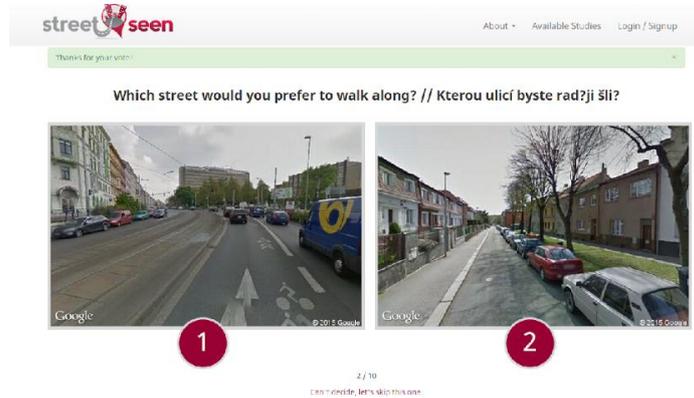
Description	Typical activities	Characteristics of representation in interaction with stakeholders
Key project team is defining the project, first list of stakeholders, high level constraints	<ul style="list-style-type: none"> Meetings with project initiator, owner, key project team Desktop research <p>Stakeholder workshop to list the first draft of stakeholder needs, issues and initiatives</p>	Just establish project perimeter

Data gathering phase

Description	Typical activities	Characteristics of representation in interaction with stakeholders
<p>Obtain available data on issues, needs, context:</p> <ul style="list-style-type: none"> Open data from authorities Data gathering and processing Measuring Additional measurements through technology (IoT) Studies Interviews 	<ul style="list-style-type: none"> Data gathering and processing Measuring Interviews Workshops Broader communication to identify further stakeholder, gather input & issues, polls etc. 	<p>Experts / professionals will need realistic geometrical data of the existing situation to work on in further phases.</p> <p>First ideas approach do not need on site representation of solutions.</p> <p>Images of similar projects of other parts of the world can be used for discussion to find out desires, problems, preferences...</p>

One example of participation online tool for gathering first approach preferences are “visual preference surveys”. It is a kind of poll with choice / grading system between different pictures. A content analysis on this type of poll can help to figure out stakeholders first feelings.

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StreetSeen application - Ohio university. Printscreen. Source : <http://streetseen.osu.edu/>

GRADE EACH PHOTO OF PUBLIC SPACE NEEDED IN OVIEDO

A **B** **C**

Source: cityofarcata.org Source: City of Oviedo Source: City of Oviedo

49. Photo A

-3 -2 -1 0 1 2 3

Visual Preference Survey of the city of Oviedo. Printscreen. Source: <https://www.surveymonkey.com/r/?sm=Rc7NnLG0Y9dljk7kfzBLaw%3d%3d>

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Analysis phase

Description	Typical activities	Characteristics of representation in interaction with stakeholders
<p>Further analyzing and fine-tuning data gathered; checking assumptions.</p> <p>Formalizing listing of legal constraints</p> <p>Formalizing listing of objectives needs.</p> <p>Formalizing stakeholder maps, relations, expectations, relations, synergies, conflicts of interest.</p>	<p>Content analysis.</p> <p>Spatial analysis.</p> <p>Cost analysis.</p>	<p>Visualization should help to highlight different densities of the variables of analysis in superposition to the spatial perimeter.</p> <p>They could be animated to show the evolution in time.</p>

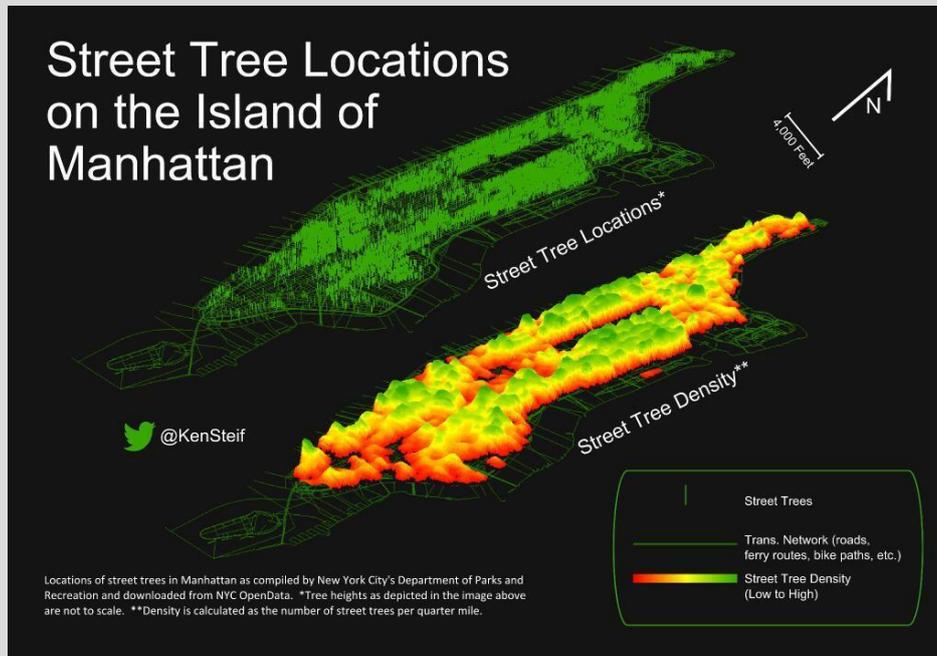
This phase is very important in order to focus the subject of discussion in urban project proposals. Sometimes it is not necessary to build a whole new project of city, but to learn more about what is already there and use it more, or use it differently. It is interesting to cross information about “living experience” of inhabitants in the perimeter, with objective data about physical reality in that place.

In terms of representation a color and / or a height scale system can be useful methods to visualize densities and intensities of quantitative data.

Here are some examples of data analysis relevant at this phase of the project:

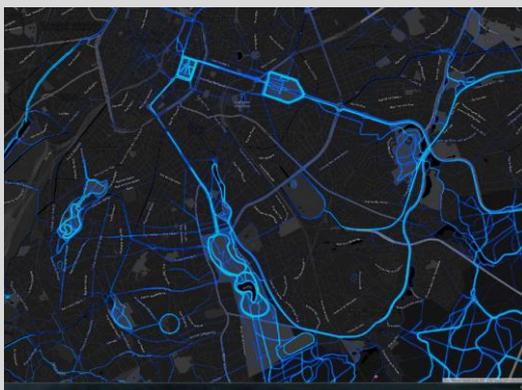
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Physical reality:

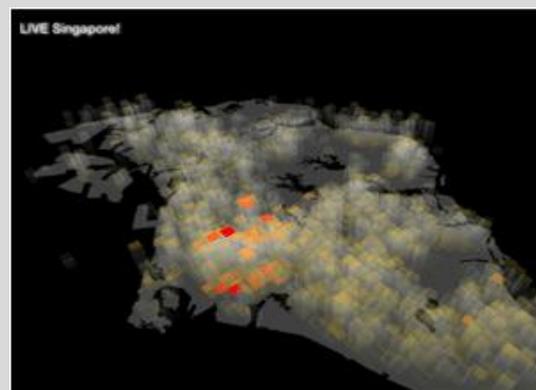


Street trees in Manhattan. Source :
<http://urbangeographies.tumblr.com/post/69092836803/street-trees-in-manhattan-check-out-this-3d>

Living experience:



Strava users running paths in Brussels. Stravalabs global heatmap - Printscreen. Source:
<http://labs.strava.com/heatmap/#14/4.36780/50.82206/blue/run>



Real-time talk in Singapore. Source:
<http://senseable.mit.edu/livesingapore/visualizations.html>

One specific variable in analysis is time. It is interesting to understand how a site is used in

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different hours of the day along the week, or the impact of specific events. Even if video animations are used sometimes to visualize big data², it is not possible to exchange with stakeholders a document which is moving. It is better to keep some snapshots at relevant hours. Otherwise, it is necessary a simulation tool which would measure the impact of a proposal.

On the other hand there is a very useful system of spatially representing time: the isochrones visualizations. These maps deform the geometrical information in proportion to travel time:



Isochrones maps of Singapur. Source: <http://xiaoji-chen.com/blog/2011/isochronic-singapore/>.

² For example, see « Lisbon's Slow traffic areas. Data Visualisation 2010». Pedro Miguel Cruz. Source: <https://www.youtube.com/watch?v=WYucZEa0vr8>

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Ideas and alternative solutions phase

Description	Typical activities	Characteristics of representation in interaction with stakeholders
<p>Experts (e.g. architects) develop solutions & alternatives</p> <p>Stakeholders can be involved to</p> <ul style="list-style-type: none"> • Create ideas for solutions • Evaluate & improve ideas for solutions 	<ul style="list-style-type: none"> • Workshops, idea generation and idea improvement with stakeholders • Virtual environments to help idea • Simulation • Quantification of cost and other performance indicators (for example number of new jobs, reduction in hours of traffic jam) 	<p>Project is represented in its context. The level of detail will depend on the phase of development of the design process, and the expected feedback from the stakeholders.</p> <p>If several architects are working on the same competition, each team may have done a different lecture of the site, so the radius of the context around the project may need of adaptation.</p> <p>In order to integrate feedback from stakeholders the visualization method should enable the possibility of drawing, manipulating, pointing out comments or similar). Nowadays printed documents are used.</p>

Communication and Evaluation phase

Description	Typical activities	Characteristics of representation in interaction with stakeholders
<p>Developed proposals are presented to stakeholders and</p>	<ul style="list-style-type: none"> • Distributing information and gathering feedback through different 	<p>For the moment available tools for representation do not enable to show simulations of the project</p>

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Description	Typical activities	Characteristics of representation in interaction with stakeholders
<p>public for:</p> <ul style="list-style-type: none"> • Informing, engaging • Feedback • Suggestions <p>Feedback is evaluated, impact of proposed changes is assessed</p> <ul style="list-style-type: none"> o Qualitative, Quantitative, Performance evaluation <p>Potential solutions and impact are iterated to come to a final proposal supported by a large representations of the stakeholders.</p>	<p>media.</p> <ul style="list-style-type: none"> • Social feedback on virtual environments with mockups. • Interactive simulation and impact Visualization. • Workshops around specific issues to generate broad support for final solutions. 	<p>impacts (traffic, environmental advantages, etc.).</p> <p>Nowadays representation is used to show new functions in its future locations, or to visualize the volumes or the aesthetics of the new built forms.</p>

Communication of an urban or architectural project usually follows a progressive explanation which addresses the following subjects:

- Urban Project

↓

Architectural Project

↓

 1. Site analysis
 2. Concept / metaphors / main ideas
 3. Occupation of the terrain, relation between voids and built forms.
 4. Volume: height, skyline changings, relation to the existing context
 5. Flows, access, entries...
 6. Functional organization
 7. Architectural language
 8. Material choice / System of construction
 9. Interior design

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Finalizing and Agreements phase

Description	Typical activities	Characteristics of representation in interaction with stakeholders
Final solution is: <ul style="list-style-type: none"> • Selected • Elaborated & engineered • Submitted for approval authorities • Contracted 	Decision making, voting. Collaboration in engineering, contracting	<p>Final phase’s images tend to be realistic for communication with general public.</p> <p>Final documents between experts and professionals must be clear, geometrically accurate, and they need to support a printed format.</p>

Realization and Construction phase

Description	Typical activities	Characteristics of representation in interaction with stakeholders
Preparation works (Phased) Construction works (Phased) commissioning and acceptance	Issue, conflict, complaint management Solving issues arising with above tools	Final documents between experts and professionals must be clear, geometrically accurate, and they need to support a printed format.

Management phase

Description	Typical activities	Characteristics of representation in the interaction with stakeholders
Facilities management Traffic management	Issue, conflict, complaint management Solving issues arising with above tools	For facilities management the trend is to use a BIM model.

In summary, these guidelines are used in further stages of the C³PO project to evaluate how the visualization methods proposed by the project partners can be integrated in the co-design process.

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Context of visualization

Different visualization modes require usage of various tools (for example printing an image versus creating a 3D model). Moreover, there could be different contexts for the communication and exchange on urban projects. Visualization choice will clearly be impacted depending on the communication language and the devices or tools available in the context of visualization. It is also important to adapt ergonomics and costs for new devices or tools.

The most common visualization contexts currently are:

Most typical visualization contexts	Characteristics of representation in the interaction with stakeholders
Person to audience: <ul style="list-style-type: none"> o Public Exposition (public survey to inhabitants) o Private exposition (professional jury) 	Everyone in the meeting must see the same images at the same time. Nowadays projectors, and presentations are used. The exposition may be completed with printed panels and physical models. Audience is able to exchange about them in groups.
Peer to peer <ul style="list-style-type: none"> o Working team exchange 	Everyone in the meeting must see the same images at the same time. Nowadays printed documents are mostly used (where it is possible to draw and write comments). Sometimes projectors are also used to show plans or 3D models in progress. In order to integrate changes and feedback in the collaboration process the visualization method should enable the possibility of manipulating the visualization and /or integrate remarks.
Person to object / to machine <ul style="list-style-type: none"> o Verification / Quality Control organisms o Press releases o Online posts or applications o Media broadcasting o Forum and social networks 	Some stakeholders may intervene by distance in the project, just examining the documents produced. It is the case of the administration when it delivers a building permit.

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Most typical visualization contexts	Characteristics of representation in the interaction with stakeholders
debates	<p>Paper format is nowadays compulsory. Even though some cities like Brussels have the project of converting this issue in an online procedure.</p> <p>General public is usually informed by the media in a one-way information transmission. There are procedures to complaint about the project to the public administration.</p> <p>Discussions around a project can also be held in online spaces. Counter movements or counter projects are sometimes published in social networks and online spaces. A good communication strategy can impact urban projects.</p>

Once all the previous items have been considered, it is possible to define characteristics of the image that support the project objectives and integrate their production in the timeline of the project.

Level of Detail (LOD)

The term “Level of Detail” (LOD) is used to explain how much detail is to be included when preparing visualization for an urban or architectural project.

The LOD should be adapted **to the scale of the project**:

- In large scale projects, LOD is low.
 - o Big areas of the city and context around the urban project can be simplified to white volumes with the shape and height of the buildings.
 - o Programming can be expressed by different puzzle-like colored volumes.

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Masterplan Val-Benoit Project. Liège. - Baumans-Deffet, Architecture Alain Dirix, MSA - Source: <http://www.valbenoit.be/fr/val-benoit>

- o Streets can be expressed by axes or colored surfaces (no differentiation between car lanes and sidewalks).
- o Flows, intensity, densities can be represented by a color or a thickness scale.



Malmö road system. - Space Syntax visualization. Source: <http://malmo.yimby.se/tag/space+syntax>

- o High densities of vegetation can be simplified to a green surface
- o No presence of individual elements, furniture, singular vegetation
- o No differentiation of materials

The nearer the project to the human scale, the higher the LOD (it tends to be realistic):

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- o Gives information about the aesthetics of the project (colors, shape, textures, and lighting) of buildings or public spaces.
- o Helps to illustrate the ambient and activities expected to happen around the project (presence of people, vehicles, objects, animals)



*Chirec Hospital (Brussels) - Assar Architectes. Source:
<http://www.assar.com/en/projects/chirec-delta>*

On the other hand, LOD can also be adapted to the inputs and outputs expected on the **exchange with stakeholders**, according to the phase of development of the project.

- o At earlier stages it is easier to include other stakeholder's feedback. LOD will be low, as discussion may turn around big principles, connections and programming.
- o Semantic information will be especially interesting for analyzing purposes. In terms of visualization it will be a real step forward to include it as proposed in point 4.3.
- o At later stages the possibilities of integrating changes decrease. LOD will be appropriate to the objective. If it is aesthetic the LOD will be higher that if it concerns volumes.
- o The aim of the interaction will progressively become to get "approval". At that point LOD will be high and the experience of visualization usually tends to create a positive feeling in order to "sell" the project.

Point of view

The choice of the Point of View for the visualization depends on the objectives of the interaction.

Aerial and axonometric point of view:

- o It is better for explaining relationships between different parts in a big scale context

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- o It is also useful to explain programming, flows, big principles
- o It is adequate for context analysis
- o It gives better understanding about the object (for example a building)



ANFA EL BEIDA & JAWHARAT ANFA Project. Housing project in Casablanca - Assar Architects

Human point of view

- o It gives information about the aesthetics of the project (colors, shape, textures, and lighting) of buildings or public spaces.
- o It helps to illustrate the ambient and activities expected to happen around the project (presence of people, vehicles, objects, animals).
- o It is compulsory when communicating about interior design.



ANFA EL BEIDA & JAWHARAT ANFA Project. Housing project in Casablanca - Assar Architects

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Production

Production is more efficient if all the previous steps have been followed so the visualization is adapted to the subject of discussion.

Visualization is an important issue in urban projects. The way stakeholders give and receive information may have a big impact on final results and decision making. New technologies can offer a great opportunity to go deeper in city analysis and help to substantiate decisions, engaging large groups of stakeholders, but they can also be used as an attractive manipulation tool with no real effects on important challenges of urban life such as climate change, traffic jams, criminality rates, unemployment and other issues.

4 Stakeholders in city co-design

4.1 Identifying stakeholders

As any complex process city co-design requires identification and managing a number of various groups of stakeholders involved. There are several approaches to determine the stakeholders (Mathur et al, 2007). Some take more narrow approach and limit stakeholder to those who have power and influence over the project. This is mainly driven by self-interest and pragmatism, in order to limit the influence of stakeholders. Others take a more holistic, democratic approach and include anyone who claims to have an interest.

Taking a wider approach has more advantages than just being democratic or inclusive. Consulting more stakeholders leads to acquiring more knowledge, allows learning socially and not only technically, leads to projects that are better supported and have less conflicts.

There is a growing consensus in sustainable urban development to merge both approaches, addressing both the need to consult broadly as well as with ones, who have power and influence.

Typically a process of identifying stakeholders goes through steps of (1) establishing an initial list with one or more focus groups, (2) completing this list with questionnaires or checklists and (3) a snowballing technique. (Reed, 2009)

It is important to have a good list as outcome of the first two steps. The below framework (amended from Mathur et al., 2007) to categorize stakeholders suggests a methodology to include a wider group of legitimate stakeholders and have a good initial list.

Stakeholders' categorization

Category	Groups	
Those affected by the project	Directly affected	Users of the buildings ... of facilities ... of spaces Inhabitants, employees, students, visitors, shop-owners & shoppers, etc.
	Indirectly affected	Local surrounding community members General public Associations, community based groups Specific demographic groups
Those who affect the project	Who determine the context	Authorities (local, regional, central area, urban planning)

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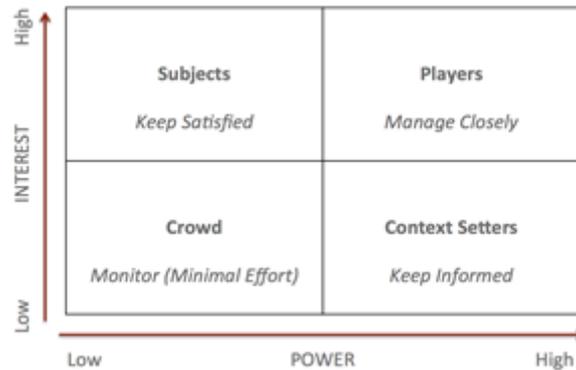
Category		Groups
		Government agencies (environment, etc.) Banks, insurance companies
	Directly involved in delivering the project	With financial stake <ul style="list-style-type: none"> ● Client ● Owner ● Investor ● Developer Experts <ul style="list-style-type: none"> ● Architect ● Engineers ● Utility & Public transportation companies
	Others who are / may be interested	Environmental / social organizations Politicians and elected officials, political parties, municipalities, municipality officials Media Researchers, experts Interest groups, lobbies Action groups, NGOs

Snowballing technique is a general research method used for growing the sample with the help of previous respondent. In order to complete the list of stakeholders, ‘snowballing is believed to be an effective way of identifying the stakeholders (Ananda and Herath, 2003). In snowballing, one ask the initial stakeholders who else might be stakeholders in the project. It is important to use snowballing in combination with objective method like the initial list shown above, in order to avoid social bias (the bias would be in inviting only stakeholders that are known in certain social circles, if the snowballing technique is only used starting in those circles).

4.2 Stakeholder analysis and mapping

The stakeholder analysis and mapping process usually starts with mapping stakeholders in a Power versus Interest grid (see Figure below). There are also alternatives - usually stakeholders are mapped to two dimensions (importance/influence, impact/priority, power/interest, readiness/power, support/opposition, constructive/destructive) - but the power/influence is the most used.

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Power versus Interest grid with common management approach

In a basic approach, stakeholder management approaches only differ based on this segmentation (see typical approach mentioned for each segment in the Figure above)

In addition to this analysis, there are variations of add-on analysis processes (Bryson, 2004), like for example a stakeholder influence analysis: mapping which stakeholders influence others (indicated with arrows between the stakeholders on the power versus interest grid).

Another grid used is the participation-planning grid, mapping for each project phase how different stakeholder groups will be managed or involved. Typically, five levels of engagement are used:

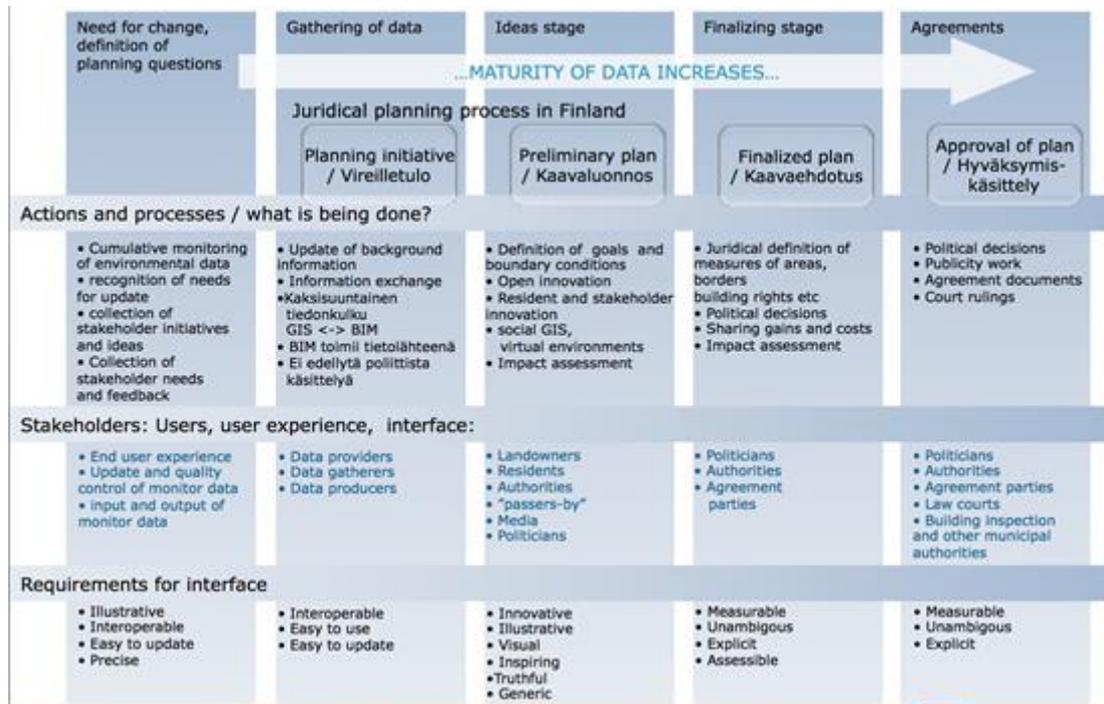
- Inform (“We will keep you informed”)
- Consult (“We will keep informed + listen to you + inform how your feedback was used)
- Involve (“We will work with you to ensure your concerns are reflected in the solutions + inform how your feedback influenced the decision)
- Collaborate (“We will incorporate your advice to the maximum extent possible”)
- Empower (“We will implement what you decide”)

For each major project phase, stakeholder groups are either not present at all, OR classified in one of the above five level of engagement boxes.

The above stakeholder mapping and analysis techniques stay very general in terms of the collaboration processes required, they also keep collaboration interaction limited to a small number of stakeholders.

In the field of city planning and city design, there are stakeholder interaction models that map the stakeholder interactions in order to initiate collaboration with a wider group of stakeholders (see figure below).

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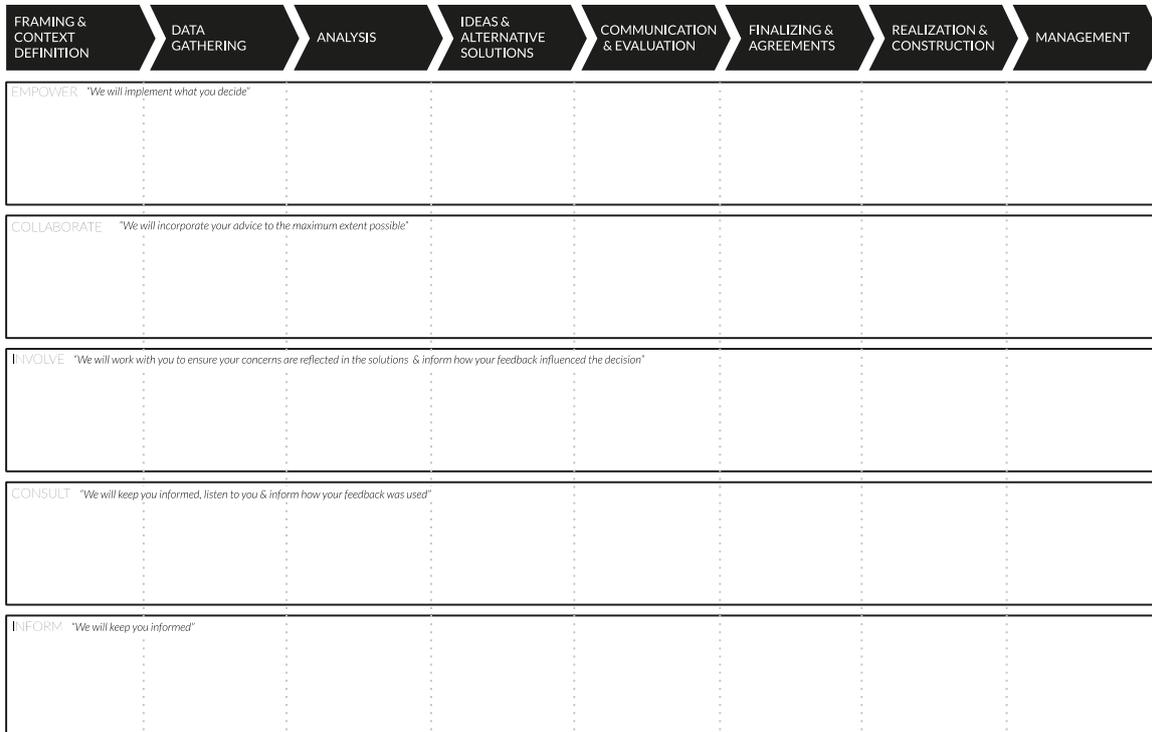
Challenges and information needs in collaboration process of city planning (Excerpt from BIMCity material 5th Feb 2015 - Anssi Savisalo - Finnish Consulting Group)

Co-design as an urban design process is focused on communication between different stakeholders. These participants can be mapped in several levels of engagement and decision-making power who will give their input in punctual moments or all over the project (see figure below). In consequence, there will be a number of interactions which will need of adapted solutions of visualization and representation.

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STAKEHOLDER MAP

STEP 1
 Decide which stakeholders (from the stakeholder map) you want to involve in your process, when and how much. Place them on the overview accordingly. If you already know how you want to involve them, add this as well.



Example of interactions with different visualization needs depending on the phase of the project and the level of participation of the stakeholders. Self-created content based on stakeholders maps developed in C³PO WP6 with Createlli and StudioDotts. Images by Assar Architects.

The approaches described above are mostly suited from a city point of view. However, more and more citizens take the initiative to signal problems or opportunities in the public space, or go even further and take action to improve it. This is an important trend to reckon with in C³PO. The above mentioned stakeholder mapping techniques need to be developed taking into account this new, bottom-up urban development approach (meaning not just collecting the inputs from citizens, but also growing initiative from the citizens' side).

4.3 Stakeholder management software

Stakeholder management software exists in two main domains:

- Specific stakeholder management software, focused to manage the stakeholders for specific programs (like Darzin, Staketracker, Line Up, Stakeholder Circle). These solutions are more geared to engage stakeholders (i.e. individuals/public, landowners, and all manner of stakeholder groups) in different projects.
- Applications for EHS (Environment, Health & Safety) and CSR (Corporate Social Responsibility) / sustainability management (like Enablon, Intalex). In those applications there is usually a module for stakeholder management. Usually these

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modules are oriented to companies/organizations and their relations with customers and stakeholders/ people within and outside the company.

Stakeholder Analysis functions

One of the main features of these programs is that they help to organize and process stakeholder information in order to have better and more efficient relationships with them.

Main features:

Stakeholder listing. The stakeholders related to the project are shown in a list where one can see information about them. It allows sorting the stakeholder list by key attributes.

- Graphs. All the programs allow better visualizing stakeholder information through different graphs. For example one could see how many people are positive, negative or neutral about a certain proposition of the city council.
- Maps. Programs allow better visualising stakeholders data through maps. One could see for example where the person lives or see different types of maps to better analyze certain urban area.
- Filter/search data. Programs have filters making it easy to send out information to targeted groups and carry out detailed analysis of the stakeholder engagement data. For example: most of the people living in a neighborhood do not support a project for reducing noise from the road nearby. To understand the reason for this surprising opinion, one can filter the data of responses, which could reveal that people living near the blocks do not like the appearance of the blocks.

Interesting differentiators:

- An analysis section where you can weigh the level of supportiveness, receptiveness, power, urgency and proximity of the stakeholder and the overall project.
- Track all the changes in the stakeholder profile through the life of the project.
- Having the possibility to view the objectives each stakeholder has in the project

Relations:

- Relating stakeholders to other stakeholders and defining the relationship
- Stakeholders can be related to interests (i.e. the 'things' that stakeholders are interested in, or for example a river or a playground) or other stakeholders
- Interests can be related to other interests and the relationship defined (e.g. an important tree can be related to a playground)
- Stakeholders are related to a relevant engagement process and to a Stakeholder Manager (the person responsible for the relationship)
- Relations between stakeholders can be mapped.

Stakeholder Communication

After you have a clear vision of your stakeholders, programs allow you to communicate with

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them.

Main features:

- Built-in communication system. From where you can inform your stakeholders sending emails, notification, letters, reports or even make phone calls through your stakeholder lists
- Import/export Data. Most of the programs can import/export data to multiple formats and some of them offer integration with other software solutions. Also programs can add data like emails, appointments from other software.
- Tasks. If you want to involve the stakeholders there are programs where you can allocate tasks to members in your team and you can also set deadlines for this tasks and even monitor their progress to completion
- Surveys/questions. If you want to consult your stakeholders, there are some other programs that allow you to create feedback or submission forms
- Reports. Most of the programs make standard and configurable reports turning the gathered stakeholder data into useful information in order to better analyze this information or even to inform stakeholders. One of the programs searched doesn't make the reports but provides useful information (graphs, stakeholder mapping, comments, feedback) to do it.

Interesting differentiators:

- Workflow, every stakeholder can be tracked through different types of workflow.
- Reminders. Track commitments and complaints with automatic email notification and reminders. (e.g. if you don't get a response by a certain date you get a notification)
- Meetings have three actions, a pre-meeting distribution of the agenda and other documents, the meeting itself and a post meeting with action items.

Issue and complaint management

Some other programs have specific modules to manage issues or complaints. You can see different issues/complaints listed by priority, assign an issue manager, view the issue status: opened/close or see the level of the issue.

Collaboration features

For collaboratively addressing issues there is one program (Line Up) that offers a collaborative message centre, which allows stakeholders to work together using, logs, processes and workflows.

Some other programs have integrated online engagement platforms (Staketracker) so that the public can openly discuss topics based on interest in them. Finally, the information entered is automatically passed through to the programs as the back-end database.

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5 Technologies and standards

5.1 Urban information

City co-design process and platform development requires a combination of various technologies for urban data and information exchange, each of those have own standards. These standards can be classified in two groups:

- Technical standards, including syntaxes and data models
- Domain standards, including ontologies

5.1.1 Technical standards

The main syntaxes used in Web data interoperability are XML and JSON.

The main syntaxes used in Web data interoperability

Syntax	Description
XML	<ul style="list-style-type: none"> • Simple, flexible text format derived from SGML (ISO 8879). • Mostly used by Web services
JSON	<ul style="list-style-type: none"> • Lightweight data-interchange format. It is easy for humans to read and write. It is easy for machines to parse and generate. • Mostly used by restful API

A comparison between XML and JSON has been made by Oracle. A summary is given below.

A comparison between XML and JSON

Features	Comparison	Comment
Simplicity	JSON has a smaller grammar and maps more directly onto the data structures.	XML can easily be used as simply as JSON syntactically. All major programming environments have robust XML support.
Extensibility	XML is extensible because it is a mark-up language. JSON is not extensible because it does not need to be. JSON is not a document markup language, so it is not necessary to define new tags or attributes to represent data in it	

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Features	Comparison	Comment
Interoperability	XML and JSON are open interoperability standards	
Exchange Formats	XML and JSON can be used as an exchange format to enable users to move their data between similar applications	
Structure	XML and JSON provides a structure to data. JSON's data structure is a map whereas XML is a tree.	
Self-Describing Data	XML and JSON have this in common.	
Image	XML documents can contain any imaginable data type - from classical data like text and numbers, or multimedia objects such as videos, to active formats like Java applets or ActiveX components.	JSON does not have a <[CDATA[]]> feature, so it is not well suited to act as a carrier of sounds or images or other large binary payloads. JSON is optimized for data.
Internationalization	XML and JSON both use Unicode.	
Adoptation	XML is being widely adopted by the computer industry	JSON is just beginning to become known. Its simplicity and the ease of converting XML to JSON make JSON ultimately more adoptable. The use of JSON is limited to web client-server scenarios. Within that domain it is popular. Outside of that domain XML completely dominates
Namespace	Only XML supports namespace.	

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Features	Comparison	Comment
Validation	XSD validation for XML; no validation for JSON	

Data model

RDF is a standard data model for data interchange on the Web. RDF is based on the idea of identifying things using URIs, and describing resources in terms of simple properties and property values. This enables RDF to represent simple statements about resources as a **graph** of nodes and arcs representing the resources, and their properties and values (W3C). RDF has several syntaxes (Turtle, N3, etc) and XML is one of those (known as RDF/XML).

Entity-Component model (Alatalo, 2011) is a common design in contemporary game engines. It is utilized in the open source realXtend project (realXtend, 2015) which provides a reference implementation for realtime collaborative 3D applications. On the abstract level, a similar EC model is used also in Unity and other game engines. In the EC model scenes or applications consist of entities which are not typed. Components are added to entities to add arbitrary data: for example the position or the name of the entity. In programming terms, the entities are aggregates of components—instead of for example inheriting properties from base classes. This data model is specified in <https://github.com/realXtend/tundra/wiki/Scene-and-EC-Model>. In addition, realXtend specifies a set of components which are a domain standard for 3D scenes using this data model. The realXtend Entity-Component model uses TXML format which has an XML syntax.

5.1.2 Domain standard

Several domain standards for exchanging urban information exist. Most of them are based on XML. Each protocol describes a specific dimension of urban information (e.g., OGC - geospatial and location standards by the Open GIS Consortium; aecXML - BIM information which uses Industry Foundation Classes (IFCs), LandXML - a data structure widely used in infrastructure planning which the IFC does not yet cover, etc.). Tentative ontologies have also been developed in areas related to GIS/BIM applications. A selection of relevant ontologies in this area is listed in the table below.

A selection of ontologies in the areas related to GIS/BIM applications

Information layer	Name	Data format	Description	Owner	Open
GIS	DGN	/	CAD file formats supported by MicroStation Interactive Graphics Design System (IGDS) CAD programs	Microstation	No

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Information layer	Name	Data format	Description	Owner	Open
GIS	DWG	Binary	Binary file format used for storing two- and three- dimensional design data and metadata	AutoCad	No
GIS	NCZ	Binary	Netcad file format	Netcad	No
GIS	GML	XML	XML based open standard (by OpenGIS) for GIS data exchange (vector formats) - OGC	OGC	Yes
GIS	Esri	Binary	Proprietary binary and metadataless ASCII raster formats used by Esri (raster format)	Esri	No
GIS	GeoJSON	JSON	A lightweight format based on JSON, used by many open source GIS packages	OGC	Yes
BIM	IFC	UML/XML	Open standard for BIM developed by IFC	IFC	Yes
BIM	aecXML	XML	Created by IFC to create a vendor-neutral means to access data generated by Building Information Modeling	IFC	No
BIM	LandXML	XML	Non-proprietary standard for data exchange among the land development, civil engineering and surveying communities	OGC	Yes

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Information layer	Name	Data format	Description	Owner	Open
GIS	GeoSPAR QL	RDF	Simple ontology for OGC standards literals and topological relationships developed by OpenGIS (Perry & Herring, 2012)	OGC	Yes
GIS	CityGML	XML/U ML	Unified 3D city model. Common information model for the representation of 3D urban objects defined in UML: geometric and topological model, multipurpose model, multiscale model, extensible	OGC	Yes
BIM	Ontology for BIM Exchanges		Formal building information modeling based on the IFC definitions (Industry Foundation Class) (Venugopal, 2012)	IFC	
Electricity grid	SmartGrid Ontology (Lu, 2010)		Ontology of electricity grids; currently used especially for data validation against the ontology		
BIM	IFC BIM	object-based file	ISO: open international standard for BIM data that is exchanged and shared among software applications used by the various participants in a building construction or facility management project	IFC	Yes

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Information layer	Name	Data format	Description	Owner	Open
Urban planning	OUPP: Ontology for Urban Planning Process (Métral, 2006)		Ontology linked to CityGML; modeling of urban planning projects including the communication between the different stakeholders	Falquet et.al, 2011	Yes
Transportation	OTN: Ontology for Transportation Network		OTN [Lorenz et. al, 2005] is extracted from Geographical Data Files (GDF) which is developed as a standard for storing geographical data. OTN is used to model traffic and transportation networks.	http://www.pms.ifi.lmu.de/reverse-wga1/otn/OTN.owl	Yes
Application	Tundra Entity - Component model. TXML	XML	Definition of an application, for example an end user web service. May include references both to geometry data (e.g. CityGML) and application specific graphics and software modules (similar to data and script links in HTML) (Alatalo, 2011)	realXtend.org	Yes

W3C and OGC initiative

In January 2015, the W3C and the Open Geospatial Consortium (OGC) announced a new collaboration (opengeospatial.org, 2015) to improve interoperability and integration of spatial data on the Web. They are evaluating the use of **Linked Data** for managing the complex evolution and integration of spatial data.

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5.1.3 Conversion between different standards/formats

Conversion between different standards/formats

Information layers	Name	Description
BIM	IFC-to-RDF conversion service	Having the IFC ontology at our disposal, we are able to generate RDF instances based on IFC instances. The latter can be obtained from existing BIM applications.
GIS to Application	CityGML to TXML	Adminotech has implemented a conversion from CityGML data to TXML.

5.1.4 Urban ontology/modelling

The recent technologies dealing with smart cities and urban planning mostly focus on semantically enriched virtual 3D city models which support urban modelling in many ways. As noted in C³PO objectives, such models can be benefited for the purpose of environmental and energy planning, disaster management, noise simulation, urban planning, and public participation in planning processes. Such applications need a commonly accepted data model for storage and exchange of geometry, semantics and relations of the modelled features is needed. CityGML (Musialski, 2012) is such an interoperable data model which has been issued by the Open Geospatial Consortium (OGC). The existing 3D city and building models mostly rely on CityGML and thus it has become an encoding standard for the representation, storage, and exchange of virtual 3D city and landscape models. In line with CityGML the foremost studies and propositions that can be used in urban planning or city modelling are summarized in the following table.

Studies on urban ontologies

Name	Authors	Year	Dimension	Focus
Building Information Modelling for Smart Built Environments	Jianchao Zhang, Boon-Chong Seet and Tek Tjing Lie	2015	BIM	Investigate how BIM can contribute to the development of SBE
New concepts for structuring 3D city	Biljecki, F. , Ledoux, H. , Stoter, J.	2014	GIS	Propose a new Level of Detail (LoD) concept for CityGML buildings that differentiates a

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Name	Authors	Year	Dimension	Focus
models - An extended level of detail concept for CityGML buildings				Geometrical Level of Detail (GLOD) and a Semantical Level of Detail (SLOD).
Maintenance of Buildings Using BIM Methodology	A.Z. Sampaio, Diogo Simões	2014	BIM	Implementing the benefits provided by BIM on a software tool used as support to maintenance of buildings
Building Information Modeling	Karen M. Kensek	2014	BIM	A book about fundamentals and applications of BIM
The Methodology of Interactive Parametric Modelling of Construction Site Facilities in BIM Environment	Mária Kozlovská Jozef Čabala Zuzana Struková	2014	BIM	Present the methodology for execution of 3D construction site facility allocation model (3D CSF-IAM), based on principles of parametric and interactive modelling
A WEB-BASED COMMUNICATION PLATFORM FOR BUILDING INFORMATION MODELS	WOONSEONG JEONG and WEI YAN	2013	BIM	Research and development of a new communication platform using Building Information Modelling (BIM) and a web-based interface, enabling real-time information update and interactive visualization of design and construction information
GeoSPARQL	Perry & Herring	2012	GIS	Simple ontology for OGC standards literals and topological relationships developed by OpenGIS

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Name	Authors	Year	Dimension	Focus
The use of GIS-based 3D geological tools to improve hydrogeological models of sedimentary media in an urban environment	V. Velasco, R. Gogu , E. Vázquez-Suñe , A. Garriga, E. Ramos , J. Riera, and M. Alcaraz	2012	GIS	Presents a software platform representing a working environment to integrate 3D geological models of the sedimentary media in regular hydrogeological modelling methodologies.
Transaction rules for updating surfaces in 3D GIS	Gerhard Gröger, Lutz Plümer	2012	GIS	Presents a solution which is based on efficient transaction rules for updating 3D surface models
GRASS GIS: A multi-purpose open source GIS	Markus Neteler, M. Hamish Bowman, Martin Landa, Markus Metz	2011	GIS	GRASS has been under development for more than 28 years, has strong ties into academia, and its review mechanisms led to the integration of well tested and documented algorithms into a joint GIS suite which has been used regularly for environmental modelling.
"Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry	Salman Azhar	2011	BIM	http://ascelibrary.org/doi/abs/10.1061/(ASCE)LM.1943-5630.0000127
3D City modeling for	Aneta Strzalkaa,	2011	BIM	http://www.tandfonline.com/doi/pdf/10.1080/10789669.20

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Name	Authors	Year	Dimension	Focus
urban scale heating energy demand forecasting	Jürgen Bogdahn, Volker Coorsb & Ursula Eicke			11.582920#.VNtotfmsWqk
A 3D GIS spatial data model based on conformal geometric algebra	YUAN LinWang, YU ZhaoYuan, LUO Wen, ZHOU LiangChen & LÜ GuoNian	2010	GIS	3D GIS data model based on conformal geometric algebra (CGA). In this approach, geographic objects of different dimensions are mapped to the corresponding basic elements (blades) in Clifford algebra, and the expressions of multi-dimensional objects are unified without losing their geometric meaning
Topology of surfaces modelling bridges and tunnels in 3D-GIS	Gerhard Gröger, Lutz Plümer	2010	GIS	Present a method which verifies the occurrence of handles in surfaces, thereby contributing to the semantic-topological consistency in GIS, close the gap between the global topological definition of handles in surfaces and the local definition of semantical handle objects in GIS - tunnels, bridges, arcades
Technology adoption in the BIM implementation for lean architectural practice	Y. Arayici , P. Coates, L. Koskela , M. Kagioglou , C. Usher, K. O'Reilly	2010	BIM	Explains a comprehensive and systematic evaluation and assessment of the relevant BIM technologies as part of the BIM adoption and implementation to demonstrate how efficiency gains have been achieved towards a lean architectural practice.

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5.1.5 Tools and software

In city modelling there exist many tools and software which are widely accepted by experts and researchers. The list of the leading tools can be seen in the following table.

Tools and software for city modelling

Tool/Product Name	Subject	Focus
NoesisGUI by Noesis	3D Modelling	NoesisGUI is user interface framework built on hardware accelerated vector graphics. They offer a modern and elegant approach to the problem of user interface in real time applications.
Netcad Planet and Planet 3D	CAD / 3D Modeling	Planet is a planning solution, essentially a Netcad module that is used to draw urban plans and perform plan revisions and changes. It provides an extensive set of tools and various templates for urban planners and requires Netcad main module to run. Provided that the data includes the land model (3D mesh representing the land), Planet 3D module can be activated to visualize the plans in 3D and perform various analyses.
3DEXCITE DELTAGEN by Dassault Systemes	3D Modelling	Efficiently create persuasive high-end 3D visuals in realtime. The ultimate flexibility generates maximum creative freedom at all stages across the product life cycle. Even the most demanding of visualization experts will find all the features they need here, while its comprehensive array of functions makes it perfect for a wide range of industrial sectors. Data from all professional CAD systems is instantly brought to life in outstanding visual quality and in realtime.
3DEXCITE DELTATEX by Dassault Systemes	3D Modelling/Scanning	With its bespoke feature set and intuitive GUI, it is easy to scan in physical samples, then develop new design variations on-screen, and so create highly realistic images of your color and material concepts in realtime. This creates a highly realistic experience that streamlines decision-making and provides suppliers with the information they

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Tool/Product Name	Subject	Focus
		<p>require to develop new materials. And, as DELTATEX is part of our Visualization Platform, you can seamlessly apply your materials to virtual prototypes in 3DEXCITE DELTAGEN for maximum workflow efficiency. Saving you the task - and costs - of making physical prototypes.</p>
<p>3DEXCITE PICTUREBOOK by Dassault Systemes</p>	<p>3D Modelling/Platform</p>	<p>the data management and creative collaboration platform speeds up processes and creates full transparency for visual data - from CAD files to high-end 3D visualizations. While simple for beginners to use, it provides a high level of security and accessibility thanks to platform-independent online access. Manage large volumes of visual data and keep it connected and up to date.</p>
<p>3DEXPERIENCE by Dassault Systemes</p>	<p>3D Modelling/Platform</p>	<p>The 3DEXPERIENCE Platform is a revolutionary platform for the simulation user and the enterprise. For the Simulation Specialist, the 3DEXPERIENCE Platform provides evolutionary functionality to extend his or her current set of expert tools. Capabilities such as high-performance visualization for very large models, batch and rule-based meshing, and collaborative assembly are unique to the 3DEXPERIENCE Platform, providing additional capability, efficiency, and throughput for existing simulation users, all based on the market-leading Abaqus technology.</p>
<p>OpenSceneGraph</p>	<p>3D Modelling</p>	<p>The OpenSceneGraph is an open source high performance 3D graphics toolkit, used by application developers in fields such as visual simulation, games, virtual reality, scientific visualization and modelling. Written entirely in Standard C++ and OpenGL it runs on all Windows platforms, OSX, GNU/Linux, IRIX, Solaris, HP-Ux, AIX and FreeBSD operating systems. The OpenSceneGraph is now well established as the world's leading scene graph technology, used widely in the vis-sim, space, scientific, oil-gas, games and virtual reality industries.</p>

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Tool/Product Name	Subject	Focus
AutoDesk	3D modelling and urban planning	Autodesk is a software tool for urban and regional planning which aims to help users for sharing information with other agencies to promote increased efficiency and coordination. http://www.autodesk.com/industry/civil-infrastructure/land-planning
ESRI	3D modelling and urban planning	ESRI is 3d city plan designer with editing tools, high visualization capabilities and a geodatabase. http://www.esri.com/software/cityengine/features
Oracle Spatial and Graph	Data modelling	Oracle Spatial and Graph is an advanced data modelling tool having features for geospatial, location-based and graph data management and analysis that can be used for urban planning.
OpenStreetMap	GIS	OpenStreetMap is built by a community of mappers that contribute and maintain data about roads, trails, cafés, railway stations, and much more, all over the world. OpenStreetMap emphasizes local knowledge. Contributors use aerial imagery, GPS devices, and low-tech field maps to verify that OSM is accurate and up to date.
Capaware	GIS	Capaware! is conceived as a system of 3D terrain representation with multilayer representation of diverse types of resources capabilities and executed applications integration feature. With OpenSceneGraph as the graphical engine, Capaware! enables the creation and modification of new layers of data through access to remote servers where they are.
Geospatial	GIS	The Whitebox GAT project is an exciting new open-source GIS project. Whitebox is as much a philosophical approach to geomatics as it is a GIS/Remote Sensing package. This philosophy of transparency, from which Whitebox derives its name, has led to the development of some rather

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Tool/Product Name	Subject	Focus
		unique and innovative features in the software.
GeoTools	GIS/Toolkit	GeoTools is an open source (LGPL) Java code library which provides standards compliant methods for the manipulation of geospatial data, for example to implement Geographic Information Systems (GIS). The GeoTools library implements Open Geospatial Consortium (OGC) specifications as they are developed.
GDAL	GIS/Library	GDAL is a translator library for raster and vector geospatial data formats that is released under an X/MIT style Open Source license by the Open Source Geospatial Foundation. As a library, it presents a single raster abstract data model and vector abstract data model to the calling application for all supported formats. It also comes with a variety of useful commandline utilities for data translation and processing.
Orfeo Toolbox by French Space Agency (CNES)	GIS/Toolkit	ORFEO Toolbox (OTB) is distributed as an open source library of image processing algorithms. As the motto of OTB goes, Orfeo Toolbox is not a black box, OTB encourages full access to the details of all the algorithms. OTB is based on the medical image processing library ITK and offers particular functionalities for remote sensing image processing in general and for high spatial resolution images in particular. Targeted algorithms for high resolution optical images (Pleiades, SPOT, QuickBird, WorldView, Landsat, Ikonos), hyperspectral sensors (Hyperion) or SAR (TerraSarX, ERS, Palsar) are available.
MapWindow	GIS	The MapWindow GIS project includes a free and open source desktop geographic information system (GIS) with an extensible plugin architecture; a GIS ActiveX control; and C# GIS programmer library called DotSpatial. We would be happy to have you join our project.

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Tool/Product Name	Subject	Focus
QGIS	GIS	QGIS is a cross-platform Open Source Geographic Information system with an international support community of enthusiastic users, developers and supporters.
uDig	GIS/Framework	uDig is an open source (EPL and BSD) desktop application framework, built with Eclipse Rich Client (RCP) technology.
GRASS GIS	GIS/Framework	a free and open source Geographic Information System (GIS) software suite used for geospatial data management and analysis, image processing, graphics and maps production, spatial modeling, and visualization. GRASS GIS is currently used in academic and commercial settings around the world, as well as by many governmental agencies and environmental consulting companies.
Tekla BIMsight by Tekla	BIM	Tekla BIMsight is a free professional tool for construction project collaboration. The entire construction workflow can combine their models, check for clashes, and share information using the same easy-to-use BIM environment. Tekla BIMsight enables project participants to identify and solve issues already in the design phase before construction.
Trimble Locus	GIS	Trimble Locus solution for local government is a productized set of modular software applications and services for managing built environment data and carrying out planning and building process tasks from land use planning to building supervision, asset management and customer service. The advanced data management enables modeling and managing of all information related to natural and built environment and needed in the local government building process tasks.
Immeractive	BIM	Immeractive SA develops and markets interactive 3D visual solutions for architecture, real estate,

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Tool/Product Name	Subject	Focus
		urban planning, regional planning, heritage, museums, and tourism.
Solibri Model Checker (SMC) by Solibri	BIM	Solibri Model Checker helps find and visualize issues and problems before and during construction. It will also provide a wealth of information that can be taken off throughout the building's life-cycle and utilized for needs that include area calculation, accessibility and building code compliance. Find out more below on the functionality.
Vico Office Suite	BIM/Platform	Vico Office™ is purpose-built for construction, and is designed as a tightly-integrated, BIM-neutral platform to which multiple types of BIM models can be published, synthesized, and augmented with cost and schedule information. To maximize efficiency and meet the distinctive needs of the various construction process trades and phases, Vico Office is structured in a modular way, providing you with a tailored, yet expandable solution and a consistent, easy to use environment.
BIM 360 by AutoDesk	BIM/Platform	BIM 360™ construction management software enables almost anytime, anywhere access to project data throughout the building construction lifecycle. BIM 360 empowers those in the field to better anticipate and act, and those in the back office to optimize and manage all aspects of construction performance.
Innovaya Visual 4D Simulation	BIM	Innovaya Visual Simulation associates Building Information Models (BIM) objects with scheduling activities, performing 4D construction planning and constructability analysis. It effectively improves project communication, coordination, and construction logistics planning. With its robust 3D engine and extremely easy-to-use interface, Visual 4D Simulation helps you build optimized task sequences resulting in project time savings and play what-if scenarios with traditional GANTT chart

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Tool/Product Name	Subject	Focus
		schedules.

An overview of urban reconstruction approaches is given (Musialski, 2012). In this study, the authors roughly group the methods according to their outcome and report about interactive methods using both user input and automatic algorithms as well as about fully automatic methods. According to authors, urban reconstruction can be categorized into 4 areas: 1. Point clouds and cameras; 2. Buildings and Semantics; 3. Facades and Images; 4. Blocks and Cities.

5.1.6 Data sources

Open data

The Commission’s work in the area of open data is focusing on generating value through reuse of a specific type of data - public sector information, sometimes also referred to as government data. That is all the information that public bodies produce, collect or pay for.

Examples are: geographical information, statistics, weather data, data from publicly funded research projects, and digitised books from libraries.

Open data frameworks in Europe

The Inspire directive

The EIF was the first step towards interoperability and use of Open Standards in the European Union. The European Union then introduced the INSPIRE directive in 2007, aiming to enforce data interoperability between actors (<http://inspire.jrc.ec.europa.eu/>).

The INSPIRE directive aims to create a European Union (EU) spatial data infrastructure. This enables sharing the environmental spatial information among public sector organisations and better facilitate public access to spatial information across Europe.

A European Spatial Data Infrastructure assists in policy-making across boundaries. Therefore the spatial information considered under the directive is extensive and includes a great variety of topical and technical themes.

INSPIRE covers a wide range of thematic areas for several scales of interest. The following figure proposes a representation of INSPIRE’s scope for some thematic areas. It shows that INSPIRE datasets potentially cover different scales of interest, from local to global scale. This multi-scale information may be reused by the INSPIRE view service in order to propose scale-dependent portrayal: the data displayed would be the most suitable for the user’s zoom level. More detailed data may be displayed for low zoom levels, and more generalised data for higher zoom levels. For example, detailed building geometries may be displayed for low zoom levels and replaced by built-up areas when zooming out.

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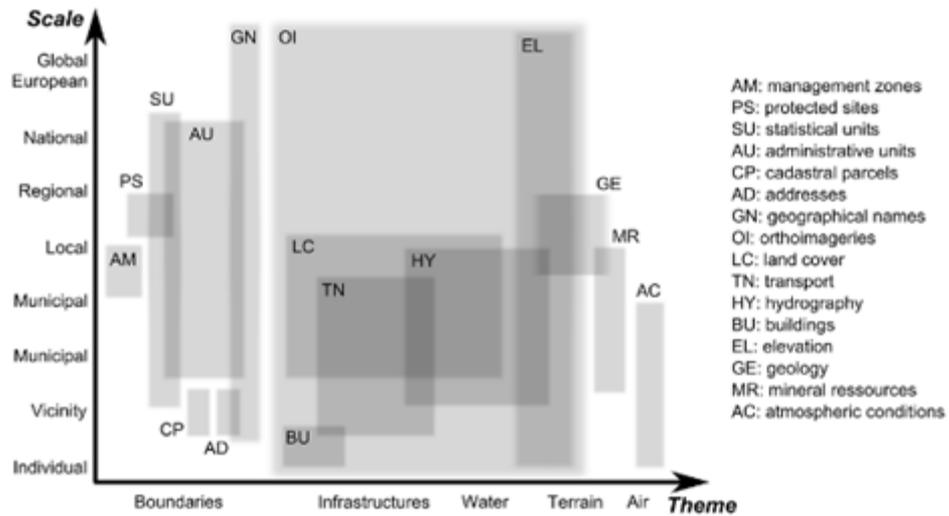


Figure 1. Proposition for a INSPIRE scope representation in a theme/scale space (Gaffuri & Tóth 2013).

Proposition for INSPIRE scope representation in a theme/scale space (Gaffuri & Toth, 2013)

Finnish municipal GML data model

In Finland, the Association of Finnish Local and Regional Authorities has defined a specific data schemes for exchanging municipal GIS information. The Finnish adaptation of GML for cities and municipalities is called KuntaGML (KRYSP = Municipal Built Environment Digital Services)_- see <http://www.ogcnetwork.net/node/621>.

KRYSP can be considered as a municipality level implementation of INSPIRE providing also public access to the data. This data is shared out from the municipalities by utilizing standard WFS services. Local solution providers, like Trimble Solutions Corporation, have implemented into their municipal solutions data transformation into KRYSP model and dedicated WFS services for publishing the information.

The KRYSP data model consist of among others topography, land parcels, buildings and land use plans, which all are parts of C³PO core ontology. This data can be used as data source for C³PO Finnish city pilots.

The following table describes the KRYSP WFS service of city of Oulu.

KRYSP WFS service of city of Oulu

Attribute	Description
Country	Finland
General Title	City of Oulu data service
Subtitle	WFS of the city's built environment spatial data

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Attribute	Description
Uniform Resource Local (URL)	http://kartta.ouka.fi/TeklaOgcWeb/WFS.ashx?
Author	City of Oulu
Author E-mail	karttapiste@ouka.fi
Maintainer/Publisher	City of Oulu
License	According to agreement, registration needed.
Category (information layer)	[Environment, Geography and Meteorological]
Type of Information	Tourist map, valid land use plan, city base map (topographic and administrative data), building information
Period	Current status
State of Data	Real-time data
Coverage	City area
Catalog/Discover	Standard OGC WFS querying
Data Acquisition	Internal - Survey / Research, Everyday service operations
Data Provision	Online view
Feedback	Request Dataset forms, Comment on Datasets http://kartta.ouka.fi/IMS/en/Map
Language Interface	Finnish

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Attribute	Description
Language Data	Finnish
Data Format	WFS (KRYSP Municipal GML)
Domain standard	OGC WFS

Netcad Planet Data Format (Netcad Drawing Files)

Planet is a separately licensed Netcad module that is focused on urban planning. It essentially builds upon existing Netcad abilities and provides field-specific templates for planners. The module runs on Netcad itself, so the resulting file is a Netcad drawing file (NCZ file).

NCZ is a binary file format that is proprietary to Netcad (just as DWG files to Autodesk). NCZ is *not* an open format, so the user needs Netcad to open these files.

NCZ can be considered as a container format since it may contain several types of data depending on the project at hand. (i.e. database connection information, GIS layers metadata, CAD objects and attributes)

Planet is a CAD-based module, therefore NCZ files prepared with Planet will contain raw CAD objects and their attributes (if any) in binary format. Again it should be emphasized that the files can only be loaded and processed by Netcad and not any other software, but this data can be exported to SHP (ESRI shapefile) files and then converted to RDF files via a manual process. It was already done manually within the first iteration of the project as a PoC to create two domain ontologies based on Planet's vocabulary as described in Deliverable 5.1.

The Engage project

The aim of the ENGAGE Project is «the deployment and use of an advanced service infrastructure, incorporating distributed and diverse public sector information resources as well as data curation, semantic annotation and visualisation tools, capable of supporting scientific collaboration and governance-related research from multi-disciplinary scientific communities, while also empowering the deployment of open governmental data towards citizens.»

This ENGAGE report (www.engage-project.eu/) published in May 2014 aims to give a state-of-the-art analysis of open government data and initiatives. The research went on the 27 EU countries and focused on a central government level. The categorization of the data sources is the following.

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The categorization of the data sources

Attribute	Description
Country	The country that the dataset originated from
General Title	A title for the data source
Subtitle	A subtitle for the data source.
Uniform Resource Local (URL)	The URL for the data source.
Author	The initial author of the public dataset
Author E-mail	The author's email
Maintainer/Publisher	The organization responsible for publishing the dataset.
License	The Licence of the dataset (e.g. Open Government License UK, Creative Commons).
Category (information layer)	One or more category themes that the dataset belongs to. The categorization according to the content of the datasets was: [Arts and Recreation], [Business Enterprise, Economics, and Trade], [Budget, Revenues & Expenditures], [Construction, Housing, and Public Works], [Crime and Community Safety], [Demographics], [Education], [Elections], [Emergency Services], [Energy and Utilities], [Environment, Geography and Meteorological], [Health and Disability], [Labor Force and Employment Market], [Law Enforcement, Courts, and Prisons], [Political], [Tourism], [Urban Transport], [Defense], [Multi / Various].
Type of Information	A brief description of the data source category
Period	The chronological period concerning the dataset
State of Data	Whether the information provided is static or dynamic (e.g real-time data)

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Attribute	Description
Coverage	The regional span covered by each dataset.
Catalog/Discover	The different ways to browse for specific information throughout the website; these are referred to as follows: Free text search, Browse of categories, Comprehensive Knowledge Archive Network (CKAN, Field-based search, Filters, Map / Spatial, SPARQLSearch.
Data Acquisition	How the provider has generated / produced the data available in each data source: Internal - Survey / Research, Internal - Back office / Everyday service operations, External - Harvesting, External - Uploaded by Public Agencies, External - Uploaded by Users.
Data Provision	The set of services offered to the user (Online View of Dataset / Download file/ Charts/Map/ API)
Feedback	Feedback mechanisms: Request Dataset forms, Rate Datasets, View popular demands / vote best data requests, and Comment on Datasets
Language Interface	The language(s) the user interface is available in
Language Data	The language(s) the datasets themselves are available in
Data Format	The format of the available datasets (Excel/ PDF/CSV/XML/JSON just to name a few)
Domain standard	If available, the domain standard (metadata standard) for the data catalog of the data source (CityGML, etc)

5.2 Urban platform

As C³PO develops a platform for urban co-design, the three key aspects of it needs to be analyzed: data storage (particularly, cloud data storage), different products enabling performance and scalable computing as well as existing knowledge on the software

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platforms for smart cities.

5.2.1 Cloud storage

Cloud storage is a model of data storage, which in simplest sense can be as and advanced USB flash drive which we use to store objects such as music, pictures and documents. It is advanced, because the cloud storage providers are responsible for keeping the data available and accessible, and the physical environment protected and running. Thus users don't have to carry anything and they can access their files from anywhere having internet connection. With its handy features and wide audience, it is very popular recently and one of the most salient cloud services.

Safir Depo (Safir object store); is a cloud storage service which is being developed by TÜBİTAK BİLGEM. Safir Depo provides compression and deduplication of the objects stored in order to use the available space more efficiently. To offer a secure storage support, objects are stored encrypted. Changes made on the stored objects are versioned. Archiving and data migration among different storage services are also supported.

Safir object store is able to index the metadata of the objects and contents of the documents and offers a search service on this index. Search requests on different type of document content and objects are performed easily and quickly.

5.2.2 Performance and scalable computing

A brief comparison of the following products in terms of availability, versioning, logging, encryption, time-limited access and pricing is as follows.

Comparison of the products

	Amazon S3	Google Cloud Storage	HP Cloud Object Storage	Microsoft Azure Blob Storage	Rackspace Cloud Files	Safir	FiWare
Availability	99.99%	99.00%	99.90%	99.90%	99.90%	99.90%	99.90%
Versioning	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Audit Logs	Yes	Yes	No	No	Yes	Yes	Yes
Encryption	Yes	No	No	No	Yes	Yes	No
Storage Cost (cents/GB /mo)	3.0	2.6	9.0	2.4	10.0		

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	Amazon S3	Google Cloud Storage	HP Cloud Object Storage	Microsoft Azure Blob Storage	Rackspace Cloud Files	Safir	FiWare
Transfer Out Fees (cents/GB)	12	12	12	12	12		
Time-limited Access to Objects	Yes	Yes	Yes	No	Yes	Yes	

5.2.3 Software platforms for smart cities

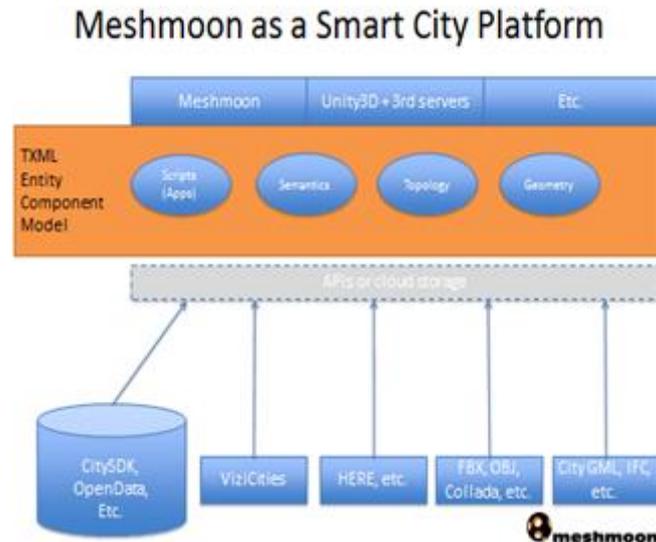
Meshmoon is an open source based, multiuser 3D software platform for creating, publishing and hosting 3D scenes. Usually, an artist creates 3D content in a 3D modelling tool, such as Unity, Blender, 3DMAX, Maya, etc. Once the 3D model is ready, s/he exports it to Meshmoon for further use and publishing. Meshmoon has a Unity exporter for exporting mesh, material and texture assets to native Meshmoon formats. It also provides Unity Meshmoon shader that matches visuals with the Meshmoon client renderers (Meshmoon, 2015).

For smart cities, Meshmoon platform has the following benefits:

- Truly open
- Scalable
- Independent of any system provider
- Independent of 3D format
- Already working and tested software platform for application development

The following picture illustrates an overall architecture for Meshmoon as a smart city platform.

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Overall architecture for Meshmoon as a smart city platform

5.3 Visualisation and augmented reality

As visualization plays a crucial role in city co-design, its aspects needs to be analyzed more in-depth, that is why below we discuss GIS visualization, AR and VR, 3D models and analyze the existing tools for visualization.

5.3.1 GIS visualization

OGC has an XML schema that describes appearance of map layers, called SLD (<http://www.opengeospatial.org/standards/sld>). It is supported by many desktop and server applications (open source / commercial). SLD addresses the need for users and software to be able to control the visual portrayal of the geospatial data.

An example can be found below (source: GeoServer documentation).

Visualisation standards for urban planning in Turkey are regulated by Turkish Ministry Of Environment And Urbanization. A Major change has been introduced on 14.06.2014 and an amendment is published on 30.01.2015. <http://www.csb.gov.tr/gm/mpgm/index.php?Sayfa=sayfa&Tur=webmenu&Id=13044>

An example from GeoServer documentation

```
1 <?xml version="1.0" encoding="ISO-8859-1"?>
2 <StyledLayerDescriptor version="1.0.0"
3   xsi:schemaLocation="http://www.opengis.net/sld StyledLayerDescriptor.xsd"
4   xmlns="http://www.opengis.net/sld"
5   xmlns:ogc="http://www.opengis.net/ogc"
6   xmlns:xlink="http://www.w3.org/1999/xlink"
7   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
8   <NamedLayer>
9     <Name>Simple point</Name>
10    <UserStyle>
11      <Title>GeoServer SLD Cook Book: Simple point</Title>
12      <FeatureTypeStyle>
13        <Rule>
14          <PointSymbolizer>
15            <Graphic>
16              <Mark>
17                <WellKnownName>circle</WellKnownName>
18                <Fill>
19                  <CssParameter name="fill">#FF0000</CssParameter>
20                </Fill>
21              </Mark>
22              <Size>6</Size>
23            </Graphic>
24          </PointSymbolizer>
25        </Rule>
26      </FeatureTypeStyle>
27    </UserStyle>
28  </NamedLayer>
29 </StyledLayerDescriptor>
```

This standard covers symbols (line types, thickness values, hatch details, symbol representations, RGB color codes, etc.) for all elements in an urban plan. An example from the standard (for natural protection zone) is shown below.

Netcad fully supported the above mentioned (current) symbology with some amendments made during the course of the first iteration in C³PO.

An example from the standard (for natural protection zone)

1.DERECE DOĞAL SİT ALANI				
DETAY SINIFI	ALAN KULLANIMLARI			
DETAY ALT SINIFI	KORUNACAK ALANLAR			
GÖSTERİM				
ALAN			SINIR	
SEMBOL	TARAMA	RGB	TİPİ	RGB
		ŞEFFAF		255/0/0
GEOMETRİ TİPİ		TARAMA TİPİ AÇIKLAMASI		
ÜİP	ÇOKLU POLİGON	ÇİZGİ KALINLIĞI: 0.4 mm 1mm aralıklı çift çizgiler, çift çizgiler arası 3 mm yatay tarama		ÇİZGİ KALINLIĞI: 0.3 mm 5 mm düz çizgi aralıklı 3 mm çaplı dolu daireler ve kapalı alan içinde kalacak biçimde çizgi eksenine 45 derece açılı 3 mm aralıklı, 2,5 mm uzunluğunda tarama ** Uygun aralıklarla sınır üzerine D1 yazılacak
NİP	ÇOKLU POLİGON	ÇİZGİ KALINLIĞI: 0.3 mm 1mm aralıklı çift çizgiler, çift çizgiler arası 3 mm yatay tarama		ÇİZGİ KALINLIĞI: 0.3 mm 5 mm düz çizgi aralıklı 3 mm çaplı dolu daireler ve kapalı alan içinde kalacak biçimde çizgi eksenine 45 derece açılı 3 mm aralıklı, 2,5 mm uzunluğunda tarama ** Uygun aralıklarla sınır üzerine D1 yazılacak
ÇDP	ÇOKLU POLİGON	ÇİZGİ KALINLIĞI: 0.2 mm 1mm aralıklı çift çizgiler, çift çizgiler arası 3 mm yatay tarama		ÇİZGİ KALINLIĞI: 0.3 mm 5 mm düz çizgi aralıklı 3 mm çaplı dolu daireler ve kapalı alan içinde kalacak biçimde çizgi eksenine 45 derece açılı 3 mm aralıklı, 2,5 mm uzunluğunda tarama ** Uygun aralıklarla sınır üzerine D1 yazılacak

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5.3.2 Visualisation of 3D scenes

COLLADA is the Chronos consortium standard for real time 3D scenes. It uses XML. Even though for example FBX is more common in the game industry, Collada is basically the only open alternative with a standard specification (FBX is closed, proprietary and secret).

COLLADA is used for 3D geometry also in the KML/KMZ files created by SketchUp and utilized in Google Earth. The KML has ge positioning and possible other info, with a link to a COLLADA (.dae) file for the 3d model when one is associated with e.g. a building (see <https://www.khronos.org/collada/>).

For transmission, Chronos has a new standard draft: the OpenGL/WebGL Transmission Format, **gLTF**. It is a subset of COLLADA with an optimized binary format for geometry. All the geometry for the objects in a scene is combined in a single file where the data is in binary arrays which can be uploaded directly to the GPU. The geometry data can be also compressed, optionally with special geometry compression techniques. The overall scene and materials are described in a JSON file which refers to the binary file for geometry arrays. Chronos provides an open source COLLADA-to-gLTF converter for this optimized publishing (see <https://github.com/KhronosGroup/gLTF>).

For even more efficient transmission and visualization the **POP buffers** by Fraunhofer's X3DOM team provide progressive loading and hence quick visualization of complex geometry data. It could be especially interesting for large cities to provide both a low-detail overview that opens quickly over the web, and ability to zoom in to view e.g. a building in high detail. POP buffers provide unified seamless level of detail (LoD). It may be possible to use POP buffers as the compression for the binary geometry in gLTF (see <http://x3dom.org/pop/>).

City 3D scenes, or at least parts of them, are visualized in AR using the VTT's existing outdoor AR framework (OnSite). OnSite software is updated to meet C³PO project requirements, especially new data formats and online access to the scenes are most likely required. During the project, some of the latest AR technologies from VTT are implemented in OnSite to allow robust tracking, more easy to use GUI and better AR experience for the end users.

VTT inspects the option to utilize Meshmoon's platform to provide up-to-date 3D scenes in TXML-format. Meshmoon's SDK also allows access to the 3D scenes located in server. However, these scenes are not usable as-is for AR. Some work is going to be needed for authoring the 3D scenes for OnSite (or outdoor AR generally). Also some other options are examined, like Trimble's SketchUp, as an authoring tool for AR and/or 3D scene provider.

5.3.3 Augmented reality

Urban scene analysis is also critical in AR applications and urban reconstruction practices. For instance, Bredif et.al published TerraMobilita/iQmulus 3D urban analysis benchmark to evaluate the current state of the art in urban scene analysis from mobile laser scanning (Bredif, 2014). In this study a very detailed semantic tree for urban scenes is proposed. Another interesting study was reported by Zhao et.al in which an approach that parses registered images captured at ground level into architectural units for large-scale city modeling (Zhao, 2010). This technique is a baseline for AR applications in C³PO Project.

Since people can access location-based information anywhere and at any time by using mobile devices (such as smartphones), Augmented Reality (AR) applications have come to foreground as a new interaction modality. The location or scene information is commonly presented using a spatial representation, such as 2D or 3D maps or directly by images like

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panoramic or normal views. In this sense, AR technologies and approaches can be divided in two basic groups: marker-based systems and marker-less systems. Kan et al. (Kan, 2011) explains marker-based systems by use of specific marker for 3D tracking and positioning which is employed to identify the corresponding virtual object and its location and position in the real-world environment. The second approach, marker-less solutions, means that marker-less pose trackers mostly rely on natural feature points which are visible in the user's environment. Performance of marker-less approaches is highly dependent to the features used to register scenes and scene recognition methods. Such methods require fast computation time, robustness with respect to changing lighting conditions and image blurring, robustness against observation from different viewing angles, and scale invariance or changing viewing distance (Herling, 2011). A way to release the performance challenges is to have tracking initialization performed interactively by the user, based on some known landmark or such, before switching to automatic feature based tracking by the AR system (Woodward, 2011).

Use of AR in urban planning is one of the most attractive ways of increasing public participation and awareness. As Allen et al. (2011) proved AR-based interaction solutions are great way to increase public participation in urban planning processes. Olsson et al. (2012) describe use cases where mobile AR was successively employed in decision making process by two city planning committees in Finland. By using such interactive tools citizens can view the available 3D models and vote for the models according to their personal preference. One of the primary solutions for AR illustrating the potential of enhancing real life images in real-time for exploration of the urban environment is the Touring Machine (Feiner, 1997). Touring Machine simply displays information overlay on camera images which is the widely accepted method in today's applications (Gotow, 2010), (Schmalstieg, 2011). Another interesting approach is known as the HYDROSYS framework which is based on the AR visualization for environmental geographic information (Nurmine, 2010), providing a method to combine measurements and simulation data with geographic information.

Although a wide range of AR applications for urban planning exist, three forthcoming systems influence the novel approaches: Tinmith-Metro, Urban Sketcher and Vidente. In the Tinmith-Metro mobile AR platform was developed to visualize the effects of any modifications or renovations made in a building over its surroundings (Piekarski, 2001). This system provides participation of and interaction with the user but it is not designed to allow for a degree of realism suitable for a general, public audience and requires substantial instrumentation of the user. Urban Sketcher was developed within IPCity research Project in order to "encourage and improve communication on urban design among stakeholders. (Sareika & Schmalstieg, 2007)" Urban Sketcher can directly attract users since it may alter the real scene by sketching 2D images which are then applied to the 3D surfaces of the augmented scene. This application presents an effective public participation, however substantial instrumentation of the environment is not sufficient. The third system, Vidente was developed as a mobile AR system replacing traditional printed plans with electronic plans augmented with real world scenes. Vidente utilizes features and abstract attributes of a geographic information system (GIS) which are transcoded into 3D scenes via a multi-stage pipeline (Schall et al., 2009). Vidente presents high quality visualization. But as the visualization quality increases, the complexity increases, too, causing run-time problems like pauses.

Beyond these solutions, the studies of Heuveline et.al address the AR for urban simulation visualization in Karlsruhe, Germany in order to investigate effects of urban wind flow on building heating (Heuveline, 2011). Tatzgern et.al presented an overview of techniques

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allowing the exploration of large real World objects (Tatzgern et al, 2015). Carozza et.al (2014) proposed a markerless AR application which is based on monocular vision and does not rely on beacon-based localization technologies (like GPS) or inertial sensors. A recent case study is demonstrated in Vienna where an AR and web 2.0 applications are experimented in participative traffic planning processes (Reinwald et al., 2014). 3D scene understanding is another key topic in 3D AR applications. For instance, a principled generative model of 3D urban scenes was proposed by Geiger et.al which takes into account dependencies between static and dynamic features of traffic situations at intersecting roads (Geiger, 2011). A very recent whitepaper overviews (Perey et al., 2014) how AR-assisted 3D visualization can be used to cost-effectively address diverse needs of professionals performing routine and emergency tasks in urban environments. This whitepaper presents future scenarios of simple use cases that can be applied to urban design and planning. One can find very useful information about handheld AR, data sources, sample projects, links and more at http://studierstube.icg.tugraz.at/handheld_ar/cityofsights.php. A very recent study accessible in this site presents the design and implementation of a physical and virtual model of an imaginary urban scene, namely the “City of Sights” – that can serve as a backdrop or “stage” for a variety of AR research (Gruber, 2010).

Note that, 3D AR applications, no matter what the interaction tool is used, AR glasses, tablets, smartphones or head-mounted displays, attract people to participate in urban planning processes. However, the designer should consider practical issues in order to keep users attention. The applications should not preclude users from real world scenes and keep the attention long with reasonable concentration. Selection of the interfacing device is also critical. For a wider acceptance, the prices of AR devices should be at an acceptable level. Since they are widely used, smart phones and tablets can be good alternatives to AR glasses or Head-mounted devices. Moreover, when dealing with 3D, the AR applications should take into account the computing power and memory usage effectively. In C³PO, the 3D AR and visualization applications should take care of the abovementioned factors for ease of use and better acceptance.

5.3.4 List of existing tools

- Indoor Augmented Reality Software Tool (BAH): BAH has developed an indoor AR application for Android Tablets and demonstrated in Dolmabahce Palace Museum. This tool is developed in an abstract way which can easily be adapted to different scenes and contents if data is provided in sufficient amount and quality by the data owner.
- ARKINECT (ERARGE): With the support of BAH, ERARGE has developed an AR tool that can utilize a Kinect Sensor. ARKINECT can be used for body therapy especially for people with diseases like Parkinson, etc.
- 3D Visualization Tool (BAH): BAH developed a 3D visualization tool that can operate fast enough even in conditions with low computation and storage power. This tool has been experimented in historical sites, like Dolmabahce Palace, on touch screen devices.
- 3D Modelling and Reconstruction Software (ERARGE): ERARGE has a set of utility tools that can acquire 3D point cloud, extract mesh data and enable image wrapping by using Leica’s 3D Acquisition Hardware.

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- ERARGLASS™ (ERARGE)-Augmented Reality Glass and Software: ERARGE, has a set of utility codes that can convert CAD drawings to 3D mesh data, pose estimation and visualization tools for Android platforms. ERARGLASS may work with well-known AR glasses like META Pro.
- Planet 3D is a built-in extension to the Netcad Planet module. It is used to visualize the plans in 3D by:
 - generating object details (textures, etc.)
 - processing / reflecting elevation data on existing objects
 - simulating functional areas according to the plan.
- ALVAR SDK (VTT). ALVAR is leading 3D Tracking Mika Hakkarainen (VTT): SDK developed by VTT. A marker based Windows version of ALVAR was open sourced in 2012, while current development is done on the commercial libraries ALVAR Mobile (marker based) and ALVAR Tracker (markerless).
- AROnSite (VTT). AROnSite is VTT's mobile AR application dedicated for architectural visualization, supporting various data formats (e.g. BIM, Collada etc.), tracking modes (e.g. feature based) and lighting controls (e.g. light direction, intensity).
- DigiSpaces (VTT). The DigiSpaces application enables various indoor building maintenance services, based on aligning the BIM model with point clouds of the real environment.

5.4 Urban planning and simulation tools and practices

5.4.1 Urban planning

Brief information on Netcad's urban planning solution Planet and its 3D extension Planet 3D has been given in sub-sections 5.1.6 and 5.3.4 and current practices in Turkey has been summarized in sub-section 3.1. Planet can be considered a de-facto in Turkey considering its current coverage (over 85%).

There are other major CAD or GIS based solutions for urban planning, both licensed and free, some of which are:

- Esri's Urban and Regional Planning Tools:
<http://www.esri.com/industries/urban-planning>
- Autodesk's Land Development tools:
<http://www.autodesk.com/industry/civil-infrastructure/land-development-planning>

5.4.2 Traffic modelling

Traffic has always been a problem in city life as it affects even millions of people everyday and the cost of lost time, energy, pollution and life quality cannot be estimated. So, traffic modelling is one of the most crucial sub-topics of urban planning and there has been a great attempt to develop models aiming to optimize multimodal transportation by taking into account the pedestrian behaviours. The following topics reflect the current novel trends in

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traffic modelling which are planned to be discussed throughout the project C³PO.

Traffic Modelling and Chaos

Over the last decades, traffic jams have attracted the interest of many researchers in the field of statistical physics (Chowdhury, 2000), (Orosz et al., 2010). Traffic jams have been studied via several traffic flow models, such as the optimal velocity model without any delay and with a driver's delay (Bando, 1998), (Orosz & Stepan, 2006), the intelligent driver model (Treiber et al., 2000), the full velocity difference model (Jiang et al., 2001), the extended optimal velocity model with the next-nearest-neighbor interaction (Jin et al., 2011), and three-phase traffic flow model (Kerner & Klenov, 2009). In these studies, the stability conditions of the uniform traffic flow have been derived. The uniform traffic flow is described as such a state that the equidistant vehicles move at the same constant velocity. When the stability conditions meet, everything goes well and free flow appears. However, as usual in real life conditions, the traffic flow is metastable or unstable. In such cases, the traditional approaches may not work well.

Due to various reasons, such as traffic accidents, lane reductions and on-ramps, traffic might be influenced negatively. In order to suppress the traffic congestion in an optimal velocity traffic model without any driver's delay taken into account, a delayed-feedback control of both displacement and velocity differences is proposed by Jin and Hu (Jin & Hu, 2013). Although this approach presents promising results, the proposed delayed-feedback control is valid in a more wide range of control parameters. Because the delay-independent stability criteria are known to be rather conservative and the feasible ranges of both feedback gains and time delay are relatively narrow. This drawback narrows the implementation of the proposed model in very complex situations where the traffic has a chaotic structure.

In recent years, methods based on chaos theory have come to ground. For instance, Suzuki et.al proposed a chaotic Ising-like dynamic signal analysis model where the green and red lights of a traffic signal can be viewed as the up and down states of an Ising span (Suzuki et al., 2013). One can control the traffic signals in decentralised way where the signals interact with each other. Here, the idea is to model such interacting signals on a finite-size two dimensional lattice having Ising-like Dynamics that undergoes a ferromagnetic phase transition. The behaviour of traffic signalization can be accepted as probabilistic and the model can be realized by chaotic billiard Dynamics that arises from coupled non-chaotic elements. This technique was experimented in Kyoto city in Japan and promising results were obtained.

In line with chaotic approaches, Aihara et. al proposed to utilize the optimal "on-off" laws for traffic signals which are based on the bilinear control problem with the binary constraints (Aihara, 2013). They proposed a Lyapunov function based feedback law for regulating traffic congestions. They also concentrated on a real-time optimal signal law which is based on novel binary optimizations. The results were tested in Tokyo traffic and very effective recommendations for traffic signalizations were presented.

Existing tool

Chaos™ (ERARGE): This software is based on nonlinear dynamics which have been applied to model probabilistic behaviours of time-varying events. This model has been realised by chaotic billiard dynamics that arises naturally from non-chaotic elements. The tool is developed as a JAVA API and can be adapted to web-based applications. However, it is

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recommended to use this tool in offline applications as it deals with big amount of data and applies complex algorithms.

Visual and Multimodal Traffic Modelling

Modern traffic is usually characterized by a mixture of vehicles and pedestrians, called multimodal traffic. Most of the studies are based on the interactions between different transportation modes. Among the foremost studies, Jiang & Wu (2006) studied the interaction between vehicles and pedestrians in narrow channel numerically (Jiang & Wu, 2006). Cheng et al. (2008) and Yao et al. (2009) proposed models to simulate conflicts in vehicle-bicycle traffic flow (Cheng, 2008; Yao et al., 2009; Ma et al., 2011) adopted an extended finite-grid cellular automaton model to study the dynamic features of pedestrian-vehicle conflicts (Ma et al., 2011). Nearly all studies on pedestrians and vehicles show that traffic flow at a certain critical value of density is unstable and transits from free flow to jammed flow. A comprehensive analysis of state-of-the-art can be seen in (Bellomo, 2011) and (Bellomo, 2014).

The recent studies on visual traffic modelling have shifted from high-resolution estimation of vehicle state and instead, and focused on extracting patterns through unsupervised machine learning (Morris, 2013). Majority of the studies usually focus on low-level analysis of vehicle tracking but holistic approaches covering the behavioral analysis of streaming entities is less addressed (Tian et al., 2011), (Buch, 2011).

There exist too many research studies that model traffic by analysing video input acquired from surveillance cameras. These studies can be divided into two main clusters: (1) trajectory clustering and (2) topic modeling. In trajectory clustering moving objects, such as vehicles and even pedestrians, are observed over a long training phase. The training trajectories are then clustered into groups of similar trajectories. Note that clustered trajectories from prototypical patterns of motion. Among the widely used techniques in trajectory clustering are probability trees, adaptive route envelope model, Hidden Markov Models, Neural networks and Gaussian chains (Morris, 2013).

In topic modelling, traffic data is accepted as a mixture of various topics, like done in language modeling, and each word in the document is generated from a single topic. Note that the topic models are able to recognize relationships through the co-occurrence of simple features at different hierarchical levels. The existing methods usually apply probabilistic latent semantic analysis (pLSA), latent Dirichlet allocation (LDA) and Dirichlet process mixture model (DPMM) over optical flows or trajectory data (Buch, 2011).

When compared with trajectory clustering, techniques based on topic modelling are becoming widespread as they are less complex, require low computation power and less dependent on robust tracking of vehicles which is sensitive noise, lighting conditions, shadows, occlusion and pose variance. However, when applied properly and the environmental conditions are under control up to some extent, trajectory clustering may give more accurate results.

Existing tools

- Motion and Crowd Analysis Software (BAH): This tool can extract flow data, including the type of objects either vehicle, person, or else, from street cameras. The tool Works on raw MPEG videos and apply short-time invariant features, optical flows and object recognition techniques to identify the moving vehicles and

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pedestrians. The tool is developed in Visual C++ and has a standalone API that can be adapted to other applications.

- Supplementary tools (ERARGE): ERARGE has a supplementary tool that can acquire online Yandex traffic data as a JavaScript application. Moreover, Bootstrap and ChaosTM is also be used to analyze traffic flow data.

Bootstrap

Bootstrap is the process of taking repeated subsamples from a larger sample (with or without replacement) and calculating the statistic of importance based on this subsample. By applying bootstrap, subsample distribution is then used to infer information about the population as a whole. Bootstrap has been applied in various fields. The foremost studies about its application on traffic modelling have come to ground especially in the last decade. For instance, Rilett et al. used the technique to estimate the variance of freeway travel time forecasts derived from an artificial neural network (Rilett et al., 1999). Brundell-Freij focused on complex transport models by applying both Monte Carlo simulation and bootstrap techniques to show how different kinds of variation in the input data affect the quality of the final model estimates (Brundell-Freij, 2000).

In traffic modelling the bootstrap technique can be utilized to obtain estimates of the transportation mode share confidence intervals from a limited number of surveys (Wood, 2004). This technique is useful as it only counts the traffic entering the city center and extracts confidence interval, or estimated traffic, in terms of confidence interval on a limited number of observations. These observations referring to different regions of the city are then combined to obtain a general city traffic model. For instance, according to the additional surveys which were conducted in Leeds City Center in May 2004, more reliable adjustments were applied to traffic signals after a four-day Monte Carlo simulation rather than the one usual day.

Existing tool

Bootstrapping Tool (ERARGE): This tool is based on the substitution and simulation principle using the already acquired data and create “new” data and recalculate an estimate (Zoubir & Iskander, 2004). This tool works on any kind of numerical data, like traffic flow or energy consumption, to approximate measures of an estimator such as its distribution function. The developed tool is designed for offline analyses but it can be adapted to online applications as well. The tool can be facilitated as a JAVA API.

Other tools available on Internet

The traffic modelling studies usually rely on GIS-based (Geographic Information System) systems that have been designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. Yandex Maps, Bing Maps and Google Maps are mapping applications on the web open to public access to traffic data. The existing APIs benefit from the cooperative communication between vehicles, which is well known as Vehicular Ad hoc Network (VANET) (http://en.wikipedia.org/wiki/Vehicular_ad_hoc_network).

Majority of the traffic monitoring applications utilize OpenStreetMap (www.openstreetmap.org/), which is a collaborative project to create a free editable world map. Many traffic simulation systems exist. Two of the best known systems are MATSIM

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(MATSim, 2007) and VISSIM (Fellendorf, 1994). MATSIM models cars with queuing theory and thus is suitable for large scale simulations. Contrarily, VISSIM models cars with a high-fidelity model and thus suitable for highly realistic studies for micro simulations. There exist open source applications filling this gap such as SUMO (Simulation of Urban MObility http://www.dlr.de/ts/en/desktopdefault.aspx/tabid-9883/16931_read-41000/) which facilitates OpenStreetMap. Although it presents advantages SUMO is not capable of the simulation of multimodal traffic, because of the lack of microscopic simulation models for bicycles and pedestrians. To cover multimodality, MAINSIM is introduced as an effective simulation tool (Dallmeyer, 2013).

6 Business models for city co-design solutions

In this section, we describe the first round of reviewing C³PO platform potential competitors and its business opportunities.

6.1 Mapping the competitors of the C³PO platform

C³PO being a collaborative city co-design platform combines in one at least three different functions demanded by Internet of Things. Thus, the platform competitors could be classified in accordance to its different functions and different combinations of these functions in urban development context in particular:

1. City data access, acquisition, transformation, analysis, management and integration (data integrators of different levels)
2. Applications development support and dissemination (IoT platforms, software development platforms)
3. Enabling user (stakeholder) involvement, participation and city co-design (Collaborative platforms, crowdsourcing instruments and tools for co-design)

In the table below, we discuss six examples of potential competitors of C³PO platform in respect to different platform functions and combinations of these functions. We look at the data integrators - bigger scale with very generic area of application as *Oracle* is, and smaller scale companies as *Schneider-electric* focused more specifically on data management of urban infrastructure to serve the needs of municipalities and private companies-utilities. *Mtuity* is another example of company that provides services of city data integration, analytics and visualization. **The advantages** of such data integrators compared to C³PO are well-developed concepts, access to large-scale databases, and high level of customization, while among disadvantages are complexity of solutions, which increases its price, and limited coverage of co-design tasks.

Since C³PO provides a basis for different city co-design applications, platforms supporting app development and dissemination specifically in the area of smart city development (as *ThingWorx* acquired by PTC in 2015 offers) also appear to be C³PO's competition. Such big-scale platform in addition to support of app development and its marketing, consulting, training and business model development provides its clients an access to extensive network or ecosystem for search for System Integrator/Network Provider Partner, which in turn is a very valuable offer especially for small and young enterprises. However, apart being a network, marketplace and base for app development *ThingWorx* itself does not acquire and process city data and does not have a specific focus towards city co-design. It is a large-scale extensive network working as a matching tool.

Another group of C³PO competitors includes different kinds of tools separately for city design and collaborative tools, as well as tools allowing combinations of these tasks. *SpaceSyntax* and *Sito* are examples of companies providing software, services, research and consulting in urban space planning and design, but these solutions are mainly targeting experts and often are missing involvement, collaboration and communication of different groups of city stakeholders, even though the companies acknowledge the growing role of participatory design.

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Examples of C³PO platform competitors

Company / Brand name	Value proposition: main products and services	Target clients	Business model / Main revenue streams	Advantages compared to C ³ PO	Disadvantages compared to C ³ PO
1. Oracle	<u>Smart City Platform</u> - modular solution set for transformation consolidating IT infrastructures, support current and future systems, and improve service delivery.	Public sector: local government	Software and services supply contracts (by Named User plus or Central Processing Units), licensing, consulting.	*Strong analytics *Access to global data bases *Compatibility with other Oracle products commonly used by many organizations	*Price *Complexity and high dependency on other related IT infrastructure to be supported by Oracle
2. Schneider-electric	<u>Software solutions</u> for data integration, analysis and management	Public and private sector: cities, municipalities, and private companies-utilities	Software and services supply contracts	*High degree of localisation and customization *Ready to use solutions, no additional apps involvement	*Missing citizen involvement, lack of complex stakeholder involvement *Fragmented solutions, focused exclusively on city infrastructure, not on design
3. Mtuity	Provider of Atlantis - an <u>IoT software platform</u> . Main functions to help in managing smart communities, analyzing data and sharing information with the citizens and businesses.	Public and private sectors: citizens, businesses.	Collaborative complex business model involving ecosystem and selling access to it, training and consulting in software development	*Strong partnership	*Missing citizen involvement, lack of complex stakeholder involvement *Lack of access to various local data sources and complex data integration
4. ThingWorx (Acquired by PTC in 2015)	<u>Purpose-built IoT platform</u> : connects multiple systems, supports developing new	Software developers, system	Collaborative complex business model involving	*Extensive network *Marketing and selling opportunities for apps	*Price *Lack of exclusive focus towards smart city development

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Company / Brand name	Value proposition: main products and services	Target clients	Business model / Main revenue streams	Advantages compared to C ³ PO	Disadvantages compared to C ³ PO
	applications, has a market place to advertise the solutions, access to ThingWorx Ecosystem for search for System Integrator/Network Provider Partner	integrators, mobile network operators	ecosystem and selling access to it, training and consulting in software development	developers *Business strategy development and consulting *Training in software development	*Lack of access to various local data sources and complex data integration
5. SpaceSyntax	<u>Software solutions</u> for space planning, <u>design and visualisation</u> of urban planning (incl. simulation and modelling), <u>training, research and consulting</u>	Public and private sector in urban planning and development, architecture and design	Software supply and design services contracts, licencing, consulting, training	*Scientific-based solutions estimating value and costs of urban development policies, strategies, plans, and designs * Links geographical data to economic issues (land value, rental income, safety, etc.)	*Simulation requires additional developments due to data limitations (access, accuracy) *Missing collaboration between stakeholders, disregard emotions or symbolic variables *Lack of 3D visualisation - only experts clearly understand solutions
6. Ontopica	<u>Software tools and services for e-participation</u> of citizens and also employees within organization	Public and private sector: cities, municipalities, state institutions of development, private firms of different sectors	Software and services design and supply, consulting, training, advising, concept development, monitoring, PR	*Big variety of communication and collaboration tools *High level of customization when it comes to collaborative tasks	*Missing big city data acquisition and processing *Exclusive focus on e-participation, doesn't cover the whole cycle of collaborative city design

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At the same time, German company *Ontopica* offers variety of tools for e-participation also for city development, but here solutions are mainly limited only to involvement and collaboration and do not include data processing.

A number of platforms allowing city data gathering and stakeholders’ involvement exist nowadays, but they serve as C³PO potential partners rather than competitors. Among them are, for example *OpenCities platform* (<http://opencities.upf.edu/web/index.php/en/>) working as a catalogue of open city data and collecting static and dynamic data, *AmsterdamOpenData* (<http://www.amsterdamopendata.nl/web/guest/home>) collecting and providing open city data, and *WheelMap* (<http://community.wheelmap.org/en/>) allowing development of the city to make it more friendly for disabled people.

In the next section, we review business models relevant for C³PO based on this overview of different potential C³PO competitors and also on their business models.

6.2 C³PO ownership model and data storage

For the complex solutions as C³PO platform the optimal choice of the platform ownership model and decision on data storage (local vs. cloud data storage) are essential for the further business development. The C³PO project consortium has initially narrowed the potential options of ownership and related business model down to four:

1. Industry standard, which is jointly developed with, and accepted by all the major companies in the industry;
2. Open source;
3. Owned by a consortium partner with a local data storage;
4. Owned by a consortium partner without local data storage (cloud).

To assist the consortium in these decisions an in-depth research was carried out by the team of students from Lappeenranta University of Technology. In addition to extensive literature review on the topic three semi-structured interviews were conducted with the managers of three different Finland-based organizations working in the field, particularly: Invenco (data storage and data analytics services), FCG City Portal (the owner and developer of MAPGETS platform) and The Six City Strategy (6Aika - is a co-operation of six Finnish cities (Helsinki, Espoo, Vantaa, Tampere, Turku and Oulu) to tackle common challenges by involving the whole urban community and creating structure to open data, participation and innovation).

The results of this small scale study reveal the key benefits and challenges of each of the options. Those are summarized in the following table.

Comparison of the four platform ownership models

Ownership model	Benefits	Challenges
1. Industry standard	1. Positive impact on interoperability & standardization → easier integration of different	1. Time consuming to achieve 2. Standardization might result into market monopolization 3. Might negatively affect the speed

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Ownership model	Benefits	Challenges
	systems 2. Favourable position to become an industry platform leader	of product development & poorly impact competitiveness in case of new innovative entrants 4. In case of shared ownership model a challenge of ownership distribution arises
2. Open source	1. Potential to be quick & inexpensive 2. Transparency (of also a public sector) 3. Community oriented, simultaneous value co-creation for multiple stakeholders 4. An alternative to software piracy 5. Option of licenses on code modification	1. Diverse quality of code provided by different developers 2. Different control mechanisms have to be implemented to enhance reliability & compatibility of the code
3. Owned by a consortium partner with a local data storage	1. Quick data access 2. High level of data security	1. Costly 2. Scalability
4. Owned by a consortium partner without local data storage	1. Scalability 2. Accessibility of data 3. Cost efficient	1. Security 2. Clients' perception of the cloud data storage

Industry standard did not gain significant support by the interviewees. Some of the interviewed specialists even assumes that industry standard could hinder the technological development and might monopolize the business. Instead of that, the standardization of data formats was proposed to improve interoperability and opportunities for integration. Open source ownership model was the most supported model within the interviewed parties and also within the literature analysed. Therefore, the research suggests that open source is the optimal starting point for C³PO. This type of ownership is further elaborated in the following paragraphs.

Open source software (OSS) development projects have been widely applied. In the core of Open source (OS) is a model of open, shared software development. As was studied by

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Weerawarana and Weeratunge (2004) OSS enables to create value and new business opportunities for private firms, reduce costs of IT investments for both private and public sectors along with strengthening efficiency and effectiveness of the government. Today, solid part of the Internet Infrastructure is based on OS phenomenon. Among it is Linux which greatly influenced operating systems market and still remains profitable under its business model. Other examples, which are using OS distribution model, are Sendmail, BIND and Apache HTTPD Server Project. Original software was developed by an individual or a group of people in one location but became accessible worldwide enabling customization and localization of the systems before deployment. Readily available OS made the process easier and faster.

Shaikh (2016) mentioned adoption of OS in the UK and Finnish public sector - an interesting example from the Joinup project carried out by the European Commission. Joinup is a collaborative platform, which allows access to various cases of OS adoption across Europe to facilitate sharing of experience on e-Government. Among examples of particular services are software for e-government services, online education, library systems and electronic invoicing.

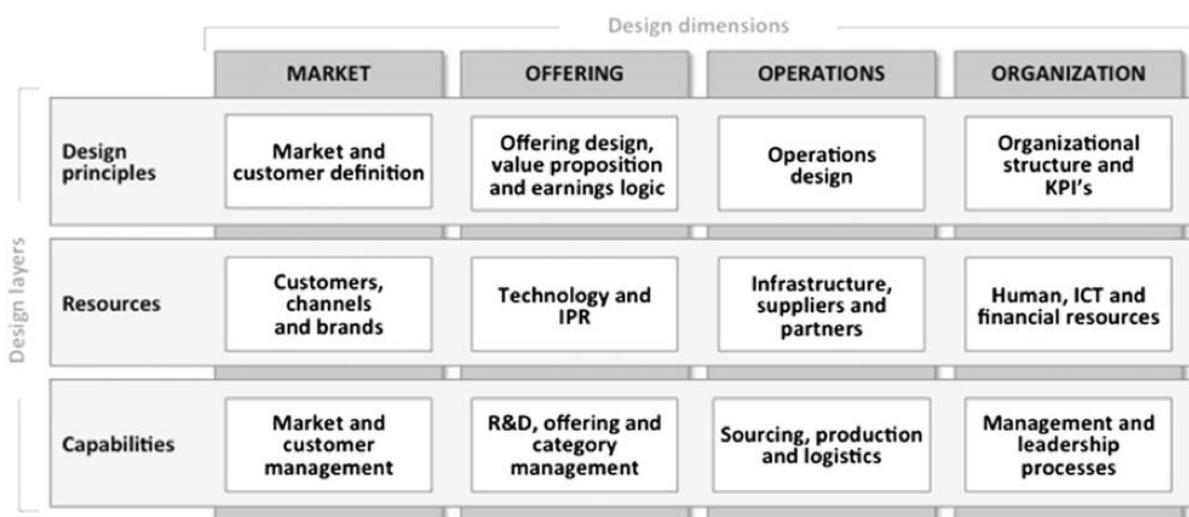
In contrast to proprietary software (for example iTunes developed by Apple), where a customer has to agree to terms and conditions of the end-user license agreement and is not allowed to modify or distribute software for free. The main element of open source software is freedom. By principle of OS, any person can participate in a software project. However, certain control mechanisms must be implemented. The extent to which a participant may influence OS project may be dependent on the history of participants, their previous activity and contribution. Control and direction setting authority is essential to consider as OSS development projects are highly dependent on the quality of developers' community. Licenses can still be used in OSS. There is a wide range of licenses: some may restrict open modification of the code (i.e. GPL or BSD licenses) (Bonaccorsi & Rossi, 2003), but generally license gives a permission to modify software and share it with others. It may also allow a user to sell modified software under specified conditions.

Weerawarana and Weeratunge (2004) examined the area of business models applied in OSS projects. Usually business models are built around technical support and integration services, add on products, periodic subscriptions, updates (functional and fixed) as well as custom software development contracts. Therefore, for C³PO business related services are seen as a key revenue stream.

Other findings of the research shed a light on the increasing importance of cloud for data storing. Cloud is one of the distinct features and competitive advantage of C³PO. The best option of data storage varies from case to case, however, the general trend is still towards a cloud storage. One of the key reasons for shifting towards cloud are lower costs of such a service compared to local data storage. Certain customers might be resistant to move their data into cloud portraying cloud as unsecure, even though the security of cloud is improving with popularization and improvement of data encryption. Considering the constant improvement of cloud security, the challenge remains not in choosing a safer storage place but in influencing the customers' perception of the cloud storage. Cloud brings multiple benefits by enabling data accessibility and scalability of the platform.

6.3 C³PO business model canvas

Designing a business model even for traditional goods and services requires going through different dimensions of the market and value propositions which take into account the actual company resources and capabilities. Thus, while discussing business model design, Storbacka et al., (2012) suggests looking at four design dimensions (market, offering, operations and organizations) as well as at three design layers (design principles, resources, capabilities) - see figure below.



A Framework for Business Model Design (Storbacka et al., 2012)

Considering its relevance to the project, this matrix should be taken into consideration while developing an ICT tool as C³PO platform, as it requires elaboration and detalization of planned actions for running a healthy business.

We extend the level of analysis, to Business Model Canvas developed by Osterwalder et al. (2010) for more generic level business model design (see business model canvas developed for C³PO below.)

The most crucial sections to explore at this stage, are value propositions (what C³PO is offering), customer segments (who is going to pay for it) and revenue streams (modes of revenue), that is why we are focusing in more details on these three aspects.

C³PO creates values for the different main actors involved in the C³PO ecosystem (see table below). These actors comprise (1) ICT companies, (2) cities and citizens that represent the main stakeholders as well as (3) data providers.

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C³PO stakeholders and value propositions

Actor	Final business value
Cities	<p>Improved decision making process: reducing cost and duration of the decision process: resource planning and decision-making process can be managed more effectively since C³PO offers the opportunity to involve stakeholders earlier. The provided support covers the whole co-design process and shortens the communication channels between all stakeholders during the process.</p> <p>Mitigated urban development risk through better planning and prediction: enabling cities to reach intended outcomes and to cost-effectively manage future initiatives.</p> <p>Improved legislative background: enabling governments to revise civilian laws regulating the life in cities (i.e. the respect of specific quality of life standards, eGovernment processes, mitigation plans in case of natural disasters in relation with citizens' daily life).</p>
Citizens	<p>Living environment and sense of belonging to their city: C³PO allows citizens to participate to city's decision making process (participative applications) and get actively involved in brainstorming about and problem solving of conflicting interests.</p> <p>New ways for citizens to co-participate in the development of their place to live and work.</p>
ICT companies	<p>New business opportunities: C³PO enhances value and innovation by enabling new applications based on multi-domain collaborations: vertical integration, as well as applications exploiting smooth and efficient data exchange between multi-domain stakeholders. C³PO foresees to expand existing markets to companies, as well as opening the city development market for technologies/processes used in other use cases.</p> <p>Enhancing the application value to current customers: accessing to a higher amount of data / support of more business processes compared to the current use.</p>
Data providers	<p>Data are necessary enablers of the C³PO solution. Cities and utility providers (e.g., large industrials ensuring the city infrastructure - e.g. energy, water, transport, etc.) collect data and can make their data assets available to C³PO.</p>

At the current stage of C³PO platform development a set of value propositions include:

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- City data integration from different sources (including open data and data provided through partnerships with municipalities, land use planners, state agencies, business owners, etc.)
- City data analysis and visualisation (including 3D modelling and applications integration)
- Simulation (of different city process and design options)
- Interaction between all the stakeholders (using variety of communication channels and tools)
- Co-creation involving all the stakeholders (interactive map-based solutions providing a room for multi-dimensional feedback processing)
- New business creation opportunities.

The C³PO customer segments include various groups of stakeholders. Among the main are municipalities and authorities (as well as other public sector entities) interested in city development, optimizing the city costs and creating value for citizens. The main value proposition for them is a ready to use solution for city design and development, which involves acquisition and processing of citizens feedback and meets particular city developers functional and user-interface requirements. The second potential customer segment is data integrators for which C³PO could serve as a tool for data access, processing and integration. Another potential customer group includes private constructing companies, architects and other types of city developers and utilities also demanding a ready to use solution for city design and planning, which would provide them with all the required information including city authorities plans, land use regulations and restrictions. Powerful visualization tools should serve the needs of consulting companies especially operating with clients in the fields of engineering, construction, architecture. Application developers could win from working with C³PO in access to the integrated data as well as potential marketing possibilities.

Possible revenue streams include customized subscriptions and contracts on platform access, customized service packages (separately data integration, analysis, visualization, simulation or various combinations of these services).



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C³PO Business Model Canvas

<p>KEY PARTNERS</p> <ul style="list-style-type: none"> Municipalities Land use planners Authorities (local, regional) Government agencies (environment, energy, etc.) Applications' developers City developers (architects, engineering & constructing companies) Utility & Public transportation companies Investors Land and real estate owners Associations, community based groups 	<p>KEY ACTIVITIES</p> <ul style="list-style-type: none"> Data integration from different sources Data transformation Additional services: Marketplace, Developer community, Access to third-party applications, eco-system development 	<p>VALUE PROPOSITIONS</p> <ul style="list-style-type: none"> Data integration from different sources Data analysis and visualization Simulation Interaction between all the stakeholders Co-creation involving all the stakeholders New business creation opportunities 	<p>CUSTOMER RELATIONSHIPS</p> <ul style="list-style-type: none"> Long-term contracts Subscription B2B customers 	<p>CUSTOMER SEGMENTS</p> <ul style="list-style-type: none"> Municipalities (leiedal.be) Authorities (local, regional, state) Big city data integrators (e.g. Schneider-electric, Oracle) Constructing companies Architects Consulting companies (engineering, construction, architects) Application developers
	<p>KEY RESOURCES</p> <ul style="list-style-type: none"> IT infrastructure IPR Platform architecture Software developers 		<p>CHANNELS</p> <ul style="list-style-type: none"> Big events on smart cities and software solutions Local developers meetings Presentations targeting particular client 	
<p>COST STRUCTURE</p> <ul style="list-style-type: none"> Platform hosting and maintenance Data access Software development Consulting services IPR 			<p>REVENUE STREAMS</p> <ul style="list-style-type: none"> Business related services: consulting, planning, production, support services Customized subscriptions Customized service packages (data integration, analysis, visualization, simulation) Platform access contracts (e.g. for applications development) 	

6.4 Business model for connected products as smart city development platforms

Development of Internet of Things, collaborative tools and growing power of networks result in a dramatic changes and business model innovations both in value creation and value capture (see figure below). Developers of new generation solutions or connected products, which imply involvement of different stakeholders, continuous and real-time data collection and simultaneous value creation (as C³PO is), should no longer serve only current customer needs, but be proactive and predict customer needs, preferences and problems to serve them before competitors. Product and services need to be real time and over-air updated and developed through information coverage and data access, which in turn is enabled by extensive network. When it comes to value capture, making money in the world of connected products is no longer limited to physical sales of products or services, since other revenue streams appear after the initial product sale, including value-added services, subscriptions, and apps, which can easily exceed the initial purchase price (Hui, 2014).

How the Internet of Things Changes Business Models (Hui, 2014)

THE INTERNET OF THINGS REQUIRES A MINDSET SHIFT Because you'll create and capture value differently.			
		TRADITIONAL PRODUCT MINDSET	INTERNET OF THINGS MINDSET
VALUE CREATION	Customer needs	Solve for existing needs and lifestyle in a reactive manner	Address real-time and emergent needs in a predictive manner
	Offering	Stand alone product that becomes obsolete over time	Product refreshes through over-the-air updates and has synergy value
	Role of data	Single point data is used for future product requirements	Information convergence creates the experience for current products and enables services
VALUE CAPTURE	Path to profit	Sell the next product or device	Enable recurring revenue
	Control points	Potentially includes commodity advantages, IP ownership, & brand	Adds personalization and context; network effects between products
	Capability development	Leverage core competencies, existing resources & processes	Understand how other ecosystem partners make money

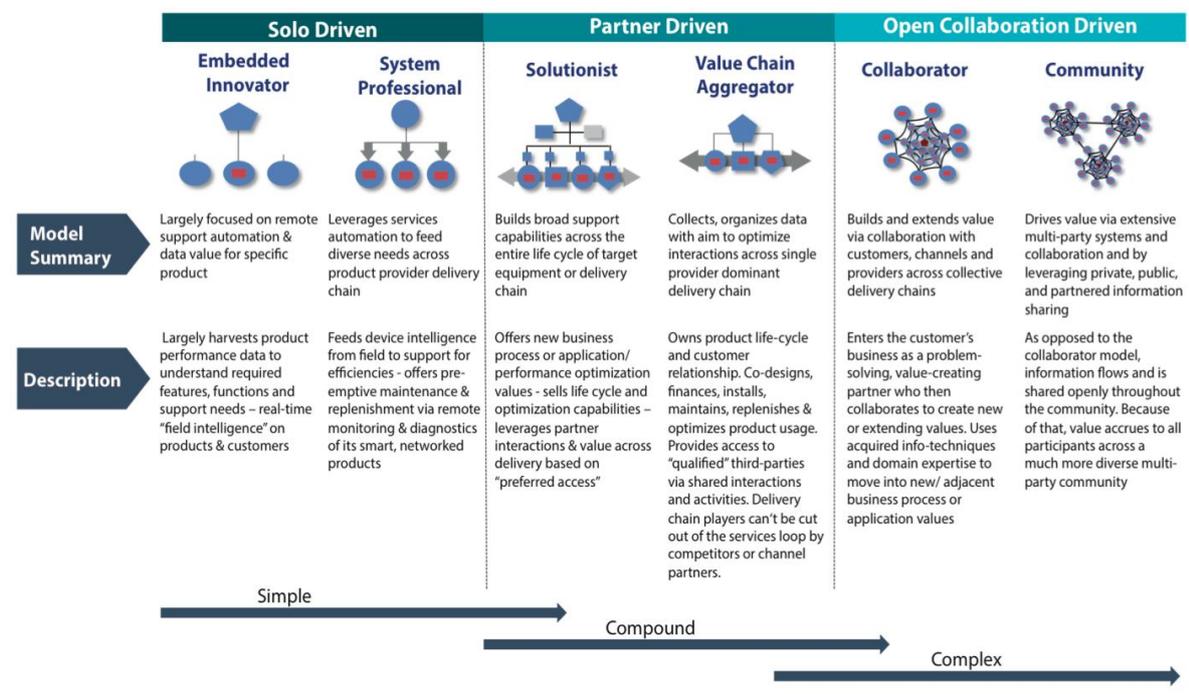
SOURCE SMART DESIGN

HBR.ORG

Harbor Research (2014) in respect to business model evolution describe three types of business models applied by modern smart system and service developers: solo driven (product lifecycle is designed in a way that it is to be driven by its developer alone), partner-

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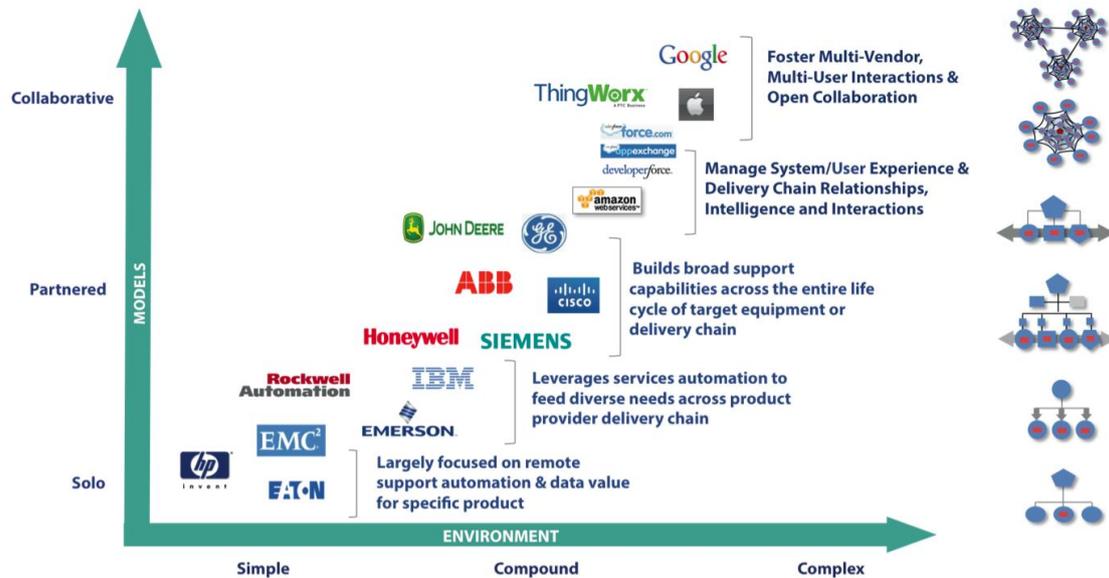
driven (closely collaborating partners create multi-level value) and open collaboration (extensive third-party collaborations and contributions) - see figure below. All these models and sub models described on the figure are applicable and allow value capturing, but selection of the most effective for certain product or service allows maximization of the value captured even if it is a great challenge to build the model itself. Each model is also addressing a certain type of environment perceived for particular value propositions. Solo models could work in a simple environment and do not require complex network building. Partner driven models are to be built in compound environment and require shared interactions and activities. Open collaboration driven models are to be built and to encourage a complex environment allowing multi-vendor and multi-user interactions.



Smart systems and services business models (Harbor Research, 2014)

Harbor Research illustrates a matrix of business models and environment to be built with particular companies examples (see figure below). As we can see, one of the potential indirect competitors of C³PO platform (ThingWorx) runs a collaborative business model involving a huge network of partners into continuous and open collaboration.

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Smart systems and services business models are progressive (Harbor Research, 2014)

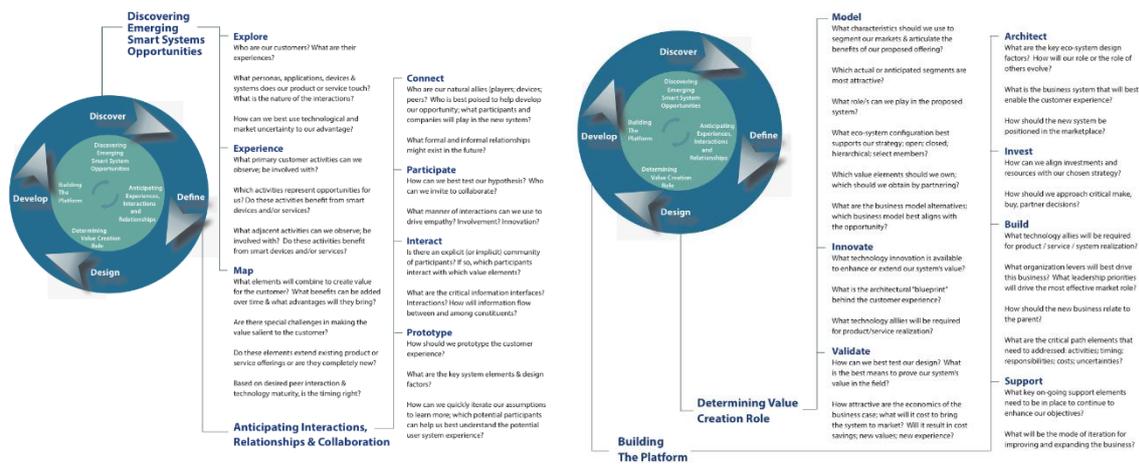
When it comes to business model development specifically for solutions and products oriented towards smart city creation and elaboration, this field is rapidly growing nowadays and still is very immature (Zanella & Vangelista, 2014). One of the works by Walravens & Ballon (2013) provides a comprehensive matrix as a tool for business model development specifically oriented on smart city solutions. This matrix lists a number of choices to be made in building a business model with an emphasis on control versus governance over the platform users, data, stakeholders involved, etc.

	Value network	Technical architecture	Financial architecture	Value proposition
Business design parameters	Control parameters		Value parameters	
	Control over assets	Modularity	Investment structure	User involvement
	Concentrated vs. distributed	Modular vs. integrated	Concentrated vs. distributed	Enabled, encouraged, dissuaded, or blocked
	Vertical integration	Distribution of intelligence	Revenue model	Intended value
	Integrated vs. disintegrated	Centralized vs. distributed	Direct vs. indirect	Price/quality Lock-in effects
	Control over customers	Interoperability	Revenue sharing	Positioning
	Direct vs. mediated Profile and identity management	Enabled, encouraged, dissuaded, or blocked	Yes or no	Complements vs. substitutes branding
Public design parameters	Governance parameters		Public value parameters	
	Good governance	Technology governance	ROPI	Public value creation
	Harmonizing existing policy goals BS regulation Accountability and trust	Inclusive vs/ exclusive Open vs. closed data	Expectations on financial returns Multiplier effects	Public value justification Market failure motivation
Policy goals	Stakeholder management	Public data ownership	Public partnership model	Public value evaluation
Organizational	Choices in (public) stakeholder involvement	Definition of conditions under which and with whom data is shared	PPP, PFI, PC...	Yes or no Public value testing

Matrix of business models for smart city solutions (Walravens & Ballon, 2013)

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Following the cycle given on the figure below, we continue exploring C³PO potential customers, their needs and experiences in parallel with solution development enabling continuous feedback gathering and validation of solutions during workshops and meetings with city developers and citizens in the trial cities. We focus on precise mapping of the value creation and capturing ensuring continuous interactions and collaborations between the partners in the consortium, collaborations across their own networks as well as interaction between citizens and city developers in trial cities through development and usage of collaborative tools.



Smart Systems Business Model Design Process (Harbor Research, 2014)

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7 Related projects

The next table presents some related European and national projects and their relevance with C³PO.

Examples of the related European and national projects and their relevance to C³PO

Project	Technical Focus	Relation to, and difference with C ³ PO
Smarticipate (2016 - 2019)	<p>Participants: London, Hamburg, Rome.</p> <p>The project is aimed at using open data to enable co-creation, giving citizens a possibility to shape their city.</p> <p>http://www.smarticipate.eu/platform/</p>	<p>The project is similar to C³PO as it involved in the creation of a web platform, which enables citizens to support decision making process on city development.</p>
Open Cities, People Smart Cities, Fireball (ongoing) - CIP, ICT PSP, FP7	<p>Validating and experimenting the open Innovation methodologies to the public sector in a scenario of future internet services for smart cities</p>	<p>Creating and managing smart urban ecosystems based on an open innovation approach</p> <p>Use and experimentation of Open APIs provided by cities and governments</p> <p>C³PO can benefit from the experience and the different experiments</p>
Digital Social Innovation for Europe (DS14EU) (ongoing)	<p>The goal is to provide a platform for sharing of movements and opportunities in digital social innovation environment. The project also promotes laws and programmes, which make data and digital platforms open.</p> <p>https://digitalsocial.eu/about-the-project</p>	<p>C³PO can benefit by adopting best practices discussed through DSI platform.</p> <p>https://digitalsocial.eu/projects</p>

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Project	Technical Focus	Relation to, and difference with C ³ PO
<p>Experimental co-Design Approaches: Investigating possibilities for creating networks of resilient citizens and civic actions of urban resilience through hybrid platforms (EcoDA) (2015-2017)</p>	<p>The project is part of Horizon 2020 (the EU Framework Programme for Research and Innovation). The aim of the project is to create an open source platform (digital toolkit & processes) in order to enhance urban resilience.</p> <p>Based in London, Paris and Bucharest.</p> <p>https://codesigningresilience.net/</p> <p>https://codesigningresilience.net/about-us/</p>	<p>The project shares the same focus with C³PO on collaborative technologies, particularly, on connecting distributed local resilience initiatives and co-producing strategies with potential to create a system change by development of an open source platform.</p>
<p>The Six City Strategy (6Aika) (2014-2020)</p>	<p>Participants (Finland): Helsinki, Espoo, Vantaa, Tampere, Turku and Oulu. The goal of the strategy is to tackle common challenges by involving the whole urban community. Under this strategy projects are focused on creation of structure to open data and harmonization of standards, participation and sharing of best practices. Projects are categorized into: open innovation platforms, open data and interfaces, and open participation and customership.</p> <p>https://6aika.fi/in-english/</p>	<p>The strategy supports sustainable urban development, creation of know-how, business and jobs. It is similar to C³PO in the focus on city co-design by involving different stakeholders. C³PO can benefit from emerging open datasets as a result of 6Aika projects. It can also utilize experience from 6Aika projects particularly focused on open innovation platforms, their development and testing.</p>

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Project	Technical Focus	Relation to, and difference with C ³ PO
ALMANAC (2013-2016, FP7)	The project is developing a service delivery platform that integrates Smart City Information System for green and sustainable Smart City applications.	The common aim with C ³ PO is in collecting all the city data in one place and also in applying co-design approach. The difference is that contributors are preselected, while C ³ PO platform is to be used by everyone.
Energizing Urban Ecosystems (EUE) (2012-2016)	The goal of the EUE research program is to “Building solid foundations for the comprehensive understanding of the planning, design and management of the future urban areas and ecosystems, and turning this accumulating intellectual capital and know-how into successful, global business processes”. http://rym.fi/program/energizing-urban-ecosystems-eue/	EUE has the vision of “a globally networked cooperation platform for various R&D projects of urban planning and development” whereas C ³ PO focuses more on a flexible core platform that can be used or extended to various smart city applications.
Butterfly Effect (SME Chaosarchitects, Finland based, since 2015)	The project focuses in the developing of computer and phone-based prototypes that enable cooperative design through location-based social media. In addition it also carries these proposals to real life cases and tests them in real cities through tactical urbanism practices.	The project is focusing on participation, but participation is limited to reporting, providing data on city spots and future evaluation of design proposals. The difference with C ³ PO is that the company is doing the design work, not users. Moreover, the data is collected from citizens. At least in 2015 there is no other data collection, e.g. data from other stakeholders (authorities, local business owners).
SubUrban Lab	Web-based co-design	Same challenges in co-design processes.

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Project	Technical Focus	Relation to, and difference with C ³ PO
JPI Urban Europe 2013-16	tools for urban living labs that enable different stakeholders to participate in urban development.	Technical focus in the improvement of energy efficiency in less-valued sub urban areas. C ³ PO enhances co-design process with simulation features related to equipment functioning and to people behavior.
Urban IxD (2013-14, FP7)	Define a coherent multidisciplinary research community working in a new research and/or application field	Bringing together the design and technology field within the context of city / urban design. In C ³ PO the focus is specifically on collaboration and co-creation, which differs from the Urban IxD project.
SmartCities (2012) - ERDF	A people-based network between cities and research centers aimed to develop better eServices to citizens in the North Sea Region.	First attempt to a co-design approach to include citizens in designing and developing eServices. C ³ PO goes beyond by focusing of semantic data modelling over a cloud-based architecture. Also in its collaboration approach it goes beyond co-design including the citizen, covering collaboration (a) with the entire network of all stakeholders and (b) throughout the entire project life-cycle of the city development project
SmartCities+ (2012-2013) - French project	Developing a smart city platform integrating 3D navigation functionalities	C ³ PO leads this experience further, by integrating the co-design aspects, together with the AR and advanced visualization capabilities, and by adding scalability to the smart city platform
PRE - Built Environment Process Re-Engineering (2011-2013)	Usercentric business models for the real estate and construction industry by utilizing BIM.	Explored a wide range of new BIM-based procedures and business models for the real estate, construction and infra sectors. VTT in cooperation with consulting company FCG Finnish Consulting Group carried out implementation of mobile AR solutions and (first in the world) piloted

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Project	Technical Focus	Relation to, and difference with C ³ PO
		<p>the technology with city officials in actual land use cases.</p> <p>C³PO uses PRE as an application in the wider co-creation context.</p>
<p>Smart Urban Spaces (2009-2012) - ITEA2</p>	<p>Interoperable platform for contactless and mobile City services</p>	<p>This project proved the challenge of interoperability in the city services, but it did not address planning and participation at all.</p> <p>C³PO capitalizes the experience on city services interoperability, while adding planning and participative features to the platform.</p>
<p>OUTSMART (2011) - FI-PPP</p>	<p>Providing services and technologies based on an open and standardized infrastructure in five areas: Water and Sewage, Street Lighting, Waste Management, Water and Environment and Sustainable Urban Transport.</p>	<p>Standardization of different types of information required by the C³PO platform for supporting the different dimensions of city co-design</p>
<p>CitySDK (2012-) - ICT PSP</p>	<p>Smart City Application Ecosystem relying on open source service developer toolkit that can be applied for different cities</p>	<p>C³PO platform is also an open ecosystem using interoperable technologies and supports also the use of different applications in different cities</p> <p>C³PO platform goes beyond by providing an access to an integrated multi-dimensional information stored in a centralized and scalable semantic-based repository, and by facilitating the city-scale co-design process</p>
<p>EPIC (2011-2014) - CICT PSP</p>	<p>Developing a scalable and flexible pan-European platform for innovative, user-driven public service delivery</p>	<p>Use and experimentation of Cloud computing technologies for e-government service applications</p>

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Project	Technical Focus	Relation to, and difference with C ³ PO
SMARTiP (2010-2013) - CIP-ICT-PSP	Identifying innovative but sustainable ways of building the capacity of citizens and public services to work together with innovators and digital developers	C ³ PO leverages the experience gained in using different digital collaboration & engagement techniques. C ³ PO goes beyond this and provide a focused collaboration process for the different phases in an urban development project, using online collaboration technology to support both online & offline engagement tools & events to enable and strengthen the collaboration in the complex ecosystem around a city development project.
The ToolBox (2008) - Danish project	Developing a hands-on tool that can be used to visualize different scenarios within the design phase of urban design projects	Comprehensive list of different applications that can be candidates to the C ³ PO platform

8 Conclusions

The above state of the art summarizes current knowledge of the project consortium on the project related methodologies, trends and technologies. It serves as a starting point for developing the cloud-based semantic platform for participatory city design called C³PO. There are still many issues, which require elaboration by C³PO project and similar ongoing and follow-up initiatives. Those issues lie in the key C³PO domains:

- city data acquisition, integration, analysis and transformation
- visualization of the city co-design processes and linked data
- enhancement of the integrated solutions and platforms supporting stakeholder involvement
- integration of different participation and co-design tools
- development of the technical standards
- further development and evolution of the business models and business strategies for the integrated city co-design solutions.

C³PO consortium, setting up this state-of-the-art and proposing future perspectives (Albats et al., 2016), is looking forward to further collaborative developments to support city co-design solutions.

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