Autonomous, Real-time, and Dynamic Configuration of Public Space in Smart Cities
Challenges and Opportunities for Urban Planners

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Abstract
Although there is not yet a worldwide accepted formal definition of what a Smart City is, the concept is already very used in architecture, engineering, and human sciences and is one of the most important research and development areas of the near future. The article focuses on the observation that smart cities are near to being ready to have the capability to temporarily reconfigure the use of their public spaces, either autonomously or in a human supervised way. A smart city can rearrange the way a portion of its public space (e.g.: squares, accessible streets, stations, parks, ...) is used, directly communicating with people, vehicles, drones, road signs and other elements that use and manage the public space. This can be done autonomously by "the city" (e.g. traffic jam detection, statistical prediction, ...) or under human-driven requests (e.g. large meetings or crowded events, emergencies, road works, ...). Such capability is mostly made possible by technology (ICT, robotics, nanotechnologies, ...) but can be improved and governed through careful urban planning and design. Ruling and leveraging such features is a very new field in urban planning and design and is very important to effectively take advantage of the smart city paradigm regardless of the size of the smart city. In smart cities, the public space has also gained a virtual expansion through cyberspace, leading to a new concept where virtual and real spaces intersect, meet, and, often, melt together. The paper analyses the public space definition in a smart city, its arrangement in different classes, and the ways of reconfiguring it. Then the challenges that urban planning first, and urban design second, must face to leverage in the best way such opportunities are explored, and a first set of guidelines to develop a methodology for this scope is described. The paper considers both normal conditions and emergency conditions (including epidemics) and describes the principles of a new methodology to enhance urban planning, leveraging this smart city's ability to dynamically reconfigure the public space.

Keywords
Smart City, Public Space, Urban Planning, Urban Design, Change Management

Introduction

In the 60s an avant-garde architectural group inside the London Architectural Association, known as "Archigram", developed many different ideas that tried to implement Le Corbusier's thought "Une maison est une machine à habiter" (a house is a machine for living in). Members of this group, also influenced by Futurism, proposed many projects that had, as a common frame, the creation of cities or buildings using an approach based on the ability to change the space (public or private does not matter) using elements that were machines. Peter Cook's "Plug-in City", Ron Herron's "Walking City", the "Instant City" initiative, and other utopian projects, all aimed to use machinery to change the way of building a city. At the same time, Cedric Price conceived the "Generator" project. In this idea, starting from a set of orthogonal foundations, standard building blocks, all of the same measures, could be moved by automated cranes and used to continuously change the city space to adapt to changing requirements. Price's idea was conceived not only in using traditional drawings or sketches: he also involved two computer experts, John and Julia Frazer, to work as his consultants to develop a software that was able to organise city layout to respond to changing requirements from "The City" or from the citizens. It also suggested that each building component should have inside a single-chip microprocessor to allow it to become the controlling processor. The Generator, conceived in the second half of the '70s (1976-1979), was influenced by the so-called Artificial Intelligence Golden Age. At the Dartmouth Conference in 1956, organised by Martin Minsky and John McCarty (young computer scientists) and by Claude Shannon and Nathan Rochester (both senior scientists), the term "Artificial Intelligence" (abbreviated as AI) was formally accepted and was distinguished from cybernetics, also defining for it a specific mission. After this conference, there was an explosion of enthusiasm among computer scientists and computer professionals that propagated it even outside their circle.

After 1974, while computer scientists started understanding that AI was not as easy as expected, the excitement about its opportunities had spread out of their control and this was the environment that allowed Archigram and Price to speculate about their architectural projects that, almost always, digressed towards something more like to science-fiction than to architecture. Times were not ready for such visionary thinkers.

Today, when talking about smart cities, the Internet of Things, autonomous vehicles, cooperative robotics, and other technologies it is inevitable to think about Archigram and Price. The Generator in particular, while not the only one, contains these concepts in an embryonal form. But today's times are not those of forty years ago: the technologies are real, often well established or near to being mature.

What is missing today is not the technology, which is evolving very fast, but the ability to introduce formal or empirical methodologies that can help architects and engineers to build the smart city, whatever this term could mean. As practically demonstrated by the Generator, the cooperation between the architectural side and engineering side (meaning ICT and robotics engineers) is important and can be even stated as necessary today. But methodologies to implement this cooperation are still late. The reasons for this delay will be investigated at the end of this paper but, before, it is mandatory to understand how it can be realised today and which are the issues.

Definitions

Although a common, formal, and complete definition of what a Smart City is has not yet been provided, the existing ones all have a common ground that can be used to define a framework of what could be and what could not be a Smart City. This common background is based on the use of artificial intelligence, robotics, the Internet of Things and other technologies related to information processing, communication and automation. The list of these technologies is continuously growing and changing. Changes are in both capabilities and cost reduction. According to this analysis, smart cities are today mostly considered both from an engineering (ICT and robotics) point of view and an architectural point of view (i.e. aesthetics, space usage, sociological impact, …). Smart cities are then considered as entities able to optimise some processes, like energy consumption or traffic flow and they are designed following this approach. In this optimization perspective, at least two important items are missing in current approaches to smart city planning and are:

- The ambition is to leverage the capability of smart cities to dynamically rearrange space (public and private)
- A methodology that connects the architectural world with the ICT & Robotics engineering world, to let the two worlds cooperate effectively and efficiently, to provide the best results from many different points of view which will be discussed later

These items are based on the fact that, excluding Archigram's ideas and few others, nobody has evidenced the capability of the Smart City to reconfigure spaces, opening new opportunities for architects and new challenges for engineers. Many definitions can be found in the literature but, in this paper, a new one will be given, starting from the one provided by the European Commission (Russo, Rindone, Panuccio, 2010) which can be considered a good summary of most of them, and completing it with the ability to reconfigure space usage:

"A smart city is a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business. A smart city goes beyond the use of information and communication technologies (ICT) for better resource use and less emissions. It means smarter urban transport networks, upgraded water supply and waste disposal facilities and more efficient ways to light and heat buildings. It also means a more interactive and responsive city administration, safer public spaces and meeting the needs of an ageing population. ***It also can temporarily reconfigure the use of its public spaces, either autonomously or in a supervised way.".***

This new version, proposed by the author, contains evidence of the above-described capability of space reconfiguration.

According to this definition of a Smart City, it is clear that the tendency to rely on data, to render the urban environment making it more rational and efficient, most directly aligns with the logic of modernization. Digital applications first appeared to be bound to the cyberspace, a virtual public space, but this space has spread becoming a new “public space of interactions” – practically an “electronic agora” that “subverts, displaces and radically redefines our notions of gathering place, community and urban life” (Mitchell W. J., 1995). The diffusion of computers in a quick and pervasive way has altered the nature of our interaction with (or inside) our environment. Monitors and screens are the new windows through which to observe the world (Koolhaas, 2002). Today, the assets of digitalization have overcome the boundaries of the virtual space because, with recent developments in digital technologies, smart applications are appearing everywhere to optimize urban life (i.e.: urban services and urban spaces/environments). The smartphone is now the "megacity survival kit, a digital Swiss Army” (Townsend, 2015). Smartphones, but not only them, have spread everywhere and disrupted social interactions and urban services, thanks to the technological miniaturization that is allowing anything to be “smart” (e.g.: Internet of Things).

This virtualisation of relationships and interactions has led to the understanding that these small and even smaller devices are a sort of “black boxes” that are “richer in functions but poorer in transparency” (Anceschi, 1996). The same pattern is present and should be considered when designing Smart Cities.

Urban public space has always been the core of the urban (human) activity and has political, socio-economic and historical connections (e.g.: Ancient Greeks Agorà, Medieval Square, Ancient Roman Forum, …). Sennett (2017) defines this space as “a place where strangers meet”. Dovey (2016) expands this definition as the "primary site where a sense of the ‘common' becomes embodied in everyday life before it becomes ‘community'". The term “public space” means a space reserved for the public itself. Other definitions emphasize this stating that public spaces are “the triumph of the public over the market” (Iveson 2007), asserting that they are ‘ceremonial spaces’ for both celebration and protestation and are used by people to be “included in the public represented through the space”. According to such a vision, the uses and the design of the public spaces are essentially political as well as subconscious (Benjamin, 1935-1999). But this vision has been abandoned in time due to the reduction of conflicts: Sorkin (1999) summarizes modern city planning as a ‘conflict avoidance’ activity where enemies of public space are privatization, identity politics, and [urban] sprawl. These concepts have led to the ‘anti-urban character’ that is a main feature of the large-scale suburbanization, of the closed communities, or of high buildings, where the interaction of the street level is diminishing (Dovey, 2008).

Public spaces are now facing a huge transformation led by the fourth industrial revolution (Schwab 2019) and this draws attention to the new dimensions of the proliferation of digital goods and services. As much as the dominant modes of production and politics formed everyday life throughout history, the fourth industrial revolution would, or even already begin to, challenge the ways we collaborate, produce, consume, communicate, and make sense of the world. Smart City technologies that are being used today are extremely pervasive and diffused everywhere, often as invisible presences, permeating and filling the entire ecosystem of existing urban infrastructure and services, and are therefore very hard to detect and concretize. Despite this, daily urban life is getting more and more dependent on these smart technologies provided through the various layers of digital infrastructure. In this way, the digital has begun to deeply influence public life not only on a small but also large scale. The recent COVID-19 emergency has dramatically demonstrated that we can be actively present at a set of activities at once without changing the location (as forecasted by Amin and Thrift in 2002). According to Amin and Thrift, the city, born as “a vast narrative structure that constantly re-presents itself”, is changing, becoming “something that is beginning to read us” (Amin and Thrift, 2002). The places in Smart Cities “code/spaces” where “software and the spatiality of everyday life become mutually constituted” (2011) and, as Graham (2005) asserts, “coded worlds” or “computerized spaces” operate beyond the virtual, exerting “their power over the geographies and life-worlds of capitalism”. According to Graham, aiming for a more secure, computer-based society that is theoretically freed from risk, crime, or congestion, entails the risk to avoid contact with the “failed consumers”. Whereas, to meet the ‘other’ is the essence of public space.

In this vision, we get a heterogony of intents, a real unintended consequence that causes the loss of connection while building a hyperconnected world. At the same time, the new virtualisation of public spaces, if used to enforce crime suppression, security, efficiency and more, will lead to a reduction of natural behaviours that protect individuals and communities from such risks. What will happen if, suddenly, such a system loses its capability to prevent undesired events in a context when no one is ready to manage dangerous circumstances?

As a trendy concept, Smart City became a label that many urban actors are willing to say they have attached to their public spaces. Anyway, currently, there is no real place that we may consider a Smart City as a whole yet (Townsend, 2013). Nevertheless, academic circles (but not only them) indicate two distinct examples of Smart Cities: Songdo in South Korea and Masdar in UAE (Sennett, 2012); (Hollands, 2015); (Albino, Berardi, & Dangelico, 2015); (Kitchin, 2015).

Both examples are not exempt from criticism. For example, Sennett describes Masdar as follows: “There's no stimulation through trial and error; people learn their city passively. User-friendly in Masdar means choosing menu options rather than creating the menu.” About Sondo, Calvillo et al. (2015) describe it as follows; “a system that theoretically continues to produce wealth-without-end through the construction of huge conduits for bandwidth and of vast quantities of environmental sensors, all focused on the monitoring and indexing of its inhabitants’ online and offline behaviours.”

There is, anyway, an important relationship between Smart City and the public space. The medium and experience of the public space have been expanded by digitalization and now many "smart" applications are shaping the urban space, aiming at an optimized urban life thanks to the pervasive application of ICT, in most cases using smartphones. Even though the concrete physical space is being transformed (and augmented) by digital technologies, there is also a growing awareness coupled with the threats of digitalization. This awareness is exploiting its risks and changing the purpose of these technologies to comply with citizens' needs like privacy or freedom.

Being smart or digital citizens requires action rather than just "following the script as smart citizens". Then, for smart citizens, cyberspace is a "relational space in which digital citizens come into being through digital acts" (Işın & Ruppert, 2015). Cyberspace is not separated from the real world nor is it an independent space of freedom. Cyberspace is governed by the code. But there is a dilemma, which is potentially relevant to the 'code/space' of smart cities as asserted by Işın and Ruppert; "one obeys the laws as code not because one should; one obeys…because one can do nothing else". Thus, the afore-mentioned quantitative communities become extremely vulnerable to algorithmic biases or discrimination by design. This kind of influence on people is hard to be detected and harder to be demonstrated but it is a real risk. In this sense, the new digital public space suffers from the risk of hidden manipulation "by design",

Digital technologies are an immense, exponential and promising sea that opens new horizons, in the sense of augmented spaces, to perceive the new definitions of citizenship, participation and democracy in many creative ways. Such an approach spatially holds "a real possibility to approach a dynamic re-composition of spaces, places and territories articulated and influenced by information technologies at many different scales." (Duarte & Firmino, 2009).

Today it is not clear which will be the direction in which the future Smart Cities and their public spaces will evolve but they will change and be re-defined. Greenfield (2017) emphasizes the urgent need to develop an understanding of how those technologies work and to ask rightful, critical questions whenever we come across new uses of such technology. Greenfield's call for a new understanding is crucially and fundamentally applicable to the practice of architecture and urban planning since the cities of the future are the most contingent areas of technological interventions.

The influence of the city on smart spaces is not only at the reality augmentation level but also in their function adaptation in time. As already stated before, even the physical public space can be rearranged to provide different functions in time. And this can be done autonomously by the Smart City itself, according to an automated decision algorithm that will change the use of the space with "Smart City needs". This concept will be further investigated later.

According to Sennet (in the Latham interpretation 2017) "the design and architecture of cities, along with the rituals of their use play a central role in the formation of society's social and political culture". In his book "Building and dwelling: Ethics for the City", Sennett addressed the Smart City concept as a dual-frame. This framework favours the "open city" against the "closed city" due to the "over-determined form". In his essay, "The Public Realm", Sennett asserts that "the closed system has paralyzed urbanism, while the open system might free it". For Sennett "open" is not a measure of aesthetics but rather a quality, a feature, of the urban form. Sennett (2018) has then associated the closed form with the so-called "prescriptive Smart Cities" that "does mental harm; it dumbs down its citizens", in contrast with the open form of the so-called "coordinating Smart Cities" that "stimulates people mentally by engaging them in complex problems and human difference". Sennett defines the aim of the "sheer efficiency" as an unbalanced attribute of Smart City effects, where "the prescriptive city becomes unbalanced in divorcing functioning from questioning". In his opinion, the technology must be used to coordinate rather than control, where the produced data is "limited and un-purposed" while "comprehensive participation and decision-making are truly enabled". In a coordinating Smart City model, the digital processes are transparent, and people are encouraged to get involved with the data processes by interpreting and acting on them. Thus, this is a "performative citizenship" model.

In "Building and dwelling: Ethics for the City", Sennet defines five open forms for coordinating Smart City. 1) "synchronic space", where several activities are happening at the same time as it is at an agora or a bazaar. He makes an "invitation to mix rather than impose mixing", offering a "spatial experience both stimulating and disorientating" – that requires orientation. 2) In the "punctuated space", he uses (allegorically) the punctuation marks to conceive the urban space as a meaningful language with orientation points. 3) the "porous space" comparing the built environment with organic forms that have a metabolism. He continues to define porosity as follows; "there is an open flow between the inside and outside, yet the structure retains the shape of its functions and form". 4) the "incomplete space". An incomplete form is not a 'shell' even though shells would provide unexhausted possibilities and porosity but rather a 'type form'; "a piece of urban DNA which takes on different shapes in different circumstances". Within its constraints, variations and improvisations are possible - a loose fit. 5) "seed planning" where the shifting complexities are coordinated. Sennett criticized all master planning approaches that "divides a city up into a closed system where each place function relates logically to other places". In contrast, he suggests "farmed cities" which are conceptually functioning as "an initially unrealized, incomplete form – a seed" that is provided with "the time to grow into its surroundings." Thus seed-planning is dynamic and does relate to the form of an urban project with the function at a minimum level.

In this paper, a methodology is defined as made by two fundamental elements: a descriptive language and a creative process. Descriptive language has the scope to describe what people are talking about. The language should be mainly graphical because drawings are concise and expressive. It should also have the ability to define something to be measured because we cannot improve what we don't measure. Just to cite Edward W. Deming, an engineer who was one of the founders of the Quality concept, "You can't manage what you don't measure". A creative process has the scope to define the steps to reach the desired goals starting from some initial state. The creative process describes how things must be done to achieve success.

Types of public spaces in smart cities

A smart city can manage the flow of information, people, vehicles, goods, and services. And this can be done autonomously or be humanly supervised. Before smart cities, urban planners and urban designers could already design by conceiving multiple uses for public space (consider the medieval square, which had many uses ranging from meeting areas for business, for public decisions, for executions, for markets and more). In smart cities, public space usage can be "instantly" changed "simply" by reorganising how the smart city manages itself. For example, a road can be used as parking during normal traffic hours and as an arterial during peak hours, and this will be done automatically: smart vehicles simply will leave the road free when "The City" will ask and will park there when "The City" will allow. And this can be done better if vehicles are shared, re-allocating sharing requests on vehicles parked on such roads to move them without wasting energy and time, for example. In a few words, urban planners and designers can have a stronger degree of freedom in planning public space usage.

A challenge in city planning is the alignment in time between the planning process and social and economic dynamics that influence planning or are produced by planning itself. One approach could be to design the city as a system that can adapt (or be adapted) to changing contexts. The Generator by Cedric Price not only could be reconfigured by its human inhabitants to support their different activities, but it also could rearrange itself in the case it had been left in the same configuration for too long. The "too" should deserve a more formal definition and this could be done assuming that the project of the city can be interpreted as a transposition of Pask's conversation theory (Pask 1975). In his theory, Pask considered social systems (which are dynamic by nature) as symbolic and language-oriented systems where the responses depend on the interpretation that a person does about another person's behaviour. So, this conversation theory describes the interaction between two or more cognitive systems, and how they engage in a dialogue over a given concept and identify differences in how they understand it. Pask's studies originated from his cybernetic research when he attempted to explain the learning mechanisms of both living organisms and machines. To better explain the last sentences, a Smart City can temporarily reconfigure its public spaces to respond to inhabitants' explicit requests (e.g.: made by law enforcement agents or by the city major) or react to citizen's behaviour, learning from them through a conversation in the Pask's sense (e.g.: reconfiguring space in some way that leads to an improvement of some behavioural parameters of citizens in the space or its neighbouring). This last decisional process has not been configured by the city nor derived from simple statistical analysis or optimisation algorithms but has been learned by the City itself "conversing" with citizens. In this sense we can consider having two different processes of decision making: an explicit decisional mode where requests from some "privileged" citizens or organisations will be satisfied rearranging public space and a second one, the self-learning mode, where the City learns by itself how to reconfigure public space, conversating with citizens.

The second mode, the self-learning one, where a Smart City can decide autonomously to change after a learning process will not be considered in this paper and only the explicit mode will be discussed. The self-learning mode will be detailed in future work.

In this section, the main different types of public spaces will be enumerated and defined. Their extension into cyberspace will also be analysed in this and the next section.

Although the definition and the discussion of what is a Public Space and the differences between it and an Open Space is a very wide topic, this paper will make a simple classification of typical Smart City types of public spaces starting from the taxonomy provided by Carmona (2010) in his "Contemporary Public Space, Part Two: Classification" paper and shaping them according to Smart City capabilities, including their extension into cyberspace. The extension into cyberspace can be made by both digital twins and the provision of additional services

The classification proposed by Carmona is summarized in the following table: In the table above are described the classes of possible public spaces that can be found in a city and that can be rearranged by the smart city. But this list, in the case of a smart city, is not complete because the extensions of these "real" public spaces into cyberspace are missing.

Extension of real public spaces into cyberspace

All public spaces depicted above can have extensions into cyberspace. This extension can lead to a sort of "augmented reality" that is the mixing of the real public space with its cyberspace extension and that will be called, to avoid misunderstandings, "augmented public space".

Augmenting the public space can be done in many ways, in the following table some of them will be described. The table aims to provide enough examples of how the augmentation of public space can be done. It is focused on the possibility to augment public spaces and will not consider most of the aspects of the smart city that are related to sustainability or security, although these concepts will remain valid. The use of these augmentations will be cleared in the next section.Mixing the above augmentations can lead to very interesting results that go beyond the scope of this paper.

In the next section, thanks to the use of these augmentations, various ways of public space reconfiguration will be shown.

Space type	Distinguishing characteristics	Examples
Natural/semi-natural urban space	Natural and semi-natural features within urban areas, typically under state ownership	Rivers, natural features, seafronts, canals
Civic space	The traditional forms of urban space, are open and available to all and cater to a wide variety of functions	Streets, squares, promenades, pavements
Public open space	Managed open space, typically green and available and open to all, even if temporally controlled	Parks, gardens, commons, urban forests, cemeteries
Movement space	Space is dominated by movement needs, largely for motorised transportation	Main roads, motorways, railways, underpasses
Service space	Space dominated by modern servicing requirements needs	Car parks, service yards
Leftover space	Space left over after development, often designed without function	'SLOAP' (space left over after planning), Modernist open space
Undefined space	Undeveloped space, either abandoned or awaiting redevelopment	Redevelopment space, abandoned space, transient space
Interchange space	Transport stops and interchanges, whether internal or external	Metros, bus interchanges, railway stations, bus/tram stops
Public 'private' space	Seemingly public external space, in fact, privately owned and to greater or lesser degrees controlled	Privately-owned 'civic' space, business parks, church grounds
Conspicuous spaces	Public spaces designed to make strangers feel conspicuous and, potentially, unwelcome	Cul-de-sacs, dummy gated enclaves
Internalised 'public' space	Formally public and external uses, internalised and, often, privatised	Shopping/leisure malls, introspective mega- structures
Retail space	Privately owned but publicly accessible exchange spaces	Shops, covered markets, petrol stations
Third place spaces	Semi-public meeting and social places, public and private	Cafes, restaurants, libraries, town halls, religious buildings
Private 'public' space	Publicly owned, but functionally and user determined spaces	Institutional grounds, housing estates, university campuses
Visible private space	Physically private, but visually public Space	Front gardens, allotments, gated squares
Interface spaces	Physically demarked but publicly accessible interfaces between public and private space	Street cafes, private pavement space
User selecting spaces	Spaces for selected groups, determined (and sometimes controlled) by age or activity	Skateparks, playgrounds, sports fields/grounds/ courses
Private open space	Physically private open space	Urban agricultural remnants, private woodlands
External private space	Physically private spaces, grounds and gardens	Gated streets/enclaves, private gardens, private sports clubs, parking courts
Internal private space	Private or business space	Offices, houses, etc.

Table 1. Public Spaces Classification

Reconfiguration mechanisms

The reconfiguration mechanism of the public space in a smart city will follow a general common process that starts from a trigger event that requires the reconfiguration. This event can be a periodic event (e.g.: every Saturday the square becomes a market), which means that the event happens depending on the time, a human-forced event (e.g.: due to an emergency, these streets must be closed to some kind of traffic), which means that some human has given the order to the City to act, or a business rule event (e.g.: the traffic is jamming the main roads and part of it must be deviated to secondary roads to optimise vehicles flow), that means that some algorithmic rule (this is the real sense of "business" in this case) has been met and so proper action must be taken. After the arrival of the trigger event, the City will react by checking if the request can be satisfied or should be denied due to some constraints (e.g.: conflicting high priority requests). If the request can be satisfied, the City will start defining the boundaries of its action, and if needed developing different scenarios and choosing the best among them, then it will start applying the action(s) to overcome the request. Until the request will be satisfied, the City will monitor the evolution of the involved parameters and check that things are going in the right way, otherwise it will try to compensate for deviations or raise an alarm, if needed. When the request is satisfied, The City will return to the space default configuration. Although the term "The City" has been used up to now, it must not be considered as a central system that steers everything but as a distributed system of systems, mostly based on edge computing, that reacts to the request. The structure of this system will not be analysed in this paper, which focuses on the public space reconfiguration capability. The following sub-sections will present four different examples of potential space reconfiguration in a smart city. Other cases will not be considered in this paper for the sake of simplicity. These examples will not consider in detail why the change has been triggered but will only describe how this change can happen. Any reference to real places is a mere coincidence. The cases have been structured considering different types of spaces and implementing current and near-future technology to reconfigure them.

Augmentation type	Description	Examples
Augmented reality	When virtual reality is superimposed over reality (e.g.: by impressing the virtual images over a real-time capture through the camera of a tablet or smart glasses).	Get tracing, dietetic and performance information about goods in a shop.
Autonomous things	Autonomous things include drones, robots, ships, and appliances, that lead AI to perform tasks usually done by humans. They operate ranging from semiautonomous to fully autonomous.	Vehicles can drive autonomously and be shared when needed. They will also swarm to improve the city's quality of life (e. g. reducing traffic).
Democratization (of technology)	The capability of technology to become easier to be used by citizens.	Citizens could develop their own data analytics starting from available open data
Distributed ledgers	The use of technologies like blockchain will allow the creation of distributed ledgers where transactions of any kind are recorded and will allow a better data management	Vehicles can book parking places in an extremely easy way, even with large advance, and rearrange the booking with no human intervention and in a very quick way.
Edge computing	Edge computing means processing huge quantities of data near to their sources, reducing latency time and improving response/reaction time. This is a typical layer in the Internet of Things systems.	Cars can directly dialogue with parking places and find the nearest free.
Geolocation	Geo-referencing any object means identifying its position in the space. This can be done for items or humans and in many ways (e. g. GPS, cameras triangulation).	Instantly knowing the position of any element of the city, including citizens, and, if possible, their destination, if moving.
Hyper-automation	Through this advanced form of automation, which mixes AI and robotics, humans can remotely control shared robots to act for them. Hyper-automation also includes the capability to remotely measure many parameters.	Shopping can be done remotely even for non-standardized goods like fresh goods, dresses and more that, currently, are bought by the customer directly trying them.
Multi-experience	Multi-experience replaces technology-literate people with people-literate technology. In this perspective, the traditional idea of a computer evolves from a single point of interaction to include multisensory and multi-touchpoint interfaces like wearables and advanced computer sensors.	A weekly food shopping can be easily done at home using an App to order what is needed, cooperative robotics to prepare and package it and autonomous vehicles to deliver it.
Virtual reality	2D or 3D virtual reality allows the creation of a virtual representation of any object (e.g.: park, street, touristic place) or concept (e.g.: traffic flow, available parking map) that can be displayed to a human being and with which the human can virtually interact.	Virtual tour of a touristic place or a restaurant. Virtual tour of shelves in a supermarket.

Table 2. Some types of augmentations for public space

Example 1: parking, street, main traffic arteria
Scenario

The City, at 8:00, orders all vehicles to not park in Baker Street and to those that are already parking there, to move to different places in the neighbourhood, already assigned them by The City. This is because, up to 9:00, Baker Street must become the main artery in inbound traffic flow. Small streets that merge into Baker Street are assigned as a temporary stop to let passengers leave their vehicles and go to work in the building near them, without hampering the main traffic flow. All vehicles are autonomous, so they obey this order with no human intervention. At 9:00, The City checks that the traffic has reduced its intensity and that Baker Street is not yet needed as the main artery, so the Street Becomes a pedestrian-only road where shops are open, and people can move around to get some coffee or buy something. Many mobile shops made by autonomous vehicles can park in the zone. The pavement in the middle of the road automatically reverts and opens, showing a medium-size children's playground allowing the neighbouring kindergarten to take children there to play. Around noon, the City decides that the mobile shops must move away (and they autonomously do this) and allows local restaurants to fill the road with tables and chairs. The weather report forecasts rain, so a covering is placed by an automated system all over the street and wind barriers are automatically put at the beginning and the ends of the street to repair from the windchill that has also been forecasted. At 14:30 the restaurant service closes and the road returns to being a normal street where low-intensity traffic is allowed, closing coverage, lowering the wind barrier and asking shops to remove tables and chairs, also hiding the children's playground. Now Baker Street is mainly used to gather people leaving their work. At 16:30 traffic in the city is increasing and The City requires Baker Street again as the main artery, as in the morning, asking autonomous vehicles to leave it free of parking and diverting a portion of the traffic through it. When traffic flow reduces, around 20:00, Baker Street returns to be a normal, low traffic street and it becomes a one-way street, with a central portion used for two-lane traffic, and both sides as an area to deposit and pick up people that move to go to local pubs, bars, clubs and more. Then it cycles again from 8:00.

Comments about the scenario

In this simple example, the space that The City reallocates is an urban street. It has been made possible by the existence of autonomous vehicles (cars, mobile shops) that can easily respond to City requests. It is also based on the possibility of the children's playground being hidden below the road floor. Also, the anti-rain covering, and wind barriers have their role in this space reallocation. The use of the street as a normal road, pedestrian-only, high traffic arteria, one-way two-lanes street is made possible by changing road signs, most of which are virtual, i.e.: visible only through virtual or augmented reality but readable by autonomous vehicles. The scenario is quite easy and, for some aspects, naïve, but it is near to be practically realizable: only level 5 autonomous vehicles are missing from it.

Example 2: Mall by day, entertainment city by night

Scenario

The Magic Wand Mall (or MWM) is a shopping mall where there are 208 "shops". It has been designed to allow a set of mobile walls that can be controlled by The City. These mobile walls can be used to partition the shops into different subspaces. These walls can move (moved by someone or by themselves is not important). Each shop has a "default" area ranging from 60 square meters to 3,000 square meters. To access each shop there are two ways: the first one is through main halls and corridors, beautifully decorated that will be called "human access connections". The second one is a normal set of corridors of standard width of 4 meters, with white walls, and connected to the mall warehouse. These corridors will be called "restock corridors". The mall, as usual, will have two different access types: the main entrances, that face toward the human access connections, and the goods entrance, which faces toward the restock corridors. At 19:00 The City analyses the inventory of all malls and shops that are in it and the forecasts for goods requests for the next day. This process ends around 23:00 and requests are sent by The City to all suppliers to provide differences concerning what is already planned and not yet under shipment. In this way, The City has planned the entire logistic supply chain from peripheral logistic areas, just outside the city, that have been refilled during the day, up to a single shop in a single mall. At the same time, the MWM spaces are returned to their default configuration of pubs, clubs, and other entertainment places by robotic teams. Warehouse spaces (will be explained later) used as shops during the day are now hidden by mobile walls. Everything has been cleaned before 20:00.

Starting from 20:00, the shops in the MWM open to the real public (i.e.: humans) as restaurants, pubs, clubs, cinemas and other aggregational and entertainment places. This configuration is the default configuration of the public space. Up to 2:00 of the next day, people live in the MWM as an entertainment and meeting area. After the last human has left the area, the cleanings are done by automated systems (i.e.: cleaning robots). At 3:00, The Mall reorganizes its space to receive goods to be sold by remotely accessed shops: mobile walls are removed to use all the available space as storage. So, until 5:30, the MWM will be filled with robots that are refilling the warehouses which were hidden by mobile walls and also the space used by people as pubs or restaurants just a few hours ago.

In this case, customers, from their homes or using mobile apps from anywhere, virtually visit the shops in the mall and choose goods to be bought. In some cases, shopping-AIs (i.e.: Artificial Intelligences programmed to buy daily products basing their choice on their tastes) will make the order. In both cases, humans and AI, using hyper-automation and multi-experience, can virtually try dresses, smell scents of food, try fruit consistency and do other sensorial activities remotely. For all day, until 19:00, the MWM is closed to the public (or only a portion of it can be open), while most of it is used as storage space for virtual shops. At 19:00 the loop begins again.

Comments about the scenario

In this scenario, the same space, which has been designed as an entertainment or meeting place, is used for half of the day as storage from where buy goods acting from remote. Using citizens' behaviour prediction and other kinds of statistics, The City can rearrange this space to both support the need for meetings and the need for shopping. This scenario requires a bit more technology than what is currently available, but the trend ensures that in a few years it will be possible to be realized. Using a mall in this way will improve sustainability: the supply chain will use spaces that, after being freed by customers that buy goods, will be reused during the night for different purposes. This scenario can be evolved into the next one.

Example 3: The Mini-Generator without cranes

Scenario

In this scenario, space is a building with many floors but no walls (or only a few walls). Provided that it has various goods hoists that can move large loads from one floor to another, it is possible to reconfigure the space dynamically (as dreamed in The Generator). The only issue is about the interior design. And this is the main issue that will be faced in this sub-section. Changing the space configuration is not difficult: even today's automation level, using already existing forms of cooperative robotics, can provide mobile walls that can be put practically anywhere. Also, electrical connections should not be a problem: connecting from the ceiling and distributing through mobile walls specialised connections. Hydraulic connections can be provided through the floor or ceiling, directly to furniture, even in the case of gas furniture (for cooking). Climatization can be provided, again, by hiding pipelines in floors or ceilings. The problem is that spaces that must be used by humans need specific furniture to be provided and decorations and designs that must be changed in the blink of an eye. So, we will assume that the mobile walls are not a problem and we will focus on furniture change. There are at least three different ways we can arrange different furniture. The first one is using furniture which moves autonomously, i.e.: that are mobile devices that know where to go and how to connect. It's easy and the only issue is where to put them when they are not used. The second one is to use furniture moved by someone else (e.g.: a robot that carries them and robots which position and connect them). Also, in this case, there is again the problem of where to put them when not used. In both cases, there is also the issue of damages during transportation. The third one is using furniture that is assembled starting from a common set of reusable components (e.g.: panels, small doors, glass windows, taps, sinks, …). In this case, the needed storage space will be lower but there is the problem of decoration: all elements are raw and need specific decoration to be used. The solution to the decoration issue, and probably, but with the need to further develop the technology, for the elements or furniture storage, is the use of nanotechnologies. Using nanotechnologies will soon be possible to paint surfaces creating changing patterns (remotely controlled) and also create sensorial and interactive walls. In this way it will be possible to change the aspect of raw elements, giving them the desired aesthetics and also specific surface performance (e.g.: waterproof, smooth, cold, hot, lighting, …). Such nanotechnologies promise that using nanorobots, simple structures can even be built. Structures interesting in this scenario range from intelligent seals for gas or hydraulic connections (for safety reasons but not only), passing through the creation of simple small elements like glasses, lamps and more, up to complex elements like furniture and even walls. For these last two, the technology is rather far to be ready, but for small scale applications, it is promising.

If we assume that nanotechnologies or even swarms of small robotics components can be used to realize and decorate furniture, in cooperation with the assembly of standard elements, we can entirely reshape a building by acting on all non-structural elements. What is assumed in the last statement, is that the City will be able to reconfigure public space for periods longer than one day or a few hours through mobile walls, modular furniture, and smart decoration. So, the building considered in the scenario will be able to be reconfigured by The City according to its needs. For example, it could start as a business building where there are offices and food services and then, after a few months, when the request for apartments near it has grown, be partially readapted by The City as residential. When a convention is needed, part of the offices will be arranged like a conference room. With the arrival of inhabitants in the building apartments, also some schools will be needed and, for nine-month each year, some space will be used for educational purposes.

Comments about the scenario

Although based on technologies that have to be further developed, this scenario gives reality to Price's Generator project and considers space (not public only but also private, like an office or an apartment) as something that can be shaped by The City (autonomously or under human control) to fill specific needs. In this perspective, the (public) space becomes a place where people meet other people to socialise and maintain the human contact that has been revealed to be important during the COVID-19 lockdowns: people have discovered how good is working at home but also the need to meet colleagues and other people. In a few words, people have discovered that they need a balance between smart working (or studying) and physical contact at the office (or school). This scenario is remarkably interesting because it allows us to find these balance points even considering change drivers like the growth of the average age of people. A city should support social changes by reshaping its space and this can be done if the technologies depicted above are used. Last, but not least, with the above approach, extended to any existing building, The City will be able to plan its whole reshaping to improve the overall quality of life, compensating for some urban planning/design errors or requirements changes.

Example 4: Public Space and 3D printers
Scenario

Large scale 3D printers are today able to build an A-class house from scratch in a few hours. Anti-seismic, cheaper, sustainable houses can be quickly created directly on-site with this technology.

Soon, even large buildings could be created using the same technology. In this way we can imagine that The City will be able to rule an army of such 3D printers, equipped with AI and with an adequate degree of autonomy and will be capable of expanding itself, creating new buildings, new roads, and even new districts.

In this way, The City can permanently change its (public) space. But the scope of this paper was a temporary reconfiguration and 3D printing does not allow this. Mixing 3D printing with nanotechnologies can lead to an interesting result: buildings will have very special features thanks to the nanotechnologies and can be demolished with up to 100% recycle due to the capability of nanomaterials to be easily separated and reused. Although this technology must be further developed, the trend is clear and remarkably interesting opportunities are on the horizon. Using this kind of approach, The City will be able not only to change its space (public or private can be considered the same) but also do this "temporarily", which does not mean hours or days but surely can be done for periods of many months or years. In this way, The City will support urban planners and designers to realize their ideas, giving both the data analytics to make decisions and the manpower to physically realize them.

Comments about the scenario

This last scenario requires a lot of technology that is not yet available and puts some questions about the energy efficiency of a process of creation and destruction, but the answer depends on a deep analysis of advantages and disadvantages. In this case, the Urban Planner and the Urban Designer will find in data analytics gathered from The City an important source of information to support the decision and can create not only simple renderings of the future urban forms but also very detailed simulations that will increase the effectiveness of their work.

Challenges for urban planners and urban designers

Considering all the above considerations, the Urban Planner and the Urban Designer have to take into account the capability of the smart city to reconfigure public space. The Generator, in the end, has arrived, to use a metaphor, and it is time, as in Generator, to put together Architects (i.e.: Urban Planners/Designers) and engineers (i.e.: ICT and Robotic engineers) to work together. This is the first challenge that has to be faced. But Price and his consultants did it in the past, so it should be possible now. But there is a fundamental difference: the level. The Generator was a utopian project, never realized, and did not have to face reality (i.e.: time, maintenance, errors, failures, …) while a Smart City is something that must live for a very long time and adapt to very quickly changing technologies and less-quickly changing social needs. What is needed is something that can be improved in time and that will allow us to reproduce successes and learn from failures to avoid repeating them. This is a methodology, according to the definition given in section 2. Putting together the language and the process, it will be possible to create these interdisciplinary teams and get the maximum from them. This interdisciplinarity is physiological in computing and has already been developed in other contexts: bio-informatics (for ICT application to medicine and healthcare), info-logistics (for ICT application to logistics) and more are, by now, well-established disciplines, where interdisciplinary teams work in a very efficient and effective way. But in these fields the solution was affordable: medicine, healthcare, logistics, chemistry and more are disciplines where there are already very rigorous procedures and, except for advanced and theoretical research, creativity is not the first quality people should have. In Urban Planning and Urban Design (and, in general, in Architecture) we have a very creative, soft-skilled, emotional, human-sciences oriented approach that must be met with the aseptic, cold and schematic mind thinking of ICT and Robotics engineers. In this case, the lack of a common methodology that preserves both approaches leaves the two parts of the team to work separately. To use a metaphor, the architectural portion is the left hemisphere of a brain while the engineering one is the right hemisphere. If we want our brain to work, we have to let them strictly cooperate while preserving the identity and peculiarities of each one. Today such bridging is missing, and architects and engineers work separately on these topics. And no methodology is yet available and no research in such a sense is reported. And this is a serious issue that should be deeper analysed and, if found a real issue, solved.

A set of methodology definition requirements

The above-cited methodology should comply with the following requirements that can be considered an initial set of guidelines for its implementation. In the table below, UP and UD refers to Urban Planners and Urban Designers while ICT refers to ICT & Robotics Engineers:

Final considerations and further development

The capability of a Smart City to rearrange its space is an opportunity to develop new strategies of urban planning and, at the same time, manage risks contained in smart city development. This capability is a topic that needs further analysis and could represent a new, important, degree of freedom. The methodology will be further developed in research about risk analysis and management in a Smart City. Such research will also investigate the application of Pask's Conversation Theory to Smart City self-organisation as a driver for a Smart City Intelligence.

Title	Description
Methodology goal	The scope of the methodology is to transfer requirements and specifications from UP/UD to ICT
Expressive capability	The methodology will be able to describe requirements and specifications for both UP/UD and ICT
Initial state	The methodology will start from UP/UD requirements and/or specifications
Final state	The methodology will end with ICT requirements
Bottom-up change management	The methodology will be able to transfer changes on the ICT side (in technologies or requirements) towards the UP/UD side, tracing up to impacted UP/UD requirements and specifications
Top-down change management	The methodology will be able to transfer changes on UP/UD side requirements and/or specifications towards the ICT side, tracing up to impacted ICT requirements
Risk analysis support	The methodology will be able to define all elements needed for a risk assessment or a risk analysis.
Measurability of kernel entities	The methodology will define some core entities that will have applicable measures and that can be used to evaluate in a quantitative where the methodology is arrived, from where it has started and where it has to go
Expandability	The methodology will define a mechanism to extend it and adapt it when needed without the need to alter its kernel
Structure	The methodology will be composed of both a descriptive language and a creative process

Table 3. Methodology requirements

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