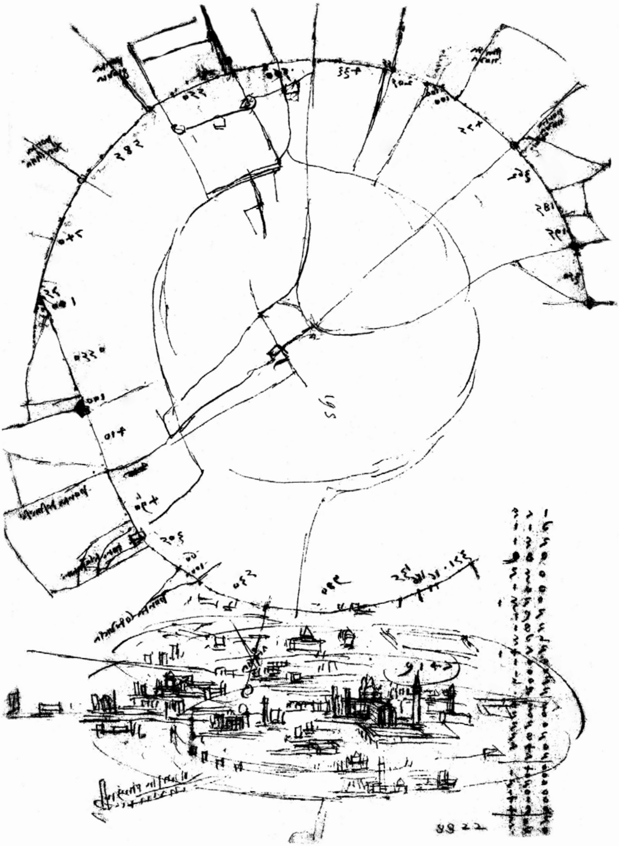
FEDERICO
CINQUEPALMI

Towards (R)evolving Cities

Urban fragilities and prospects in the 21st century



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Towards (R)evolving Cities

Urban fragilities and prospects in the 21^{st} century

FEDERICO CINQUEPALMI

UNIVERSITÀ DEGLI STUDI FIRENZE
DIDA DIPARTIMENTO DI ARCHITETTURA

This volume is the result of thirty years of studies and research on policies and technologies applied to the environmental, energy and building sectors, with particular focus on processes and phenomena related to urban systems: research and studies carried out in some of the main academic centers in Italy and abroad, namely the IUAV university of architecture in Venice, the National Research Council (Consiglio Nazionale delle Ricerche - CNR), the Sapienza University of Rome, the National Agency for New Technologies, Energy and Sustainable Economic Development (Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile - ENEA), the National Institute for Environmental Protection and Research (Istituto Superiore per la Protezione e la Ricerca Ambientale - ISPRA), and the US National Oceanic and Atmospheric Administration (NOAA), as well as United Nations Educational, Scientific and Cultural Organization (UNESCO), Food and Agriculture Organization (FAO), Organization for Economic Co-operation and Development (OECD), the University of Massachusetts (Boston) and Cambridge University. The research and studies have found concrete applications in the policies of the Italian Ministry of the Environment and Protection of Land and Sea, and the Ministry of Universities and Research, from 1999 until today.

This publication has been subject to an acceptance and qualitative peer review procedure, based on a blind review evaluation by the Scientific Committee of the DIDA Department of Architecture. All DIDA publications are web open access, allowing an effective open evaluation by the international scientific community.

The English text has been elaborated and verified under the supervision of Prof. Ann Katherine Isaacs (University of Pisa).

Cover: Leonardo da Vinci (1452 - 1519), Atlantic Code (Codex Atlanticus), folio 199 (reverse). Plan of the city of Milan with indication of city gates (top) and bird's eye view of the city of Milan (bottom).

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This volume is not simply a translation of the text published in November 2019, *La città fragile: dalla smart alla (r)evolving city* (Didapress, Firenze 2019). The impact of the COVID-19 on urban systems has confirmed the relevance and timeliness of the topic. The present March 2021 edition, therefore, also underlines the complex impacts of the pandemic, from the perspective of both urban metabolism and the related technologies.
The revised edition includes a new methodological foreword by Prof. Saverio Mecca of the University of Florence, entitled 'Urban fragilities in the 21st century' (pp. 13-23), and an entirely new sub-chapter by the author entitled 'The challenges of pandemics in urban societies' (pp. 164-178). The author has also substantially revised and integrated the sub-chapters 'Resilience and adaptation of urban systems' (pp. 178-190) and 'Information management systems for teleworking, e-teaching and e-learning and telemedicine' (pp. 207-219) in consideration of the even greater social and economic importance of digital tools due to the social distancing caused by the pandemic. The discussion about new tools applied to building and urban management has been expanded with a sub-chapter dedicated to the issue of 'Managing urban environments with Digital Twin models' (pp. 227-235), and sub-chapter focusing on 'Risk management and insurance tools for urban resilience' (pp. 244-251), written with the technical contribution of Giulia De Toma.
Even the 'Conclusions' (pp. 253-261) now contain updated and more ample considerations on the methodologies involved, as well as a substantial integration of the text that takes into account the new scenarios produced by the COVID-19 outbreak. In addition to the necessary integration of the bibliography, the 'Insights' (the case studies at the end of the volume), have also been revised by their respective authors, Carlo Pisano and Elisa Pennacchia, while two new texts have been added: 'Cognitive digital twin for building management systems: a case study in Rome' by Dr. Sofia Agostinelli (pp. 293-304) and 'Evolutionary cities: from theory to practice' by Prof. Riccardo Maria Pulselli (pp. 307-318).

…to my mother and father, and to their dreams

Saverio Mecca*

URBAN FRAGILITIES IN THE 21ST CENTURY

According to the United Nations demographic statistics service, 2010 marked a real turning point in human history. That year the number of people inhabiting urban areas (3.42 billion) surpassed that of those living predominantly in rural areas (3.41 billion). In 1950 only 30% of humankind lived in urban areas, while projections for the year 2050 predict that 68% of the world population will live in cities, indicating an increase of 84%, passing from 3.4 billion at the end of 2009 to 6.3 billion in 2050[1]. Cities have thus become the focal point of complex problems ranging from the adverse effects of global warming, climate change, and the consequent aggravation of physical and psychological health problems, inequality, and alienation, reduction of economic opportunities, social fragmentation, and conflicts.

* Saverio Mecca (M.Arch.) Full Professor of Building Production and Management at University of Florence (Italy), Dean of the Faculty from November 2009 to December 2012 and afterword Dean of Department of Architecture until December 2019, and President of the National Conference of Architectural Schools of Italy. At present President of the Italian Society of Science, Technology and Engineering of Architecture (ISTeA).

[1] United Nation Department of Economic and Social Affairs, UNDESA 2009, *Urban and rural area* (UNDESA).

Cities are living laboratories, experimental sites for co-producing innovative solutions to contemporary global challenges, transforming emerging problems into opportunities, in order to define a model of urban development consistent with the objectives of the Smart Growth of Society, as postulated in Goal 11 of the 2030 Sustainable Development Goals (SDGs)[2]: "*Making Cities Inclusive, Safe, Resilient and Sustainable*"[3].

During 2020, we witnessed an acceleration of many processes that in previous times we perceived less clearly, underestimating their importance and relevance. That acceleration has forced many of us to address – step-by-step and learning by doing – the dimensions and complexity of our societies, and their physical concentration within city boundaries.

Demographic transformations, pandemic diseases, climate change, and extreme climatic events are among the emerging phenomena that must be evaluated while taking into account the need to guarantee that urban systems continue to be fully operational and able to preserve urban and ecosystem services and citizens' quality of life. Today these are the essential terms of

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[2] UN General Assembly 2015, *Transforming our World: the 2030 Agenda for Sustainable Development* (A/RES/70/1), New York.

[3] The Sustainable Development Goals are: 1) No Poverty; 2) Zero Hunger; 3) Good Health and Well-being; 4) Quality Education; 5) Gender Equality; 6) Clean Water and Sanitation; 7) Affordable and Clean Energy; 8) Decent Work and Economic Growth; 9) Industry, Innovation, and Infrastructure; 10) Reducing Inequality; 11) Sustainable Cities and Communities; 12) Responsible Consumption and Production; 13) Climate Action; 14) Life Below Water; 15) Life On Land; 16) Peace, Justice, and Strong Institutions; 17) Partnerships for the Goals.

the discussion about the environmental, cultural, infrastructural, and human sustainability in our cities. Considering the complexity of climate challenges with respect to our progressively over-urbanized planet, we do not intend to address here the international debate about the true causes or, rather, the contributing causes of global warming and climate change, nor about the role to be attributed to human development.

Contemporary global challenges are substantially related to environmental, climatic, and demographic crises. They require evaluation models that entail a sustainable approach for the management of urban areas, bearing in mind that cities are the places where humankind is most highly concentrated on the planet. Such an overcrowded world, where billions of people live crammed into urban systems, frequently with poor hygienic conditions, exposes citizens and communities to close proximity with animal species that can potentially bring new diseases, as may have occurred in the scenario of the COVID-19 pandemic outbreak.

Such global challenges, only apparently novel, and more insidious and unexpected than volcanic eruptions, earthquakes, or extreme climate events, prove to be substantially more intrusive and destabilizing in their effects on communities and economic organization, revealing the “fragilities” of the postindustrial development model.

All our usual reference points disappeared suddenly, forcing us to reorganize completely the ways we work, study, and conduct our interpersonal relationships.

Societies have had to return to the ancient principles of interpersonal distancing as the only effective tool for limiting diffusion of the virus.

Thanks to our advanced communication technologies, we have been largely able to preserve our basic societal and economic functions, probably selecting those that are most fundamental. Bearing in mind the priorities, as we now perceive them, we have been forced to reorganize our personal and societal urgencies, forcibly adapting ourselves to a new "slower-motion" way of life.

The pandemic has forced contemporary societies to evolve in just a few weeks from a late nineteen-century model to a twenty-first-century digital era model that brings with it new ethical and social implications that still need to be fully explored and understood.

It can be assumed that the reduced physical mobility we now experience will continue to characterize the post-pandemic world. This however will not imply isolation of individuals and communities: all interpersonal communications, as well as work or education, that in the recent past required medium to long distance travel, will need to be carefully considered and undertaken only in cases of real necessity. The social right to mobility, which is even stated in the preamble of the Treaty on the Functioning of the European Union (TFEU)[4] will be

[4] The Treaty on the Functioning of the European Union (TFEU), or treaty of Lisbon, is one of the multilateral treaties forming the so-called constitutional basis of the European Union (EU), together with the Treaty on European Union (TEU), often recalled as Treaty of Maastricht). Built upon the basis of the Treaty of Rome (1957) and renamed in 2009, when it was signed in Lisbon. In article Article 20 (ex Article 17 TEC), establishing the terms of European citizenship, the

preserved through innovative digital tools, reducing the need to use public transportation for reaching workplaces or educational locations. This will produce substantial positive effects on air quality and ecosystem services, as we already seen in spring 2020 during the nearly global lockdown during the first COVID-19 outbreak.

The current experience of physical distancing has shown us that it is possible to bring people closer using digital tools, integrating virtual and in-presence activities. Big Data, semantic web, Digital Twins and multidimensional models, micro and macro simulations accompanied by systems for the collection, management, and interpretation of data, have all shown their worth. Information and knowledge are being directed towards innovative forms of scientific and professional work, leading to design creativity, and are also opening new scenarios for digital cities, as well as innovative working methodologies, involving especially universities and research centres, and creating new educational ecosystems.

People's physical mobility, reduced to strict working and education necessities or leisure, will be increasingly enhanced and complemented by flows of data, information, and knowledge, with an increasing need for advanced digital tools and highly performing networks. This new approach will require social and territorial reorganization, a new approach to public transport,

treaty states that EU citizens have: "*(a) the right to move and reside freely within the territory of the Member States*" (Consolidated versions of the Treaty on European Union and the Treaty on the Functioning of the European Union (TFEU) [2016] OJ C202/1.)

relevant transformation of teaching and learning methodologies and smart/flexible working, thus changing in the medium long term our way of conceiving cities and urban life, at least in Europe and other advanced economies. Living at a short distance from our places of work or education will become a necessity rather than a convenience, and will help to bring humanity back to smaller communities and a physically and socially healthier life, bringing the concept of "proximity" back into the current urban agenda.

Since the first steps of mankind towards an urban environment, the very idea of the city has responded to the fundamental need for proximity. Since the eighteenth-century Industrial Revolution, proximity has been conceived only in terms of physical proximity and density, whether of concentrations of people, productive activities or living spaces. With the growth in dimensions of cities this dense urban model has become more a source of social isolation and interpersonal distancing than of connection, not only among people or social groups, but also towards nature and wildlife, restricted to domesticated green areas, choked within city borders.

The unexpected 'social experiment' of the 2020 pandemic, temporarily prohibiting physical proximity, has brought to light new models of social and working relationships, based on digital tools and networks. Leaving behind the nineteenth-century conception of proximity, we now feel the need to interpret it in a more complex manner, in which physical proximity, while still recognized as necessary for some activities and social life, can be complemented and integrated by digital proximity.

Moving beyond the current idea of a 'Smart city' towards the new concept of the (R)evolving city, will mean above all rethinking radically the so-called "Smartness" of an urban area. While we cannot ignore that the *New frontier* for the development of contemporary urban civilisation must take into account the modern technological signs of progress, we cannot consider them the definitive answer to all contemporary urban issues.

The (R)evolving city 'evolves' by implementing circular economy principles, bearing in mind the well-being of its citizens. The (R)evolving city consumes without devouring, recycles while metabolizing, limits its ecological footprint, and ultimately guides its inhabitants with maternal and gentle care towards a new forms of awareness as citizens. The citizens of the (R)evolving city will become proactive actors in that evolution, leaving behind them certain destructive attitudes inherited from the past and reaching a higher level of social and environmental awareness. They will need to move towards better integration within the urban and natural ecosystems, becoming more and more respectful of their reciprocal relations as well as towards their living environment. In my view, two major areas of research, training, and experimentation are now vital: the first centers on big data, digital twins, and socially responsible and transparently managed artificial intelligence. The second, tightly connected to the first, can be defined as the search for solutions based on nature and culture, leading to dynamic and planned environmental and socio-cultural sustainability, integrated with socio-economic sustainability.

The innovation brought by big data introduces a radical innovation of cognitive and design processes. The digital twin model, processing and relying on big data, leads the way towards a new technology transition. We will be moving from a normative and prescriptive scientific approach (mostly relying on standard-based theoretical truths and generating a rigid interpretation of reality), towards a behavioral performance technology, based on open systemic epistemologies, able to provide an equivalent representation of reality, closer to a biological or life sciences approach .

In the context of strategies related to Goal 11 of the 2030 Sustainable Development Goals (SDGs), "*Making Cities Inclusive, Safe, Resilient and Sustainable*", nature and culture-based solutions, defined as "…actions inspired, supported or copied from nature"[5], have recently emerged as one of the main political factors in the transition of cities, as they meet several objectives simultaneously.

Cities and places, in general, are the emblem of the indissoluble union of nature and culture: the natural environment, society, and culture have generated over the centuries a tangible and intangible heritage that constitutes the identitary substratum that defines places and communities. It represents a resource that contributes to the territorial capital of regions, strengthening social

[5] "…*Nature-based solutions are actions inspired by, supported by or copied from nature that aim to help societies address a variety of environmental, social and economic challenges in sustainable ways.*" EPRS | European Parliamentary Research Service, European Parliament Briefing (November 2017) PE 608.796 EN: *Nature-based solutions - Concept, opportunities and challenges*, Strasbourg.

cohesion, employment, and economic growth, and stimulating policies based on local communities.

Nature and culture-based solutions are often the least expensive, most resilient, and most effective in the long run. They can create jobs and economic growth and can promote the sustainability of cities and territories. Culture, intended as the inherited and developing knowledge, know-how and beliefs of a community (as in its Latin root, *Colere*, to cultivate, but also to care for, to worship) is what allows citizens and communities to take care of and relate to the urban and the natural environment, on the one hand, and to other individuals and communities on the other. It is not so much space itself that generates belonging or rootedness, but rather the human capacity to think and construct space by giving it meaning.

The recognition of belonging to a territory implies identification with the territory and the preservation of the place: its protection also implies the protection of the community that lives in it and thus of its cultural identity. Membership and identity are therefore similar and are related to the concept of "inhabiting", which Heidegger defined as the fundamental problem of the new anthropology.

The traditional heritage of Mediterranean cities constitutes an immense resource that has great potential for defining the principles of sustainable design and contemporary architecture. The value of traditional Mediterranean urban culture, its methods and strategies, is unfortunately underestimated and its teachings rarely applied in the recent Western construction trends.

Some very important green and sustainable lessons can be learned from it, and have huge potential for being applied today. The traditional heritage of Mediterranean cities represents a resilient response to the environmental and climatic constraints, as well as the socio-economic and cultural characteristics of societies, to changes and challenges over the centuries. In addition, the materials and architectural components it employs react flexibly to the climate and adapt to different locations.

This is a lesson that comes from the past, from social systems based on knowledge and techniques, also known as traditional knowledge, not linked to a simple technological paradigm, but closely related to the social and cultural system. Indeed, they are an integral part of it. They can inspire cultural practices and processes of social resilience, aimed at providing a strategic response to today's critical and destabilizing events, in order to restore the equilibrium of the system or, rather, to create a new "harmonious" equilibrium, where the innovative twenty-first-century concept of "proximity", offering a new equilibrium between physical and digital interpersonal contacts, will also play an important role.

These techniques, knowledge, and tools define not only a metaphysical and ontological model, but also a new metabolic model, clearly distinct from what is emerging from rationalist and scientific thought. The metabolic model promotes values such as holism, development of long-term multi-functional integrated solutions, contextualization, and respect for natural laws and the careful and conscientious use of natural resources.

This richness of meanings transcends mere functionality, and leads to sharing and caring for the common good and finally to *Autopoiesis*, maintaining and renewing the conditions for human well-being.

THE CHIEF FUNCTION OF THE CITY IS TO CONVERT POWER INTO FORM, ENERGY INTO CULTURE, DEAD MATTER INTO THE LIVING SYMBOLS OF ART, BIOLOGICAL REPRODUCTION INTO SOCIAL CREATIVITY.

Lewis Mumford*
1961, *The City in History*

Using a metabolic approach to analyze an urban system, in other words looking at the city as a living organism, and therefore approaching the urban growth using the logic and analytical tools applicable to living beings, seems to be a valid starting point, not only to understand the complexity of contemporary urban dynamics, but also to be able to mitigate the negative impacts generated by cities. The term Metabolism (from the ancient Greek Μεταβολή, meaning "Change") defines the set of chemical reactions that take place within each cell of a living organism, reactions that provide the energy needed both for life processes and for producing new organic matter. Living organisms are unique in their ability to transform raw biological materials into energy, and to use it for carrying out their daily activities such as growth, movement and reproduction. In biology, the definition of "metabolism" is:

> […] the sum of the chemical reactions that take place within each cell of a living organism and that provide energy for vital processes and for synthesizing new organic material[1].

*Lewis Mumford (1895 - 1990) was an American historian, sociologist, philosopher of technology and American literary critic. Particularly known for his studies of cities and urban architecture, Mumford was influenced by the work of the Scottish theorist Sir Patrick Geddes and worked closely with his associate the British sociologist Victor Branford.

This definition was developed during the first half of the twentieth century by Hans Leo Kornberg[2], working in collaboration with his colleague and friend Hans Adolf Krebs[3]. Such a definition can easily be applied to urban systems when they are considered as living organisms, based on flows of materials and energy exchange, both with the external environment and among their various internal components.

Metabolic approaches to the urban context

In the second half of the twentieth century a metabolic perspective on human settlements led to the definition of several innovative approaches which have allowed us to read cities as open systems characterized by a

He was a contemporary and friend of Frank Lloyd Wright, Clarence Stein, Frederic Osborn, Edmund N. Bacon, and Vannevar Bush.

[1] Kornberg, H. L. 1998, *Metabolism (Biology)*, in Britannica.

[2] Sir Hans Leo Kornberg, Fellow of the Royal Society, (1928 - 2019) was a German-born British-American biochemist. He was the "Sir William Dunn" Chair of Biochemistry at the University of Cambridge from 1975 to 1995 and Master of Christ's College, Cambridge from 1982 to 1995. He is co-author of the text *Energy Transformations in Living Matter* (1957) and author of many papers on cellular metabolism. Krebs H. A., Kornberg L., 1957, *Energy*, *Op. cit.*

[3] Sir Hans Adolf Krebs (1900 - 1981) was a German-born British biologist, physician, and biochemist who pioneered the study of cellular respiration, a biochemical process in living cells responsible for extracting energy from food and oxygen and making it available to drive life processes. He is best known for his discoveries of two important sequences of chemical reactions that occur in human cells and many other organisms, namely the citric acid cycle and the urea cycle. The former, known as the 'Krebs cycle', is the key sequence of metabolic reactions that provide energy to human cells and other oxygen-respiring organisms. His discovery earned Krebs the Nobel Prize in Medicine in 1953. With Hans L. Kornberg he also discovered the glyoxylate cycle, which is a slight variation of the citric acid cycle found in plants, bacteria, protists and fungi. Krebs died in 1981 in Oxford, where he spent 13 years of his career from 1954 until his retirement in 1967 at the University of Oxford.

constant and consistent exchange of flows and energy[4]. The relationship between cities and their territory, especially after the first industrial revolution has often been described in terms of conflict. The ecologist Eugene Odum[6] in the early '60s defined the urban system as "a parasite of the rural environment" because, unlike other ecosystems, it is heterotrophic: it needs materials, resources and energy, and is dependent on neighboring areas. Odum stated that:

> As populations and energy use increased, the early cities grew, and surrounding agricultural lands were often converted to urban uses. The recycling of nutrients was discontinued. These are two of the most serious problems associated with urban development; the loss of prime agricultural lands as they are covered by streets, parking lots, and buildings and the pollution of rivers, streams, and lakes as wastes are discarded instead of recycled for productive purposes[5].

As a result of his studies on the exchanges between urban and rural environments, in 1973 Odum introduced a new unit of measurement to evaluate energy flows and stocks: the *Emergy* (a contraction of the terms 'embodied' and 'energy'), which indicates the total equivalent solar energy used directly and indirectly for the production of goods and services[6].

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[4] Foster C., Rapoport A., Trucco E. 1957, *Some unsolved problems in the Theory of non-isolated systems*, in L. von Bertalanffy, *General systems, Society for General Systems Research*, Washington, vol. 14, pp. 9-14.
[5] Odum, E. P. 1963, *Ecology*, Rinehart and Winston, Holt: New York, p. 201.
[6] Odum, H. T. 1973, *Energy, Ecology and Economics*, Ambio, vol. 2, n. 6, pp. 220-227.

The need for a new model of development in order to reconcile economic growth and the equitable distribution of resources began to emerge in the '70s, following the awareness that the concept of classical development, linked exclusively to economic growth and specifically to the increase of the Gross Domestic Product (GDP), would soon cause the collapse of natural systems. In his essay entitled *The Economics of the Coming Spaceship Earth* (1966), the economist Kenneth Boulding[7] stated:

> For the sake of picturesqueness, I am tempted to call the open economy the "cowboy economy," the cowboy being symbolic of the illimitable plains and also associated with reckless, exploitative, romantic, and violent behavior, which is characteristic of open societies. The closed economy of the future might similarly be called the "spaceman" economy, in which the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy[8].

Boulding introduced the idea of the Earth as a closed system; he rejected the myth of the indefinite expansion of consumption, refuting the full validity of GDP[9], as

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[7] Kenneth Ewart Boulding (1910 - 1993) English economist, pacifist and poet naturalized American. A religious mystic, systems scientist, and philosopher, he was a co-founder of general systems theory.

[8] Boulding K. E., *The Economics of the Coming Spaceship Earth*, in H. Jarrett (ed.) 1966. *Environmental Quality in a Growing Economy*, pp. 3-14, Johns Hopkins University Press, Baltimore.

[9] The concept of Gross Domestic Product (GDP), albeit in a sketchy form, was already expressed in a similar way to the current one by economist Adam Smith in his most famous work *The Wealth of Nations* ("... *The annual labour of every nation is the fund which originally supplies it with all the necessaries and conveniencies of life which it annually consumes, and which consist always either in the immediate*

developed in its modern form by the economist Simon Kuznets[10], who did not include the cost of pollution and limited natural resources among his parameters. Along the same lines, at the end of the sixties, the first essays by the Americans Herman E. Daly[11] and Clarence Edwin Ayres[12] were published. They stressed the link between the negative effects of economic activities on the environment, the flow of materials through each production process and the entire economy.
The 1973 oil crisis, due to the Arab-Israeli war of Yom Kippur[13] and the sudden interruption of the supply

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produce of that labour, or in what is purchased with that produce from other nations. […]. It is the great multiplication of the productions of all the different art, in consequence of the division of labour, which occasions, in a well-governed society, that universal opulence which extends itself to the lowest ranks of the people". Smith A. *1776., An Inquiry into the Nature and Causes of the Wealth of Nations, Straman,* London). The modern concept of GDP was developed for the first time by Simon Kuznets in a report commissioned by the United States Congress in 1934. In this report, Kuznets warned against using GDP as a measure of wealth. After the Bretton Woods conference in 1944, which established the creation of the International Monetary Fund, GDP became the primary tool for measuring a country's economy. Simon Kuznets, 1934. "National Income, 1929-1932." 73rd U.S. Congress, 2nd session, Senate document no. 124, pp. 5-7.

10 Simon Smith Kuznets (1901 - 1985) was an American economist and statesman who received the Nobel Prize in Economics in 1971 for his empirical interpretation of economic growth, which led to a new and deeper understanding of economic and social structure and the process of development. Kuznet made a decisive contribution to the transformation of economics into an empirical science and to the formation of quantitative economic history.

11 Herman Edward Daly (1938) American economist and ecologist, professor at the School of Public Policy at the University of Maryland, College Park in the United States.

12 Clarence Edwin Ayres (1891 - 1972) leading thinker of the Texas school of institutional economics during the mid-20th century.

13 Yom Kippur (in Hebrew יום כפור yom kippùr, 'Day of Atonement') is the Jewish religious holiday that celebrates the Day of Atonement. Yom Kippur is the Jewish holiday of greatest solemnity and is solemnized by an

of hydrocarbons, was a turning point for the study of financial and energy flows in contemporary socio-economic systems. For the first time, Western countries became clearly aware of the fragility and precariousness of a production system based on fossil energy sources, evidently exhaustible and above all coming from politically unstable territories. This situation led governments and entrepreneurs to estimate the amount of energy consumed by each process in order to reduce its use, in the first place because of rising monetary costs[14].

Various scholars then began to measure not only energy flows but also those of materials that occur in production processes and in urban environments. These measurements were accompanied by a description of the flow of money, taking a further step towards the logical combination of economic and physical-biological phenomena. Thus, we began to talk about energy cost, that is cost in terms of

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absolute fast. During the fast it is forbidden to eat and drink, and applies the same requirements for the Sabbath with regard to work and other prohibited activities. So it is clear why the Arab coalition decided to attack, in the day in which the whole state of Israel was in a situation of weakness.

[14] The war actually ended after about twenty days with the proclamation of a cease-fire between the two sides. Almost all Arab and anti-American countries, in support of Syria and Egypt, doubled the price of oil, decreasing exports by about 25%, to warn other nations not to support Israel. This process led to a staggering increase in the price of oil, up to three times the price before the Suez crisis. In Italy the government promoted a national plan called 'economic austerity' for energy saving that included among other measures: prohibiting driving on Sundays, ending television programs early and a reduction in street and commercial lighting. At the same time the Government rethought its energy policies, promoting the construction of nuclear power plants to limit dependence on fossil fuels. Cinquepalmi F., *Analisi delle problematiche ambientali connesse alla filiera dell'energia in Italia in riferimento al traffico marittimo degli Idrocarburi e ai possibili strumenti di gestione del rischio*, final doctoral thesis- Doctoral school of Energy Engineering 2008, Sapienza University of Rome (Tutor Prof. Maurizio Cumo)

raw materials and environmental cost of goods, where the latter were defined as the production of waste and scrap, in liquid, solid or gaseous form, related to the production and use of a unit of mass of each commodity. Nicholas Georgescu-Roegen[15] in his text *Energy and economic myths* of 1972, coined the term 'bioeconomy' to suggest the need for adaptation of economic activities to natural biogeochemical and energy cycles, stating that our planet could be considered as a closed system whose resources are not infinite. He stated that:

> The Second Law of thermodynamics tells us also that the whole universe is subject to a continuous qualitative degradation: entropy increases and the increase is irrevocable. Consequently, natural resources can pass through the economic process only once: waste is irrevocably waste. Man cannot defeat this law, any more than he can stop the law of gravitation from working. The economic process, like biological life itself, is unidirectional[16].

In 1972, the Club of Rome[17] published the well-known report "The Limits to Growth", resulting from the work

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[15] Nicholas Georgescu-Roegen (1906 - 1994) Romanian mathematician, statistician and economist. He is best known today for his groundbreaking 1971 text, *'The Entropy Law' and the Economic Process*.

[16] Georgescu-Roegen N. 1976, *Energy and Economic Myths: Institutional and Analytical Economic Essays*, Pergamon, New York p. 98.

[17] Founded in 1968 at the Accademia dei Lincei, the Club of Rome is composed of current and former Heads of State, senior United Nations officials, high-level politicians, government officials, diplomats, scientists, economists and business leaders from around the world. The aim of the Club of Rome is to promote a constructive dialogue between business leaders, politicians, and those who lead international agencies, as well as those in universities and schools and in the media. The documents and reports produced by the Club of Rome aim to help decision-makers and the public better understand major global issues, with a particular focus on sustainability issues. They often make specific policy proposals and seek to foster a greater sense of civic responsibility. As of July 1, 2008, the organization is based in Winterthur, Switzerland.

of 17 researchers from the Massachusetts Institute of Technology (MIT). The text, still of extreme interest even if a bit dated, is based on a mathematical model of the world aimed at the analysis of five main trends, namely increasing industrialization, population growth, agricultural production, the widespread use of non-renewable resources and pollution[18].

The urban ecological footprint

After a period of scientific eclipse, the concept of urban metabolism developed in the mid-20th century was revived in the first decade of the 21st century[19 20].

It is interesting to note, however, that notwithstanding the current popularity of this approach, there is actually no unanimous consensus in the literature about what constitutes its foundational elements. Kennedy and others[21] (2011) identify Abel Wolman[22] (1965) as the father of the concept of metabolism, based on his study of the replenishment process of a hypothetical

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[18] *"The team examined the five basic factors that determine, and therefore, ultimately limit, growth on this planet: population, agricultural production, natural resources, industrial production and pollution"*. Meadows D.H., Meadows D.L., Randers J., Behrens III W.W. 1972, *The Limits to Growth*, Universe Books, New York, pp. 11-12.

[19] Sabine Barles is professor of environmental studies, urban planner and civil engineer, at the *Laboratoire d'architecture urbanisme et société de l'Institute Français d'Urbanisme* specializing in research in the field of 'urban metabolism'.

[20] Barles S. 2010, *Society, energy and materials: the contribution of urban metabolism studies to sustainable urban development issues*, «Journal of Environmental Planning and Management», vol. 53, n. 4, pp. 439-455.

[21] Kennedy C., Pincetl S., Bunje P. 2011, *The study of urban metabolism and its applications to urban planning and design*, «Environmental Pollution », vol. 159, n. 8-9, pp. 1965-1973.

[22] Wolman A. 1965, *The metabolism of cities*, «Scientific American», vol. 213, pp. 179-190.

city, replenishment that took into account not only consumables, energy and food supply (inputs), but also the related waste production (outputs). In fact, Burgess[23] (1925), a sociologist of the Chicago School, already in 1925 had used the term metabolism, in substance comparing urban growth to the processes of a metabolic system[24], although he referred mainly to the sociological analysis of the population.

Burgess, with Park and McKenzie (1925), analyzed the idea of the city, conceived in the Chicago School of Sociology[25] as a predominantly economic and market-based system. They proposed a definition for the city as more than the mere sum of the individuals, physical

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[23] Burgess E.W. *et al.* 1992, *The Growth of the City. Suggestions for Investigation of Human Behavior in the Urban Environment*, Chicago University Press, Chicago.

[24] "Social organization and disorganization as processes of metabolism: these questions may best be answered, perhaps, by thinking of urban growth as a resultant of organization and disorganization analogous to the anabolic and katabolic processes of metabolism in the body". Burgess, *Op. cit.*, p. 53.

[25] In sociology, the work of the Chicago School in the 1920s and 1930s (sometimes also referred to as the 'ecological school') are considered to be the foundation of the emerging urban sociology and urban environment research. The School operated by combining sociological theory and ethnography, along with fieldwork in the challenging context of the industrial city of Chicago. Although it produced the involvement of scholars from several US universities, the term is often used interchangeably to refer to the sociology department of the University of Chicago. Major scholars of the Chicago School in the 1920s/1930s included Nels Anderson, Ernest Burgess, Ruth Shonle Cavan, Edward Franklin Frazier, Everett Hughes, Roderick D. McKenzie, George Herbert Mead, Robert E. Park, Walter C. Reckless, Edwin Sutherland, WI Thomas, Frederic Thrasher, Louis Wirth, and Florian Znaniecki. Also the activist, social scientist and Nobel Peace Prize winner Jane Addams maintained close ties with some members of the Chicago School of Sociology, not to mention close relationships with the greatest architects and designers of the time, first and foremost Frank Lloyd Wright.

structures and economic activities, thus developing one of the theoretical assumptions proposed by Weber[26] and published posthumously in 1921. The city is conceived as a way of thinking, a set of customs and traditions, feelings and organized behaviors, all interacting and transmitted as a tradition.

The city cannot be considered a mere physical mechanism or an artificial construction: it is intertwined in the life processes of the people who live there and "is therefore a product of nature and in particular of human nature"[27]. On the other hand, the ecologist Eugene Odum[28], in line with what turns out to be a criterion more focused on the biological and ecosystemic approach, has stated that the modern city is comparable to a parasite:

> […] the city is a parasite on the natural and domesticated environments, since it does not grow food, and it dirties its own air and water[29].

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[26] Weber M. 1921, *The City* (not Weber's title), Collier Book, New York, cap. 2, p. 1212.

[27] "The city […] is something more than a congeries of individual men and of social conveniences, streets, buildings, electric lights, tramways, and telephones, etc.; something more, also, than a mere constellation of institutions and administrative devices-courts, hospitals, schools, police, and civil functionaries of various sorts. The city is, rather, a state of mind, a body of customs and traditions, and of the organized attitudes and sentiments that inhere in these customs and are transmitted with this tradition. The city is not, in other words, merely a physical mechanism and an artificial construction. It is involved in the vital processes of the people who compose it; it is a product of nature, and particularly of human nature". Park, *Op. cit*. 1915 p. 1.

[28] Eugene Pleasants Odum (1913 - 2002), American biologist and professor at the University of Georgia known for his pioneering work on ecosystem ecology. He was with his brother Howard T. Odum the author of the seminal *Fundamentals of Ecology* (1953).

[29] Odum, *Op. cit.*, p. 17.

Trying to propose an innovative vision for a possible model of integrated urban metabolism, C. Kennedy and other researchers produced a clear definition in a 2007 paper where they defined it as the sum of technical and socio-economic processes occurring in cities, resulting in growth, energy production and energy waste containment[30]. Already in the early 1990s, the Swiss ecologist Mathis Wackernagel[31], together with his student William Rees of the University of British Columbia, developed an innovative indicator of 'spatial dimension' to estimate humanity's demand for natural resources. This indicator came to be known as the Ecological Footprint, firstly defined as:

> […] the area of biologically productive land and water that is required for an individual or an activity to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practice[32].

The growing concern about climate and global changes, with respect to which the overall ecological footprint of urban systems is of obvious relevance, implies the use of advanced models for the assessment of urban metabolism, models that allow determining the overall picture in order

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[30] Kennedy C., Pincetl S., Bunje P. 2011, *The Study of urban metabolism and its applications to urban planning and design*, «Environmental Pollution », vol. 159, n. 8-9, p. 1.

[31] Mathis Wackernagel (Base, 1962) is a Swiss-born sustainability advocate and President of Global Footprint Network, an international sustainability think tank, a non-profit organization focusing on development and promotion of metrics for sustainability.

[32] Wackernagel M., Rees W. E. 1997, *Perceptual and structural barriers to investing in natural capital: Economics from an ecological footprint perspectiv*e, «Ecological Economics», vol. 20, n. 1, pp. 3-24..

to design urban policies aimed at maintaining levels of sustainability, health and quality of life in cities. It involves identifying material and energy flows resulting from urban socioeconomic activities as well as regional and global biogeochemical cycles.

After several international negotiations, the Convention on Biological Diversity (CBD)[33] in 2005 came to an internationally agreed definition of Urban Ecological Footprint, as the area of the planet required to sustain each citizen's lifestyle, considering not only food, but also materials, energy, water and other natural resources[34], definition refined and approved in 2014 (CBD, 2014)[35].

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[33] The Convention on Biological Diversity (CBD), is one of three multilateral treaties signed after the Earth Summit in Rio de Janerio in 1992. The Convention has three main objectives, including: the conservation of biological diversity (or biodiversity); the sustainable use of its components; and the fair and equitable sharing of the benefits arising from genetic resources.

[34] Convention on Biological Diversity (CBD) Subsidiary body on scientific, technical and technological advice (SBSTTA) 2005, *Indicators for assessing progress towards the 2010 target: ecological footprint and related concepts*, (Note by the Executive Secretary), UNEP/CBD/SBSTTA/11/INF/20, Montreal.

[35] The Ecological footprint according to the Convention on Biological Diversity (CBD) is: "...the amount of land necessary to sustain each citizen's lifestyle, considering not only food but also materials, energy, and water and other natural resources". It compares per capita footprint (the equivalent, in hectares, of the area needed to produce all the resources consumed per capita) and biological capacity (the average equivalent productive area available per capita). Secretariat of the Convention on Biological Diversity, Cities and Biodiversity Outlook-Executive Summary. Montreal (2012), p. 4. In the same report, reference is made to the fact that, as of 2012, more than 100 cities or regions had used the methodology of ecological footprint analysis to support urban planning policies. In 1995, the City of London's ecological footprint was 125 times the size of the city, meaning it required an area the size of the entire productive land area of the United Kingdom to provide resources necessary to sustain its citizens (CBD 2012), p. 4. The footprint assesses demand by measuring the area of land (and water) required to support a defined human activity, given the prevailing technology. The footprint

URBAN METABOLISM	
Categories	**Description**
NATURAL FACTORS	The geomorphological location of the city as well as climatic conditions, surrounding landscape and natural resources have a major influence on urban metabolism and especially energy consumption.
FUNCTIONAL ROLE OF THE CITY	Analyzing typology and intensity of the main economic activities. Industrial cities tend to have higher metabolic flows than financial or political centers.
INCOME LEVEL	Affecting directly and indirectly the quality, efficiency and waste production of urban metabolism.
URBAN POLICIES AND MANAGEMENT PRACTICES	Policies and managements in urban areas could make the difference in the application of the metabolic model, especially on waste recycling: i.e. the re-claim of materials such as copper and iron. Literature on industrial ecology has evaluated the potential of urban extraction in relation to the consumption of natural reserves of the same resources.
URBAN PLANNING AND DESIGN CHOICES	Spatial distribution of buildings and infrastructures, directly impacts on choices related to transport systems, energy efficiency of buildings and the heat island effect.

Tab. 1 Analysis categories for urban metabolism (Bai and Schandl 2010).

The ecological footprint is a method of assessing the needs of the human species in the biosphere and estimating the extent to which the regenerative capacity of the planet is used by human activities. The application of the integrated urban metabolism model is precisely aimed at identify and quantifying the flows of inputs such as water, energy, materials, nutrients and outputs, namely heat dispersion, pollutants and waste. According to this

therefore depends on the size of a population and their material standard of living, including the use of energy, food, water, building materials, and other consumables.

logic, the main factors influencing urban metabolism can be grouped into five categories, summarized in Table 1.

When the demand for goods and services exceeds available limits, consumption clearly becomes unsustainable and fewer resources are available for wild species, leading to a negative impact on biodiversity, not to mention the risk of a drastic reduction in ecosystem services[36] for the population.

An interesting exercise aimed at understanding the effectiveness of applying an integrated metabolic model at different historical stages of human social evolution is the one developed by Fischer-Kowalski[37] and Haberl[38] (1998)[39], shown in Table 2.

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[36] The Millennium Ecosystem Assessment has defined ecosystem services as 'the benefits that people derive from ecosystems'. In addition to providing services or goods such as food, timber and other raw materials, i.e. plants, animals, fungi and micro-organisms provide essential regulating services such as pollination of crops, prevention of soil erosion and purification of water from the air, the oxygen we breathe and a wide range of cultural, social, recreational and spiritual services. Millennium Ecosystem Assessment 2005, *Ecosystems and Human Well-being: Synthesis*, Island Press, Washington, DC. p. V.

[37] Marina Fischer-Kowalski born in Vienna in 1946, is an Austrian social ecologist, sociologist and university professor of social ecology at the Alpen-Adria-Universität Klagenfurt and founder of the Institute for Social Ecology in Vienna.

[38] Helmut Haberl, Director of the Vienna Institute of Social Ecology, Alpen- Adria Universität, Austria.

[39] Fischer-Kowalski M., Haberl H. 2007, *Socioecological Transitions and Global Change. Trajectories of Social Metabolism and Land Use*, Edward Elgar Publishing, London, p. 30. The two scholars focus on a time span from the Neolithic to the present day, summarising the changes that have taken place in three fundamental phases. During the first phase (Neolithic society), we can speak of uncontrolled solar energy metabolism, since society had no role in the reproduction of resources and the resulting energy flows were therefore minimal. In the second phase (agrarian society), the natural environment begins to be shaped by the needs of the community, and the metabolic relationship between man and nature begins to change. The system begins to control energy,

MODES OF LIVELIHOOD AND TYPES OF METABOLISM			
Conditions analysed	**Socio-Temporal Periods**		
	Neolithic society (hunter-gatherers)	**Agricultural society**	**Industrial society**
POPULATION DENSITY (CAP/KM^2)	0.025	<40	>400
BIOMASS USE (%)	>99	>95	10-30
MATERIAL USE (TONS/CAP/YEAR)	0.5-1.0	3-6	15-25
PER CAPITA ENERGY USE (GJ/CAP/YEAR)	10-20	40-70	150-400
TYPE OF METABOLISM	Uncontrolled solar energy system	Controlled solar energy system	Fossil energy system
COLONISATION OF NATURAL SYSTEMS	None or minimal	Domestication of terrestrial ecosystems	Integral
CHANGES IN THE NATURAL ENVIRONMENT	None	Pervasive changes in agricultural ecosystems at the local scale	Global changes in biogeochemical cycles
SUSTAINABILITY OF LIVELIHOODS	Extinction of hunted/harvested species	Balancing resource extraction and consumption	Resource depletion

Tab. 2 Interactions between society and nature evolved throughout history according to the interpretation of Fischer-Kowalski and Haberl (1998).

This model highlights the interactions that historically have affected the relationship between society and nature. According to this scheme of metabolic evolution, the two Austrian researchers show how increases in population density, and the use of raw materials and energy per capita, correspond to a substantial modification of the natural systems that in the future could lead to a complete exhaustion of the resources available to humankind.

Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA)[40] was developed at the end of the 1970s in the wake of renewed focus on global challenges. Thanks to the pioneering work of Boustead[41] and research by the Freiburg-based Öko-Institut and the German IÖW (Institut für Ökologische Wirtschaftsforschung Gmbh), LCA became a tool applicable not only to a product, procedure or service, but also to a building. It can be considered an 'eco-

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thanks to the new technologies available to the community. The most widely exploited energy source was biomass, which covered 95% of energy inputs, with marginal contributions from wind and hydropower. The industrial revolution brought about a radical metabolic change as biomass was almost entirely replaced by fossil fuels, with significant repercussions on the environmental system.

[40] The term LCA (Life Cycle Assessment) was coined in 1990 by the Setac (Society of Environmental Toxicology and Chemistry) congress to identify, describe and unambiguously unify the objectives of life cycle analysis. The ISO (International Standards Organization) subsequently standardised it.

[41] Ian Boustead, English physicist (1960 - 2011). In 1972, he joined the Open University (OU) as a Staff Tutor in the Faculty of Technology. During this time, he became interested in energy reporting, publishing with Dr. Gerry Hancock in 1978 the *Handbook of Industrial Energy Analysis*. With his pioneering work Boustead made a major contribution to the development and practice of the LCA (Life Cycle Assessment) methodology.

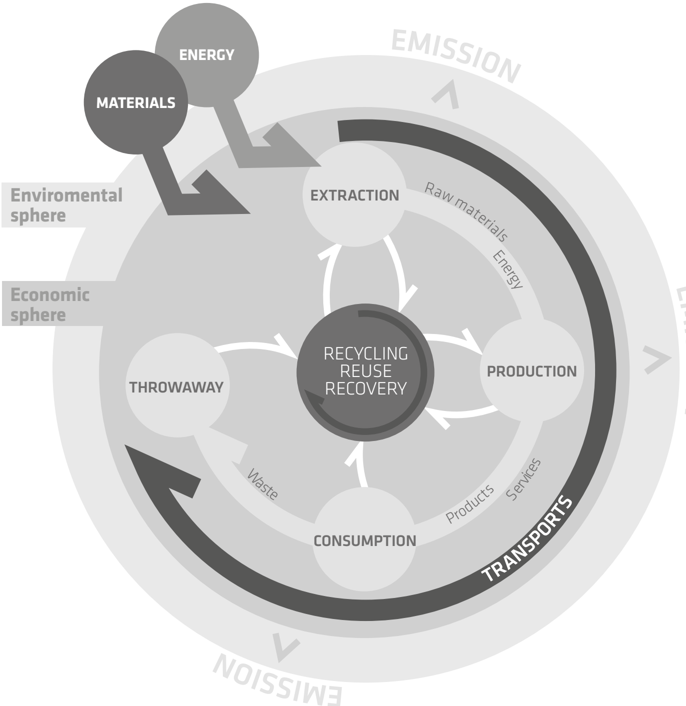

Fig. 1 Life Cycle Assessment (LCA) diagram.

scale' that measures the amount of water, energy, raw materials, materials, waste and emissions that each process consumes and entails, taking into account the cumulative environmental impact 'from cradle to grave', so to speak (Fig. 1).

LCA, which currently complies with UNI EN ISO 14040, is carried out on the basis of input and output data. For each individual process, raw materials, recycled product parts and energy carriers are examined as inputs, and emissions into water, air, land, by-products and waste are examined as outputs. The treatment and disposal processes for the latter are included. The sum of all inputs and outputs forms the basis for estimating the potential environmental impact of a product/process.

Only using this measurement is it possible to identify the consequences of production processes and possible ways to mitigate or eliminate them. During the International Geosphere-Biosphere Programme Conference held in Tokyo in 1988, the notion of 'industrial metabolism' was introduced for the first time, highlighting how the industrial system is based on the exploitation of raw materials extracted from the environment, subsequently transported and transformed, and finally discarded.

The inventor of some of the key principles of sustainable development, the economist Herman E. Daly, states that the main rule of microeconomic optimisation is to grow only to the point where marginal costs equal marginal profits, a principle summarised in the economic approach called the 'when to stop' rule. Macroeconomic systems, on the other hand, based on GDP growth, disregard the 'when to stop' rule: for them, GDP can grow indefinitely, as it is not considered detrimental to anything else.

The 'when to stop' rule gave rise to the three basic principles defined by Daly in 1991 for achieving sustainable development, namely that:

- the rate of resource extraction must be equal to the capacity for regeneration;
- the rate of waste production must be equal to the absorption capacity of the ecosystems into which the waste is introduced;
- regeneration capacity and absorption capacity must be considered as 'natural capital': if they cannot be

> maintained, there is 'consumption of capital' and therefore no sustainability[42].

Daly reiterates the need to ensure the ecosystem's continuing ability to sustain the flow of materials and energy from natural sources through the entire human economy, then returning to nature as waste. In the context of ever-increasing anthropic pressure, linked to indiscriminate global production and consumption, the concept of circular economy responds to the concrete need for sustainable development.

Circular economy

The term Circular economy dates back to 1990, when it was used in a book by two British economists, David W. Pearce[43] and R. Kerry Turner[44], entitled *Economics of Natural Resources and the Environment*[45]. The two authors, basing their idea on reflections by the economist K. Boulding[46], pointed out that the economy is not an open and linear system but a closed and circular one, as depicted in Figure 2[47].

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42 Daly H.E. 1996, *Beyond growth: the economics of sustainable development*, Beacon Press, Boston.

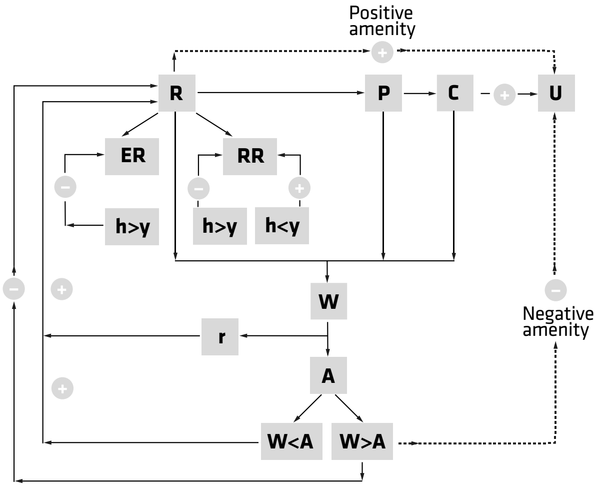
43 David W. Pearce OBE (1941 - 2005) Professor Emeritus in the Department of Economics at University College London (UCL). He specialised in and was a pioneer of Environmental Economics.

44 R. Kerry Turner (1948) associate professor in the School of Environmental Sciences and former professor of environmental economics and management at the University of East Anglia, UK.

45 Pearce D. W., Turner R. K. 1989, *Economics of Natural Resources and the Environment*, Johns Hopkins University Press.

46 Author of: *The Image: Knowledge in Life and Society* (1956) and *Conflict and Defense: A General Theory* (1962). He is also the originator of general systems theory.

47 Andersen M.S. 2006, *An introductory note on the environmental economics of the circular economy*, «Sustainability Science», n. 2, p. 136.



Where the following must be considered			
R	Natural resources	**U**	Utility and welfare
ER	Exhaustible resources	**W**	Waste
RR	Renewable resources	**r**	Recycling
h	High speed of extraction and exploitation	**A**	Ability to assimilate waste Into the environment
y	Resource regeneration capacity	———	Flows of materials | energy
p	Production	- - -	Utility flows

Fig. 2 The circular economy. Source: Pearce and Turner, Chapter 2 of *The circular economy*

In 2002 William McDonough and Michael Braungart elaborated further on the theme in their volume entitled *Cradle to Cradle: Remaking the Way We Make Things*. Here they introduced the 'cradle to cradle' concept (abbreviated C2C), an approach that aims at achieving a continuous cycle of use and reuse of materials, tending to eliminate the production of waste. With the support of the Environmental Protection Encouragement Agency

(EPEA)[48], the two authors designed and developed the Cradle to Cradle® certification: this can be employed to assess a single product in detail, taking into account the following parameters:

- the materials used are healthy and safe for humans and the environment;
- the product can be recycled at the end of its life;
- the design of the product shall be such as to ensure its reuse in the normal process of natural biodegradation or the reuse of all components during the packaging recycling process; the production sites must be 100% non-polluting, using renewable energy to replace fossil one, and compensate 100% of the CO_2 emissions;
- the quality of the water used in the plants must be preserved and optimised at the end of the production process;
- the company must be committed to environmental and social justice and to defending biodiversity[49].

The linear 'production-consumption-disposal' model that has largely characterized the international economy until now must be transformed into a circular one, where up-cycling and re-cycling play a key role and where what was 'disposable' is transformed into 'use and reuse'[50].

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[48] The Environmental Protection Encouragement Agency (EPEA Internationale Umweltforschung) founded in 1987 by chemist Michael Braungart, is an international scientific research and consultancy institute that works with companies, political institutions and scientific institutes, supporting them in the introduction of circular processes.

[49] McDonoug W., Braungart M. 2002, *Cradle to Cradle – Remaking the way we make things*, North Point Press, New York.

[50] Cumo F., Pennacchia E. *et. al.* 2015, *Uso, disuso, riuso. Criteri e modalità per il riuso dei rifiuti come materiale per l'edilizia*, FrancoAngeli, Milano.

Giving a new function to an object, which according to traditional standards would have been devoid of it, increasing its initial value and transforming waste (now synonymous with pollution and an affront to urban decorum) into a resource through renewal and recycling operations, are the cornerstones of the C2C model and should be increasingly adopted. This perspective informs more than one of the flagship initiatives of the Europe 2020[51] strategy: in line with the principles and objectives of a circular economy, it promotes the efficient use of resources to foster the development of green jobs and sustainable growth[52].

The Wellbeing economy and Urban systems

An interesting further development of the circular economy, which completes the reasoning that began with the Chicago School of Sociology, is the concept of the Wellbeing Economy[53].

An economy oriented according to the priority objective of increasing the GDP is destined to exceed the limits of the

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[51] European Commission 2010, *EUROPE 2020. A strategy for smart, sustainable and inclusive growth*, Communication from the Commission, Brussels.

[52] "…*To reduce resource depletion and the environmental degradation that can result, we need to replace our current production and consumption patterns with more resilient and sustainable ones, in line with the principles of a 'circular economy'. Shifting to a more productive and less resource-intensive economy requires investment in eco-innovation and can bring significant benefits in terms of both competitiveness and job creation. In a more circular economy, the value of products, materials and resources is retained in the economy for as long as possible and waste generation is minimized*". European Commission 2017, *Resource Efficiency* (Fact Sheet for the European Semester), Brussels, p. 1.

[53] Fioramonti L. *et al.* 2018, *Toward a Sustainable Wellbeing Economy*, «Sustainability», vol. 9, n. 11.

planet's capacity. By not attributing any value to natural resources and not including any judgement regarding the quality, meaning and consequences of production and consumption, this indicator inevitably conflicts with natural and social balances. These considerations in 2015 led Fioramonti and others to question the GDP as a reliable measure of 'all' economic activities[54].

As GDP is currently conceived, it only takes into account what is formally traded on the market. This means that economic activities, taking place in the 'informal' economy or within households, as well as a variety of other services freely available, are usually not taken into account for the evaluation of the economic growth, despite the fact that those activities and services, from volunteering to ecosystem services, are the enabling functions of our economies and societies.

In contrast to this fundamentally destructive path, the 'Wellbeing Economy' model strengthens social and natural capital and promotes human development based on the virtuous approach of the circular economy. Those ecosystem services which the GDP model considers to be worthless, are instead fully factored into the social infrastructure, making people completely aware of the importance of natural ecosystems for their daily lives.

[54] *"GDP is not a measure of* 'all' *economic activities. Because of its design, it only counts what is formally transacted in the market, which means that other economic activities occurring in the* 'informal' *economy or within households as well as a variety of services made available free of charge, from volunteering to the ecosystem services provided by nature that allow our economies to function, are not counted as part of economic growth"* Fioramonti L. 2015, *We Can't Eat GDP*, «Global Trends», p. 299.

According to this model, economic growth can no longer be based on exploiting natural resources in an indiscriminate way, but rather on improving the quality and effectiveness of people's interactions with each other and with ecosystems: among other things, through the use of appropriate enabling technologies.

It is surprising that, despite the practical evidence that the theoretical pillars of traditional economics are no longer functional, in essence they continue to guide the choices of governments and multilateral bodies that control the global economy, whose paradoxes are in stark contrast to the principles and objectives of the 17 Sustainable Development Goals (SDGs)[55 56]. Approved by the United Nations General Assembly for the period 2015/2030, these are subject to continuous global assessment to determine the state of their implementation[57].

Starting in 2018 a network called Wellbeing Economy Governments (WEGo), linked to the Wellbeing Economy Alliance (WEAll), was created to engage with governments. Its aim is to advance the three key principles of a wellbeing economy, namely: living

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[55] UN General Assembly 2005, *Transforming our World: the 2030 Agenda for Sustainable Development* (A/RES/70/1), New York, p. 18.

[56] The Sustainable Development Goals are: 1) No Poverty; 2) Zero Hunger; 3) Good Health and Well-being; 4) Quality Education; 5) Gender Equality; 6) Clean Water and Sanitation; 7) Affordable and Clean Energy; 8) Decent Work and Economic Growth; 9) Industry, Innovation, and Infrastructure; 10) Reducing Inequality; 11) Sustainable Cities and Communities; 12) Responsible Consumption and Production; 13) Climate Action; 14) Life Below Water; 15) Life On Land; 16) Peace, Justice, and Strong Institutions; 17) Partnerships for the Goals.

[57] Sachs J., Schmidt-Traub G., Kroll C., Lafortune G., Fuller G. 2019, *Sustainable Development Report*, Bertelsmann Stiftung and Sustainable Development Solutions Network, New York.

within planetary ecological boundaries; ensuring a fair distribution of wealth and opportunity; and allocating resources (including environmental and social public goods) scientifically, while bringing wellbeing to the center of decision-making processes of governments at every level and in particular in economic policies. The new Wellbeing Economy Alliance (WE-All)[58] is designed to facilitate this transformation. The fundamental objective of a wellbeing economy must be to implement economic/financial instruments that guarantee everyone favourable conditions of mental and physical health, greater equality and fairness, good social relations: all in an ecologically healthy context that guarantees ecosystem services, whether in a natural or urban environment. The wellbeing economy will therefore have to value economic activities based on collaboration and sharing, as well as on the principles of recycling and upcycling.

This, however, will require a redefinition of the roles of producers and consumers, blurring the traditional boundaries between the two categories, focusing on macro and micro production of renewable energy and on socially and environmentally oriented enterprises, concentrating on measures of progress that reflect real value creation[59]. A wellbeing economy must place certain unavoidable commitments at the center of its development policies, namely:

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[58] The Wellbeing Economies Alliance, or We-All, is a global movement that is engaging different countries around the need to shift economies from a narrow focus on traded goods and services (e.g. GDP) to one more broadly focused on sustainable well-being.

[59] Fioramonti L. *et al.*, *Sustainability*, *Op. cit.*, p.10.

- living within the limits of the planet, in order to achieve environmental sustainability;
- achieving and maintaining an equitable distribution of wealth and opportunity, both within and across generations;
- allocating available resources efficiently in order to ensure high levels of human well-being[60].

[60] *Ibidem*.

ELEMENTS OF DEMOGRAPHIC, SOCIO-CULTURAL AND HISTORICAL EVOLUTION OF HUMAN SETTLEMENTS

The concept of Urban Metabolism explored in the previous chapter, taking into account the balance between incoming and outgoing exchanges of materials and energy, is a useful model to describe the functioning of cities. Using the models and approaches described – such as life cycle assessment, circular economy, and cradle to cradle, and including the principles of the wellbeing economy – the integrated urban metabolism concept allows us to analyse the interactions between the contemporary city and its territory, i.e. between infrastructures and urban services, as well as between natural systems and the human species. In this chapter, the metabolic model is used as a tool for analysing the different phases of the evolution of the city and urban society, tracing the structural, social and cultural changes that in history have led to the consolidation of human beings' ways of life, eventually leading to the formation of what we now call the 'contemporary city'.

A reflection on the 21st century city, as indeed on the historical evolution of urban systems over the last ten thousand years, must involve an analysis of the related technologies that have always been 'Smart' with respect to their cultural context. In fact, urban settlements have always implicitly been 'Smart', i.e. capable of adapting to new scenarios and needs thanks to innovative approaches and solutions. It is a question of understanding how the city fits into its territorial context of reference and how its citizens respond to 'boundary conditions'. When faced by demographic change on any scale, the impact of migration or climate change, the urban metabolism has needed to respond appropriately to ensure the well-being of its citizens, and its responses have always been technological in nature. In the early days of urban settlements, the scale of the phenomena was small, in correlation with the small size of the human communities that inhabited them. Despite their seemingly primitive simplicity, the technologies employed were of astonishing technological innovativeness and provided the desired responses to the changes and challenges our ancestors had to face over time. Each of these technical innovations, from the preservation and reproducibility of fire, to the invention of agriculture, to the processing of primitive ceramics and then metals, took hundreds and sometimes thousands of years to discover and consolidate, through trial and error. Urban settlements themselves and all the related technological and design transformations, accompanied by progress in the use of materials and building techniques, have been the result of a slow and constant 'intelligent' evolution which, in relation to the era and the tools in use, have made every city a 'Smart' city.

The analysis of this urban evolutionary phenomenon, from a technological, management perspective, is key to understanding contemporary and future cities; it must

WORLD POPULATION

7 846 043 598	Current World Population
17 436 504	Births this year
165, 619	Births today
7 320 262	Deaths this year
69 531	Deaths today
10 116 242	Net population growth this year
96,088	Net population growth today

worldometers

The "people counter" website which updates in real-time about the constant growth of the human population.
World Population Prospect: the 2017 Revision – United Nations, Department of Economic and Social Affairs, Population Division (June 21, 2017) International Programs Center at the U.S. Census Bureau, Population Division. For more detailed information: World Population.

Fig. 1 Current population, growth and mortality rates.

begin with their demographic evolution, today the first element needed to understand cities.

Demography of the city

The website www.worldometers.info registers the demographic evolution of the human species on planet Earth in real time. At the precise moment this book is being written it tells us that there are 7 846 043 598 human beings living on the planet. While in actuality, of course, the website gives approximate numbers based on statistical estimates, the remarkable and indisputable fact is that the human population is now growing at a rate unprecedented in the history of the species (Fig. 1).
According to a 1960 study by Edward Smith Deevey[1], the total human population of the planet around 300 000

[1] Edward Smith Deevey Jr. (1914 - 1988), born in Albany, New York, was a prominent American ecologist and paleolimnologist and an early student of G. Evelyn Hutchinson at Yale University. He was a pioneer in several areas of research, including population dynamics, systematics and ecology.

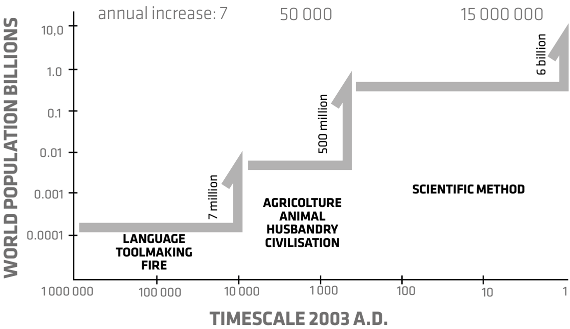

Fig. 2 Annual increase in human population (estimated) from the Neolithic period to the present day (2003 data) Deevey, E. S. (1960). Graphic revision from source: The human population. Scientific American CCIII: 195-204.

years ago can be estimated to be around 1 million. At the time of the so-called Neolithic Revolution, around 10 000 years ago, the estimated human population would have been roughly 5 million. Only 8000 years later, at the time of the Roman Empire, the global human population reached around 133 million, meaning that the human population has grown 70 times faster in the last 8 millennia than it did in the previous 300 000 years, projecting the light of an exponential growth into the future of humanity to the present day (Fig. 2).

Thus, if we include the last two millennia in this demographic progression, the average annual population growth rate over the last 10 000 years can be estimated at 123 times the rate before the Neolithic Revolution[2].

[2] Deevey E. S. 1960, *The human population*, W. H. Freeman Co, USA, pp. 195–204.

The data presented here places the demographic explosion of the human species in an irrefutably parallel relationship with the initiation and growth of the urban experience: it seems difficult, therefore, not to correlate the two phenomena. The United Nations Department of Economic and Social Affairs[3] states that, according to the 2018 data campaign, about 55% of the human population lives in urbanised environments. In 1950, only 30% of humanity lived in urban areas and, according to United Nations population projections, 68% of humans will live in cities by 2050[4].

At the end of the second millennium, the United Nations estimated that there were 371 cities having at least one million inhabitants, while by 2018 this urban typology had grown to the staggering figure of 548 with a projection that in 2030 there would be 706 cities of one million inhabitants or more. As shown in Figure 3, urban areas with more than 10 million inhabitants, often referred to as Megacities, were 33 in 2018, with the prospect that they will be 43 in 2030.

At present, the largest megalopolis is Tokyo with around 37 million inhabitants, followed by New Delhi with 29 million, Shanghai with 26 million and Mexico City and São Paulo with around 22 million each, while Cairo,

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[3] United Nations Department for Economic and Social Affairs – DESA.

[4] In recent decades, the world has been urbanizing rapidly. The global urbanization rate masks important differences in urbanization levels across geographic regions. Northern America is the most urbanized region, with 82% of its population residing in urban areas, whereas Asia is approximately 50% urban, and Africa remains mostly rural with 43% of its population living in urban areas in 2018. United Nations, Department of Economic and Social Affairs, Population Division 2018. *World Urbanization Prospects: The 2018 Revision*, p. 1.

THE WORLD'S TEN LARGEST CITIES IN 2018 AND 2030				
City size rank	city	**Population in 2018** (thousands)	city	**Population in 2030** (thousands)
1	Tokyo, Japan	37 469	Delhi, India	38 939
2	Delhi, India	28 514	Tokyo, Japan	36 574
3	Shanghai, China	25 582	Shanghai, China	32 869
4	São Paulo, Brazil	21 650	Dhaka, Bangladesh	28 076
5	Ciudad de México (México City) México	21 581	Al Qahirah (Cairo), Egype	25 517
6	Al Qahirah (Cairo), Egype	20 076	Mumbai (Bombay), India	24 572
7	Mumbai (Bombay), India	19 980	Beijing, China	24 282
8	Beijing, China	19 618	Ciudad de México (México City) México	24 111
9	Dhaka, Bangladesh	19 578	São Paulo, Brazil	23 824
10	Kimki M.M.A. (Osaka), Japan	19 281	Kinshasa, Democratic Republic of the Congo	21 914

Tab. 1 Demographic evolution of megacities (2018/2030 period). Source: *The World's Cities in 2018* (United Nations/DESA.)

Mumbai, Beijing and Dhaka are all close to 20 million inhabitants. It is difficult to deduce from these simple but disturbing figures how to define this 'mega-urbanisation' process of our species, whether in terms of quality of life or with regard to the functioning of the housing, urban and socio-sanitary systems. Considering the abnormal growth of the urban population, however, especially at latitudes where the quality of life is generally very poor, it seems clear that this process is not leading to the growth of 'ideal' cities, but rather to a carcinomic development of precarious and unhealthy shantytowns, lacking the most basic social and health services.

Delhi, in India, is the city whose estimated growth is highest: an increase of 10 million inhabitants is projected between 2018 and 2030. During the same period, it is foreseen that the population of Tokyo in Japan will decrease by about 900 000 inhabitants, as is clearly illustrated in Table 1. The same table shows how the human geography of megacities is heading towards exponential population growth in all the urban agglomerations of the southern hemisphere, with a halt or decrease in growth in the cities of the northern hemisphere or those belonging to the more developed economies.

In the list of the most populated cities, the two most striking cases are Kinshasa, the capital of the Democratic Republic of Congo, apparently destined to reach almost 22 million inhabitants by 2030, and Dhaka, the capital of Bangladesh (Fig. 3), destined to increase from about 19 million to over 28 million inhabitants, making it the fourth most populated city.

The year 2010 represented a turning point in human history. In that year, the number of people living in urban areas (3.42 billion) surpassed the number living in predominantly rural areas (3.41 billion). Current projections suggest that the world's urban population will increase by 84% by 2050, from 3.4 billion at the end of 2009 to 6.3 billion in 2050 (Fig. 4).

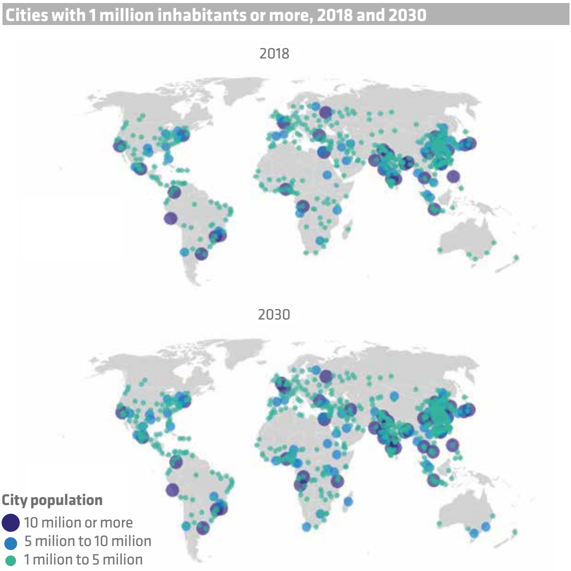

Fig. 3 Population growth in urban areas 2018/2030: agglomerations of more than 1 million inhabitants (Source: *The World's Cities in 2018*, United Nations/DESA).

By the middle of the 21st century, the world population living in cities will be numerically equivalent to the entire world population recorded in 2004. Globally, the concentration of population in urban areas has been rising exponentially since the 1950s, with particularly high rates of increase in Asia, Africa and the Latin American subcontinent, in accordance with the general population growth trends in these regions[5].

[5] United Nation Department of Economic and Social Affairs 2009, *Urban and rural area*.

From a grain of wheat: the birth of the urban idea

Most of the modern research in urban and building science, developed after Weber's considerations on the city, focuses on sociological, economic and demographic matters, as well as on structural and functional ones. The foundations of modern urbanism are laid on these approaches, even if the 'demographic' definition of a city is perhaps the one that prevails in contemporary urbanism. This approach emerges essentially from Louis Wirth's 1938 article, *Urbanism as a way of life*, in which he summarises his vision of urban systems:

> […] for sociological purposes, a city may be defined as a relatively large, dense, and permanent settlement of socially heterogeneous individuals[6].

According to this sociological view, on the one hand, cities are places where greater or smaller concentrations of population live in well-defined and not too extended areas, endowed with institutions characterised by considerable complexity, with clear subdivisions into 'classes', substantially linked to their respective socio-economic functions. On the other hand, the functional approach tends not to put much emphasis on the social and cultural nature of the urban population, focusing more on infrastructures and buildings, i.e. assessing the role that the urban settlement per se plays in a specific territorial context.

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[6] Wirth L. 1938, *Urbanism as a way of life*, «The American Journal of Sociology», vol. 44, n. 1, pp. 1-24.

According to this view, the city is essentially the scenario in which productive activities take place, and institutions carry out their functions, both in relation to the settlement itself and to the vaster area with which the city interacts. The approach we propose to use to analyse the urban question in this volume draws on both visions, and takes into account the theory that the origin of the first urban agglomerations was contemporary with the so-called Neolithic revolution[7], a turning point in the evolution of the human species.
According to G.V. Childe[8] this revolution was the moment in human history when *Homo Sapiens* went from being hunters and gatherers to cultivating plants and raising animals for food, allowing greater control over the food supply and population growth. In reality, the concept of *Révolution néolithique* is said to have been taken from a previous essay by the French philosopher, Édouard

[7] The association of the term 'revolution' with the changes of the Neolithic period is due to the Australian archaeologist V.G. Childe (1892 - 1957). In his book, *The dawn of European civilization* (1925), he still employed generic language (e.g. 'The different stages of the transformation of the food-gathering world... into this state of civilization (Bronze Age)', 1925: 302). Gordon Childe deliberately chose the word 'revolution' to define the main social, cultural and technological transformations from prehistory to the industrial revolution. As discussed by Kevin Greene (1999), Childe began using this neologism probably as early as the late 1920s and then formalised its use in *Man Makes Himself* (Childe, 1936), in which there are chapters entitled 'The Neolithic Revolution' and 'The Urban Revolution'. For Childe, these periods of change were 'real revolutions that affected all aspects of human life'. Childe V. G. 1950, *The Urban Revolution*, «The Town Planning Review», vol. 21, n. 1, p. 7.
[8] Vere Gordon Childe (1892 - 1957) was an Australian archaeologist specialised in European prehistory studies. He spent most of his life in the United Kingdom, working as an academic for the University of Edinburgh and then the Institute of Archaeology, London.

Le Roy[9] entitled *Les Origines humaines et l'évolution de l'intelligence* (1928)[10]. This event, rightly defined a 'revolution', progressively transformed *Homo sapiens sapiens*' living habits, which changed from the mobility necessary for hunting and gathering, to more sedentary lifestyles connected with the practice of agriculture.

The populations in the region commonly identified as the Fertile Crescent[11], which today coincides with Iraq, western Iran, southeastern Turkey, Syria, Lebanon, Israel, Palestine, Jordan and Egypt, gradually abandoned nomadism to dedicate themselves to cereal cultivation. Archaeo-biologists connect this event to a specific edible plant species, namely *Triticum monococcum*, commonly referred to as Einkorn wheat, deriving from a plant endemic in the hilly and northernmost parts of this geographical area.

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[9] Édouard Louis Emmanuel Julien Le Roy (1870 - 1954) was a French philosopher and theologian, professor at the Collège de France and member of the Académie française.

[10] Roy Le E. 1931, *Les Origines humaines et l'évolution de l'intelligence*, Boivin et Cie. Editeurs, Paris, p. 293.

[11] The term 'fertile crescent' was coined by James Henry Breasted in his book *Ancient Times - A History of the Early World* (Boston 1916), in which he states: "…*This fertile crescent is approximately a semicircle, with the open side toward the south, having the west end at the south-east corner of the Mediterranean, the center directly north of Arabia, and the east at the north end of the Persian Gulf. It lies like an army facing south, with one wing stretching along the eastern shore of the Mediterranean and the other reaching out to Persian Gulf, while the center has its back against northern mountains. The end of the western wing is Palestine; Assyria makes up a large part of the center; while the end of the eastern wing is Babylonia. […] This great semicircle, for lack of a name, may be called the Fertile Crescent. […] There is no name, either geographical or political, which includes this entire great semicircle. Hence we are obliged to coin a term and call it the Fertile Crescent*".

It is a short variety of wild wheat, whose plants grow to a height of no more than 70 cm, and whose ears are actually not very generous in producing grain[12 13]. The observation of this phenomenon gave rise to the first example of organised agriculture. Our ancestors, or perhaps better, our gatherer ancestresses, observed this phenomenon and began to collect those ears of corn that when ripe did not lose their grains, selecting them and planting the seeds, which improved with each successive generation, eventually producing plants that were totally dependent on man to complete their reproductive cycle[14].
This must be considered one of the first and perhaps most important technological revolutions in history, based, moreover, on a simple method of observation of reality and deduction, that is coming to understand how, thanks to basic genetic selection, greater benefits for human well-being could be obtained from nature. The increase in the availability of food in a limited area freed man

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[12] Anderson P. C. 1991, *Harvesting of Wild Cereals during the Natufian as seen from Experimental Cultivation and Harvest of Wild Einkorn Wheat and Microwear Analysis of Stone Tools*, «Natufian Culture in the Levant», n. 42, p. 523.
[13] The main difference between the wild *Triticum monococcum* and the one still grown in the region today is that in the wild variety the seed container breaks when it reaches maturity, leaving the seeds to fall to the ground, as every angiosperm plant should normally do to perpetuate its species. In reality, a genetic mutation sometimes prevents the ear from breaking and the natural dispersal of the seeds on the ground, and the consequence of this mutation is that the ears reach maturity without breaking, thus allowing them to be easily harvested. Zohary D., Hopf M., Weiss E. 2012, *Domestication of Plants in the Old World: The Origin and Spread of Domesticated Plants in Southwest Asia, Europe, and the Mediterranean Basin*, Oxford University Press, Oxford, p. 139.
[14] Hillman G., Hedges R., Moore A., College S., Pettitt P. 2001, *New evidence of late glacial cereal cultivation at Abu Hureyra on the Euphrates*, «Holocene», vol. 11, n. 4, pp. 383-393.

from the slavery of wandering in search of food, allowing an inevitable increase in population density and thus creating the conditions for the formation of the first urban agglomerations, starting in the fourth millennium B.C.
In his book *Cities and Economic Development*, the Belgian economist Paul Bairoch[15] supported the general principle that there is a direct relationship between the development of protohistoric agricultural activity and the formation of the first cities. The change in the natural relationship between man and his ecosystem led to a series of fundamental and far-reaching transformations in human society.
Coinciding with this phenomenon, an increasing number of human groups assumed a sedentary lifestyle, abandoning their original nomadism and leading to a general increase in population. The archaeologist Vere Gordon Childe is considered the first scholar to combine social patterns with archaeological data, analysing the main stages of transformation in human evolution. In his article *The Urban Revolution*, which appeared in 1950 in the «The Town Planning Review», Childe summarised the definition of the city in ten criteria (Table 2). These criteria, applicable to early protohistoric urban realities, are expressed in discursive form and were later summarised and systematised in a 2009 article published by Michael E. Smith on occasion of the centenary of the «The Town Planning Review»[16].

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[15] Paul Bairoch (1930 - 1999) was a Post-World War II economic historian specialised in global economic history, urban history and historical demography. Author and co-author of more than two dozen books and 120 academic articles.
[16] Smith M.E. 2009, *V. Gordon Childe and the Urban Revolution: a historical perspective on a revolution in urban studies*, «The Town

Criterion	Definition
I	In point of size the first cities must have been more extensive and more densely populated than any previous settlements
II	In composition and function the urban population already differed from that of any village, including full-time specialist craftsmen, transport workers, merchants, officials and priests
III	Each primary producer paid over the tiny surplus he could wring from the soil with his still very limited technical equipment as tithe or tax to an imaginary deity or a divine king who thus concentrated the surplus
IV	Truly monumental public buildings not only distinguish each known city from any village but also symbolise the concentration of the social surplus
V	But naturally priests, civil and military leaders and officials absorbed a major share of the concentrated surplus and thus formed a "ruling class"
VI	Writing
VII	The elaboration of exact and predictive sciences – arithmetic, geometry and astronomy
VIII	Conceptualised and sophisticated styles [of art]
IX	Regular "foreign" trade over quite long distances
X	A State organisation based now on residence rather than kinship

Tab. 2 The ten criteria set out by Vere Gordon Childe in 1950 for defining the genesis of a town, as summarised by Michael E. Smith in the «The Town Planning Review» centenary text in 2009.

Childe's methodological reflection, which starts from the level of analysis that his academic training as an archaeologist allowed him, is almost universally

Planning Review», vol. 80, n. 1, pp. 10-11: "…*Ten rather abstract criteria, all-deducible from archaeological data, serve to distinguish even the earliest cities from any older or contemporary village*".

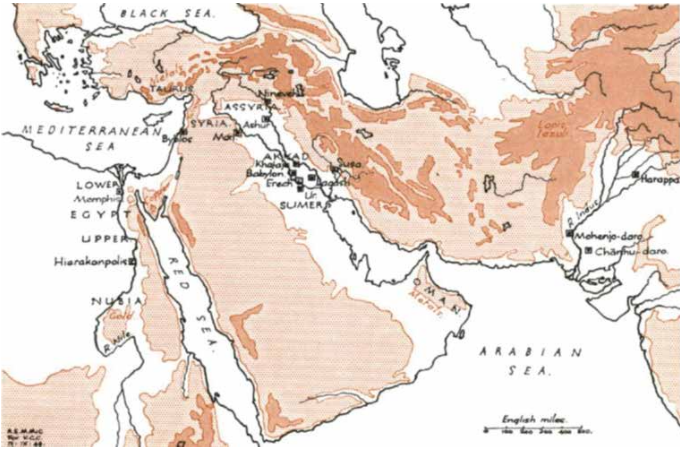

Fig. 4 The first centres of urban civilisation in the ancient world of the eastern Mediterranean and the Middle East (Childe G.V. 1950, The Urban Revolution, p. 8 in «The Town Planning Review», vol. 21, n. 1).

considered a model for modern studies of cities, from the points of view of both urban and paleo-technological studies. In reality, he describes above all the transition from a society made up of small agricultural agglomerations to complex state and urban societies, without however considering the entire planet and the parallel evolution of other civilisations, such as those of sub-Saharan Africa, China or Mesoamerica, thus restricting his analysis to the Mediterranean area and the Middle East (Fig. 4).

It can be assumed that Childe himself was aware of the fact that his text was avant-garde, and trans-disciplinary in substance, especially taking into account that he chose not to publish it in a journal of his own scientific field, but

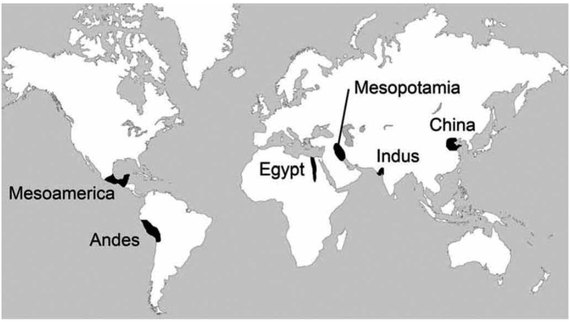

Fig. 5 Location of the six areas where the urban revolution took place independently (Source: Smith, Michael E., *The Earliest Cities, in Urban Life*. *Readings in the Anthropology of the City*, ed. by George Gmelch and Walter P. Zenner, p. 6).

rather in a journal more obviously dedicated to the study of cities, namely the «The Town Planning Review» [17] [18].
It is worth noting that the social and cultural transformation in the urban sphere, which resulted in a technological and infrastructural transformation, occurred independently in many parts of the world (Fig. 5). This does not detract from the fact that the phenomenon described by Childe is recognised, with reference to its principles, as one of the most significant changes in human socio-cultural evolution[19]. Although

[17] «The Town Planning Review» (TPR) has been one of the world's leading urban and regional planning journals since its founding in 1910. With a large international readership, TPR is an established journal of town and regional planning, providing a major forum for communication between researchers and students, policy analysts and practitioners.
[18] *The Urban Revolution* ranks eighth in the total number of academic citations (among journal articles by archaeologists) and first in citations of articles on ancient complex societies. It is the most frequently cited paper published in TPR.
[19] Smith M. E., *Op. cit.*, p. 11.

contemporary models for analysing the development of early complex urban societies have progressed far beyond Childe's original formulation, there is still substantial agreement among researchers that he correctly identified the set of social transformations underlying human society, in essence, up to the first industrial revolution, as well as the main processes involved.
In line with these methodological grounds, and in the framework of the historical and demographic evolution of the human species, the following sections will analyse some historical examples of cities, not so much for their architectural or urbanistic relevance, or for the role played in the urban planning evolution theories. Moreover, their examples highlight some remarkable technical and technological innovations, which had some influence in the evolution of urban environments.

The land of the two rivers: Mesopotamia

What we actually know today is that the urban revolution took place independently in different places and at different times, although from a chronological point of view it may have developed first in Mesopotamia, in ancient Sumer, as early as 5000 years ago. The Sumerians, at the apex of the so-called Fertile Crescent, in today's Kurdistan region between Iraq, Syria and Turkey, were apparently the first to organize themselves on a state level. Only later did this process of urban civilisation expand southwards into the lowlands between the Tigris and Euphrates rivers, the ancient region of Mesopotamia[20].

[20] Smith, *The Earliest*, *Op. cit.*

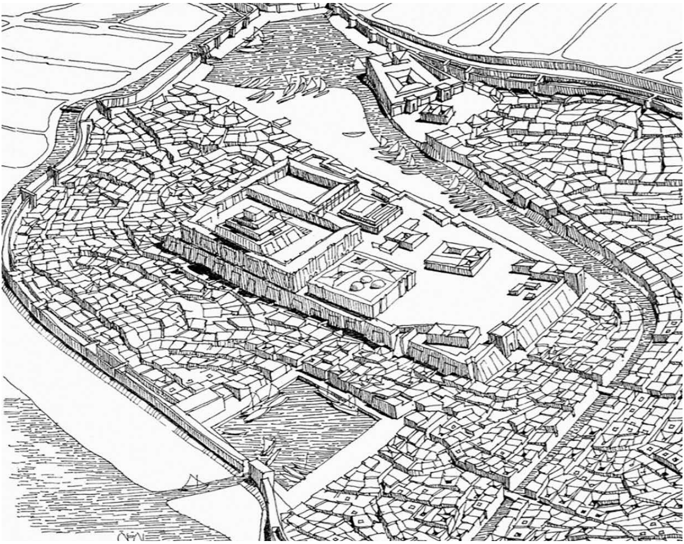

Fig. 6 Photo of the excavation of a Third millennium B.C. port in Iraq by the Sapienza Archaeological Mission directed by Licia Romano and Franco D'Agostino. (Italian-Iraqi Archaeological Mission to Mars Abu Tbeirah 2017)

Fig. 7 Reconstruction of the Sumerian city of Ur (Illustration by Claus Roloff, from the project *Cities and Modes of Production*. Source: Michael E. Smith 2009, *V. Gordon Childe and the Urban Revolution: a historical perspective on a revolution in urban studies*, Centenary Paper, TPR, vol. 80, n. 1).

Urban settlements were facilitated by and associated with the construction of the first irrigation canals, dug both for agriculture and to allow flood control and distribution of water for domestic and sanitary use. Most Sumerian buildings were made of clay bricks formed in moulds and baked in the sun for several weeks. In the case of important buildings, a layer of lime was applied to the sun-baked bricks to ensure protection from the elements[21]. Between 3600 and 3100 B.C., the city-state of Uruk (Iraq) developed centralized political control, a specialized economy, writing and the stratification of society in social classes[22].

As the population increased, new settlements, mostly in small agricultural villages, were formed around the city, one of the most populous in antiquity, with a surface area of up to three-quarters of a square kilometre and a population of several thousand. The most significant technological innovation of the Sumerian civilisation was therefore urbanisation linked to the digging of the first canals, which allowed for flood control, water transport, and water redistribution for irrigation and food[23] (Figs. 6 and 7). It is important to note that in a territory subject to a significant transition towards desertification over the centuries, the response of the Mesopotamian urban populations was precisely to develop advanced hydraulic engineering techniques, which allowed these civilisations

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[21] Moffett M., Fazio M. W., Wodehouse L. 2003, *A World History of Architecture*, Laurence King Publishing, London.
[22] Smith, *The Earliest*, *Op. cit.*
[23] Mantelli F., Temporelli G. 2007, *L'acqua nella storia*, FrancoAngeli Editore, Milano, p. 20.

to prosper in spite of increasingly adverse climatic conditions.

During the transition to the First Dynasty period, the city of Uruk (2900-2300 B.C.) saw an enormous growth of its urban area, which expanded to cover four square kilometres with a population of approximately fifty thousand people[24].

Further technological aspects of the Sumerian civilisation are related to the semi-industrial processing of the main available building material, clay. From this material came the sun-dried raw clay bricks mixed with dry straw as a binder, which, along with timber imported from the mountainous areas from which the two rivers descend, enabled the construction of all Sumerian buildings. The most significant result was the construction of stepped pyramids dedicated to places of worship and power (Ziggurat): the logic behind their construction seems quite evidently to have been to raise places of worship towards the sky in a land such as that between the Tigris and the Euphrates, which is essentially flat[25]. The same material, wet clay, was linked to cuneiform writing. The clay, laid out in layers on wooden tablets, could be engraved with a stylus to write in cuneiform script, the first known form of writing, which appeared in Mesopotamia around 3 200 years before Christ.

The first texts would have appeared around this time and the last example of cuneiform writing of which there is

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[24] Smith, *The Earliest*, *Op. cit.*

[25] Crawford, H. 1993, *Sumer and the Sumerians*, Cambridge University Press, New York, p. 85.

archaeological certainty is dated to around 75 B.C.[26]. The development of the urbanization process was accompanied by the abandonment of the surrounding countryside: this was a first example of migration from rural to urban areas, linked to the social and political context of Sumerian society. There are two probable explanations for this change, both related to the social and political context of the society of the time. Uruk, like other more or less contemporary Sumerian cities, fulfilled not only political and military functions, but also economic and religious ones.

These small city-states were centers of handicraft production, and hosted temples in which the population could worship their gods, attracting the mobility of local and regional peoples. These were complex cities for their time, with highly developed support systems and technologies, especially with regard to the management of the precious waters of the Eufrates, diverted and canalized for surprisingly modern port and commercial activities, showing that the intelligence of the city is not an exclusive characteristic of the 21st century.

The land of two kingdoms: the Nile Valley

In Egypt's Nile Valley, the cultural leap from nomadism to a settled and organised civilisation took place in the pre-dynastic period, most likely coinciding with the period of the so-called Badarian culture[27]. The first direct evidence

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[26] Watkins, L. J., Snyder D. A. 2003, *The Digital Hammurabi Project*, The Johns Hopkins University, Baltimora, p. 2.

[27] This period of the Egyptian Neolithic is named after an archaeological site, first identified at El-Badari, in the Governorate of Asyut, thanks to

of agriculture in Upper Egypt, between 4400 and 4000 B.C., dates back to this period, again in connection with an extremely advanced system of canals for agricultural use, linked to organised human settlements. For Egyptians too the city is the place of technological innovation, innovation that requires a state structure for the management of hydraulic works. Dams and canals, connected with the seasonal hydraulic regime of the Nile led in 3300 B.C. to the formation of one of the first states in history, in which the main cities were connected to the vital points for the management of river traffic and flood regimes. The Old Kingdom (2680-2134 B.C.) was a period marked by powerful and highly centralised state government[28]. Archaeological and documentary evidence indicates that the administrative centres in the individual urban centres carried out important state functions despite the country's low population density. Each settlement included a temple, living quarters for the priests, scribes and state officials and advisors who assisted the Pharaoh in controlling the vast territory along the Nile River. The walls surrounding the cities had no real defensive function such as they had in the Mesopotamian settlements, but rather a symbolic one, with the aim of delimiting the boundaries of the urban area[29].

Further characteristic aspects of Egyptian civilisation are connected to the construction techniques of palaces

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excavations carried out by the British School of Archaeology during three campaigns in 1922-3, 1923-4 and 1924-5. Brunton G., Caton-Thompson G. 1928, *The Badarian Civilisation and predynastic remains near Badari*, British School of Archaeology in Egypt, London.

[28] Smith, *The Earliest*, *Op. cit.*

[29] *Ibidem*.

and temples. While the poorest dwellings were built of unbaked clay bricks or crumbly stone, temples and funerary monuments used more resistant cut and dressed stone, almost completely excluding the use of wood, which was difficult to find in ancient Egypt[30]. The construction technique was essentially based on pillars onto which lintels made of blocks or slabs of local limestone were placed. This technique, undoubtedly innovative for the time, required well-trained workers both for cutting the stones and for transporting and assembling them. The pharaohs, regarded as sons of Ra, the Sun God, were buried in large tombs, which in time evolved into the pyramids for which the Old Kingdom is famous.

The pyramids of the kings of the 4th Dynasty, built between 2650 and 2500 B.C., are some of the greatest monuments of the ancient world, testifying to the power and grandeur of their inhabitants[31].

The pharaohs controlled a vast territory along the Nile River, administered with the help of state councillors who recorded all sorts of economic and social information for the king (Fig. 8). Compared to other ancient civilisations,

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[30] Blakemore R. G. 1996, *History of Interior Design and Furniture: From Ancient Egypt to Nineteenth-Century Europe*, John Wiley and Sons, London, p.107.

[31] The most famous and largest pyramid dating back to 2585 B.C. is the 147-metre-high pyramid of Cheops, next to which were the pyramids of Chephren (143.5 metres) and Mycerinus (70 metres). With their smooth faces at an angle of 52°, oriented according to the cardinal points, they constitute the architectural evolution of the step pyramids, which were in turn the result of the superimposition of several màstabas, the monumental tombs of the pharaohs and dignitaries. The geometric perfection of these structures is linked to their symbolic function as a link between earth and sky.

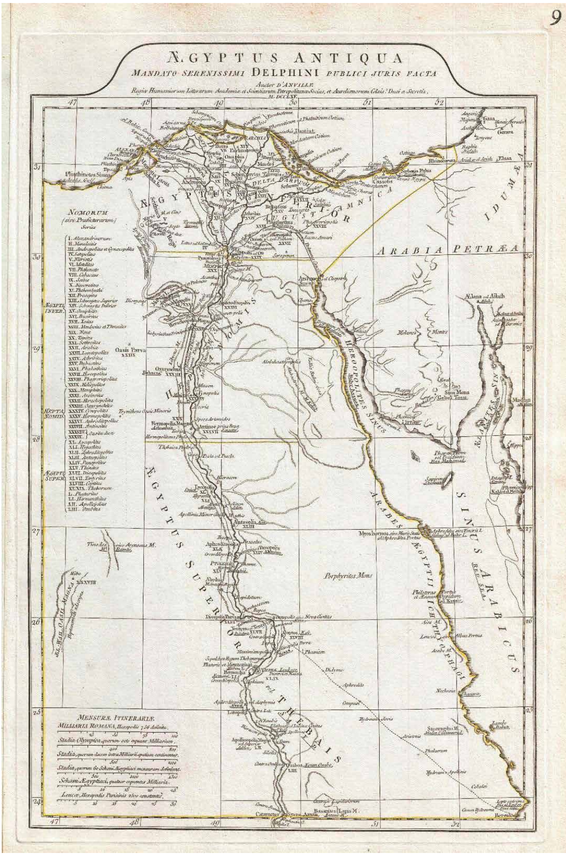

Fig. 8 Map of Ancient Egypt, evidencing Lower Egypt (Ægyptus inferior) and Upper Egypt (Ægyptus superior). Middle Egypt (Heptapolis) was substantially part of the Upper Egypt. Drawn by J. B. B. D'Anville in 1762 and published in 1794 by Laurie and Whittle, D'Anville, J. B. B., *Complete Body of Ancient Geography*, Laurie and Whittle, London, 1795. (Source: Wikimedia Commons ®, and Geographicus Rare & Antique Maps was founded in New York, New York, by Kevin James Brown in 1999).

Egyptian civilisation is characterised by the lack of large urban centres. This is particularly unusual considering the high degree of political control exercised by the pharaohs and the fact that ancient, powerful, centralised states such as this one almost always had major urban centres as capitals. Indeed, Egypt has often been called a 'civilisation without cities', but this definition only makes sense if we follow the demographic definition of the city-states mentioned above.

The development of densely populated urban centres would not occur until the New Kingdom (1550-1070 B.C.), indeed until the reign of Pharaoh Akhenaten, from 1377 to 1358 B.C., when he founded a new imperial capital at Amarna, historically considered a city from every point of view, especially in terms of design and architecture.

Civilisations far from the Mediterranean: Asia, the Americas, the Indian subcontinent and sub-Saharan Africa

In northern China, the peoples of the Longshan culture urbanised very early, about 5000 years ago and in the Indus Valley (southern Asia) Mohenjo-Daro and Harappa also became important urban centres at roughly the same time. In the Americas, early urban cultures include that of the Olmecs in Mesoamerica, and those known as Norte Chico and later Chavín in Peru. Urban centres developed in North America among Ancestral Pueblo and Mississippian peoples during the second millennium B.C. Early African cities included Great Zimbabwe (1000 B.C.) and Timbuktu (about 800 B.C.).

The Longshan culture, known as the 'black pottery culture', developed along the Yellow River valley in northeast China[32]. As in ancient Egypt, the river was the key factor in the development of agriculture and Chinese civilisation itself, but to protect against frequent flooding, cities were surrounded by walls, made of compacted clay and moats. The site of Taosi, an area covering over 300 hectares in what is now Xiangfen County, southern Shanxi, is the largest fortified settlement of this period[33]. Archaeological excavations have uncovered a palace enclosure, a residential area and an area for commoners, ceremonial centres, a necropolis, productive craft and storage districts and a semi-circular structure that served as an astronomical observatory.

The cities of Harappa and Mohenjo-Daro, in the Indus Valley, are among the most impressive urban centres of the ancient world, as evidenced by their impressive ruins, despite fragmentary information and as yet undeciphered writing. It is known that between 2 800 and 2 300 B.C. a number of small (about a quarter of a square kilometre) fortified cities housing skilled craftsmen and traders developed. The large cities were built in a later period, between 2 300 B.C. and 1 750 B.C.: Mohenjo-Daro covered about two and a half square kilometres, with a population of about forty thousand people, while Harappa was smaller, having an area of one square

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[32] Liu L. 2007, *The Chinese Neolithic: Trajectories to Early States*, «Harvard Journal of Asiatic Studies», vol. 67, n. 1, pp. 178-193.

[33] He N. 2017, *Taosi: an archaeological example of urbanization as a political center in prehistoric China*, «Archaeological Research in Asia», vol. 14, pp. 20-32.

kilometre and about twenty-five thousand inhabitants. Mohenjo-Daro was dominated by a huge acropolis built of fired bricks called the Citadel, within which towered imposing public buildings, carefully constructed using advanced architectural techniques and high quality materials[34]. In 1925-26, the British archaeologist John Hubert Marshall unearthed a large pool called the Great Bath, probably used for purification rituals[35]. The cities of the Indus Valley were carefully planned on the pattern of a rigid grid running from north to south and from east to west. The cities were divided into individual sectors surrounded by walls and connected by gates; most houses had a bathroom with water wells and a drainage system, and the main streets were equipped with an advanced and efficient sewage system.

In Southeast Asia, in the area geographically known as the Indochinese peninsula, the kings of the first state societies brought the sacred city to its highest development. The idea of the city as a reproduction of the cosmos and the idea of the king to be worshipped as a god on earth, were of fundamental importance for the construction of spectacular temple-cities that can still be seen in the Cambodian jungle. In 802 A.D. Jayavarman II, founder of the Khmer Empire, was the first to be considered as a *Devaraja*, the God-King. Khmer cities developed around square temple complexes, erected on a central series of towers leading up to a higher pinnacle in their exact centre, corresponding to the sacred Mount Meru,

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[34] Smith, *The Earliest*, *Op. cit.*

[35] Marshall J. H. 1931, *Mohenjo-Daro and the Indus Civilization*, Probsthain, London.

home of the gods. With Suryavarman II, who reigned in the 12th century, the Khmer empire was consolidated and under his rule, the huge complex of Angkor Wat was built, covering an area of almost two square kilometres. The central tower rises to a height of over sixty metres and all the architectural elements of the site fit together harmoniously: ogival towers, rooms, causeways and galleries, pools and gates were built with great precision using measurements based on sacred combinations of numbers. Hundreds of bas-reliefs, depicting deities, people and scenes from daily life, decorate the temple complex, surrounded by a 250-metre wide moat.
The death of Suryavarman II was followed by a period of unrest and looting until King Jayavarman VII came to power in 1181. He restored order to the empire and built Angkor Thom, a walled complex even larger than Angkor Wat. A fortified city of ten square kilometres within the largest imperial capital, with a huge temple complex called the Bayon, was erected in the form of a mountain in the centre of the city. Khmer culture spread throughout southeast Asia, from Burma to the China Sea, and influenced many areas, from military organisation to architecture. In particular, a water retention and drainage system was developed, using *Baray*[36], artificial water basins[37].

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[36] A *Baray* is an artificial body of water that is a common element of the architectural style of the Khmer Empire of Southeast Asia. The largest are the East Baray and West Baray in the Angkor area, each rectangular in shape, oriented east-west and measuring roughly five by one and a half miles

[37] Dumarçay J., Royère P. 2001, *Cambodian Architecture, Eighth to Thirteenth Centuries*, Smithies, Leiden.

Similarly, in present-day Peru, the well-preserved remains of Machu Picchu show that the pre-Columbian peoples of South America had an advanced knowledge of drainage and terraced irrigation systems. That area is divided into three distinct sections: the agricultural area, the religious centres and the urban system with a distribution typical where there are 'primate cities', i.e. where one city has much greater dimensions than all the others[38]. An example of this kind of hierarchical urban system during the Classic Maya period is the powerful capital Tikal, which had a population of between forty and sixty thousand people, while most of the neighbouring centres had fewer than eight thousand inhabitants. This situation was typical of most Mesoamerican cities, including Chichén Itzá, Monte Albán, Xochicalco, Teotihuacan and the more recent Tenochtitlan, founded around the beginning of the fourteenth century A.D. Present-day Mexico City is built over Tenochtitlan (Fig. 9), the capital of the Aztec empire, which had a population of approximately two hundred thousand, while the average population of its tributary city-states did not exceed nine thousand. Not only did the total number of inhabitants vary between the imperial capital and the subject cities: so did the population density, from the 15 000 people per square kilometre in Tenochtitlan, to the 5000-7500 inhabitants per square kilometre of the other central Mexican cities. Most Mesoamerican cities were political capitals whose urban development was closely linked to religious practices.

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[38] Protzen J. P. 1993, *Inca Architecture and Construction at Ollantaytambo*, Oxford University Press, New York.

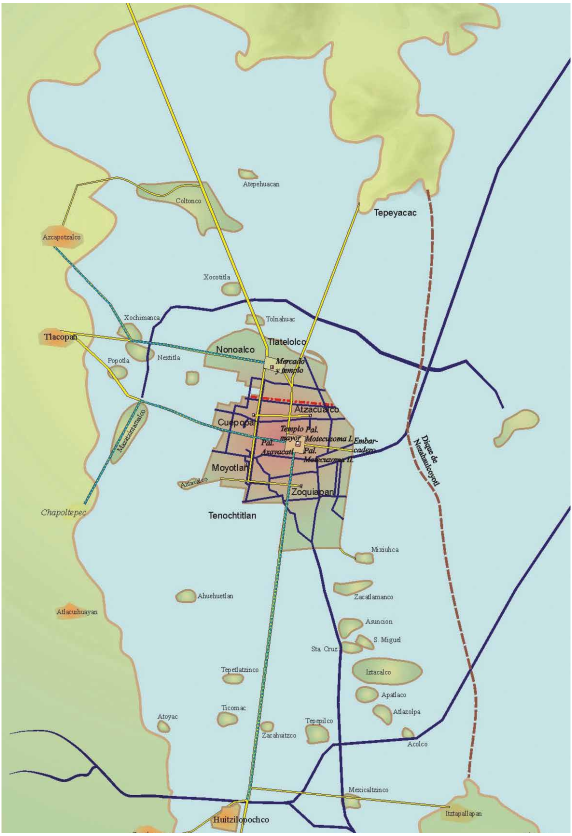

Fig. 9 Reconstruction of the ancient Aztec capital of Tenochtitlan on the site of which the modern Mexico City was built. The city was located at the centre of a vast shallow lake, later entirely reclaimed (Prem H. 2008, *Tenochtitlan and islands in the Texcoco Lake*).

The royal palace was usually located in the centre of the city and its size was a testament to the grandeur and power of the ruler. Temples, residences, playgrounds, squares and other public buildings formed the epicentre of the site[39], integrated into a coherent architectural and spatial unity. Some cities had a further important role as fortresses: in these cases they were often situated on defensible hills, surrounded by walls and moats. The orientation of the buildings was often dictated, as elsewhere, by astronomical knowledge and mythological beliefs. The imposing *Templo Mayor* pyramid in the heart of Aztec Tenochtitlan for example, was divided into four main quadrants and aligned with the course of the sun, as a visual and symbolic architectural expression of Aztec mythology.
Its structure reflects the Mexica cosmos, which was believed to consist of four parts arranged symmetrically around the navel of the universe, or Axis mundi. Outside the central urban core, the residential areas of cities were generally not designed according to a planning scheme.
An alternative layout was the central model of the ancient city of Teotihuacan that followed a grid layout (very similar to Mohenjo-Daro) of more or less orthogonal intersecting street axes that structure and organise the city plan, aligned on a north-south axis with a central ceremonial avenue (central artery) known as the 'Way of the Dead'. The urban network helped establish an order for the religious, domestic

[39] Smith M. E. 2005, *City Size in late Postclassic Mesoamerica*, «Journal of Urban History», vol. 31, n. 4, pp. 403-434.

and commercial complexes and a structural coherence that supported the management of the city and its population for centuries. In many cases the most impressive buildings in the ancient Mesoamerican cities were the temples, including the Pyramid of the Plumed Serpent[40], the Pyramid of the Sun and the Pyramid of the Moon[41]. Mesoamerican cities varied considerably in terms of their development and the nature of their economic activities. Some of them had large-scale cottage industries. The specialisation of handicrafts in Mesoamerica was generally organised at the family level and specialists, whether full-time or part-time, worked in their homes. In large, densely populated cities, urban farmers had to travel daily to their fields located outside the city. In other, less densely populated cities, ordinary citizens cultivated gardens and fields within the city itself.

Among the early urban civilisations in South America are the Norte Chico culture and the Chavìn culture, which flourished respectively in the coastal region and in the northern Andean highlands of Peru. The Chavin cities were characterised by symmetrical squares at the ends of which stood square buildings including the temple, the warehouse and a series of smaller structures

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[40] Also known as the 'Pyramid of Kukulkan' (Mayan name for the Feathered Serpent God), also known as El Castillo, is a Mesoamerican pyramid monument that dominates the centre of Chichén Itzá, a Mexican archaeological site in the state of Yucatán.

[41] The Pyramid of the Sun is the largest building in Teotihuacan and one of the largest in all of Mesoamerica. It was built along the so-called Way of the Dead, near the Pyramid of the Moon and the 'Citadel', at the foot of the Cerro Gordo massif.

for administrative functions. The different levels of complexity of the dwellings testify to the presence of a hierarchical social structure. The settlement pattern of larger villages in the lowland regions surrounded by smaller satellite villages in the highlands seems to have been a way of exploiting different agricultural opportunities in different ecological regions through locally specialised production.

In summary, ancient cities in China, the Indus Valley and Mesoamerica, as elsewhere, were a combination of buildings dedicated to spirituality and secular power: priestly castes and religious institutions owed their wealth to their ability to manage the spiritual affairs of the state and to legitimise rulers as upholders of the cosmic order. Temples, pyramids and plazas provided imposing settings for public ceremonies, which ensured the continuity of human life and the universe[42].

The nature and form of a city, ancient or modern, are closely linked to its wider social and cultural context, and have different morphological and functional characteristics. The earliest cities in Mesopotamia were compact settlements, surrounded by walls, as populations were often at war with each other (defence was an important parameter in urban design) and were located in areas where agricultural land was limited: they tended to be small cities/centres to avoid taking too much space away from agricultural fields/cultivation. The first cities of the Maya in Mesoamerica were settlements whose last outlying houses blended into the tropical forest: they had

[42] Smith, *The Earliest*, *Op. cit.*

no defensive walls, and agricultural crops surrounded the city. The peoples of central Mexico developed various types of urban settlements: the large, densely populated imperial capital of Tenochtitlan, with its focus on economic activity and administration of an empire, the many smaller towns organised as city-states devoted to religion and local administration, and other towns that focussed on particular trades or cults.
This urban heterogeneity, in spite of common features, is one of the most striking characteristics of the early cities from which, largely, all contemporary cities derive.

The rise of urban design

From its origins the city has always been interpreted according to two different points of view, namely the 'city as a womb', a place of safety and peace, and the 'city as a machine', a complex instrument of functions, requiring efficiency and effectiveness. The moment in history when these two meanings merge and overlap with greatest originality can certainly be identified in the birth of Greek and then Roman culture. As Massimo Cacciari reminds us[43], these two civilisations, although often understood in historical continuity, developed two very different concepts of the city.
In Greek, the word *Polìs* (πόλις) means seat, dwelling, the place where a 'people' with specific traditions have their *Èthos* (Ἦθος), their origin, thus generating a lineage. In Latin, *Civitas*, on the other hand, links the origin of the city to the *Cives*, a group of people gathered to form

[43] Cacciari M. 2004, *La città*, Pazzini editore, Verucchio.

the city, who, in order to live together, adopt shared laws. If the Greek *Polìs* therefore appears to be homogeneously composed of people of the same kind, the Roman *Civitas* is based instead on common interests, resulting from people of different origins gathering under the same laws. This distinction influences not only the development of different social rituals, but also the urban form itself, and especially the technological approaches developed so that these cities could survive and prosper.

Hellas

In Hellenic culture, the city is much more than just a place of assembly and defence. Founded by gods or heroes, guarding venerated sanctuaries, trading posts and wonders of the world, Hellenic cities were to all intents and purposes a place of confrontation and dialogue. The heart of those cities was the square (*Agorà*, ancient Greek: ἀγορά, from ἀγείρω meaning 'gather'), a place for the exchange of goods and ideas, to which a new concept of the people was ascribed, and whose interaction was the mother of modern democracy. In spite of its sometimes mythological origins, the city from now on no longer constitutes a symbolic materialisation of the divine plan[44], and the inspiring design principle becomes the *Nòmos* (Νόμος)[45], or the law that governs the city. And thus the plan of the city:

[44] Barbera F. 2017, *Ippodamo da Mileto e gli inizi della pianificazione territoriale*, FrancoAngeli, Milano, p. 357.

[45] In ancient Greek religion, Nomos is the daemon of laws, statutes, and ordinances. By one account, Nomos' wife is Eusebia (Piety), and their daughter is Dike (Justice).

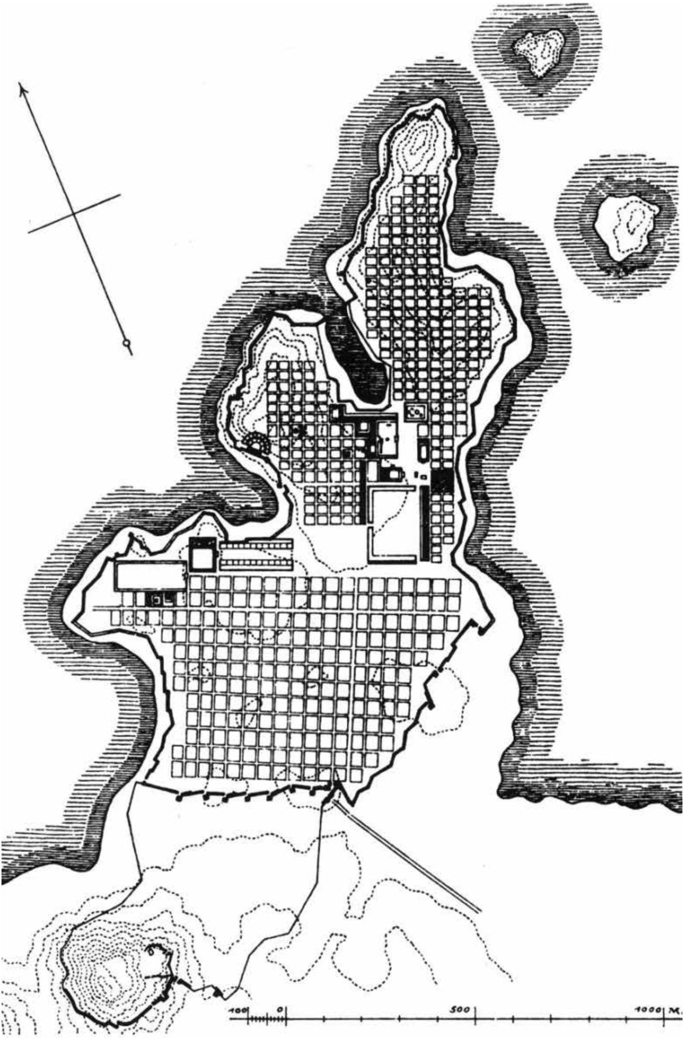

Fig. 10 Plan of the city of Miletus. (Source: Wikimedia Commons ®)

> […] is directed not to the rituality that celebrates the God who will come to inhabit it, but towards the Nous, the mind, and the city Lògos (Λόγος), which by ordering thought exercise their dominion over nature[46].

Euclid's dream: Hippodamus of Miletus

Euclid's admirable theoretical construct, which relies on just a few elements of plane geometry to rethink the entire vision and measurement of the world[47], is translated in a harmonious and linear way into the plan of Miletus. Hippodamus of Miletus (498-408 B.C.) marks an epoch-making step in urban planning: he was the first Greek architect and urban planner to use regular planimetric schemes in city planning. On the one hand, the Hippodamian urban scheme consists of a street network characterised by straight streets with orthogonal intersections, with main (Πλατεῖαι, platêiai) and secondary (Στενωποί stenopói) streets, which subdivides the space into regular quadrangular blocks, with different functions but with similar importance (Fig. 10).

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[46] Chiodi G. M. 2010, *Propedeutica alla simbolica politica*, II, FrancoAngeli, Milano.

[47] Euclidean geometry is a mathematical system attributed to the Alexandrian Greek mathematician Euclid, described in his textbook on geometry: *The Elements*. Euclid's method consists of taking a small set of intuitively appealing axioms (the point, the line and the plane) and deducing many more propositions (theorems) from them. Although many of Euclid's results had already been stated by earlier mathematicians, Euclid was the first to show how these propositions could fit into an overall logical and deductive system. With Euclid plane geometry, conceived as the first axiomatic system and an example of formal demonstration, began.

Fig. 11 Schematic city plan of Alexandria, Egypt. Source: Meyers Konversations-Lexikon. Ein Nachschlagewerk des allgemeinen Wissens, 5th edition 17 volumes Bibliographisches Institut-Leipzig 1895-1897.

On the other hand, places dedicated to worship and the administration of the city were generally located in a decentralised position on the acropolis, the highest point around which the polis was structured[48]. The Hippodamian layout characterised a number of Greek cities between the 5th and 4th centuries B.C. It was also used for the reconstruction of Miletus and the design of Alexandria derives from it.

The Hippodamian urban layout was designed to meet the specific needs of the community, the dimensions and the forms dictated by the availability of resources and the need for the population to participate in public affairs. For this reason Hippodamus held that for a city to be balanced and

[48] Nifosi G. 2008, *L'arte svelata*, Editori Laterza, Bari.

able to function appropriately, it should have a maximum population of approximately 10 000 inhabitants.

The dream of a God King: Alexandria

The city of Alexandria was also designed according to the orthogonal model. It was founded on the Mediterranean coast of Egypt in 331 B.C. between the Mareotide marsh (Μαρεῶτις) and the sea, in front of the small island of Pharos (Φάρος) on which the famous lighthouse was built[49]. This island was connected by the Heptastadion (Επτασταδιon, meaning seven stadiums long)[50], a breakwater protecting the port. The road infrastructure consisted of secondary roads parallel to the two main roads, one running north to south and one running east to west, intersecting more or less in the centre, but slightly more to the north, to form a wide square. Along the two main streets, which were about thirty metres wide, there were large columned porticoes (Fig. 11).

The dam, about 1 200 m long, allowed the creation of two distinct ports, one eastern (*Portus Magnus*) and one western (*Portus Eunusti*)[51]. The first port was in turn divided into two parts: an eastern one overlooking the royal palaces for the exclusive use of the monarchs and a

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[49] Lighthouse, from the Greek Φάρος, the name of the islet of Faro on the Egyptian coast, on which in the 3rd century B.C. the lighthouse of Alexandria was built. (AA.VV. Vocabolario Treccani 2019).

[50] Stadium, from the Greek Στάδιον. Unit of measurement of length in use by the ancient Greeks, equal to 600 feet; in the Attic system it was equal to about 177.60 m, and in the Alexandrian system to about 184.85 metres. The Stadium Race was the oldest foot race in the Panhellenic agonies (Olympic, Pythian, Isthmian, Nemean festivals), so called because it took place over the length of a stadium. (Treccani 2019).

[51] Port of good return.

western one for the city's maritime traffic: traffic and flows of goods from all over the Mediterranean, from Egypt, but also from the Red Sea, the Indies and Africa[52].
The dam and the plan for the foundation of the city were commissioned by Alexander the Great, who had identified the possibility of development in that area, thanks to the potentially profitable maritime commercial activities. The work was entrusted to the architect Dinocrates of Rhodes, who divided the area into five large quarters, indicated by the first letters of the Greek alphabet, in turn divided into other smaller areas[53].
Numerous temples were erected in honour of Greek gods and many public places were created; a third or a quarter of the city was occupied by the royal palace and other annexed buildings. In order to provide the city with the necessary supply of fresh water, given the desert conditions of that part of the Egyptian coast, a canal of some 25 kilometres branching off from the Canopic branch of the River Nile was specially designed and dug. The canal, which was also used as a waterway, reached the city and the fresh water, after being decanted into large tanks, was distributed to all the urban quarters by means of underground pipes, and then lifted by mechanical means to numerous large cisterns, which are still visible in the archaeological excavations. At a lower level the sewage system removed waste. This was a large technological infrastructure project developed in parallel with the road and palace project[54].

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[52] Pensabene P. 1993, *Elementi architettonici di Alessandria e di altri siti egiziani*, serie C, vol. 3, *L'Erma di Bretschneider*, Roma, pp. 43-44.
[53] Guidetti M. 2004, *Storia del Mediterraneo nell'antichità IX-I secolo a.C.*, Editoriale Jaca Book S.p.a., Milano.
[54] Empereur, J. Y. 1998, *Alexandria Rediscovered*, British Museum Press,

Ab urbe condita

Most ancient cities derive their fortune from the uniqueness of their geographical position: rivers, hills, islands and natural resources play a key role in shaping the future development of any urban settlement. However, very few cities share the historical and cultural destiny of the City of Rome, where geographical factors, along with the powerful impetus of the determination of its citizens and their primitive but effective technologies, helped place this urban area at the base of Western civilisation. Notwithstanding various hagiographic reconstructions and mythical accounts, it is impossible to establish the exact date of the foundation of Rome, although most modern historians and archaeologists agree that the first human settlements on the Palatine Hill date to around 5000 years ago[55].

The site of the foundation of Rome has several crucial characteristics. One of the main crossing points of the river Tiber was located downstream from the Tiber Island. Around the 9th-8th century B.C. tuffaceous hills having the typical morphology of a paleo-volcanic area formed the landscape of the site of Rome[56]. The hills dominated the lower course of the river, separated by semi-swampy little valleys and crossed by small seasonal streams or Marrane[57] that then opened out into a large alluvial plain

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Lawler, A. 2007. *Raising Alexandria*, in «Smithsonian Magazine», April, pp. 3-11.

[55] Heiken G., Funiciello R., De Rita D. 2005, *The Seven Hills of Rome: A Geological Tour of the Eternal City*, Princeton University Press, Princeton.

[56] Central Italy, particularly the region surrounding Rome, was a highly volcanic area around 600 000 years ago, dominated by the Albano crater.

[57] Marrana (or marana) s. f. [word of Mediterranean origin], Roman. -

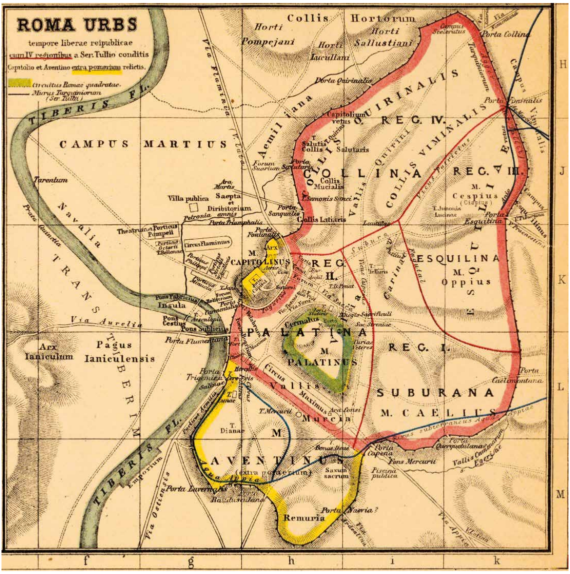

Fig. 12 The ancient plan of Rome. In green in the middle, the so-called Romae Quadratae (Squared Rome, 9th-8th century B.C.) and in light red and yellow the perimeters of the Servian walls (6th-4th century B.C.) (Heinrich_Kiepert (1818 - 899) *Roma urbs tempore liberae Republicae*, Source: Wikimedia Commons ®)

towards the sea. The transformation of the Capitoline and Palatine hills into small fortresses did not require much effort, considering their natural shape as flat-topped hills with steep and easily defensible slopes. They became the heart of the so-called *Roma Quadrata* (Fig. 12).

Small brook or ditch with water: up to where the hillock descends in the network of maranas and drains (Luzi); it is a recurring element in various place names around Rome: m. della Caffarella; m. di Grotta Perfetta; m. delle Tre Fontane.

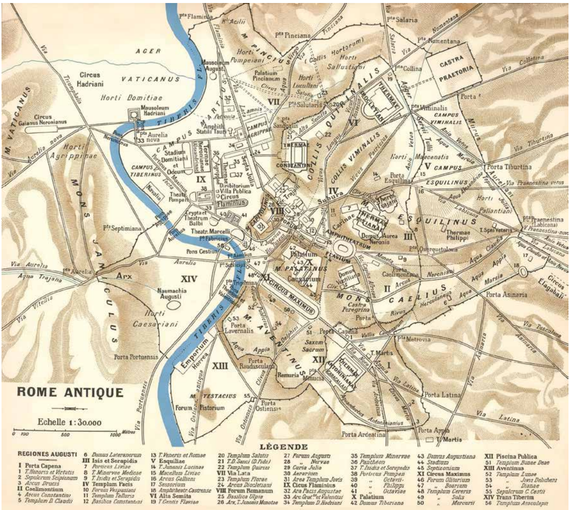

Fig. 13 Plan of the city of Rome in the imperial age (I-III century A.D.) Noveau Larousse Ilustré (Larousse XIXs. 1866-1877).

A fundamental distinction must be made between the urban structure of the city of Rome and that of the cities newly founded or conquered and transformed in the course of the expansion of the Roman Empire. The description of archaic Rome as 'square' should perhaps more properly be 'tetragonous', in line with the Greek authors who, when describing the foundation of Rome, used the term Tetragonos (Τετραγώνος) or 'quadrilateral' to describe its initial form[58]. During all Roman history,

[58] Tetragonos is a noun that geometrically describes a quadrangular perimeter, which fits well with the roughly quadrangular shape of the Palatine. Maccari A. 2019, *Pomerium, verbi vim solam intuentes, postmoerium interpretantur esse. La critica storica e antiquaria e la manipolazione del passato*, «Studi Classici e Orientali», n. 65, Pisa.

this form was reflected both in military camps and in the layout of newly founded cities. The squared form:

> in a geometric sense [it] was consciously metabolized and materialized in the urban plans of the Roman colonies, giving a historiographic evidence [of the mentality] of the Roman ruling class[59].

The evolution of Rome's urban structure, from its foundation to the imperial age, is a history of transformations, some of them major, driven by the need to make the city the stage for the Empire's triumphs[60] (Fig. 13). The city grew out of all proportion, sprawling outside the walls of the royal age, which roughly enclosed the seven hills. It was only in the 3rd century [A.D.] that the Emperor Aurelian surrounded the larger Rome with new walls, establishing the outer edge of the city until the Unification of Italy in 1870. Very few cities share Rome's unique destiny, where the geomorphologic aspects of the territory, combined with the primitive but effective technologies employed since its origin, continue to contribute to its long life and fortune[61].

These technologies are essentially based on masonry, i.e. linked to the consolidation of the Palatine and Capitoline hills in the form of the first fortifications, and the excavation

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[59] *Ivi*, pag. 143.

[60] *"Rome was not equal to the grandeur of the Empire and was exposed to floods and fires, but he embellished it to such an extent that he rightly boasted of leaving the city he found made of bricks in marble. He also made it safe for the future, as far as he could provide for posterity"*, Suetonius, Divus Augustus, L. 2, paragraph 28.

[61] Cinquepalmi F. 2019, *Rome before Rome: the role of landscape elements, together with technological approaches, shaping the foundation of the Roman civilization*, in «RI-VISTA: Research for Landscape Architecture. Digital semi-annual scientific journal», Firenze University Press, Firenze, pp. 168-183.

of the Cloaca Massima. Both these infrastructures, as well as the archaic perimetral consolidation of the Tiber Island, are in stone masonry, polygonal (Opus Siliceum)[62] and square (Opus Quadratum)[63]. From the point of view of technological innovation the Cloaca Massima is perhaps the most interesting element of archaic Rome. Excavated essentially to drain the waters of the marshy plain of Velabrum and mentioned by almost all ancient literary sources that discuss the origins of Rome, it is described as a masterpiece of hydraulic engineering and attributed to the will of the Etruscan king Lucius Tarquinius Priscus. The conduit was enormous and its main purpose was to rapidly drain the stagnant water left when the Tiber flooded as well as seasonal streams in the area[64 65]. The next technological element of great impact for the birth and consolidation of Roman power was the construction of the Ponte Sublicio (*Pons Sublicius*).
Located since the origins of Rome downstream from the Tiber Island, at the point where a seasonal ford presumably stood, it was probably built on pairs of piles,

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[62] Polygonal masonry (Opus Siliceum) widespread in central Italy between the 6th and 2nd centuries B.C. consisted of superimposing unworked stone boulders, even of considerable size, without the aid of binders, grapples or pins. This system was mainly used for terracing and retaining walls. Cinquepalmi, *Rome*, *Op. cit.*, p. 173.

[63] The opus quadratum masonry (Opus quadratum) consisted of the superimposition of square parallelepiped-shaped blocks of uniform height, arranged in homogeneous rows with continuous supporting surfaces. In the Roman area, the technique was already widespread in the 6th century B.C. and was later improved with more regularity of cut and a more articulated arrangement of the blocks. *Ibidem*, p. 173.

[64] *Ivi*, pp. 175-176.

[65] The material of choice was a type of soft-grained tuff, commonly called 'Cappellaccio', cut into stones 90 cm long (= 3 feet), 60 cm wide (= 2 feet) and 25 to 30 cm high. *Ibidem*.

driven into the river bed. The bridge, characterised by its own sacred nature, must have been built without brass or iron, held together only by its beams, according to a technology that must have allowed it to be easily dismantled in case of need. Julius Caesar described the same technology centuries later in *De Bello Gallico*, referring to the military bridge he had built over the Rhine: the method of construction typology must have been part of the consolidated heritage of Roman military engineers[66].

The birth of the modern city and the idea of the capital

There are many examples throughout history of cities founded entirely with the intention of creating ideal settlements to satisfy new political and social needs. Although Leonardo's dream of rethinking the city of Milan as Sforzinda[67] never really came to fruition, there

[66] Dionysius of Halicarnassus, in his text dedicated to Roman antiquities, stresses the sacredness of the bridge for the Romans, to which a priestly order dedicated to its custody was attached: the Pontefices, a Latin term indicating 'bridge-builders'. *Ibidem*, pp.176-177.

[67] In the *Libro Architettonico*, consisting of XXIV volumes written between 1458 and 1464, the architect and sculptor Antonio Averlino, known as Filarete (1400 - 1469), outlines the project of the ideal city he theorised in full: Sforzinda, one of the first examples of urban planning with a complex geometric design, was conceived within a wall shaped like an eight-pointed star. The theme of the ideal city also fascinated Leonardo da Vinci, who began working on it in Milan in the late 1480s. Unlike the treatise writers of his time, Leonardo's focus was not on the organisation of geometric space but rather on functional space, which envisaged a more open urban fabric characterised by wide, straight streets and a capillary presence of waterways, separating the circulation of people and goods on several levels. The originality of the project combined two important and inseparable aspects: the fusion of architecture, mechanics and hydraulics with the broader idea of urban beauty reflected in the elegance of the architecture, the porticoed streets, the palaces adorned with attics and terraces. Milan's network of canals and the radiocentric structure of the

are many examples, starting with the early Renaissance, of modern cities that have been completely rethought in terms of urban planning, such as Pienza[68], or planned from scratch, such as Palmanova[69]. Among the numerous examples from the Renaissance onwards of the foundation of cities/capitals, while taking into account the example of Madrid[70], in the following pages we will briefly illustrate

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city around the castle are the result of that design approach. Hub B. 2009, *La planimetria di Sforzinda: un'interpretazione*, «Arte Lombarda», vol. 155, n. 1, pp. 81-96.

[68] The ancient village of Corsignano in Tuscany was the birthplace of Pope Pius II Piccolomini. In 1459 the Pontiff called the architect Bernardo Rossellino with the intention of renovating the historic centre of the village, opening a square surrounded by the Piccolomini Palace, the cathedral and the bishop's palace. The urbanisation work, which lasted five years, also included the construction of a new suburban district with terraced houses: the '12 Case Nuove', the first case of social housing in history. In terms of urban planning, what was created was a theatrical scene for public life, with an original splayed perspective effect to compensate for the narrowness of the spaces. In order to give depth to the square, Rossellino was obliged to move the church backwards, placing the apse overhanging the ridge with an original supporting buttress. Wittkower R. 1998, *Architectural Principles in the Age of Humanism*, Academy Editions Ltd., London.

[69] The city of Palmanova, now in the province of Udine, was founded by the Venetians in 1493 and was designed by Giulio Savorgnan, a Venetian military engineer in 1593, and the architect Vincenzo Scamozzi who drew the urban plan, conceived as a castle city with the intention of protecting Venice from a hypothetical Ottoman invasion from the Mediterranean. In the course of little more than a century, the new idea of the city thus passed from the abstraction of the perspective drawing of the 'ideal city' to the solid concreteness of the defensive walls. Pollak M. 2013, *The 'Palmanova effect' and fortified European cities in the seventeenth-century*, in F.P. Fiore (ed.), *L'Architettura militare di Venezia in Terraferma e in Adriatico fra XVI e XVII secolo*, Olschki Editore, Modena, pp. 21-36.

[70] The city of Madrid, designated as the capital of the Spanish Crown by Philip II in 1561, actually stands on the site of a settlement that had existed since prehistoric times. Under the emir Mohamed I of Cordoba (852-886) Madrid - or Mayrit - began as a ribat, a religious and military enclave within which small groups of Muslims prepared for jihad, the holy war against the Christians of Spain. From the 12th century, under

the cases of Saint Petersburg, Washington, Paris and Brasilia. These examples are relevant in this context, not so much (or not only) because of the new and advanced urban planning concepts that guided them, but above all because of the system of technological innovations employed. Often invisible to the visitor's eye, these allowed them to be built as planned and still allow these great capital cities to function today.

The Tsar's dream: Saint Petersburg

Swedish settlers built the Nyenskans Fortress at the mouth of the River Neva[71], on the site of present-day Saint Petersburg, in 1611. It was Tsar Peter the Great at the end of the 17th century who recognized that Russia needed an open trading port to Europe[72]: he decided to found the Peter and Paul Fortress on the site of the fortress captured from the Swedes. For the construction of the new city, tens of thousands of peasants were literally conscripted and deported from all over Russia and put to work as

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the Crown of Castile, the original Muslim defensive wall was extended to accommodate the new neighbourhoods created after the Reconquista. In the 15th century, the city expanded beyond the walls, reaching around 12 000 inhabitants by the beginning of the 16th century. In order to accommodate the large number of inhabitants, an additional area was formed, called Arrabal (today's Plaza Mayor), which incorporated all the areas that had been populated since the 12th century on the outskirts of the Christian district. From the moment it became the seat of the Spanish court under Felipe II, the city with its 15 000 inhabitants began to grow exponentially, covering an area of 125 hectares with eight gateways. Magro Á. B., Carvajal O. L. E. 1989, *Madrid, de territorio fronterizo a región metropolitana*, «España. Autonomías», Espasa Calpe, pp. 517-615.

[71] Hosking G. 2001, *Russia and the Russians: A History from Rus to the Russian Federation*, Belknap Press, London.

[72] "It needed a better seaport than the country's main port at the time, Arkhangelsk, which was on the White Sea in the far north and closed for shipping during the winter", Hughes.

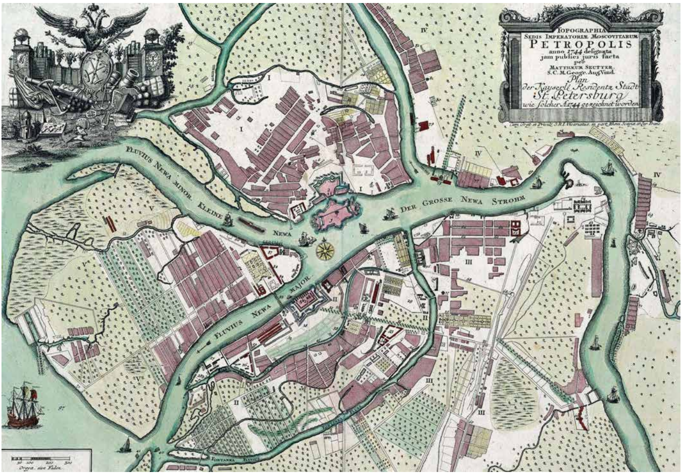

Fig. 14 Map of the first nucleus of the city of Saint Petersburg on the delta of the Neva River in the Gulf of Finland, according to the description drawn up in 1744 by Matthäus Seutter (1678 - 1756) (Source: Wikimedia commons ®).

forced labour alongside Swedish prisoners[73] under the supervision of Alexander Menshikov.

The growth of the project led to the city becoming not only Peter's new port to Europe, but also the seat of an autonomous Governorate and from 1712 the new capital of the empire[74] to the detriment of the old imperial capital of Moscow, which however remained the sacred place where imperial coronations took place. Only in 1917, following the Soviet revolution, did Saint Petersburg cease to be the capital of all the Russias as the capital and centre

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[73] Raeff M. 1994, *Political Ideas and Institutions in Imperial Russia*, Westview Press, Boulder.
[74] Cracraft J. 1988, *The Petrine Revolution in Russian Architecture*, University of Chicago Press, Chicago.

of power returned to Moscow[75]. The city was born under the worst auspices: the area was low and marshy, located many miles north of any other major centre in Russia at the time[76]. Peter's intention was essentially to counter Swedish domination of the Gulf of Finland[77] and gain access to the sea, but transforming the Neva River's marshy delta (Fig. 14) required a massive effort, both in terms of soil consolidation and overall land reclamation[78]. In the end it cost thousands and thousands of lives because of the impossible working conditions imposed on the workers[79]. Influenced by his extensive travels in the European capitals[80] and his observation of the construction techniques of the Dutch and British shipyards[81], Peter wanted to give Russia a modern, western city, rejecting the Asian and Byzantine roots of Russian culture, thus causing much discontent among the old Boer aristocracy[82]. Construction began on the right bank of the Neva around what came to be called the Trinity Square (*Troitskaya Ploshchad*), near the Peter and Paul

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75 Schmidt A. J. 1981, *The Restoration of Moscow after 1812*, Slavic Review, Cambridge University Press, vol. 40, n. 1, pp. 37-48.

76 Murrell K. 1995, *St Petersburg: History, Art and Architecture*, Philip Wilson Publishers Ltd, London.

77 Bushkovitch P. 2009, *Peter the Great. The struggle for power, 1671–1725*. New studies in European history, Cambridge University Press, Cambridge

78 Dixton S. 1999, *The Modernization of Russia, 1676-1825*, Cambridge University Press, Cambridge.

79 Dukes P. 1998, *A History of Russia: Medieval, Modern, Contemporary, c. 882-1996*, Macmillan, London.

80 Massie R. K. 2012, *Peter the Great: His Life and World*, Modern Library, New York.

81 Abbott J. 1869, *History of Peter The Great, Emperor of Russia*, Harper & Brothers Publishers, New York, pp. 139-140.

82 Figes O. 2018, *La danza di Nataša. Storia della cultura russa (XVIII-XX secolo)*, Piccola Biblioteca Einaudi, Torino, pp. 13-21.

Fortress. Soon, however, a more general plan was made according to an overall vision: Domenico Trezzini[83] who came from Switzerland, created a plan which placed the centre of the city on Vasilyevsky Island, and surrounded it with concentric canals in a manner, within the constraints imposed by the site, reminiscent of Amsterdam and the Tsar's original inspiration.

Although Peter then appointed Jean-Baptiste Alexandre Le Blond[84] as chief architect of Saint Petersburg, the basic *forma urbis* defined by Trezzini still shapes the modern city. From an urban planning point of view, the city is a palimpsest, inspired by urban fashions of the following centuries. If the network of canals created around the focal point of the Admiralty Palace was almost certainly inspired by Amsterdam, that initial plan was overlaid by a classic 18th century scheme, based on wide avenues and designed by French and Italian architects employed by Catherine II. Today's city is still one of the most evocative in the world, with its reminiscences from Pushkin to Akhmatova and the many others who have crossed its canals and walked along its immense boulevards and squares[85].

[83] Domenico Trezzini (1670 - 1734), Swiss architect and town planner; in 1703 he was chosen by Tsar Peter the Great to direct the work on a port on the Baltic Sea that would open a window on the West to Russia, which until then had been cut off from trade routes. Kahn-Rossi M., Franciolli M. 1994, *Domenico Trezzini e la costruzione di San Pietroburgo*, Octavo, Florence.

[84] Jean-Baptiste Alexandre Le Blond (1679 - 1719), French architect whom Tsar Peter the Great met in Europe during one of his trips and who contributed to the construction of St. Petersburg from 1716 onwards. Kaganov G. 1997, *Images of Space: St. Petersburg in the Visual and Verbal Arts*, Stanford University Press, Stanford, p. 15.

[85] Bell M. J. 1997, *Re-forming Architecture and Planning through Urban*

Bonaparte's dream: Paris during the Empire

Napoleon I began the modern urban transformation of the French capital with the intention of giving his own imprint to the city. The Rue de Rivoli project, the star-shaped layout of the square around the Arc de Triomphe and the planned Palace of the King of Rome were the prodromal elements of this project[86], where the Quarter of the King of Rome was conceived as a new 'imperial city', dedicated to administration, knowledge and the armed forces[87]. But it would be Napoleon I's nephew, Louis Napoleon[88], the first elected president of the Second Republic and later Emperor under the name of Napoleon III, who between 1852 and 1870 would initiate the process of modernising Paris under the Second Empire, with the help of the prefect Georges Eugène Haussmann[89].

Design: Saint Petersburg Case Study, «Architecture: Material and Imagined», vol. 64, pp. 250-254.

[86] "*...Napoleon wanted to create a real administrative city, connected to the right bank by the new Jena Bridge and which would be dominated by the Palace of the King of Rome, the imposing building built on the hill*" Buclon R. 2013, *Du Foro Bonaparte de Milan au Quartier du roi de Rome de Paris. Continuités et divergences d'une utopie républicaine à une vision impériale*, January 2013, Mélanges de l'Ecole française de Rome Italie et Méditerranée vol. 125, n. 2, Roma, p. 2.

[87] *Ivi*, p. 8.

[88] Charles-Louis-Napoleon Bonaparte, called simply Louis-Napoleon, born on 20 April 1808 in Paris and died on 9 January 1873 in Chislehurst (United Kingdom) president of the Second French Republic from 1848 to 1852 and Emperor of the French from 1852 to 1870. Son of Louis Bonaparte (Brother of Napoleon I) and Hortense de Beauharnais (First-born daughter of Empress Josephine and adopted daughter of the Emperor).

[89] Georges Eugène Haussmann, better known with the imperial title of Baron Haussmann, (1809 - 1891) Prefect of the Seine from 1853 to 1870, he directed the transformation of Paris under the Second Empire by further elaborating the vast plan of renewal desired by Napoleon III.

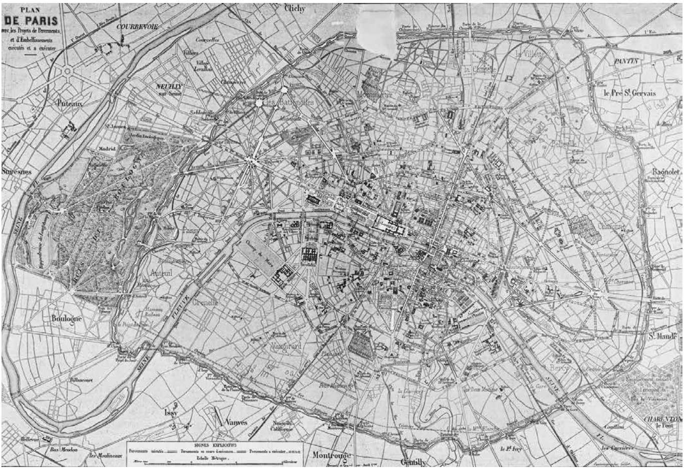

Fig. 15 Paris City Plan 1861-1869. Source: The Norman B. Leventhal Map Center (NBL Map Center) at the Boston Public Library (BPL).

The urban transformation plan was born from the need to find solutions to the problems that had emerged due to overpopulation and the unhealthy state of the oldest neighbourhoods. The functional reorganisation of the medieval fabric of the city required interventions in both the central areas and the suburbs, in order to create or transform green areas, new public buildings, sewerage networks and roads (Fig. 15).

The road network comprised the construction of two large crossing/connecting axes in a west-east and north-south direction, whose point of intersection, the Place du Châtelet, was to be transformed into a large urban hub that Haussmann designed in direct communication with the centre of civil and commercial power in the city (the Hôtel de Ville and Les Halles). In the historic

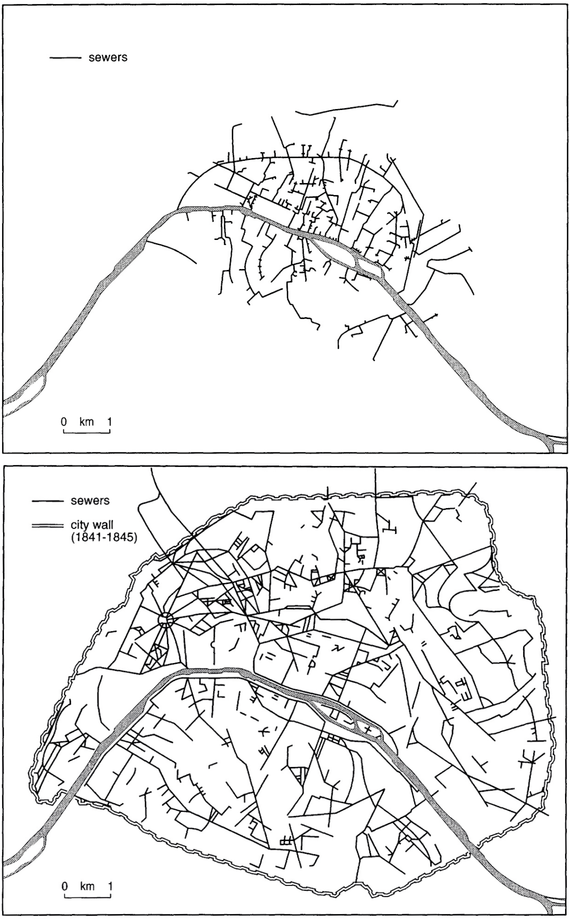

Fig. 16 Paris sewer network in 1837 (up) and Paris sewer network between 1856 and 1878 (down). Source: Belgrand E. 1887 *Les travaux souterrains de Paris V: les e´gouts et les vidanges*, Dunod, Paris.

centre of Paris, the residential blocks were demolished and replaced by a series of public buildings; the basilica of Notre-Dame was monumentalised, according to the logic typical of the period, freeing it from the buildings that over the centuries had been built around it. A further intervention was the creation of Grands-Boulevards and Boulevards exterières, the ring routes around the city.
Napoleon III's plan also provided for an extension of the administrative boundary up to the Thiers fortifications with the annexation of eleven of the surrounding municipalities. In Hausmann's modernisation of the French capital, the reorganisation of underground Paris played an important role through the implementation of innovative drainage and sanitation systems. In 1857, the programme of reconstruction of the sewers began with the construction of the Collecteur Général d'Asniéres, a new elliptical structure over four metres high and five and a half metres wide, built to ensure that waste water was transported quickly and efficiently to the Seine downstream from the city.
The sewage system was completed in 1870 (Fig. 16) with more than 570 kilometres of pipeline, more than four times the extent of the network in 1850, and in 1868 the construction of a vast siphon under the Seine connected the two sections of the Collecteur de la Bièvre[90]. These underground tunnels represented for Hausmann:

> [...] the internal organs of the metropolis, similar to those of the human body. Clean, fresh water, together with light

[90] Gandy M. 1999, *The Paris Sewers and the Rationalization of Urban Space*, «Transactions of the Institute of British Geographers», vol. 24, n. 1, pp. 23-44.

> and heat, should circulate like the different fluids whose movement and supply sustain life itself. These fluids would flow invisibly, maintaining and preserving public health without interrupting the smooth functioning of the city or spoiling its external beauty[91].

The desire to separate rainwater from human waste was an integral part of the Haussmann's original concept for building an efficient and innovative sewage system, not only for hygienic reasons, but also for not dispersing that portion of human excrement which until then had been profitably used as fertiliser for agriculture and in the production of saltpetre[92] for gunpowder. The increasing use of domestic water, which doubled between 1870 and 1890, and the cholera epidemics of 1884 and 1892 eventually made it necessary to overcome the traditional dependence on cesspools. However, the original project of water separation was not realized, and 1894 the connection between private homes and the mixed sewage system was made compulsory.

The interrelationship between technology and urbanisation was therefore one of the most important aspects of Haussmann's rationalisation work of the city, according to the Emperor's request. The provision of light and electricity, the organisation of a new mobility system and the efficient management of drinking water

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[91] Haussmann B. 1854, *Mémoire sur les eaux di Parigi, présenté a la commission municipale par le préfet de la Seine*, Vinchon, Parigi, p. 53.

[92] Potassium nitrate is one of several nitrogen-containing compounds collectively referred to as saltpeter (or saltpetre in the UK). Potassium nitrate is a chemical compound with the chemical formula KNO_3. It is an ionic salt of potassium ions K and nitrate ions NO_3. Potassium nitrate is one of several nitrogen-containing compounds collectively referred to as saltpeter (or saltpetre in the UK).

and sewage systems, together with an organic planning of public urban green areas, are the palimpsest on which Paris' urban space is still based today.
Edmondo De Amicis' brief account[93][94] of his trip to Paris for the Universal Exhibition of 1878, clearly reveals his wonder and amazement at the city he described as immense and majestic, with its wide boulevards lined with double rows of trees, the large irregular square of the Bastille 'spectacular and tumultuous', theatres and elegant cafés, splendid shops, colourful kiosks, and gaudy ornaments.

The Federal dream: Washington

The Commander in Chief of the victorious Continental Army, then first President of the United States of America, George Washington, had himself been a land surveryor from the age of 16: it was a useful and profitable profession as the colonies expanded to what was then 'the west', and vast landed properties, including that of Washington himself, were formed. The choice of a site for the capital of the new Republic was highly contentious and in the end was decided by the desire of southern landowners to avoid Northern states whose laws might interfere with slave-holding. Washington was designated by Congress to choose the precise site within a 65 miles stretch of the Potomac river, which at the time was seen as a future path to western expansion.

[93] De Amicis E. 1879, *Ricordi di Parigi*, Treves Milano.
[94] Edmondo De Amicis (1846 - 1908) Italian writer and journalist known for the educational-pedagogical novel *Cuore*.

Fig. 17 Andrew Ellicott's plan for Washington depicting the Washington City Canal that connected the Potomac River, Tiber Brook and C&O Canal to the East Branch (Anacostia River) Source: Library of Congress, Andrew Ellicott's initial Plan of the City.

Washington named a three man commission to carry out the plans for the new city. He also chose Pierre Charles L'Enfant, a French painter and engineer, to work under the commission to design the federal capital. The objective was to develop a completely new city that would not be a part of the territory of any existing state, but rather a special area for the Federal government. The designated zone or Federal District, of 100 square miles (a square with sides of 10 miles), became the present day District of Columbia, named Washington D.C. in honour of the first President. The commission entrusted the survey of the marshy area, which presented evident hydrological challenges, to Andrew Ellicott, who also drew up a plan (Fig. 17). L'Enfant intended to create a grandiose scenario for the new capital, inspired by maps of major European cities sent to him by Thomas Jefferson. He refused, however, to publish his own plan and demanded complete control over construction. Washington dismissed him and Ellicott, with the commission, took over.

As the city eventually developed it had two broad axes: East-West, where today the Supreme Court, the Library of Congress, the Capitol, the Washington Monument and the Lincoln Memorial are located, and North-South, where the Old Executive Office Building, the White House, the Treasury Building and the Jefferson Memorial are now located. Construction was slow, and the city as we know it only took shape during the 19th and 20th centuries. A network of orthogonal streets was supplemented by diagonal avenues, named after single states and a system of squares. By law the city remains 'low-rise' so that its public buildings and monuments will not be obscured. As a result the necessary residential areas are now largely in the neighbouring states, rather than in the District itself[95].

[95] Chernow R. 2010, *Washington. A Life*, Penguin, New York, pp. 662-5, 794; Minta A. 2009, *Planning a National Pantheon: Monuments in Washington D.C. and the Creation of Symbolic Space*, in Benesch K., Meikle J.L. 2009, *Public Space and Ideology of Place in American Culture*, Editions Rodopi B.V. Amsterdam-New York, pp. 21-50.

A Saint's dream: Brasilia

During the presidency of Juscelino Kubitschek[96], the capital of Brazil was moved from Rio de Janeiro to Brasilia, in the central-western region of the country. Brasilia was the name originally given to the modernist project, also known as the 'Pilot Plan', for a limited area in a central location in Brazil's geography, roughly corresponding to the site indicated by St. John Bosco as the birthplace of a future magnificent city[97].

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[96] Juscelino Kubitschek de Oliveira (1902 - 1976) was a Brazilian politician and physician, who was mayor of Belo Horizonte in 1940, governor of Minas Gerais State from 1950 to 1955, and president of Brazil from 1956 to 1961. He was later elected Senator for the State of Goiás in 1962. As President, he stimulated industrialisation, especially in the automobile sector, which led to rapid economic growth but also to an increase in public debt, both internal and external. Accused of corruption at the same time as the military dictatorship came to power, he retired from political life in 1964. He died in 1976 in a car accident in Resende, near Rio de Janeiro, in circumstances that are still unclear.

[97] In 1883 the Italian priest St. John Bosco (1815 - 1888) had a prophetic dream in which he described a futuristic city that corresponded more or less to the location of Brasilia. Today, there are numerous references in Brasilia to this educator who founded the Salesian Congregation. One of the main cathedrals, Santuário Dom Bosco, bears his name, as does the Ermida Dom Bosco, a vantage point where John Bosco is said to have declared that this city 'of gigantic fruits' would be born. On 4 September Don Bosco described his Second Missionary Dream, which he experienced at San Benigno Canavese (TO) on 30 August 1883, to the members of the Third General Chapter. Fr. Lemoyne immediately put the dream into writing and Don Bosco completed and retouched the text. Referring to the future riches of South America he said: "[...] *Between grade 15 and 20 there was a very wide and very long bosom (a plateau) which started from a point where a lake was formed. Then a voice said repeatedly: When the mines hidden in the middle of these mountains are dug, the promised land will appear here flowing with milk and honey. There will be an inconceivable wealth* [...]", Semeraro C. 2007, Don Bosco e Brasilia, «Ricerche Storiche Salesiane. Rivista semestrale di storia religiosa e civile», vol. 50, n. unico, pp. 381-384.

For the realisation of the new city, Lúcio Costa[98] was called in for the urban planning and Oscar Niemeyer[99] served as the chief architect for most of the public buildings, along with Roberto Burle Marx[100] as landscape designer[101]. In 1957 Lúcio Costa outlined this manifesto for the capital city:

> It should not be envisaged merely as an organism capable of performing adequately and effortlessly the vital functions of any modern city, not merely as an Urbs, but as a Civitas, possessing the attributes inherent to a capital[102].

The project, inspired by Le Corbusier's design theories[103], was the result of functionalist thinking which distributed

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[98] Lúcio Marçal Ferreira Ribeiro de Lima e Costa (1902 - 1998), was a Brazilian architect and urban planner who, as well as being one of the founding fathers of Brazilian modernism and head of the International School of Fine Arts, contributed for almost forty years, as an employee of the Serviço do Patrimônio Histórico e Artístico Nacional, to the study and protection of his nation's historical heritage.

[99] Oscar Niemeyer (1907 - 2012) was a Brazilian architect known for the fluid forms of his designs. He designed buildings for the Pampulha Architectural Complex, the Museum of Contemporary Art in Niterói and major buildings in the Brazilian capital.

[100] Roberto Burle Marx (1909 - 1994), Brazilian landscape architect who created many exceptional gardens in association with important modern buildings. He replaced formal European-style gardens with the lush tropical flora of his own country.

[101] D'Auria Learchi L. 2015, *La chiave*, West Press, Castellammare di Stabia.

[102] Costa L. 1957, *Relatório do Plano Piloto de Brasília*; DePHA, Brazil, p. 77.

[103] Charles-Édouard Jeanneret (1887 - 1965), Swiss architect, urban planner, designer and painter considered to be the master of the Modern Movement thanks to his theorisation of five points of modern architecture such as the pilotis, the roof garden, the free plan, the free façade and the ribbon window. Author of several books including Verso un'architettura of 1923, an indispensable contribution to the transformation of 20th century architectural thought. He has linked his name to projects such as the Villa Savoye, the League of Nations building in Geneva, the Notre-Dame chapel in Ronchamp and Chandigarh, the 'silver city' in the Punjab.

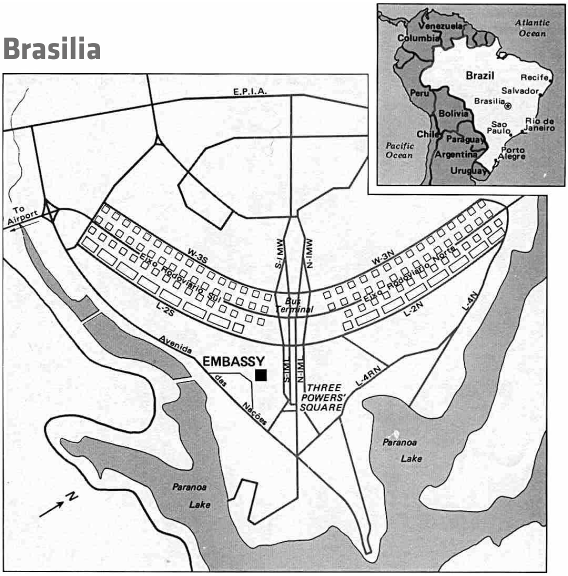

Fig. 18 City plan of Brasilia (Lúcio Costa 1956) Public domain, from the image available at www.dominiopublico.gov.br, U.S. Dept. of State, edited by Felipe Micaroni Lalli.

neighbourhoods on the basis of the activities carried out there. Brasilia was built in 41 months, from 1956 to 21 April 1960, and was inaugurated in 1961[104]. The new capital was designed to accommodate a population of 500 000 inhabitants in an area of 5 850 km². These development forecasts were put into law in 1953. The city was characterised by an airplane-shaped plan, crossed by a main curved axis, the monumental one, which extended in an east-west direction and from which two

[104] Carvalho Santos T. C. 2010, *La Brasilia pensata e quella reale*, «Dialoghi Internazionali, città nel mondo», n. 14, pp.116-135.

wings, designed as residential areas, unfolded in a north-south direction (Fig. 18).
On the curved axis a wide central highway was placed, connected to secondary roads for local traffic. The main residential areas were located along this axis[105]. The project was inspired by the guidelines of the Garden City movement[106], characterised by an abundance of open green spaces and low-density occupation, giving the urban environment a park-like feel[107]. Brasilia's empty spaces were considered elements of the modernist structure, inspired by the immense lawns of English landscapes[108].
The pilot plan for Brasilia was built having Le Corbusier's Athens Charter[109] in mind: this proposed the qualities of a

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[105] Costa C., Lee S. 2019, *The Evolution of Urban Spatial Structure in Brasília: Focusing on the Role of Urban Development Policies*, «Sustainability », vol. 11, n. 2.
[106] The Garden Cities movement was an urban planning movement of the late 19th century in England, the brainchild of Ebenezer Howard who published the book *To-morrow: A Peaceful Path to Real Reform* (reprinted in 1902 as *Garden Cities of tomorrow*) in 1898. The movement aimed to combine the primary benefits of a country environment with those of an urban structure, avoiding the disadvantages presented by both. His ideal garden city would house 32 000 people on a site of 6 000 acres (2 400 hectares), and would be designed on a concentric pattern with open spaces, public parks and six 37-foot wide radial avenues from the centre. The idea was that the garden city would be self-sufficient and once it reached full population, another garden city would be built nearby. Howard envisioned the construction of several garden cities as satellites of a central city of 58 000 people, connected to it and to each other by roads and railways.
[107] Campos, N.L.O. 2003, *Mudança no Padrão de Distribuição Social a Partir da Localização Residencial: Brasília, Década de 90*, Ph.D. Thesis, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil.
[108] Carpintero A.C.C. 1998, *Brasília: Prática e Teoria Urbanística do Brasil, 1956/1998*, University of São Paulo Press, São Paulo.
[109] The Athens Charter was a document, published in 1938 following the Fourth International Congress of Modern Architecture in 1933, which

modern ideal city, based on four fundamental principles: well-ventilated buildings close to green spaces; separation of homes from workplaces and industries away from the urban core; exclusive spaces for cultural activities close to homes; and separation of vehicle and pedestrian circulation. Bearing in mind the typical urban planning layout of ancient cities, both Greek and Roman, the cross-axial scheme was chosen and subsequently developed for Brasilia. It is a peculiar urban place, characterised by:

- a strict code of land-use that limits the functions of the various areas, separating housing from other activities;
- large superblocks (‘*superquadras*’), having straight streets with few corners;
- skyscrapers of homogeneous height, built between 1960 and 1980, sharing a concrete style and located in residential superblocks;
- a homogeneous population, mostly of middle-class workers with similar educational background and income, evenly distributed in moderately dense residential areas.

The basic scheme, however, had to be adapted to the topography of the site, as there were already plans for an artificial lake to be created with a hydroelectric dam. Because of this geomorphological limit, the city curved into the form of an airplane, rather than a cross. The lake was the most important technological feature to support the future city. The dam on the Paranoá River generated an artificial lake of the same name, with a surface area

aimed to set out the fundamental principles of the contemporary city in 95 points.

of approximately 48 square kilometres. The dam also functions as a hydroelectric plant, and was designed to supply the Federal District, although it currently accounts for only 2.5% of the local energy consumption.
A qualifying technological aspect of the project is that the roads of the city have no intersections, nor even traffic lights, but only access and exit ramps connecting large and comfortable roads, with subways and viaducts of extreme elegance and total safety. In the original plan there were no traffic lights, all cars travelled via overpasses or tunnels, in order to avoid the need for intersections. The solution adopted by the city today, in order to take into account the needs of pedestrians, little considered in the original plan, has been to design thousands of pedestrian crossings on all streets, together with a subway/surface light-rail system, still under construction. To Saint John Bosco, the Piedmontese saint who first had a vision of Brazil's great future capital, the city has dedicated a splendid church, a dreamlike space surrounded of blue crystal windows.

Understanding the city

The progressive transformation of the modus vivendi of the human species, which has now definitively evolved from *Homo sapiens* to *Homo urbanus*[110], as asserted by

[110] Johnny Grimond on 5th May 2007 issue of «The Economist» in an article entitled *The world goes to town*, states: "*WHETHER you think the human story begins in a garden in Mesopotamia known as Eden, or more prosaically on the savannahs of present-day east Africa, it is clear that Homo sapiens did not start life as an urban creature. Man's habitat at the outset was dominated by the need to food, and hunting and foraging were rural pursuits. Not until the end of the last ice age, around 11 000 years ago, did he start building anything that might be called a village, and by that time man had been around for about 120 000 years. It took another six*

Johnny Grimond[111], columnist and foreign correspondent of «The Economist», today requires a careful analysis, by both researchers and urban decision makers. Such an analysis needs to assess the ever-increasing complexity of urban contexts with respect to the possible repercussions, positive or negative, on citizen's lives.

The very meaning of the noun 'citizen' implies the definition of a cultural category, linked both to the Roman concept of *Urbanitas*[112], as well as to the economic, social and cultural propulsive role played by the urban bourgeoisie in the centuries from the Middle Ages to the French Revolution. Since the eighteenth century onwards, the French word *Citoyen* (citizen)[113] became

millennia, to the days of classical antiquity, for cities of more than 100 000 people to develop. Even in 1800 only 3% of the world's population lived in cities. Sometime in the next few months, though, that proportion will pass the 50% mark, if it has not done so already. Wisely or not, Homo sapiens has become Homo urbanus".

[111] Johnny Grimond, (1946), was a foreign policy columnist for «The Economist» from 1969 until 2002.

[112] The term *Urbanitas* (from the Latin noun *Urbs-is* and *Urbanus* - *pertaining* to a city or city life). Mostly referred to the dwellers of the Ancient Rome, the *Urbs* by definition. The etymology would come from the Latin verb *Urvare*, which finds its meaning in the act of tracing the furrow, then in the delimitation and the walls of a new city (*Pomerium*). Lately the term *Urbanitas* became synonymous of refined/polite person living in Rome. Farmer, J.C., 2008, *Catullus Urbanus: Urbanity and the Choliambic in Catullus 22 and* 39, Samford University.

[113] In the Greek polis, one was a citizen as one was born of parents who were both free and citizens, and exercised civil rights, as a rule, as soon as one reached the age of 20. The notion of citizenship is found in Roman law, where the concept of civilitas ('citizenship') designated membership of the civitas. In republican Rome, only cives were able to exercise their right to vote in popular assemblies (comitia); to carry out the solemn transactions provided for by the ius civile; to hold patria potestas and dominium over property and slaves; to escape death sentences by means of exilium. Citizenship regained centrality with the French Revolution, replacing the figure of the subject with that of the citoyen, as a component of the nation and depositary of sovereignty (art. 3 of the *Déclaration des*

Fig. 19 "*Ici on s'honore du titre de citoyen*" (Here one is honoured with the title of citizen). Example of a sign dated 1799, affixed to public places during the French Revolution. (® Bibliothèque nationale de France, Author: Manufacture Berthelot (publisher).

a universal definition of the legal and moral individual before the State, replacing the concept of "subject" (Fig. 19). The term is included in the Declaration of the Rights of Man and of the Citizen of 1789[114] and subsequently reaffirmed as a central element both in the Constitution of 24 June 1793 and later in the context of Napoleonic law. The European cultural project, as well as a large part of modern Western civilisation, is predominantly built on this body of law. The model of development

droits de l'homme et du citoyen 1789; art. 1 and 2, title III, of the French Constitution of 1791); the principle of popular sovereignty was based on it.

[114] Assemblée Constituante, *Déclaration des Droits de l'Homme et du Citoyen*, Assemblée nationale, 1789, pp. 1-8. Signé, Mounier, Président; le Vicomte de Mirabeau, Démeunier, Bureaux de Pusy, l'Év. de Nancy, Faydel, l'Abbé d'Eymar, Secrétaires.

of contemporary urban civilisation has advantages and disadvantages that are inherent in the very nature of the city.

Max Weber[115] in his essay entitled *The City* (1921), a volume published posthumously, about one year after his death, outlines a general definition of the city, focused on its fundamental nature, defining the city as a relatively closed settlement and not simply the sum of separate dwellings[116]. Having an economic approach in mind, the city would be defined as a settlement whose inhabitants live mainly from trade and commerce, rather than from the practice of agriculture. Therefore, we could reasonably apply the economic definition of the city only if the resident population satisfies most of its daily needs in the local market, and if a significant part of the products on sale in that market come from the surrounding territories[117].

Weber therefore delineated the descriptive parameters of the western city, essentially outlining five main descriptors:

1. a system of fortifications;
2. a market place;
3. a codified legislative system and its own judicial system;
4. an urban citizenship association that creates a sense of municipal belonging;

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[115] Maximilian Karl Emil Weber (1864 - 1920) was a German sociologist, philosopher, jurist and political economist. His ideas had such a profound influence on social theory and research that he is considered, along with Émile Durkheim and Karl Marx, to be one of the founding fathers of sociology.

[116] Weber, *Op. cit.*.

[117] *Ivi*, pp. 1213-1214.

5. sufficient political autonomy to allow citizens to elect their own governors[118].

Weber goes on to say that in sociological terms, the city is such when its size does not allow its inhabitants to get to know each other[119], outside the narrow range of the neighbourhood[120]. Following the definition coined in 1936 by V. Gordon Childe regarding the 'urban revolution' as the moment that marked the birth of the first cities, the theme of the ancient city was addressed above all in the years between 1960 and 1970, following the rise of the New Archaeology, which subsequently evolved towards processual archaeology, both entailing a substantial anthropological vision.

These approaches tend to emphasise the function of cities within hierarchies of settlements, hydrographical basins and regional systems of production and exchange. Within those approaches, the relationship between cities and the social life of their inhabitants has rarely been taken into account[121]. The rise of the post-processual archaeological approach in the 1980s and 1990s, with its strong emphasis on subjective analysis, has led to a change in

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[118] *Ivi*, pp.1250-1255.

[119] The fundamental concept of the anonymity of being a 'citizen' is a concept that returns strongly in the subsequent scientific elaborations of the Chicago School (see chapter 3 below).

[120] "*…the city is a settlement of closely spaced dwellings which form a colony so extensive that the reciprocal personal acquaintance of the inhabitants, elsewhere characteristic of the neighborhood, is lacking*", Weber, *Op. cit.*, p. 1212.

[121] Fisher K.D. Creekmore III A.T. 2014, *Making ancient cities: new perspectives on the production of urban places*, in Id. *Making Ancient Cities: Space and Place in Early Urban Societies*, Cambridge University Press, New York, pp. 1-31.

the way historians and archaeologists look at the built environment of the past, and the people who lived in that same space, giving an active and indeed central role to the inhabitants. This approach has inevitably influenced the vision of contemporary cities, recognising that some qualities of urban systems cannot be addressed adequately through a depersonalised analysis of infrastructures and buildings.

Recognising that people play an active role in shaping the city, in a continuous process of transformation and co-evolution, is in line with the writings of Anthony Giddens[122], Pierre Bourdieu[123] and others, who argue that it is fundamental to understand the reciprocal relationship between human action and social structures. Robert E. Park[124] in his 1915 volume on the city and related human behaviour[125] helps us to adopt the correct approach between the city and its inhabitants. Park states unequivocally that the city and its inhabitants must be considered: "[...] not as a mere congeries of persons and social arrangements, but as an institution"[126] and in

[122] Anthony Giddens (1938) is a British sociologist known for his theory of structuration and his holistic view of modern societies.

[123] Pierre Bourdieu (1930 - 2002), French sociologist known for his theorisation of the concept of field in anthropology and sociology

[124] Robert Ezra Park (1864 - 1944) American urban sociologist, considered one of the founding fathers of sociology in the United States and a pioneer in the field of sociology, understood as a discipline active and rooted in the study of human behaviour. He played a leading role in the development of the Chicago School of Sociology, working on the topics of human ecology, race relations, migration, and social disorganization.

[125] Park R. E. 1915, *The City: Suggestions for the Investigation of Human Behavior in the City Environment*, «The American Journal of Sociology», vol. 20, n. 5, pp. 577-612.

[126] *Ivi*, p. 577.

line with that: "[…] the city is rooted in the habits and customs of the people who inhabit it"[127].

While a 'space' can be seen as a passive and neutral physical environment, where social action takes place, a 'place' is an alive environment, imbued with meanings, identities and memories that actively shape it through daily practice, through the experiences of its inhabitants and through the social processes historically related[128]. In other words, just as the difference between a landscape and an ecosystem comes from the human and cultural perception, the difference between a set of buildings and a city depends on the cultural mediation of the people who inhabit it, the citizens.

The brief excursus on urban evolution in this chapter has highlighted precisely that the relationship existing between technological and design innovations, towards social and political evolution, is the key for interpreting the development of any city. If, however, it is true that the social body of a city's inhabitants shapes the city itself, it is also true that the city, having reached the metropolitan dimension, becomes an independent actor in its relationship with citizens. The same concept, as outlined in Weber, had been already proposed by Georg Simmel in the essay the Metropolis and Mental Life (*Die Großstädte und das Geistesleben*)[129], published in 1903.

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[127] *Ivi*, p. 578.

[128] Low S. M., Lawrence-Zúñiga D. 2003, *The Anthropology of Space and Place: Locating Culture*, Blackwell, Oxford.

[129] Simmel G. 1995, *Le metropoli e la vita dello spirito*, trad. it. P. Jedlowski (a cura di), Armando ed. Roma.

In the relationship between the city and its citizens, what remains to be clarified is the role of planners, architects and building managers, who sometimes support, and sometimes try to direct city development with very diverse and sometimes unpredictable results. We will examine this theme further in the following chapters.

Threats to contemporary urban systems, whether endogenous or caused by external events and changes, create challenges that urban administrators and policymakers have to face every day. Such challenges sometimes seem to undermine the very idea for which the city was born, i.e. to create a safe and comfortable place where citizens can live, preventing urban systems from turning into death traps.

Global changes intended broadly as demographic transformations, climate change, extreme weather events, health crises and energy challenges must be assessed taking into account the need to ensure the management of urban metabolic functions, while at the same time ensuring the preservation of the quality of the urban environment.

These are essentially the terms of the discussion regarding the environmental, cultural, infrastructural and human sustainability of cities. The metabolic model is a useful tool for analyzing and addressing these critical issues.

Our capacity to observe and manage open systems[1] using an urban metabolism approach must take into account

[1] European Commission 2014, *Towards a circular economy: A zero waste programme for Europe*, Brussels, 2.7.2014 COM, 398 final.

not only the in- and outflows but also the exchanges with other systems. Disruptive elements, such as extreme climatic events, intense migration processes, or the effects of pandemics must enter into the metabolic analysis in order to provide adequate mechanisms of resilience and adaptation. These elements form a functionally essential part of urban systems, defining tools for describing the dynamics and processes at work in contemporary living environments.

The metabolic approach to the city, however, cannot solve all issues relating to contemporary cities, where complexity and interactions are such as to require further analytical processes, with respect to which applying a single model, however multifaceted, would still not suffice.

Extreme climate events

Although the purpose of this book is not to take part in the international debate on the present global climate change, nor is it intended to establish the concomitant causes to be attributed to human development, what we can certainly agree is that the planet's climate is changing, and cities are seriously threatened by this phenomenon[2]. Current forecasts, broadly shared by the international

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[2] Numerous initiatives have been launched to address these issues such as: IHDP (International Human Dimensions Programme on Global Environmental Change) Urbanisation Science Project, Diversitas Science Plan on Urbanisation, IUSSP (International Union for the Scientific Study of Population) Urbanisations and Health Working Group, U.S. National Academies' Panel on Urban Population Dynamics, U.S. National Academies' Roundtable on Science and Technology for Sustainability's Task Force on Rapid Urbanisation, UNESCO's initiative on *Urban Biospheres*.

scientific community, predict an increase in the average global temperature between 2 and 3 degrees within the 21st century, which implies that the Earth will experience global unprecedented changes, at least considering the last 10 000 years.

Adaptation will be extremely difficult for a very large number of people. In the short term, some parts of the planet will benefit from this rise in temperature, especially in the northernmost parts of our hemisphere, where longer agricultural seasons and larger harvests will occur, partly due to the positive effect on plants of the increase in carbon dioxide in the atmosphere. However, climate deterioration is expected to become a dominant feature across the planet, with adverse weather events, such as heat waves, storms and floods, increasing in frequency and severity. Higher temperatures will cause melting of glaciers and polar ice caps, with sea-level rise and serious consequences over low-lying territories across the planet, affecting especially the most fragile populations and territories along the coastlines.

All those evaluations and previsions are nowadays common scientific knowledge, and are also part of a broad analysis that the British Royal Society published in 2008[3], based on the studies on planet's climate changes, that together with the related mitigation strategies, have been developed by the Intergovernmental Panel for Climate Change (IPCC)[4] since the last decade of the 20th

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[3] The Royal Society's studies are mostly based on the research produced by the intergovernmental panel on climate change. The Royal Society 2008, *Climate change controversies. A simple guide*, London

[4] The Intergovernmental Panel for Climate Change (IPCC) is an

century. A milestone for this research sector is the 2014 IPPC report, with an entire section[5] dedicated to the analysis of the effects of climate change on urban systems, where about 50% of the worldwide population lives today. In the analysis of the effects of climate change on urban areas, it is important bear in mind that one in seven citizens lives in poor and overcrowded urban conditions, with inadequate or non-existent basic infrastructures. The increasing environmental and social pressures of urban systems, combined with the effects of uncontrolled urbanization and climate change, are converging dramatically to create crisis scenarios.

Although urban areas cover less than 2% of the earth's surface, they consume about 78% of the world's energy and are responsible for more than 60%[6] of total emissions of carbon dioxide and other greenhouse gases. At the same time, urbanized environments are highly sensitive and vulnerable to the effects of climate change. While climate change is a global phenomenon, extreme local events

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intergovernmental body of the United Nations, dedicated to providing an objective, scientific view of climate change, and its associated natural, political and economic impacts and risks, and to developing possible mitigation and response strategies. The IPCC was established in 1988 by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) and was subsequently endorsed by the United Nations General Assembly. The Panel produces reports that contribute to the work of the United Nations Framework Convention on Climate Change (UNFCCC). The IPCC's Fifth Assessment Report was a key scientific contribution to the UNFCCC's Paris Agreement in 2015.

[5] Revi A. et al. 2014, Urban areas, in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge, United Kingdom and New York, NY, USA, pp. 535-612.

[6] United Nation Urban Settlement Programme (UN-HABITAT), 2011.

could produce very different and sometimes contradictory effects. Prolonged periods of drought will alternate with heavy rainfalls, snow and ice storms or other extreme weather conditions with increasing frequency, to the point where they can no longer be classified as 'extreme events'. Rise in sea level, increased rainfall, floods, increasingly intense and frequent storms, as well as alternating periods of intense heatwaves, even generating tornados, are all phenomena that climate change is already producing around the world, especially in areas that until now have usually enjoyed temperate and quite predictable weather conditions.

The world population is concentrated in dense infrastructural areas where the soil is largely impermeable because the surface is covered by buildings and asphalted roads, with a low percentage of green areas and vegetation, and mostly in coastal areas. This creates a scenario of extreme vulnerability to risks connected with the water cycle, due to the rising sea level, but also to challenges in the management of surface waters deriving from exceptional rainfall. A fundamental element for any species and obviously for the survival of the urban population, water can be at the same time a source of serious danger during extreme events. Heavy rainfall can easily produce floods in highly urbanized coastal areas where, according to UNECE[7], the world's most relevant

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[7] The United Smart Cities programme is a global initiative, established by the United Nations Economic Commission for Europe (UNECE) in collaboration with the Organisation for International Economic Relations (OiER) and other international organisations, cities, industry and the financial sector. United Smart Cities is a unique platform that brings together international organisations, companies, governments and

economic, governmental and social infrastructures lie.
The most critical areas in this regard are coastal zones, where the effects of climate change threaten more than 350 million inhabitants who live in the 72 largest coastal cities of the world, seriously jeopardizing urban services and infrastructures, as well as the citizens' quality of life. About 65% of the world's urban population currently lives in coastal locations and the population of mega-cities located on the coast or directly connected to waterways is expected to grow to 74% by 2025[8], exposing them to increasing risks of flooding, beach erosion, saltwater intrusion, river sedimentation and landslides.
Concentrating our analysis on the European Union, the coastlines of Member States extend to about 68 000 km, three times more than that of the United States and almost twice that of Russia. If we include Iceland, Norway and Turkey that, along with European Union form the European Economic Area (EEA), they reach 185 000 km[9]. Summing EU and EEA coastal zones and taking into account 50 kilometers from the shoreline, the surface area reaches 560 000 square kilometers, representing 13% of the total surface of these countries[10]. In 2011 EUROSTAT calculated that approximately half of the EU population lived less than 50 km from the sea, most

high-level decision makers to work together on a single goal: to generate and implement projects for smarter and more sustainable cities.

8 United Nations Urban Settlement, *cit*.

9 The European Economic Area (EEA) created with a multilateral treaty signed on May 2, 1992 and entered into force in 1994, joins European Free Trade Association (EFTA) members European Union with the aim of allowing EFTA countries to participate into the European Common Market without being EU members states.

10 Corine Landcover 2000 data.

of it concentrated in coastal urban areas. According to a 2011 EEA survey, 206 million people lived in Europe's coastal regions, comprising 41% of the EU population[11].
As already stated, the geographic location of urban areas is an important factor in determining their vulnerability to the effects of climate change, especially considering the rising sea level. Between 1900 and 2010 the global sea level increased by 1.7 ± 0.2 millimeters per year, but more precisely, since 1993, satellites and tide gauges record an increase of ~3.4 ± 0.4 millimeters per year [12]. It is also important to note that over the last three decades, high-intensity tropical cyclones have gradually moved from the equatorial zones, reaching the temperate areas of both hemispheres. The continuation or acceleration of this trend will increase flooding risks, especially in non-tropical coastal communities, historically less exposed to such damaging storms[13].
The geographic location of cities therefore makes them particularly sensitive to the effects of increased flooding, which have an impact on the entire infrastructure and urban structure. Particularly when flooding lasts over

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[11] European Environmental Agency (EEA) 2007, *Europe's seas and coasts, in Water and marine environment*, Copenhagen (Last modified 19 March 2019), p. 6.
[12] IPCC 2013.
[13] The New York metropolitan area on the east coast of the United States, where rising sea levels have led to a significant increase in flooding, offers an eloquent example in assessing the centrality of geographical location in the exposure of cities to climate phenomena; according to an estimate by the New York City Panel on Climate Change, by 2050 sea level rise in the metropolitan region could reach almost one metre above the current level, making it almost impossible to manage the urban metabolism as currently organised, unless major defensive infrastructures are considered in the parts of the city most exposed to such phenomena.

several tide cycles, it can produce ‘extreme events’, affecting the operation of such structures as large port facilities, petrochemical or energy industries and rainwater drainage systems. Keeping urban functions and related services fully operational will have increasing costs that are difficult to assess.

The available data referring to the territory of the European Union indicate that economic activities located less than 500 meters from the sea represent a value calculated between 500 and 1000 billion euros. In order to preserve such an economic asset, EU Member States’ public expenditure on coastal defense, mainly for fighting erosion and protecting against flooding, has been estimated at around 5.4 billion euros per year for the period 1990-2020[14].

In light of the previous considerations, a very valuable economic asset that must be considered is the sector of energy production and distribution, closely linked to urban economic development and citizens’ quality of life. As highlighted by IPCC[15], any disruption of urban structures due to climate events can have far-reaching consequences on the energy supply, causing damage on many fronts, affecting infrastructure, services (including health and emergency assistance), drinking water and wastewater treatment, public transportation systems, and road traffic management.

Rising sea levels will expose not only urban populations, but also energy production systems and other urban

[14] EEA 2007/2019, p. 6
[15] Revi, *et al.*, *Op. cit.*

related energy infrastructure, to risks. More than 6 700 power plants, providing almost 15% of the world's electricity in 2009, fall within the Low-Elevation Coastal Zone (LECZ), defined as the coastal area located within 10 meters from the sea and significantly exposed to the risks of flooding, high tides and extreme rainfall[16]. According to NASA[17], low-elevation coastal zone can be defined as:

> [...] the land area and the total and percentage population, by country, that is located in various low elevation coastal zone bands ranging from 1m to 20m elevation above mean sea level[18].

According to an overview of the impact of climate change on the electricity production sector, temperature variations will determine changes in the pattern of urban energy consumption required for cooling and heating, particularly in the more mature economies, such as United States, most of the European Union members and Japan. While in more temperate northern hemisphere regions, the increase in winter temperatures can certainly temporarily reduce energy demand for heating, this reduction will be quickly compensated by the potential increase for electricity demand during the summer

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[16] Wong, P. P. et al. 2014, *Coastal systems and low-lying areas, in Climate Change. Impacts, Adaptation, and Vulnerability*, Cambridge University Press, Cambridge, pp. 361-409.
[17] The National Aeronautics and Space Administration (NASA) is an U.S. federal agency, established in 1958, responsible for the civilian space program, as well as aeronautics, space and satellite research.
[18] National Aeronautics and Space Administration (NASA), *Low-Elevation Coastal Zone (LECZ)*, Socioeconomic Data and Applications Center (SEDAC) CIESIN, Earth Institute at Columbia University Palisades, New York 2016 (http://sedac.ciesin.columbia.edu), p. 1

period, with peaks in electricity consumption for air-cooling during heatwaves[19].
Such conditions could easily trigger Brownouts or Blackouts[20], mostly in cities located in temperate regions and particularly on the southern continents, according to the cited IPCC report[21]. Those phenomena could produce serious negative consequences on economic productivity and quality of life[22]. It is also necessary to assess the effects of climate change on the availability of raw materials for primary energy production, particularly in developing countries, where some urban areas are highly dependent on biomass fuels. There, production is particularly sensitive to the effects of climate change, considering that the crops harvested for biomass energy installations may easily reach the threshold of their biological tolerance to heat and storms, or drought may substantially reduce their yield.

19 "*…Critical energy transport infrastructure is at risk, with oil and gas pipelines in coastal areas affected by rising sea levels and those in cold climates affected by thawing permafrost. Electricity grids will be impacted by storms, and the rise in global temperature may affect electricity generation including thermal and hydroelectric stations in some locations*", Statham B. et al. 2014, *Climate Everyone's Business. Climate Change: Implications for the Energy Sector. Key Findings from the Intergovernmental Panel on Climate Change Fifth Assessment Report*, University of Cambridge and World Energy Council, Cambridge, p. 5.
20 A Brownout is an intentional or unintentional voltage drop in a power supply system. Intentional brownouts are usually used for load reduction in an emergency. The term is derived from the dimming experienced by incandescent lighting when the voltage drops. A brownout may be an effect of a mains failure or may occasionally be imposed in an attempt to reduce the load and prevent an unplanned power failure, known as a blackout.
21 IPCC 2015.
22 IPCC 2014, p. 557.

Water supply plants and urban wastewater management facilities are also increasingly threatened by changing climatic conditions, as well as by the uncertain availability of water resources, and must learn to respond to rapidly changing scenarios. The proper functioning of water supply systems and the entire urban water cycle has a major influence on urban health and well-being, as well as on urban economic activities, energy demand and the overall rural-urban water balance.

Climate change has a strong impact on water demand, as well as on the management of the water supply/offer, with expected impacts on the rainfall regime and on rainfall runoff in cities. Sea level rise could produce at the same time increased risks of saltwater infiltration into coastal underground freshwaters (the so-called salt wedge), causing alterations in agricultural production and critical issues in terms of water quality and availability, leading to serious difficulties in long-term planning of investments in the water supply sector[23].

As stated above, climate change could cause critical conditions due to excessive rainfall and flooding, as well as substantial lack of water and desertification. Drought can have multiple consequences in urban areas, primarily the failure of hydroelectric power, on which many cities' and economies are based, particularly in the urban centers of Brazil and neighboring countries, as well as in the cities of tropical sub-Saharan Africa[24]. Prolonged drought could also be disruptive for power plants relying

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[23] *Ivi*, pp. 556-557.
[24] *Ivi*, p. 558.

on water for cooling, namely nuclear and fossil fuel power plants, a phenomenon that has become increasingly frequent, even in Europe in recent years[25], causing the energy production sector to have to compete with human and agricultural consumption of water resources[26].

Water is inextricably linked with energy production, being needed for every stage of the energy cycle, from the extraction and processing of fossil fuels, to the final generation of electricity. Energy is needed as well for many processes necessary for ensuring the water supply, from locating and extracting it from aquifers, to treatment, distribution and, in some cases, desalination. These issues continue to be high on the EU energy management agenda[27].

The spread of many diseases resulting from water contamination, as well as poor food supply, are also factors that contribute to negative economic impacts, and in particular to increased migration from rural areas to cities. In fact, an estimated 150 million people are currently

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[25] This factsheet is based on the JRC technical report: Medarac H., Magagna D. Hidalgo González I. 2018, *Projected fresh water use from the European energy sector*, EUR 29438 EN, Publications Office of the European Union, Luxembourg (updated with new data in March 2019).

[26] The high temperatures and low rainfall during the summer of 2018 also led, for the first time in decades, to a water supply crisis in the city of Rome, forcing the municipality to implement selective reductions in the supply of drinking water.

[27] The EU's power sector requires significant amounts of water to operate, and water-related problems highlighted the inadequacy of power generation in the power systems of some EU Member States during the hot summer of 2018. Nuclear reactors in France, Finland, Germany and Sweden were shut down due to high water temperatures (reduced cooling efficiency) and to prevent rivers from overheating. Similar problems occurred in thermal power plants in Italy, located close to fresh water catchment areas.

subject to perennial drought conditions, calculated in theory as less than 100 liters per person per day of surface and groundwater flow in urban environments. Taking into account evolving climate scenarios and bearing in mind present and future growing population trends, the number of drought-prone people is expected to rise to one billion by 2050[28].

In addition, the WHO[29] and the WMO[30] (2012) note that climate change will have a decisive influence on social aspects and human health, having significant implications for urban air quality, already compromised by multiple sources of air pollution from both industrial and urban activities. Those combined factors will produce unavoidable consequences on human and environmental health, especially within cities. Indeed, ozone and particulate matter (PM) levels are expected to have a general increase in United States, Europe, China and Japan, with largely negative trends.

The average local temperature rise in urban areas, generating the 'Urban Heat Island' (UHI) phenomenon[31],

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[28] IPCC 2014, p. 555.

[29] World Health Organisation (WHO), established in 1948, is the United Nations agency specialising in health matters. The objective of the WHO is for all populations to attain the highest possible level of health, defined in its constitution as a condition of complete physical, mental and social well-being.

[30] The World Meteorological Organization (WMO) is an intergovernmental organisation of a technical nature, dealing with meteorology and comprising 191 Member States and Territories. It originated from the International Meteorological Organization (IMO), founded in 1873. Established in 1950, the WMO became a United Nations agency in the field of meteorology (both weather and climate), hydrology and related geophysical sciences.

[31] An Urban Heat Island (UHI) is an urban or metropolitan area that is significantly warmer than the surrounding rural areas due to human

produces significant impacts on human health, especially on the populations of low- and middle-income countries; summer heatwaves, associated with drought and high humidity conditions, have the most significant effects on the elderly and children[32].

To recapitulate and clarify the challenging impacts of climate change on cities, the main climatic phenomena to be considered and their related impacts are summarized in Table 1.

Having clear the impacts that climate change produces on urban areas, and having identified the central role of greenhouse gases in the present environmental crisis, it is important to underline that globally more than 50% of those emissions come from activities in urban areas. City managers and political decision makers at present must revise the existing model of urban development, defining as soon as possible new objectives and strategies aimed at reducing greenhouse gas emissions, while addressing local environmental problems.

The challenge is therefore to understand (and if possible to resolve) the dilemma posed by the effects of climate change on those same urban areas that, because of their abnormal energy consumption, are among the most relevant factors behind such climatic trends. Urban

activities. The temperature difference is generally greater during the night than during the day and is most evident when winds are low. UHI is most evident during summer and winter. The main cause of the urban heat island effect is due, in addition to heat-producing human activities, to soil sealing and the absence of vegetation. Solecki W.D. et al. 2005, *Mitigation of the heat island effect in urban New Jersey*, in *Global Environmental Change Part B: Environmental Hazards*, vol. 6, n. 1, pp. 39-49.

[32] IPCC 2014, p.556.

Climatic phenomena	Main impacts expected on urban areas
INCREASE IN DAYTIME AND NIGHT-TIME TEMPERATURES	- Reduction of energy demand for heating - Increased energy demand for cooling - Decrease in air quality - Impact on winter tourism
INCREASE IN HEAT WAVES	- Reduction in the quality of life for people in warm areas
INCREASE IN HEAVY RAINFALL EVENTS	- Disruption of settlements, trade and transport due to flooding - Impact on urban infrastructure and real estate
INCREASE IN DROUGHT-AFFECTED AREAS	- Water shortages for inhabitants, industries and services - Reduction in energy production potential, especially hydroelectricity, but also nuclear and fossil fuels - Potential increase in migration phenomena
INCREASE IN TROPICAL STORMS	- Damage due to flooding and high winds - Disruption of public water supply - Potential increase in migration phenomena
SEA LEVEL RISE	- Flooding in coastal areas - Decrease in freshwater availability and saltwater intrusion - Potential increase of migration phenomena

Tab. 1 Expected impacts on urban areas from extreme weather and climate conditions: Romero-Lankao, 2008; Revi *et al.*, 2014.

areas consume between 67% and 76% of global energy production, and generate about three quarters of global carbon emissions, establishing a tight correlation between environmental priorities and development prospects.

The development of a new planning and management vision for urban areas, combined with energy saving strategies, reduction of the carbon footprint and an enforced sustainable approach, will provide a better quality of life for citizens and a more attractive space for economic developments, but above all for the daily lives of the citizens themselves[33].

The demographic issue and the challenge of the ageing society

The demographic challenges that occurred in the past, above all in relation to the migratory phenomena of population and depopulation, have been the field of analysis favored by the European and American sociological schools of the 19th and 20th centuries[34]. The debate over the demographic question today directs its attention not only to migration, but also towards the ageing of the urban population, whose numerical growth is directly proportional to the general trend of the overall ageing of the human population. This is because, as already stated, since 2010 most of the world's population lives in an urban setting, and therefore in reflecting about the future of cities we cannot disregard the evaluations that derive from the issue of ageing.

In the last ten years the average age of the population, or rather what is called life expectancy, has increased

[33] United Smart Cities Program 2018.

[34] *2009 Ageing Report: Economic and budgetary projections for the EU-27 Member States* (2008 - 2060), *European Economy*, and *Demography Report 2008: Meeting Social Needs in an Ageing Society* (SEC(2008)2911).

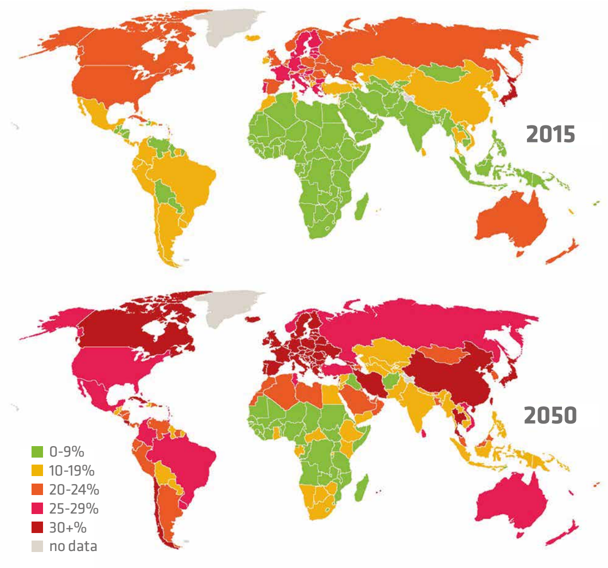

Fig. 1 Evolution of the population over 60 in 2015 and 2050.
(The World Population Prospects: 2015 Revision)

substantially more or less all over the planet, although this increase, logically, is greater in the more advanced countries. This trend is also confirmed for the coming decades by the forecasts of numerous international bodies[35]: According to the data of the World Population Ageing 2015[36] report, the number of people aged 60 and over has increased significantly since 2006 and this trend

[35] Eurostat regional yearbook, Statistical book 2020, p. 24.
[36] *World Population Ageing 2015*, Department of Economic and Social Affairs Population Division, United Nations, New York, p. 15.

is likely to increase sharply in the coming years. In the period up to 2030, the number of people aged 60 and over is expected to grow by 56%, from 901 million to around 1.4 billion, reaching almost 2.1 billion by 2050.
Within the older population, the total number of people aged 80 and over is growing even faster, and current projections indicate that by 2050 this population group will reach 434 million individuals, representing about three times the number recorded in 2015. By 2030 the macro-regions where this growth will be highest are: Latin America and the Caribbean region, with an increase in the population aged 60 and over of about 71%; Asia with an increase of 66%; Africa with 64%, Oceania with 47%, North America with 41% and finally Europe with 23% (Fig. 1). The most interesting aggregate figure is that by 2050 the over-80s will increase by 20%, with significantly faster growth in urban than in rural areas.
In the period from 2000 to 2015, the urban population aged 60 and over increased by 68% compared to only 25% in rural areas. Cities are therefore ageing far more than the rest of the world, and this is even more significant when it comes to the over-80s, whose increase in cities has been from 56% of the population in 2000 to 63% in 2015. The population of over-80s will increase from 143 million in 2019 to 426 million by 2050. These figures have been fully confirmed by the latest UN report on the subject, published in 2019[37]. Most Europeans live in small to medium-sized cities with slow or stagnant growth.

[37] United Nations 2019, *Ageing in Shaping Our Future Together*, New York.

Small cities tend to shrink, and population mobility mainly occurs from one city to another or following migration flows from non-European countries or more economically depressed areas of the continent[38].
The European population is changing in terms of composition and demographic structure, but without any significant change in size. The population is tending to age, thanks to increasing life expectancy and very little generational turnover[39]. The overall ageing of the population and its general demographic decline are processes seriously affecting most of the advanced economies, mostly in Western Europe and Japan, with unavoidable economic and social consequences on all the public policies. In 2018, about one-fifth of the European Union's population, corresponding to 19%,

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[38] The number of people who have migrated to EU Member States from outside the Union has varied in recent years. This includes persons who migrated either on a permanent basis or for a period of one year or more. Looking at the period 2013-2017, total immigration, including people moving from another EU Member State, stood at 3.4 million in 2013, and then increased by more than a third to reach a peak of 4.7 million in 2015. Total migration flows decreased by about 8% in 2016 to about 4.3 million individuals, before increasing by about 3% in 2017 to 4.4 million individuals. In 2017, immigrants with non-EU citizenship accounted for 46% of immigration, while 30% were persons with citizenship of another EU Member State and 23% were citizens returning to their country of origin. Among Member States, the largest shares of immigrants with non-EU citizenship in 2018 were observed in Italy (70% of total immigrants), Slovenia (65%) and Sweden (62%). For persons with citizenship of another EU Member State, the highest shares were observed in Luxembourg (68%), Austria (58%) and Malta (54%), while for returning citizens the highest shares were in Romania (82%), Poland (63%) and Slovakia (60%), European Commission (EUROSTAT) 2019, *People on the move, a statistical portrait*, (1.2 Immigrating to EU Member States) Brussels, p. 6.
[39] European Commission 2017, *The 2018 Ageing Report Underlying Assumptions & Projection Methodologies* (Institutional Paper).

	LIFE EXPECTATIONS AT 65							
	maschi				femmine			
	2016	2060	2070	pro-gr. %	2016	2060	2070	pro-gr. %
Eu 27	18.1	22.6	23.4	5.3	21.5	25.8	26.6	5.1
It	19.1	23.0	23.7	4.6	22.5	26.3	27.0	4.5
	LIFE EXPECTATIONS AT TIME OF BIRTH							
Eu 27	78.3	84.9	86.1	7.8	83.7	89.2	90.3	6.6
It	80.7	85.9	86.9	6.2	85.3	90.0	90.9	5.6

Tab. 2 Comparative projections (EU27 and Italy) on life expectancy at birth and at 65 years Source: Commission services based on Eurostat 2015-based population projections (European Commission, 2018 ®).

was aged 65 or older; the proportion of people aged 80 or older is expected to more than double by 2100 to reach 14.6% of the entire population (Table 2).

In 2016, life expectancy in EU at birth was 78.3 years for males and 83.7 years for females. It is expected to increase to 84.9 years for males and 89.2 years for females in 2060 and to 86.1 years for males and 90.3 years for females in 2070, while life expectancy for those aged 65 and over would be 83.1 years for men in 2016, 87.6 years in 2060 and 88.4 years in 2070, respectively. For women, the figures are 86.5 in 2016, 87.8 in 2060 and 91.6 in 2070. The term 'ageing society' indicates the current trend towards demographic ageing, which is a prevalent feature of the world's mature economies, not to be confused with the term 'ageing population', which defines that part of any population over 65 years of age[40].

[40] Glossary. September 2015. Population Europe.

The elderly have very different needs and problems compared to young and active population. Therefore, in a context where population over 60 and more is so high, urban services will have to adapt in order to provide this large section of the population with adequate care and services, while ensuring the financial sustainability of their respective systems of government.
As stated in the 2001 United Nations study on demographic analysis from 1950 to 2050, the challenge for the future is to ensure that people around the world can grow old with security and dignity and continue to participate in society as full citizens[41]. It is important at the same time to reaffirm, as did UN-DESA in its 2019 report, that:

> Eliminating age-related discrimination, including age barriers in employment, can reduce inequality, increase productivity and promote economic growth (SDGs 8, 10 and 16) […] ensuring access to employment opportunities for those who want to work is a key policy priority in promoting and protecting the rights and dignity of older person[42].

In Italy, the phenomenon of population ageing has been one of the most significant in the Old Continent and, according to some projections, in 2050 the share of persons over-65 will reach 35.9% of the total population, with an average life expectancy of 82.5 years. The average age of the population will rise from today's 44.9 years to over 50 years in 2065. Considering that the probable

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[41] UN Department of Economic and Social Affairs 2001, *Population Division, World Population Ageing 1950-2050*, United Nations, New York.
[42] UN Department of Economic and Social Affairs 2019, *World Population Ageing 2019*, United Nations, New York.

range is between 47.9 and 52.7 years, the population ageing process is certain and intense[43].

Increasing longevity is a conquest of the modern world, achieved with progress in medicine and hygiene, as well as advanced technologies and improvement in the general quality of life and lifestyle. This positive trend necessarily requires a new approach to research, primarily in the health sector, but also in all sectors related to the ageing society, implementing a strong interdisciplinary approach. Therefore, starting with health and social care policies, this new holistic approach must also take into serious consideration aspects linked to rethinking public spaces in terms of accessibility and inclusiveness.

Many steps forward have been taken since the UN launched the first International Plan of Action on Ageing in 1982 with the intention of promoting so-called active ageing in order to raise the international community's awareness of the quality of life of older people. The International Year of Older Persons was established in 1999, and in 2002 the United Nations issued an invitation to all local administrators to "build a society for all ages". In 2007 the WHO published a guide consisting of eight key elements to be taken into account in the creation of age-friendly cities: housing, social inclusion, information, participation, health services, transport, outdoor spaces and work. Finally, there is a database of age-friendly cities, also compiled by the WHO, which provides concrete examples of liveable and inclusive environments for the

[43] ISTAT *The demographic future of the country. Regional forecasts of resident population to 2065*, Statistics Report.

elderly. What is happening at the demographic level, namely that a significant and growing percentage of the population, sometimes still active and in good health is not actually part of the workforce, is a phenomenon that is taking place today for the first time in human history[44], and it is a phenomenon not adequately counterbalanced by generational change.

This phenomenon, feared by economists, jeopardizes the natural social functioning of cities, directly or indirectly unbalancing the public welfare system, with the risk of its progressive economic unsustainability. Not to mention the need to overcome the discriminatory stigma of age with respect to the ability of people over 60 to work: this means contrasting the internationally recognized phenomenon identified as "Ageism" more than forty years ago. This kind of discrimination, as well as the use itself of the term Ageism[45], is now stigmatized by the WHO, considering the phenomenon of the increase in the average age of the population and the consequent increased life expectancy as a natural evolution of the human species, which therefore requires a corresponding cultural evolution.

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[44] European Commission 2014, *Strategic Research Agenda on Demographic Change*, Joint Programming Initiative More Years, Better Lives.

[45] In Italian term, *Ageismo* (s. m.) is a neologism deriving from the English term Ageism, i.e. a form of prejudice and devaluation against an individual, due to his or her age; in particular, a form of prejudice and devaluation towards the elderly (Treccani, 2016). The term was coined in 1969 by the American physician and gerontologist Robert Neil Butler (1927 - 2010) due to assonance and analogy with the terms racism and sexism.

The ageing society, which is also closely related to the phenomenon of urbanization, is, together with the latter, one of the salient features of human development in the twentieth century, and certainly also constitutes one of the greatest challenges of the twenty-first century[46]. The perception of old age as a synonym for illness and of the elderly as passive subjects of a society that has to look after them is now often inappropriate. In 1996, the WHO, in its Brasilia Declaration on Ageing, stated that:

> [...] longer lives are an incredibly valuable resource, both for each of us as individuals and for society more broadly. Older people participate in, and contribute to, society in many ways, including as mentors, caregivers, artists, consumers, innovators, entrepreneurs and members of the workforce. This social engagement may in turn reinforce the health and well-being of older people themselves[47].

According to the Italian *Istituto Superiore di Sanità (ISS)* the proportion of people in the so-called Third Age who are not self-sufficient in the EU is about 20%, while the remaining 80% are absolutely capable of looking after their own needs and represent a precious resource in many societies (ISS, 2007)[48]. However, for the urban environment to allow active ageing of its citizens, and thus enable them to carry out daily actions independently and safely, it is necessary to think about urban rehabilitation tools and policies, summarized by the WHO as follows:

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[46] World Health 1997, *Brasilia Declaration on Ageing*, n. 4, p. 21.
[47] World Health Organization 2017, *Global strategy and action plan on ageing and health*, paragraph 10, p. 3.
[48] Istituto Superiore di Sanità (ISS) 2008, *Città a misura di anziano: una Guida (Introduzione)*, Quaderni di sanità pubblica, Rivista trimestrale 149, CIS editore, Milano, p.7.

- anticipating and responding flexibly to the needs and preferences associated with ageing;
- recognizing the wide range of capabilities and resources of older people;
- respecting older people's lifestyle decisions and choices;
- protecting those who are most vulnerable;
- promoting their inclusion in all areas of community life and recognizing their contribution.

Active ageing requires an approach that is not limited to the individual, but also involves families and the regions to which they belong, since it is not only inherent to the material conditions of older people, but includes the necessary attention to the surrounding social and cultural elements[49]. The WHO has produced guidelines for age-friendly cities following a study based on 33 cities in WHO member countries, primarily involving stakeholders who were asked to describe the advantages and difficulties they experience in eight areas of city life[50].

The reports resulting from this involvement were supplemented with data provided by focus groups consisting of carers and service providers from the public,

[49] *Ivi*, p. 5.

[50] The Global Age-Friendly Cities project was developed by Alexandre Kalache and Louise Plouffe, World Health Organization, Geneva, Switzerland, and the report was produced under their direction with contributions from Louise Plouffe; Karen Purdy, Office for the Interests of Older People and the Voluntary Sector, Government of Western Australia; Julie Netherland, Ana Krieger and Ruth Finkelstein, New York Academy of Medicine; Donelda Eve, Winnie Yu and Jennifer MacKay, British Columbia Ministry of Health; and Charles Petitot, WHO Headquarters. The research protocol was implemented thanks to the commitment of governments in no fewer than 33 cities, located on all five continents and at every latitude, also in collaboration with non-governmental organisations and academia. World Health Organization 2007, *Global age-friendly cities: a guide*. (NLM classification: WT 31).

voluntary and private sectors. This was done in order to assess the quality of life of the ageing population and if possible identify useful interventions for rethinking cities suitable for active ageing, with obvious economic, social, health and environmental benefits.
The key areas identified by the study as contributing to an age-friendly city are essentially: open spaces and buildings, transport, housing, participation, social respect and inclusion, community support and health services.
A similar approach, but perhaps organized in a more interesting manner, is the one outlined in the document drawn up by the Italian Government on this issue during the Italian Presidency of the Council of the European Union in 2014[51]. The theme examined and the leitmotif of the underlying research is that of the 'distances' that occur between older people and the world around them. It is a matter of physical, cultural, economic, generational and social distances, with respect to which the document attempts to provide various possible solutions, proposing an Italian approach to the ageing society.
In order to bridge these physical and/or virtual distances it is necessary to return to approaches that are apparently new but in reality are traditional, while taking into account the tools offered by new technologies. The Italian proposal is centered on achieving the right

[51] The study *Moving forward for an Ageing Society: Bridging the Distances*, represented a remarkable effort by he Italian Ministry for Universities and Research, which involved all the main national research actors related to the Ageing society according to a multidisciplinary approach: physicians, economists, engineers, architects and city managers. Cinquepalmi F. *et al.* 2014, *Moving forward for an Ageing Society: Bridging the Distances (Italian position paper)*, Palombi, Rome.

balance between technology and humanity, rethinking the scale of relations between people, neighborhoods and urban areas, both physically and virtually, and relating them to the real needs of older people. All this has the ultimate aim of re-establishing the necessary interconnections between the 'ageing society' and the rest of society.

The study focuses, in particular on four priority areas, considering their interactions and intersections: Health, Silver Economy, Built Environment, Welfare and Wellbeing. The Position Paper underlines how a balance between adequate distances and interconnections and bringing communities closer to the real needs of citizens will ensure the resilience of our society in view of an ageing population. A fundamental point is the recognition of the identity of older people and their fundamental role as guardians of our past in a changing world. What emerges is the need to find a healthy balance between the total depersonalization of contemporary cities and excessive interdependencies, extreme positions that cause fragility in complex human ecosystems.

This can enable a more effective, efficient and humane management of ageing, bringing citizens and communities back within more natural boundaries and environments that are more inclusive. In other words, it will be about conceptually returning to the dimension of a primitive village.

> […] this means recreating the real or virtual dimension of that primitive village, which was the starting point of human civilization, created in order to preserve the fragile elements of the community and their role. Safeguarding

> the role of senior citizens strengthens their social standing and identity and avoids the risk of isolation[52].

Moreover, the transmission of memories and knowledge is closely linked to the village dimension, as are the protection and recognition of the role of the elderly. The elaboration and transfer of inherited knowledge and culture, entrusted to the elderly in past societies, is still of vital importance for humanity today, in order to preserve the identity of a territory and a community over the years. The distances between the places where elderly people live and those where they receive services, social, economic, cultural and intergenerational distances, and last but not least distances between material and spiritual needs, are among the main difficulties to be resolved. This in order to reverse the negative perception of the Ageing Society, hopefully to be considered not as a burden, but an opportunity for a better society. Overcoming the physical distances between homes, workplaces and services, and the immaterial distances between different generations, social statuses, economic and cultural conditions, is a necessary key to deal with the ageing population.

The challenge of migrations

To talk about migratory phenomena in contemporary society requires some preliminary statements of principle: man is basically a migratory species. Most paleontologists, based on fossils that have been found, agree that the modern human species had its origin in the East African sub-Saharan region in the Pleistocene, i.e. from about 200

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[52] *Ibidem*, p. 28.

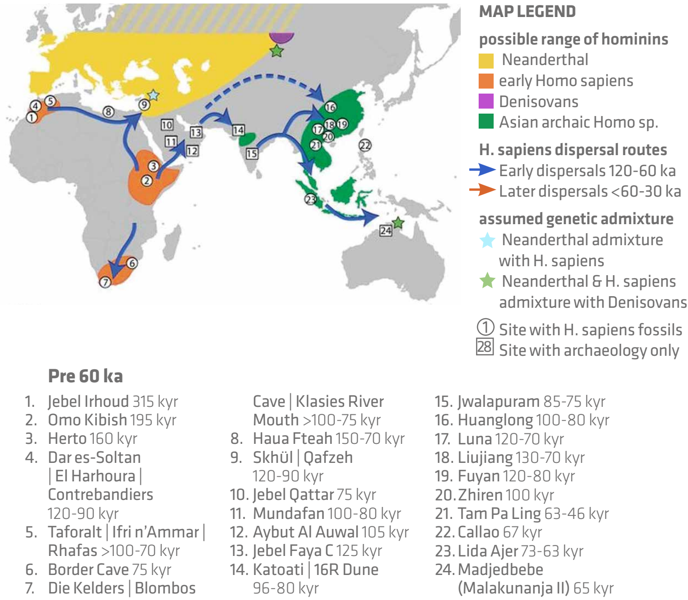

Fig. 2 The spread of the Human species from the Pleistocene onwards, showing fossil sites (source: Science n. 358, 2017).

million years ago[53]. Between 120 million and 60 million years ago, migratory waves took place that led to the first population of the whole of Africa, the Fertile Crescent and subsequently Western Europe, Asia, Oceania and finally the Americas.

Beyond the obvious scientific considerations, which invalidate any racist reasoning regarding humanity, since

[53] Bae C. J., Douka K., Petraglia M. 2017, *On the origin of modern humans: Asian perspectives*, «Science», vol. 358, pp. 1-7.

we are all Africans, it is equally evident that the history of the human species, starting from its genetic consolidation, is a history of migrations (Fig. 2).

These migratory movements may have had various motivations, but all of them can be simply traced back to a common principle: human beings emigrate to improve their quality of life[54]. This completely human characteristic, quite different from the instinctive migration of animals, is well summarized in the German term *Wanderlust*[55], rightly taken up by the Chicago School as opposed to a sedentary life without curiosity for the unknown[56]. It is, however, difficult to give an unambiguous definition of 'migrant', although there is one that is quite widely accepted and recognized by the United Nations, namely that the migrant is:

> […] a person who moves away from his or her place of usual residence, whether within a country or across an international border, temporarily or permanently, and for a variety of reasons[57].

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[54] Manning P., Trimmer T. 2013, *Migration in World History*, Routledge, London, p. 7.

[55] The term comes from the German words *Wandern* (to walk) and *Lust* (desire). The term wanderer, often mistakenly used as a false friend, does not actually mean 'to wander', but 'to walk'. Putting the two words together, it can be translated as 'desire to move, to go'.

[56] Park, R.E, Burgess, E.W., *The City*, chapter IX, *The Mind of the Hobo: Reflections upon the Relation Between Mentality and Locomotion*, Heritage of Sociology Series, Chicago University Press, Chicago 1967, p. 158.

[57] "Migrant: an umbrella term, not defined under international law, reflecting the common lay understanding of a person who moves away from his or her place of usual residence, whether within a country or across an international border, temporarily or permanently, and for a variety of reasons. The term includes a number of well-defined legal categories of people, such as migrant workers; persons whose particular types of movements are legally defined, such as smuggled migrants; as

The term encompasses a number of well-defined legal categories of people, such as migrant workers; people whose particular types of movement are legally defined, such as migrants engaged in smuggling; as well as those whose status or means of movement are not specifically defined by international law, such as international students. Migration phenomena have characterized the entire arc of human history with peaks of greater intensity linked to contingent phenomena, often caused by climatic events, famine and war. Throughout the 19th century and in the first part of the 20th century, the substantial improvement in means of transportation, capable of covering long distances, together with a complex of economic factors, meant that around 50 million Europeans emigrated to the Americas and Australia. In the same period, another 8 million migrants crossed Asia to resettle in sparsely populated regions of Manchuria, Central Asia and the Indian Ocean coast. The current long-distance migrations from Africa, estimated in about 4 million people, are on the whole minor in entity[58].

The theory of migration, elaborated by the geographer Ernest Ravenstein[59] in the period between 1880 and 1889, and which still forms the theoretical basis for the study of

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well as those whose status or means of movement are not specifically defined under international law, such as international students". International Organization for Migration (IOM) 2019, *Glossary on Migration*, Geneva, Switzerland, p. 133.

[58] Manning, Trimmer, *Op. cit.*, p. 7.

[59] Ernst Georg Ravenstein (1834 - 1913) was a German-English geographer cartographer, who worked at the Royal Geographical Society in London, and was that organization's first Victoria gold medallist. In 1885, he published a paper entitled *The Laws of Migration* in the Journal of the Statistical Society.

migratory phenomena, is condensed into what he called the Laws of Migration[60], formulated during his many years of study at the Royal Geographical Society[61], as follows:

1. We have already proved that the great body of our migrants only proceed a short distance, and that takes place consequently a universal shifting or displacement of the population, which produces "currents of migration" setting in the direction of the great centers of commerce and industry which absorb the migrants. In forming an estimate of this displacement, we must take into account the number of natives of each county, which furnishes the migrants, as also the population of the towns or districts, which absorb them.
2. It is the natural outcome of this movement of migration, limited in range, but universal throughout the country, that the process of absorption would go on in the following manner: The inhabitants of the country immediately surrounding a town of rapid growth, flock into it j the gaps thus left in the rural population are filled up by migrants from more remote districts, until the attractive force of one of our rapidly growing cities makes its influence felt, step by step, to the most remote corner of the kingdom. Migrants enumerated in a certain center of absorption will consequently grow less with the distance, proportionately to the native population which furnishes them, and a map exhibiting by tints the recruiting process of any town ought clearly to demonstrate this fact.
3. The process of dispersion is the inverse of that of absorption, and exhibits similar features.
4. Each main current of migration produces a compensating counter-current.
5. Migrants proceeding long distances generally go by preference to one of the great centers of commerce or industry.

[60] Ravenstein E. G. 1885, *On the Laws of Migration*, «Journal of the Statistical Society of London», vol. 48, n. 2, pp. 167-235.
[61] *Ivi*, pp. 191, 198, 199.

6. The natives of towns are less migratory than those of the rural parts of the country.
7. Females are more migratory that males[62].

What is interesting to note, however, is that the vast majority of people do not migrate across the borders of their own country, but rather within them. In fact there were approximately 740 million internal migrants in 2009 compared to approximately 244 million international migrants globally, or 3.3% of the world's population. At a time when immigration seems to be one of the most debated issues of the political agenda, it has actually been estimated that only 258 million people live in a country other than their country of birth.
The main reasons for emigration seem to be to find a job or to reunite with family members who have emigrated previously. There are also migrants seeking to escape conflict or natural disasters and while throughout history the total number of migrants seemed to grow in direct proportion to the increase in population, since 1960 the percentage of migrants has remained stable at around 3% of the population with an increase to 3.4% calculated from 2017[63]. In Europe, migration has long been high on the EU's political agenda and was among the Commission's 10 political priorities for the period 2015-2019. The European migration crisis of 2015[64], in which

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[62] *Ivi*, pp. 198, 199.
[63] International Organization for Migration 2017, *World Migration Report*, pp. 2-13.
[64] During 2015, the European Union recorded more than one million incoming refugees and migrants reaching European shores by sea. Seventy-five per cent of the migrants in the so-called 'migration crisis' came from the war zones of Syria, Afghanistan and Iraq. Most of the new

it was estimated that almost 4 000 people[65] lost their lives at sea, contributed to keeping migration on as a highlight the European Agenda, searching for ways to achieve responsible and fair immigration, and directing attention to the external southeastern borders, the most exposed to the phenomenon. However, the European demographic decline, counterbalanced by Africa's demographic explosion, will ensure that Europe continues to be a major destination for migrants in the future[66].

Apart from migrants fleeing conflicts, whose motive for moving is often to seek an escape from a clearly life-threatening situation, it is difficult today to distinguish between economic migrants and climate migrants, as the two phenomena are often closely related. According to the World Organization for Migration[67], environmental migrants are people or groups of people who, for compelling reasons of sudden or progressive change in the environment that adversely affects their living conditions, are forced to leave their country or choose to do so, either

arrivals, at least 850 000 people, crossed the Aegean Sea from Turkey to the Greek islands, with minors accounting for about 25% of the total arrivals in Greece, Italy and Spain, often unaccompanied or separated from relatives. In the year in question alone, an estimated 3 771 people lost their lives in the Mediterranean Sea trying to reach European shores. United Nations High Commissioner for Refugees (UNHCR) 2016, *Global trends, forced displacement in 2015*, Geneva, p. 32.

[65] The United Nations High Commissioner for Refugees (UNHCR) is a United Nations body founded in 1950 to ensure international protection of refugees and respect for the right to asylum, to prevent forced repatriation practices, to promote voluntary return and integration in host countries. It is based in Geneva.

[66] European Commission 2018, Joint Research Centre, *Atlas of Migration 2018*, Publications Office of the European Union, Luxembourg.

[67] IOM 2019, *Glossary on Migration*, p. 29.

temporarily or permanently, by moving within their own country or abroad[68].

There is no doubt that in absolute terms the present age is facing unprecedented human mobility, in line with the increase in the overall population on the planet. The fact that migration today is essentially an urban problem can be deduced from the data provided by the International Organization for Migration (IOM)[69] in a vast 2015 report dedicated to the relationship between migration and urban systems[70]. This migratory mobility is essentially linked to urban systems, both in terms of internal and international mobility[71]. Compared to the overall migration numbers, i.e. 258 million international migrants (of which about 19 million are refugees)[72] and about 740 million internal migrants within individual states[73], about 50% of the international migrants reside in the ten most urbanized and high-income regions, i.e. Australia, North America, Europe, the Russian Federation, Saudi Arabia and the Gulf monarchies[74].

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[68] IOM 2007.

[69] The International Organization for Migration (IOM) was founded in 1951 in Geneva. It is the main Intergovernmental Organization in the field of migration counting 173 Member States. As of September 2016, it became a United Nations Related Agency.

[70] International Organization for Migration (IOM) 2015, *Migrants and Cities: New Partnerships to Manage Mobility*, in «World Migration Report», Geneva, pp. 2-3.

[71] IOM 2015.

[72] ILO 2018.

[73] United Nations Development Programme (UNDP), Human Development Report 2009. *Overcoming barriers: Human mobility and development*, p. 1.

[74] United Nations, Department of Economic and Social Affairs, Population Division, *International Migration Report 2013*, p. 1.

According to the World Labour Organisation[75], there are about 164 million migrants who contribute to the functioning of our societies[76] through their work, accounting for 59.2% of the total number of international migrants. With regard to the sectors of employment, an indispensable key to interpreting the phenomenon of urban migration, the data show – as was largely predictable – a concentration of migrants in certain economic sectors, with respect to which gender differences must be taken into account. In 2013, 106.8 million migrant workers out of a total calculated in 2013 of 150.3 million, i.e. 71.1%, were employed essentially in service activities, i.e. 26.7 million (or about 17.8%) in industry, including manufacturing and construction, and 16.7 million (or 11.1%) in agriculture and food production.
Similarly, according to 2013 ILO data, of the 67.1 million domestic workers worldwide 11.5 million are international migrants, or 17.2% of all domestic workers and 7.7% of all migrant workers worldwide. In other words, one in six domestic workers worldwide is an international migrant. Likewise, in 2013, about 73.4% (or 8.5 million) of all migrant domestic workers were women. Southeast Asia and the Pacific host the largest share of such migrants, with 24% of the world's migrant domestic workers,

[75] The International Labour Office (ILO) is a specialised agency of the United Nations that works to promote social justice and internationally recognised human rights, with particular reference to labour rights in all their aspects. It was the first specialised agency to become part of the United Nations system in 1946, but its foundation dates back to 1919 within the League of Nations. It has 187 member states.
[76] ILO 2019, *Global Estimates on International Migrant Workers - Results and Methodology*, International Labour Office, Geneva, p. 5.

followed by Northern, Southern and Western Europe with 22.1% of the total and the Arab States with 19%[77]. In other words, most international migrants move to countries with more favorable economic conditions and contribute to the prosperity of those countries through their work. Since these workers are predominantly concentrated in urban areas, it is indisputable that migrants can contribute to the functioning of the world's richest cities[78]. What is certain is that urbanization patterns, as well as climate change and environmental change, will require adaptation and resilience that is assessed and implemented at the local level, with a

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[77] ILO 2015, *Global estimates of migrant workers and migrant domestic workers: results and methodology*, International Labour Office, Geneva, p. xiii.

[78] Five million legal immigrants create jobs, produce almost 9% of the GDP, and pay 11.9 billion euros a year to the social security system. But it is the 150 000 asylum seekers who monopolize the debate, and not the Italian demographic emergency. These are the conclusions - based on data and facts - reached by the Leone Moressa Foundation in its 2018 report on the economics of immigration - 'Prospects for integration in an ageing Italy' - presented at Palazzo Chigi. For a manageable and orderly immigration, therefore, legal channels are needed that also allow the arrival in Italy of more qualified workers: today the only regular access routes are family reunifications and the 'lottery' of asylum requests. Federico Soda, director of the International Organization for Migration office for Mediterranean based in Rome, also spoke at the presentation of the dossier at Palazzo Chigi: "*In order to fight the smugglers and transform a mass of irregular migrants into orderly immigration, we need legal, regular, programmed channels*". Luigi Vignali, Director General for Italians Abroad and Migration Policies at the Italian Ministry of Foreign Affairs, recalls that the most important cooperation for development is the one financed by the emigrants themselves: "*5 billion a year of remittances leave Italy for poor countries, while Public Aid for Development amounts to 4 billion*". And that is not all: "*Remittances from all over Europe come to 66 billion, while the Union has allocated only 4 billion for an investment plan in Africa*". The Moressa Foundation report indicates that while in 2011 foreign workers accounted 9% of the population, in 2017 they reached 10.5%. This high number of workers produces an added value of 131 billion per year (8.7% of the Gross Domestic Product).

bottom-up approach, elaborating new development paradigms that are as inclusive as possible, and that include migrants, both as individuals and organized in groups and associations[79].

The challenges of pandemics in urban societies

In 1979, the Municipality of Venice promoted a very uncommon exhibition, located in Palazzo Ducale[80], and dedicated to the plague outbreaks that over the centuries ravaged the city. The exhibition catalogue, entitled "Venice and the Plague 1348/1797"[81] approached the different waves of various plagues historically, analyzing their effects from various points of view in a transversal and integrated manner.

The exposition and especially its catalogue was not only based on the works of art and architecture connected with the plagues in Venice. The number of scientific texts in the catalogue, linked to each other in a very interesting comparative analysis, dealt with the demographic, social, cultural, architectural, artistic, but also juridical, epidemiological and sanitary effects of the pestilences, analyzing their influence on the urban, social and

[79] International Organization for Migration (IOM) e Joint Migration and Development Initiative (JMDI) 2015, *Mainstreaming migration into local development planning and beyond* (White Paper), Geneva, p. 11.

[80] The Doge's Palace (Italian: Palazzo Ducale) is a palace built in Venetian Gothic style, in the inner center of the city of Venice (Italy). The palace was the seat of the Government of the Venetian Republic, as well as the residence of the Doge of Venice, the supreme authority of the former Republic. Construction started in XII century, and the building was extended and modified in the following centuries. It became a museum in 1923.

[81] Assessorato alla cultura e alle belle arti 1979, *Venezia e la Peste, 1348-1797*, Marsilio editori, Venezia.

cultural development of the city of Venice. The plague outbreaks, caused by *Yersinia pestis bacterium*[82], are considered the most devastating pandemics in written history. The first, identified as the pandemic called the Plague of Justinian, is estimated to have killed from 15 up to 100 million of people, about 25–60% of population of Europe[83]. This pandemic continued to break out in successive waves, later identified with the Black Death, which most probably killed from 75 up to 200 million people in the 14th century, and continued to ravage different parts of the world in successive waves until the 20th century, causing substantial depopulation of urban areas and desertion of rural territories[84].

82 *Yersinia pestis* is a bacterium causing the Plague, transmitted from rodents to humans by the bite of infected fleas. It was the cause of some of the most-devastating epidemics in history, mainly the Black Death of the 14th century, when as much as one-third of Europe's population died. Britannica, T. Editors of Encyclopaedia 2020, *Plague*, https://www.britannica.com/science/plague.

83 "…*Recent isolations of Y. pestis DNA in prelaboratory European human remains has validated the long-held assumption that the same pathogen was present during the 3 pandemics (4, 13–17). Based on molecular and historical research, a broad consensus (hereafter "the maximalist position") has developed across disciplines that estimates JP mortality in the tens of millions, with numbers ranging between 15 and 100 million, or alternatively, 25 to 60% of the estimated population of the Late Roman Empire*". Mordechai L. et al. 2019, The Justinianic Plague: A*n inconsequential pandemic?*, Yale University, New Haven, vol. 116, n. 51, pp. 25546-25554.

84 "…*the outbreak of the Second Pandemic in Europe, the Black Death, had dramatic effects on the countryside in several European regions. As villages were depopulated and fields were abandoned, landscapes were transformed. Less anthropogenic pressure resulted in the "rewilding" of the landscape and a widespread process of secondary ecological succession of uncultivated species into former fields or pastures.*", *Ivi*, p. 25550.

The pandemic caused by COVID-19[85] that since the fall of 2019 is ravaging the global population does not present substantial differences with respect to the pestilences that have affected humankind since written history began. From the dawn of history, a number of infectious diseases have caused catastrophic pandemics, killing millions of people over the millennia and in recent centuries too. Throughout human history, there have been a great number of pandemics caused by different pathogens, among them cholera, smallpox, tuberculosis, typhus and typhoid fevers and plague.

Pandemics have been always, and are still today, strongly related to personal mobility and overpopulated cities, both factors facilitating the outbreaks. Despite contemporary advances in the medical and health sciences, some significant aspects of the historical pandemic waves are still evident today. Again, we have experienced the consequences of the relatively poor knowledge of how a new virus is transmitted and of the mechanisms of infection in the initial phases of what was considered an epidemic outbreak, until it was ineluctably classified as a pandemic in mid-March 2020[86]. But we have also had to rediscover the multifaceted interaction between an unknown new virus and the human metabolism, yielding

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[85] The Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) is the name given to the new coronavirus of 2019. COVID-19 is the name given to the disease associated with the virus. SARS-CoV-2 is a new strain of coronavirus that has not previously been identified in humans. (source: Italian Ministry of Health 2021) http://www.salute.gov.it/portale/nuovocoronavirus/dettaglioFaqNuovoCoronavirus.jsp?id=228&lingua=italiano#1.

[86] WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020 (Geneva)

different results in different infected subjects, and very different possible prognoses. Last but not least, we have had to address not only the complexity of demographic, social, cultural, architectural, artistic effects, but also the regulatory, epidemiological, sanitary and educational impacts, which have have come to focus mainly on the management of buildings and urban systems. It is impossible to cope with effects of any pestilence without carefully considering the complex factors that contribute to an urban ecosystem.

In this regard, Professor Andreina Zitelli[87], in one of her contributions to the catalogue[88] of the Venetian exposition, in a text dedicated to the way Venetian authorities handled the plague, stated that:

> [...] rather than against the nature of any disease, it is toward the physical and social environment [...] that disease control tools are created, developed, and maintained, laying the foundation of modern preventive medicine. However, it is important to note that those actions are often conditioned by political evaluations, especially considering those measures strongly affecting the cities' economic life[89].

[87] Prof. Andreina Zitelli (1942), Professor of General and Applied Hygiene (disciplinary sector MED42). Specialization in Soil and Water Microbiology at the Pasteur Institute in Paris. Professor at the University of Padua and at the IUAV university in Venice, she is an Expert in environmental negotiation. She has been member of the national Environmental Impact Assessment (EIA) Commission and Expert of National Commission for Integrated Environmental Authorizations (AIA).

[88] Zitelli A. 1979, *L'azione della Repubblica di Venezia nel controllo della peste. Lo sviluppo di alcune norme di Igiene pubblica*, in Venezia, *Op. cit.*, pp. 111-122

[89] *Ivi*, p. 112 "*Più che contro la natura del male, è verso l'ambiente fisico e sociale, attraverso il quale quella natura imperscrutabile si esercita, che nascono, si sviluppano e si mantengono i dispositivi di controllo*

This methodological framework, well synthesized with clear thinking and realism by professor Zitelli in 1979, seems to fit the present COVID-19 governamental strategies and policies well.
The World Health Organization (WHO) established the official outbreak of the epidemic emergency in December 2019, when the WHO country office in China received the information about the outbreak of an atypical pneumonia of unknown etiology detected in the city of Wuhan in China's Hubei province[90]. The

della malattia, ponendo le basi della moderna medicina preventiva. Non senza realismo d'altronde va rilevato che questa azione appare spesso condizionata da valutazioni di necessità politica, soprattutto verso quelle misure che coinvolgono molto direttamente la vita economica della Città".

[90] On 31 December 2019, the WHO China Country Office was informed of cases of pneumonia of unknown etiology (unknown cause) detected in Wuhan City, Hubei Province of China. From 31 December 2019 through 3 January 2020, a total of 44 cases of patients with pneumonia of unknown etiology were reported to WHO by the national authorities in China. During this reporting period, the causal agent was not identified. On 11 and 12 January 2020, the WHO received further detailed information from the National Health Commission China that the outbreak was associated with exposures in a specific seafood market in Wuhan City. The Chinese authorities identified a new type of coronavirus, which was isolated on 7 January 2020. On 12 January 2020, China shared the genetic sequence of the novel coronavirus for countries to use in developing specific diagnostic kits. On 13 January 2020, the Ministry of Public Health, Thailand reported the first lab-confirmed imported case of the novel coronavirus (2019-nCoV) from Wuhan, Hubei Province, China. On 15 January 2020, the Ministry of Health, Labour and Welfare, Japan (MHLW) reported a lab-confirmed imported case of the novel coronavirus (2019-nCoV) from Wuhan, Hubei Province, China. On 20 January 2020, the National IHR Focal Point (NFP) for Republic of Korea reported the first case of novel coronavirus in the Republic of Korea. As of 20 January 2020, 282 confirmed cases of 2019-nCoV had been reported from four countries including China (278 cases), Thailand (2 cases), Japan (1 case) and the Republic of Korea (1 case). The cases in Thailand, Japan and Republic of Korea had come from Wuhan City, China. Among the 278 cases confirmed in China, 258 cases were reported from Hubei Province, 14 from Guangdong Province, five from Beijing Municipality and one from

first patients were apparently epidemiologically linked to a possible zoonosis[91], occurring probably in the Huanan Seafood Wholesale Market of the city of Wuhan[92]. The World Health Organization in January 2020 classified the problem as a Public Health Emergency of International Interest and then on 11 March 2020, switched to classifying it as a pandemic, a classification confirmed on 12 March[93]. Due to the rapid international circulation of people, especially in connection with air travel, in a very few weeks the virus reached high levels of diffusion in many countries of the world. By January 2021, more than 98.8 million cases had been confirmed worldwide, with more than 2.12 million deaths, directly or indirectly ascribable to the COVID-19 infection[94].

In Europe, Italy was among the first EU member States affected by the virus, even if it is hard to say when the virus actually reached southern Europe[95]. Cases recorded by

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Shanghai Municipality, WHO 2020, Novel Coronavirus (2019-nCoV) Situation Report, Geneva.

[91] Zoonotic disease, also called zoonosis, any of a group of diseases that can be transmitted to humans by non-human vertebrate animals, such as mammals, birds, reptiles, amphibians, and fish. A large number of domestic and wild animals are sources of zoonotic disease, and there are numerous means of transmission. Eidson M. 2018, *Zoonotic disease*, Encyclopedia Britannica.

[92] Cerami C. et al. 2020, *Covid-19 Outbreak In Italy: Are we ready for the psychosocial and the economic crisis? Baseline findings from the PsyCovid Study*, Pavia University.

[93] WHO Coronavirus disease 2019 (COVID-19) Situation Report, 52.

[94] COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU), coronavirus resource center 2021 (https://coronavirus.jhu.edu/map.html)

[95] According to a study of 2020 an unexpected very early circulation of SARS-CoV-2 among asymptomatic individuals in Italy was found several months before the first patient was identified in early September 2019, even long before the first official reports from the Chinese authorities, casting new light on the onset and spread of the COVID-19 pandemic.

Italy	Cumulative cases	Total deaths	Transmission classification
31 January 2020	2	0	External
12 March 2020	12 462	827	Local transmission
17 January 2021	2 368 733	81 800	Cluster of cases

Tab. 3 Progression of the pandemic in Italy according to the WHO situation reports from January 2020 to January 2021 (WHO Geneva 2020/2021)

the Italian Ministry of Health, together with Regional survey systems, registered a progression from the first two confirmed cases of 2019-nCoV acute respiratory disease, both related to Wuhan City[96], up to 12 462 total cases in March 31, 2020 with a total number of deaths of 827 in only three months (Table 3).

By 17 January 2021, the WHO report for Italy indicated a total number of 2 368 733 confirmed cases, with 81 800 total deaths[97] (Tab. 3).

The European Centre for Disease Prevention and Control (ECDC)[98] COVID-19 situation update for the

Apolone G. et al. 2020, *Unexpected detection of SARS-CoV-2 antibodies in the prepandemic period in Italy*, in «Tumori Journal», PubMed.

[96] WHO 2020, *Novel Coronavirus (2019-nCoV) Situation Report*, 11.

[97] WHO, Covid-19 Weekly epidemiological update, data as received by national authorities as for 17 January 2021.

[98] The European Centre for Disease Prevention and Control (ECDC) is an agency of the European Union (EU) established in 2004 in Solna, Sweden, with the aim of strengthening Europe's defenses against infectious diseases. ECDC mission is to strengthen Europe's defenses against infectious diseases, covering a large number of activities, such as surveillance, epidemic intelligence, response, scientific advice, microbiology, preparedness, public health training,

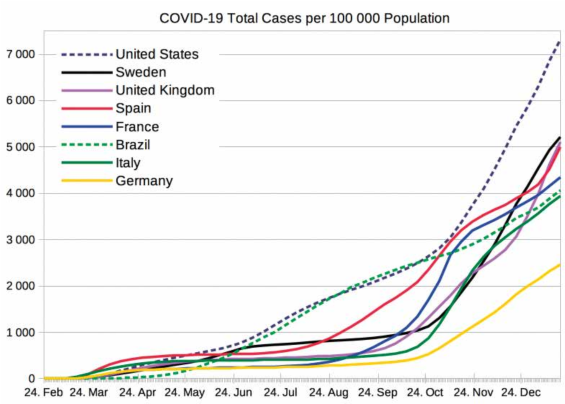

Fig. 3 COVID-19 total cases per 100 000 population (source ECDC 2021)

EU/EEA, as of week 2/2021, indicated that 17 906 888 cases have been reported in the EU/EEA with a total number of 425 618 deaths since January 2020[99] (Fig.3). Plagues have always represented a factor of major social and cultural transformation, leading human societies to effect substantial and even radical changes: Justinian's plague certainly accelerated the end of antiquity and the beginning of what we came to call the Middle Ages[100];

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international relations, health communication, and the scientific journal Eurosurveillance.

[99] *ECDC Communicable disease threats report*, Week 3, 17-23 January 2021, Solna, Sweden.

[100] "*…The Justinianic Plague (circa 541 to 750 CE) has recently featured prominently in scholarly and popular discussions. Current consensus accepts that it resulted in the deaths of between a quarter and half of the population of the Mediterranean, playing a key role in the fall of the Roman Empire*", Mordechai L. et al., *Op. cit.*, p. 25546.

the medieval plague brought Western Europe from the Middle Ages toward the energetic impulse of the Renaissance.
The history of these epidemics, if analyzed and retraced, presents in fact many analogies with today's situation that the *Übermensch*[101] of the 21st century, with his unshakable faith in science, thought he had left to the medieval chronicles. Again humanity has been forced to experience deserted cities, confinement in the home, masks hiding one's face and above all, millions of deaths all over the world, with scenes of separation from one's dearest affections and heartbreaking despair.
Of the many possible global crises, a pandemic was not among the first to be considered as most immediately dangerous. After having experienced fears of an atomic war, multiple waves of terrorism and more recently the effects of global climate change were the greatest sources of collective concern. Modern scenarios related to possible pandemics envisioned diseases whose virulence would cause millions of sudden deaths, but no one predicted that a disease with a relatively low mortality rate could lead to the paralysis of our societies and our development model: a development model that since the second part of the nineteenth century substantially never halted its progress in terms of technology, expansion of markets and economic complexity and interdependence,

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[101] The *Übermensch* (transl. "Beyond-Man," or "Superhuman") is a concept in the philosophy of Friedrich Nietzsche. In his 1883 book *Thus Spoke Zarathustra* (German: *Also sprach Zarathustra*), Nietzsche has his character Zarathustra posit the *Übermensch* as a goal for humanity to set for itself. It is a work of philosophical allegory, with a structural similarity to the Gathas of Zoroaster/Zarathustra.

but most of all of the dramatic increase in the mobility of millions of people for work, entertainment and study.
The best representation of such *Wanderlust*[102] of the modern man is certainly the European program of mobility, ERASMUS, that from its creation in 1987 has allowed more than nine million people, mainly university students, but also academics and professionals both in Europe and around the world, to become mobile[103].
However, education is just one of the societal sectors that we must analyze in order to assess the impacts related to pandemics. According to United Nations[104], about 90% of COVID-19 cases are connected to cities. This implies that we must consider urban areas as the focus of the pandemic, highlighting on the one hand the essential role of municipalities as front-line responders of this crisis,

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102 See also footnote 55.
103 Beginning in the early 2020s, health restrictions due to the COVID-19 progressively imposed by governments around the world led the global aviation system to a substantial implosion, leaving sadly on the ground the 21st century *Homo Vagans*. In a few weeks a number of low-cost air carriers dissolved in a chain of bankruptcies, leaving millions of astonished passengers unable to fly back home, and forcing governments - including Italy - to use air bridges for the repatriation of their compatriots, including thousands of European students in mobility around the world. The fear of contagion, as well as the fear of not being able to receive adequate treatment, contributed to the growing anxiety, while millions of students and faculty were anxiously working to save what remained of the 2019/2020 academic year. Reports on lay-offs and bankruptcies followed, with British airline FlyBe succumbing first to market pressure, declaring bankruptcy on 5 March 2020 (Business Insider, 2020). Major airlines including Scandinavian Airlines (17 March 2020), Singapore Airlines (27 March 2020) and Virgin (30 March 2020), as well as tour operators including German TUI (27 March 2020) have already requested tens of billions of US dollars in state aid. Gossling S., Scott D., Hall M. 2021, *Pandemics, tourism and global change: a rapid assessment of COVID-19*, Journal of Sustainable Tourism, vol. 29, n. 1, pp. 1-20.
104 United Nations sustainable development group (UNSDG) 2020, *Policy Brief: COVID-19 in an Urban World*, SG office, New York, p. 2..

Actions	Main impacts expected on urban areas
TACKLING INEQUALITIES AND DEVELOPMENT DEFICITS	- Understand inequalities and commit to disaggregated data gathering and utilization - Provide safe shelter for all and consider a moratorium on all evictions - Make large-scale public investments in affordable and adequate housing and slum upgrading - Ensure that public services are uninterrupted, equally accessible for the urban poor and other vulnerable groups and payments in default forgiven or deferred: - Ensure equitable access to health supplies, facilities and resources - Guarantee equitable distribution of vaccines - Ensure that the most marginalized communities and individuals play leadership roles in immediate response, design and planning efforts
STRENGTHENING THE CAPACITIES OF LOCAL ACTORS, PARTICULARLY LOCAL GOVERNMENTS	- Ensure collaboration across levels of government and subnational jurisdictions - Enhance local government budgetary capacity with policy measures and dedicated funds in stimulus packages - Promote accountability and transparency - Ensure that communication campaigns reach all urban communities - Support local governments in avoiding disruptions of essential public services
PURSUING A RESILIENT, INCLUSIVE, GENDER-EQUAL AND GREEN ECONOMIC RECOVERY	- Bolster micro, small and medium enterprises (MSMEs) and support a safe restarting of businesses - Sustainable economic development strategies - Ensure that social protection schemes also serve the most marginalized - Build future-ready cities - Urban compactness could be a goal while de-densification could be resisted - Ensure resilience plans are based on disaggregated data - Develop and implement multi-hazard resilience plans - Invest significantly in the care economy

Tab. 4 Summary table of the key commitments and action to cope with a pandemic. UNSG office, Policy Brief: *COVID-19 in an Urban World*, july 2020, pp. 5-8.

Main sectors of urban analysis	Sub-thematic categories
I ENVIRONMENTAL QUALITY	- Air quality impacts of lockdowns - Environmental factors - Urban water cycle
II SOCIO-ECONOMIC IMPACTS	- Social impacts - Economic impacts
III MANAGEMENT AND GOVERNANCE	- Governance mechanisms - Smart cities
IV TRANSPORTATION AND URBAN DESIGN	- Transportation - Urban design

Tab. 5 Main sectors of analysis and Sub-thematic category for the management of pandemics within urban systems (Sharifi A., Khavarian-Garmsir A. R. 2020) .

and on the other the need for an in-depth analysis of the different impacts of pandemics on urban-related sectors. A very comprehensive policy brief, issued by the UN Secretary General's office in July 2020, underlines the key policy areas for urban environments to be considered within a pandemic response, as summarized in Table 4. Pandemic challenges affecting all different sectors of urban metabolism would probably require a dedicated in-depth study. However, taking into account the most recent scientific literature we can propose a simplified checklist of the sectors to be taken into account in order to evaluate the possible sectorial response. The analytical scheme of the major issues that the pandemic has shown to be key for post-COVID-19 planning[105], as reported in the

[105] Sharifi A., Khavarian-Garmsir A. R. 2020,*The COVID-19 pandemic: Impacts on cities and major lessons for urban planning, design, and*

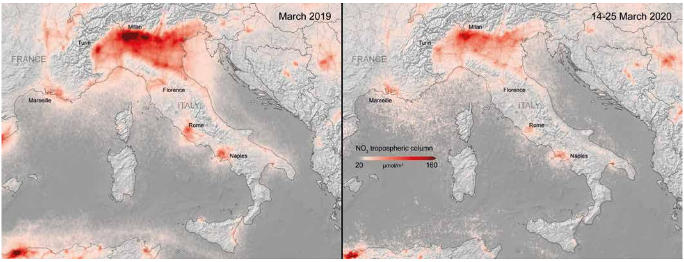

Fig. 4 Comparative Nitrogen dioxide (NO_2) concentration over Italy, during March 2019 (left) and March 2020 (right), showing the substantial air quality improvement due to the pandemics mobility restrictions in spring 2020. [Source:© Copernicus Sentinel-5P satellite data (2019-20), processed by KNMI/ESA.]

study by Ayyoob Sharifi, Amir Reza Khavarian-Garmsir, provides a fourth level of analysis shown in Table 5[106]. Concerning the four main sectors of urban analysis as in Table 6, for **Environmental quality** (sector I in Table 5) lockdowns imposed worldwide, in order to prevent the virus spreading, led to a significant decrease in pollutant emissions into the atmosphere, with an unexpected improvement of air quality and ecosystem services, especially with regard to highly populated urban areas[107] (Fig. 4).

The **Socio-economic impacts** (sector II in Table 5) were almost everywhere catastrophic. According to the

management, in «Science of the Total Environment», vol. 749, p.11.

[106] *Ibidem*.

[107] This estimate shows that the cities with the greatest reduction of NO_2 concentrations in this period were in Spain (Barcelona: 59 %, Madrid: 47 %), Italy (Milan: 54 %, Turin: 47 %, Rome and Genoa: 39 %, Naples: 36 %), France (Marseille: 49 %, Nice and Lyon: 34 %, Paris: 30 %, Lille: 27 %), Switzerland (Geneva: 47 %), Turkey (Ankara: 46 %), Germany (Munich: 37 %, Bremen: 36 %, Berlin: 33 %, Hamburg: 28 %, Frankfurt: 27 %), the United Kingdom (Bradford: 36 %, Manchester: 31 %, Glasgow: 29 %, London: 26 %), and Belgium (Antwerp: 29 %). , European Environment Agency (EEA) 2020, *Air quality in Europe - 2020 report*, p. 20.

EU Commission[108] global trade registered a dramatic deterioration in the second quarter of 2020, as did commercial sectors; and demand in the travel and tourism has basically disappeared.
Referring to **Management and governance** (sector III in Table 5), the response capacity of urban areas has been strongly connected with the level of effective digitalization of management, services and processes. What seems evident in all advanced economies (essentially in the G20 countries), is that management strategies and technological support from digital devices, robotics, and artificial intelligence (AI) were essential for urban and social resilience, for reducing the need for human contacts, and even for maintaining basic services. Finally, for **Transportation and urban design** (sector in Table 5), the pre-COVID-19 models of public transportation and urban design showed all the limits of an approach that did not take into account the risk of personal proximity as a factor in the virus' spreading in highly populated urban areas.
Taking into account the three sub sectors dedicated to *Smart Cities*, *Transportation* and *Urban Design* (Table 6)[109] the analysis highlights a number of major issues revealed by the pandemic and related to major recommendations/implications for post-COVID-19 planning. Referring to the present situation, it seems that since December 2019 the basic use of digital tools was still restricted to their application to a society structured as in

[108] European Commission 2020, *European Economic Forecast, Autumn 2020*, Publications Office of the European Union, Luxembourg.
[109] Sharifi, Khavarian-Garmsir, *Op. cit*.

the nineteenth-century; today the evolution and common understanding is that during 2020 all main structures and functions of cities and societies have evolved definitively towards a real digital society.
Education at all levels, services offered by public administration and private companies, and public and private workers have all been forced to switch from on paper and in presence activities to fully digital ones. In other words, the COVID-19 outbreak may come to represent not only a harsh, indeed tragic, moment for contemporary society, but also an opportunity for an important evolutionary leap, connected with the digital transition. Bearing this in mind, the list of "Major recommendations and implications for post-Covid planning" (as in Table 6), provides a very useful framework for post-COVID-19 urban metabolism research. Each of those recommendations leads to possible enabling technologies, already existing or to be developed, with the aim of coping effectively with the post-pandemic urban scenarios.

Resilience and adaptation of urban systems

The concept of resilience, now generally used in all scientific fields, is essentially a concept borrowed from materials physics and engineering, describing the capacity of a metal to absorb energy elastically before breaking when subjected to a load or an impact[110]. The term resilience, understood as the ability to endure

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110 Cavallotti C. 2008, *Enciclopedia della Scienza e della Tecnica*, Treccani, Roma.

Sub-thematic categories	Major issues revealed by the pandemic	Major recommendations/ implications for post-covid planning
1. SMART CITIES	1.1 Smart solutions have contributed to developing more effective and efficient response and recovery measures (e.g., identifying and isolating infected individuals, reducing human-to-human contacts in service delivery, etc.)	1.1.1 Public access to real time and geo-referenced data enables better response and recovery from adverse events 1.1.2 Techno-driven approaches should not undermine privacy issues and be misused to reinforce power relations
	1.2 Techno-driven approaches have been successful in containing the virus, but have raised concerns regarding privacy protection and transparency	1.2.1 Human-driven approaches are more suitable for citizen empowerment 1.2.2 Combined approaches are better suited for containing the pandemic, dealing with privacy concerns, facilitating coordination and information sharing, and controlling the spread of misinformation
2. TRANSPORTATION	2.1 Increased transport connectivity is a risk factor that may contribute to the diffusion of infection diseases	2.1.1 Smart mobility restrictions, based on the transmission risk of different transportation modes, is essential for containing the spread of the virus
	2.2 Public transportation may increase the risk of transmission during pandemics	2.2.1 More attention to minimizing potential public health risks of public transportation is needed
	2.3 The pandemic may increase negative attitudes towards public transportation	2.3.1 Modal shift to cycling and walking offers a unique opportunity to further promote active transportation
3. URBAN DESIGN	3.1 Density alone is not a key risk factor contributing to the spread of the virus	3.1.1 Better access to amenities and public health infrastructure make high-density areas less vulnerable to pandemics
	3.2 Some cities lack appropriate levels of green and open spaces to meet outdoor exercise and recreation demands of their citizens while fulfilling social distancing requirements	3.2.1 Considering multiple other benefits of compact urban developments, planners should continue promoting them 3.2.2 More space should be allocated to pedestrian areas and open spaces

Tab. 6 Major issues revealed by the pandemic and Major recommendations/implications for post-COVID-19 planning (Sharifi A., Khavarian-Garmsir A. R. 2020) .

even extreme stress and return to an initial state, is now commonly used in many scientific disciplines such as psychology, economics and ecology. The use of the term in this broad sense has undoubtedly passed from the English language into the common international scientific language, although it is clearly a Latin word, consisting of a prefix *re* combined with the conjugation of the verb *salire*, with the simple meaning of returning and jumping back, but also of retreating and contracting[111]. With reference to climate change, the IPCC Panel clarifies what the resilient mechanisms are[112], specifically in the ecological systems, as in Table 7.
In order to define a resilient system, four descriptive qualities have been identified, strongly linked to factors of technological and social innovation. These factors can be summarized with the four adjectives: **Small, Local, Open, Connected**[113] [114], four simple descriptors with characteristics aimed at achieving flexibility and innovativeness in order to make any impact limited and

[111] Glare P. G. W. 1980, *Oxford Latin Dictionary*, Fascicle VII, Oxford University Press, Oxford.
[112] Pérez A., Herrera Fernandez B., Cazzolla Gatti R. 2010, *Building Resilience to Climate Change*, IUCN Editore, Gland, p. 11. From IPCC, Intergovernmental Panel on Climate Change 2007, *Summary for Policy Makers*, in M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, C.E. Hanson (eds.), *Climate Change 2007: Impacts, Assessment and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK.
[113] Manzini E. 2013, *Small, Local, Open and Connected: Resilient Systems and Sustainable Qualities*, «Journal of Design Strategies», vol. 4, n. 1, pp. 8-11.
[114] Cottino P., Zandonai F. 2015, *Imprese per comunità resilienti: i molteplici (e incompiuti) apporti della cooperazione alla vita delle comunità locali*, «Animazione Sociale», n. 5, pp. 26-37.

Impact	Definition
Vulnerability	as the degree to which a system is susceptible to, or able to cope with, the adverse effects of climate change.
Exposure	the extent to which a region, resource or community experiences climate change. It is described by the magnitude, frequency, duration and/or spatial extent of a climate event or pattern (IPCC, 2007).
Sensitivity:	representing the degree to which a system is affected, directly or indirectly, by climate-related stimuli (IPCC, 2007).
Adaptive capacity:	understood as the ability of a system to adapt to climate change at moderate potential damages, to exploit opportunities or cope with consequences (IPCC, 2007).
Adaptation	or in other words, adjustments by natural or anthropogenic systems in response to existing or foreseeable stimuli, or effects due to damage limitation or exploitation of favorable opportunities (IPCC, 2007).

Tab. 7 Impacts and their definitions related to resilient mechanisms (IUCN 2010 and IPPC 2007)

manageable. These synthetic but clear descriptors can be articulated and defined in order to understand their effects on different systems. Their characteristics are:

- **Resilient physical system**: dispersion instead of compactness; being a collection of small semi-autonomous units; use of standards; mobility; use of secure materials and technologies that guarantee rapid error detection.
- **Resilient operating system**: efficiency; reversibility; autonomy and increasability.

- **Resilient social system:** compatibility with different value systems; the ability to satisfy several objectives at the same time; fair distribution of benefits and costs; improving accessibility;
- **Resilient economic system:** use of incremental funds; favoring a high cost-benefit ratio; guaranteeing investments with short-term results; allowing costs and benefits fairly shared.
- **Resilient environmental system**: minimization of negative impacts together with an extensive and renewable resource base.

Boosting adaptation strategies is of major importance in areas linked to biodiversity and natural resource management[115]. This is crucial not only to help achieve biodiversity and conservation goals, but also to maintain the contribution of biodiversity and eco-systemic services to social adaptation and the overall resilience of human environments. With regard to the impacts of global changes on urban systems, it is important to recall that the resilience of complex systems lies in their capacity to resist, absorb, contain, and respond, promptly and effectively, to stress phenomena, by implementing response and adaptation strategies, while preserving and restoring functioning mechanisms.

Urban resilience can be defined as the level of disruption that cities can tolerate before reorganizing with renewed

[115] Heller N. E., Zavaleta E. S. 2009, *Biodiversity management in the face of climate change: A review of 22 years of recommendations*, «Biological Conservation», n. 142, pp. 14-32.

infrastructures and processes[116]. It is measured by the city's ability to balance well the management of ecosystems, infrastructure and human functions. On urban resilience there is an increasing level of global attention, considering that since 2010 it almost went under the radar, or was not properly understood, but since 2015 it has become a global priority, also included within the UN General Assembly agenda[117]. Indeed, cities can be conceived as multisystem realities, composed of a number of interconnected and overlapping systems (physical, operational, economic, environmental), each requiring a specific approach with regard to resilience.

Thus, the systems contributing to urban and territorial metabolisms must have resilience, not only on their own, but also in relation to all the other related systems, in order to contain the negative effects of individual failures affecting the others.

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[116] Alberti M., Marzluff J. M., Shulenberger E., Bradley G., Ryan C., Zumbrunnen C. 2003, *Integrating Humans into Ecology: Opportunities and Challenges for Studying Urban Ecosystems*, «BioScience», vol. 53, n. 12, pp. 1169-1179.

[117] Point 34: "*We recognize that sustainable urban development and management are crucial to the quality of life of our people. We will work with local authorities and communities to renew and plan our cities and human settlements so as to foster comunity cohesion and personal security and to stimulate innovation and employment. We will reduce the negative impacts of urban activities and of chemicals which are hazardous for human health and the environment, including through the environmentally sound management and safe use of chemicals, the reduction and recycling of waste and the more efficient use of water and energy. And we will work to minimize the impact of cities on the global climate system. We will also take account of population trends and projections in our national rural and urban development strategies and policies*", referring to Goal 11: "*Make cities and human settlements inclusive, safe, resilient and sustainable*", UN General Assembly 2015, *Transforming our World: the 2030 Agenda for Sustainable Development* (A/RES/70/1), New York, pp.13, 18.

The dynamic nature of the adaptation promotes both resilience of ecosystems and human societies, in addition to technological options, mainly focused on physical infrastructures. Many studies, however, have shown that 'defensive' adaptation strategies often have a negative impact on biodiversity, especially with regard to cementing coastlines and watercourses in order to to protect from coastal and inland flooding[118]. In long term, if the ecological characteristics governing the modified ecosystems are disturbed, they may cause what is called 'bad-adaptation'. In contrast, adaptation strategies that are integrated with natural resource management, can lead to positive outcomes for both people and biodiversity[119].
The main solution adopted in the most advanced cities is based on the operational and structural redundancy of services to ensure the main metabolic functions, so that the failure or malfunction of a particular system does not generate a chain reaction of failures, risking the collapse of entire system. In this framework, the evaluation of the governance of urban areas is certainly not of residual importance. Its main characteristic should be flexibility, a concept on which many researchers seem to agree, prefiguring the creation of an entirely flexible society, able to adapt to critical situations and taking advantage

[118] Campbell A. et al. 2009, Review of the Literature on the Links between Biodiversity and Climate Change: Impacts, Adaptation and Mitigation, «Technical Series», n. 42, pp. 8-11.
[119] CBD (Convention on Biological Diversity) 2009, *Connecting Biodiversity and Climate Change Mitigation and Adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change*, «Technical Series n. 41», Secretariat of the Convention on Biological Diversity, Montreal, Canada, p. 126.

of any positive future opportunities[120] [121]. This flexibility should be directly proportional to the complexity of the system to be managed, and should be consistent with a prompt reaction, and of course supported by the necessary financial and technical instruments. This framework of analysis should also include the political dimension of a city, where city authorities should genuinely respond to the priorities and needs of all inhabitants by taking into account potential risk factors and measures to contain their adverse effects[122].

Current scientific knowledge on the resilience of urban systems, however, is still generally judged insufficient[123], and this lack of scientific knowledge is even more difficult to understand if we consider that reducing urban resilience increases vulnerability, exposing cities and people to greater risks[124]. Impact analyses and their results often do not provide clear scientific evidence and guidelines: some urban systems maintain their sustainability while carrying out rapid urbanization; others maintain it with slow growth, and still others with internal transformations. Such characteristics of self-

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[120] Berkes F., Folke C. 1998, *Linking Social and Ecological Systems. Management Practices and Social Mechanisms for Building Resilience*, Cambridge University Press, Cambridge.

[121] Barnett J. 2001, *City Design: Modernist, Traditional, Green and Systems Perspectives*, Routledge, New York.

[122] Satterthwaite D., Dodman D. 2013, *Towards resilience and transformation for cities within a finite planet: Environment and Urbanization*, pp. 291-298.

[123] CSIRO (the Commonwealth Scientific and Industrial Research Organisation) 2007, *Urban Resilience Research Prospectus*, Stockholm University, Stockholm.

[124] ICSU (International Council for Science) Series 2002, *Resilience and Sustainable Development*, «Science for Sustainable Development», n. 3, p. 37.

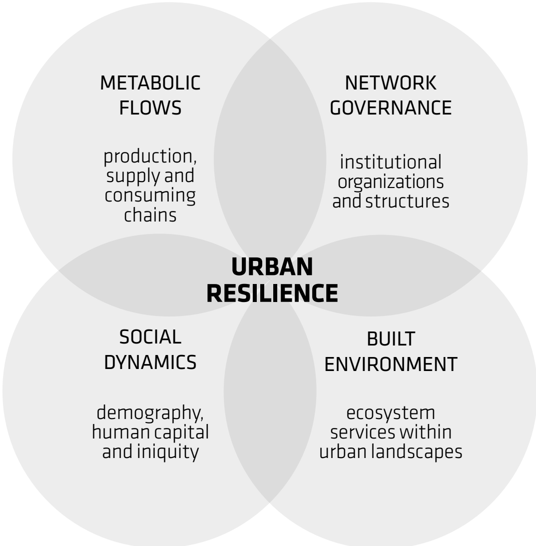

Fig. 5 Four interconnected research themes to prioritise research in urban resilience (Source: CSIRO 2007, Arizona State University, Stockholm University, Urban Resilience Research Prospectus).

organization, adaptation and dynamics, based on multiple spatial and temporal scales, underline how research on sustainable urbanization would ultimately benefit from a resilience-based approach.

An initial proposal for defining the structure of complex urban systems and the relationships between them identifies four interconnected topics (Fig. 5) relevant for the resilience of urban systems. It is a multi-level approach focusing on:

- **metabolic flows** considered as the support of urban functions, human well-being and quality of life;

- **governance** of networks and grids;
- **societal adaptation** in order to cope with urban challenges;
- **social dynamics** of citizens and communities, and their relationship with the built environment that defines the physical patterns of the urban form;
- **spatial relationships** and interconnections[125].

Understanding the resilience factors of urban systems is a useful tool for dealing with ongoing climate change and lack of natural resources with specific reference to fossil fuels, presently fundamental for energy production. This requires careful planning of possible future scenarios, integrating farsighted political vision with theoretical/ scientific models, verifying possible alternatives in order to cope with present and future crises, linked to climate change, Peak oil[126] and other urban fragilities.

There are three main possible scenarios: in brief, the possible collapse of most advanced societies (in case of total inaction); development of adaptation strategies based on the best available technologies; or else planning evolutionary scenarios consisting of extensive modifications of current development models.

The last one is considered the most promising, and by some scholars the only possible way to achieve future resilience of cities. Faced with a convulsively transformative world, the need to achieve consolidated urban resilience targets has inspired the *British Transition Cities* experience: a planning and management approach formalized in

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[125] CSIRO, *Urban, cit.*
[126] Hopkins R. 2008, *The Transition Handbook. From oil dependency to local resilience*, Green Books, Devon.

the early 21st century by Rob Hopkins[127], and based on the transformation of existing urban areas, according to a low-energy consumption model, enhancing internal microgeneration of energy towards reaching possible self-sufficiency[128]. From the experience of the *Transition Cities* and their specific "resilience" approach, we can propose a few principles to be considerated:

- diversity and creative redundancy;
- modularity applied to governance networks;
- strategies and development policies locally adapted;
- balancing all available resources, including in the concept of 'resource' those resulting from new development models, as well as efficiency and savings in consumption[129].

According to Peter Newman[130], future cities must integrate resilience principles in infrastructural projects from their early stages. In essence, he defines seven main urban models that identify the resilient city, namely: *Renewable energy city*, *Carbon neutral city*, *Distributed city*, *Photosynthetic city*, *Eco-efficient city*, *Pace-based city*, *Sustainable transport city*. Newman argues that these models often intersect and overlap, all converging towards resilience. At present there are no cities that fit all seven

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[127] *Transition Italy*, 2015, http://transitionitalia.it/.

[128] Hopkins R., *Manuale pratico della transizione*, Arianna Edizioni, Cesena 2009.

[129] The energy saved by efficiency nowadays is largely considered a new form of energy production. Several countries are calling this resulting energy source 'white energy'.

[130] Peter Newman is Professor at the Curtin University Sustainability Policy (CUSP) Institute in Perth, Australia, teaching The Principles of Sustainability. He is a member of the Australian Federal Government's Board of Infrastructure.

models of development: only the most innovation-based cities reach the goal of corresponding to the definitions of one or two of them[131].

A resilience approach is by definition highly participative: it offers the possibility of sharing the scenarios foreseen with local communities, therefore reviewing and integrating all plans and programmes of territorial management, offering an opportunity for interaction also from a social and economic point of view, and ensuring security for citizens and infrastructures. Having clarified this approach, the three keywords of urban resilience are:

- **Diversity** intended as the basic principle ensuring diverse alternatives for future planning options;
- **Redundancy** ensuring multiple functionalities as options;
- **Interconnection** linking different planning and temporal scales, but also digital and technical grids and tools.

While diversity and redundancy both ensure the possibility of alternative scenarios to cope with possible urban fragilities, it is necessary to adopt a more cautious approach to "Interconnection". A resilient system/city might not necessarily be fully interconnected, considering that an excess of interconnectivity could produce interdependency as a side effect, transforming punctual stresses into a systemic problem. In any case, redundancy, conceived largely as creative, planning and

[131] Newman P. 2010, *Resilient Infrastructure Cities. Developing Living Cities: from analysis to action*, Scientific publishing Co., Singapore, cap. IV, pp. 7-78.

technological redundancy, remains the most interesting among the three mentioned keywords[132].
Leaving considerable margins during the design and planning phases, in terms of materials, urban density, availability of multiple networks and grids and in general multiple technological solutions, gives the city wider margins of safeguard functionalities and reactivity, assuring appropriate responses even in case of extreme conditions and events.

Resilient cities and communities

As we have seen, pursuing the resilience of cities enables a very pervasive approach and its comprehensive application influences, directly or indirectly, all the managing, planning and design factors of both existing and newly planned urban areas. The careful application of resilience principles helps to improve the general quality of local, metropolitan and regional planning, taking into account climatic, environmental and socioeconomic aspects. Although in the recent past resilience was mainly considered as opposed to vulnerability, currently the scientific community includes socioeconomic factors, as well as managerial, organizational and technological ones, in the broad concept of resilience.
Conceiving urban resilience strictly as environmental sustainability would produce unpredictable and even negative effects on the management of natural,

[132] Low B., Ostrom E., Simon C., Wilson J. 2003, *Redundancy and Diversity: do they influence optimal management?*, in Folke C., Colding J., Berkes F., *Navigating Social-Ecological Systems*, Cambridge University Press, Cambridge, pp. 83-114.

socioeconomic and infrastructural resources which must be considered fundamental parts of any long-term strategy for sustainable development. This implies that strategies that only focus on sustainability could result in striving for unsustainable goals if the focus is only on improving efficiency within urban areas.

In urban contexts and related surrounding territories, however, resilience is based on refining existing relationships. To produce adequate responses, before any possible extreme event, the evaluation framework must be clear, bearing in mind that flexibility is in general the most suitable option, considering that higher flexibility increases the chances for recovery. A logical framework comprising resilience and adaptive skills also includes current hazards and future risks, improving preventive strategies and mitigation/recovery processes[133]. The implementation of appropriate management tools, as well as land, building and planning management is also fundamental for urban resilience.

Last but not least, establishing mechanisms and approaches aimed at adaptation, flexibility and innovation, understood as the ability to solve problems, improves response processes. This kind of approach, together with social empowering and an enhanced idea of community, leads to shared and aware decisions, thus contributing to improved dialogue between decision makers and civil society, developing stronger social ties,

[133] Klein R. J. T., Nicholls R. J., Thomalia F. 2003, *The Resilience of Coastal Megacities to Weather-Related Hazards*, in *Building Safer Cities. The Future of Disaster Risk*, vol. 3, World Bank ed., Washington, pp. 101-120.

as well as better recognized and accepted leadership, triggering mindful reactions[134].

Consciously managing natural and human environments and ensuring socio-ecological sustainability means considering environmental consequences in a transformative and adaptive framework, anticipating and if possible guiding transformations for future urban ecosystems.

[134] Colucci A. 2012, *Le città resilienti: approcci e strategie*, Jean Monnet Centre, Pavia.

TECHNOLOGICAL SYSTEMS, DIGITAL TOOLS, AND SMART GRIDS SERVING URBAN COMMUNITIES

World population growth in urban areas underlines the increasing criticalities linked to urban management and administration, today reaching levels of such complexity that managers and policy decision makers are often forced to focus primarily on the mere maintenance of services, structures, and networks for the safety of citizens, perhaps neglecting other important aspects linked to the quality of life and general well-being, such as ensuring the pleasantness of the architectural and planning, or assuring redundancy of services.

Urban complexity forces us to adopt an interdisciplinary approach, in order to interrelate environmental quality, quality of structures and services, and quality of life. These three factors are not related in a linear sequence, but rather influence each other according to mutual cause/effect relationships. Such complexity produces a multiplication of variables, generating very dissimilar and even contradictory scenarios.

In order to organize an effective response to the complexity of contemporary urban management issues, we could start from the surrounding urban territorial scale, trying to organize limited territorial areas, applying a few virtuous principles to elementary units/modules of territory.

Those modules, identified by the number of inhabitants (between 1 000 and 2 500 citizens), the structural characteristics of the buildings, and the general use of the empty spaces (both those with infrastructure and green) can be defined as urban cells[1]. Once the critical issues of each cell have been evaluated, and possible optimization strategies designed in view of available internal resources and impact mitigation, its relationship with the portions of territory bordering on it can be tackled, thus constructing a physical and conceptual relational network between the different urban areas.

An urban cell can be considered as an "elementary territorial unit"; aggregation of those cells contributes to the creation of networks or Smart Grids[2]. Those grids were initially conceived to facilitate optimized management of energy resources. But energy is only one of the flows of urban metabolism that can be studied using this methodology; economic flows, flows of people, materials and waste can also be added, and last but not least, information flows (big data) can be analyzed and modified, to maximize the sustainability of the processes and raise the quality of life, with the final objective of making the current urban agglomerations increasingly inclusive future Smart Cities and Communities.

Furthermore, in order to achieve the ambitious objective of simultaneously satisfying material and immaterial needs and consequently obtaining a general condition of

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[1] Gehl J. 2011, *Life Between Buildings: Using Public Space*, Island Press, Washington.

[2] Wang W., Xu Y., Khanna M. 2011, A *survey on the communication architectures in Smart grid*, «Computer Networks», vol. 55, n. 15, pp. 3604-3629.

well-being, it is necessary to refer to technological tools that can provide solutions both for the mitigation of the individual impacts described in the previous chapters and for the realization of an integrated management system.
A critical analysis aimed at defining an integrated approach in the urban environment, for the use of new technologies, has led to the identification of innovative techniques and systems considered indispensable for the virtuous development of innovative cities.

Smart grids and microgeneration
Microgeneration, or better Micro Combined Heating and Power (micro-CHP), usually refers to joint production of electricity and heat by a cogeneration plant with an output of less than 50 kW of electricity. In the most common configuration, a micro-CHP consists of a gas-fired engine with internal combustion where mechanical energy is converted into electricity, and the waste heat is conveyed into a recovery system producing thermic energy. Microgenerators are technologically advanced devices, able to integrate or fully replace heating boilers, and provide, at least in part, the electricity needed for self-consumption[3].
The European Directive 2004/8/EC[4] dedicated to the promotion of cogeneration in Italy was made operational by Legislative Decree 20/2007, which also regulates

[3] Nextville, *Micro-cogeneration: definition, market, potential, obstacles*, http://www.nextville.it.
[4] Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC.

several definitions within the energy sector, including cogeneration, small cogeneration units, and micro-cogeneration. Cogeneration is described in the Decree as a single process of energy generation, producing either thermic and electrical energy, thermic and mechanical energy, or thermic, electrical, and mechanical energy. Small cogeneration and micro-cogeneration units are defined as cogeneration units when they generate, respectively, less than 1 megawatt (MWe) and less than 50 kilowatts (kWe)[5].

Several studies have been conducted at the European level on the development of the microgeneration sector and the opportunities connected with it. One of the most interesting is the CODE project[6], co-financed by the European Commission, and the following CODE-2 project, which set up a market consultation in order to define Member states' and EU roadmaps for cogeneration. The objective of microgeneration technology is to achieve energy efficiency by converting primary energy into heat and electricity at the end-user level. This process minimizes energy losses at the power grid level, and heat losses in centralized electricity production[7] [8].

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[5] Legislative Decree n. 20 of 8 February 2007, Implementation of Directive 2004/8/EC on the promotion of cogeneration based on a useful heat demand in the internal energy market, as well as amendment to Directive 92/42/EEC (G.U. n. 54 of 6 March 2007).

[6] European Commission, Intelligent Energy Europe, Cogeneration Observatory and Dissemination Europe (CODE) https://ec.europa.eu/energy/ intelligent/projects/en/projects/code.

[7] CODE 2 Cogeneration Observatory and Dissemination Europe, Micro-CHP potential analysis European level report, December 2014 http://www.code2-project.eu/.

[8] As highlighted in the introduction of the European Parliament's 2013 resolution on microgeneration, *"Microgeneration must be an essential*

Microgeneration is gaining importance due to the present high cost of energy production, along with the ever-increasing energy demand, and the need to minimize environmental impacts. The reduction in the size of energy production systems makes it possible to phase out large production plants, even those larger than 10 MWe, and to develop smaller production systems, with the aim of reaching a capillarization of energy consumed, allowing wiser planning of production and consumption.

Such a new approach to precisely localized consumption and planning can be defined as Smart Energy, intended as an intelligent and efficient use of energy but also as an opportunity for a more precise evaluation of the energy produced. Constant collection of energy flow data allows consumers to keep their real-time energy consumption and the details of their production systems, and to adopt recommended or automatic management of energy flows, also connected to dynamic load profiles and to cheaper time slots. A similar integrated system will be

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element of future energy production if the Union is to meet its renewable energy targets in the long term […]. It contributes to increasing the overall share of renewables in the EU's energy mix and enables efficient electricity consumption close to the point of generation while avoiding transmission losses" and "states that microgeneration should contribute to the achievement of long-term objectives; therefore calls on the Commission and the Member States to improve the implementation of the strategies for small-scale electricity and heat generation contained in the current EU policy framework, thereby recognizing the importance of microgeneration and promoting its deployment in the Member States", motion for a resolution 06.09.2013, tabled following question for oral answer B70217/2013 pursuant to Rule 115(5) of the Rules of Procedure on microgeneration - small-scale electricity and heat generation (2012/2930(RSP)) – Merkies J. A., on behalf of the Committee on Industry, Research and Energy.

able to manage other resources in addition to electricity, such as gas and water[9].
Smart Energy is therefore a new system that favors small-scale plants and innovative fuels, minimizing environmental impact from production plants, reducing the final energy cost for consumers, standardizing energy demand, encouraging users to produce their own energy, using clean sources and making it available on the grid, and finally introducing high levels of automation and data management. Micro cogeneration is closely related to improved energy efficiency, decreased pollutant emission, and reorganization of local production and economic activities, therefore providing the dynamic and intelligent management that seems necessary in the urban context.
Smart Grids, representing the evolution of traditional grids both in terms of electric generation and distribution and for system control, make a useful contribution to this goal. Smart grids are characterized by increasing flexibility in relation to external events, managing not only the transit of energy, but also bi-directional data flows. Consumers/users become at the same time energy producers and data consumers, and those intelligent grids can pursue efficiency objectives autonomously and in real-time.
A smart grid can be designed through the widespread use of micro-generation, thus enabling the improvement of system efficiency, reducing distances and the unavoidable connected load losses and dispersions typical of large-

[9] Maggi S. 2012, *A tutta energia!*, Fieldbus & Networks, pp. 56-58.

scale distribution grids. It can be designed as an integrated management of many small well-coordinated distributed power plants, in order to compensate consumption peaks, with continuous data flow, and also able to manage two-way energy flows. With the growing use of distributed renewable sources, and highly distributed microgeneration plants, mostly private, it becomes critical to have an efficient, centralized control of the energy distribution networks, bearing in mind that the generation capacity of renewable systems tends not to be very constant, depending on local weather conditions.

The energy grids, equipped with smart sensors, with a continuous multidirectional data flow, managing all different sources of power distributed along the network, and under central management control, will became what we can think of as an "Internet of Energy". However, in order fully to implement this new vision of smart grid, all electric devices and every microgeneration system will have to be smartly connected to the grid, in order to constantly exchange data, communicate in real-time with the control center and with other devices on the network[10].

The most comprehensive definition of a Smart grid emphasizes the following three aspects:

- **sensing, automation, and communication technologies**, designed both to increase grid reliability and integrate renewables and diffuse sources, keeping in mind the potential growth of electric vehicles;

[10] Bellifemine F. L., Borean C., De Bonis R. 2009, *Smart Grids: Energia e ICT*, «Notiziario Tecnico, Telecom Italia», anno 18, n. 3.

- **smart metering systems,** installed at the level of final users/consumers, in order to stimulate peak reduction, mainly through appropriate pricing policies;
- **appropriate smart interfaces** between the smart metering systems and domestic technologies/ apparatus, allowing customers to see their consumption profile in real-time even on single domestic appliances, monitoring also remotely via smartphone[11] [12].

This is a completely different system compared with those presently in use. The present model of centralized energy grid control foresees automatic interactions only for basic functions, requiring human intervention for any advanced request. The future smart grid is an energy network, fully equipped with smart sensors, intermediate actuators for automatization of the grid, communication nodes, control and monitoring systems. It is a network with different reference scenarios and where the energy cost is adjustable over time: final user metering will communicate with user devices that, in turn, coordinate to adapt the consumption profile accordingly[13]. In order to create a network that enables the development of a smart grid, a structure made up of other networks is required, which can be summarized as follows:

- **local domestic**, to interconnect the meter systems of energy utilities with local monitoring and control

[11] AARP, National Consumer Law Center, National Association of State Utility Consumer Advocates, Consumers Union, and Public Citizen 2010, The need for essential consumer protections. Smart metering proposals and the move to time-based pricing.
[12] Goldoni G. 2012, *Regulation&Deregulation. Le sfide della Smart grid*, Energia, n. 4, pp. 40-54.
[13] Bellifemine, *Op. cit.*

systems, including microgeneration and energy storage plants, electric or hybrid mobility systems, domestic sensors on lights as well as heating and cooling systems, thermostats, boilers, household appliances, and, in general, all equipment able to generate, consume and control energy within the domestic environment;

- **district**, to interconnect the meters in neighborhoods or buildings, in order to manage the energy balance at an aggregate level;
- **metropolitan or extended**, to redirect data to energy suppliers; it includes all management e-platforms for both energy distribution and ICT;
- **Inter-Grid**, to enable smart grids in different countries to intercommunicate dynamically, managing energy on a consumption basis, but also relying bilateral agreements and policies[14].

Sustainable mobility technologies

Cities and metropolitan areas are today also considered major driving forces for national economies. This implies that a country's competitiveness is also measured by assessing the efficiency of services (mostly those connected to mobility), livability, and opportunities offered by major cities. Those sectors have direct influence on the quality of life in urban areas, as well as on air quality, road traffic and general accessibility to services.

This is the reason why a cutting-edge infrastructural policy must start from a few basic objectives, such as:

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[14] Elettronica Oggi 2021, *Smart Grid and distribution networks*, Fiera Milano Media SpA., n. 491, Milano.

strengthening and integrating local, regional and national public transport systems, particularly promoting rapid mass transit rail systems (metros and trams); creating the conditions for cycling and walking; and making available innovative digital tools applied to urban and extra-urban mobility in order to promote shared mobility services.

In Italy, the Ministry of Infrastructures and Transport (MIT), in order to cope with such critical issues, has recently set up a series of initiatives, to be included in the "Sustainable Mobility Urban Plans" for Italian cities. The entire MIT action is based on four strategies, namely: useful, flexible, and shared infrastructures; modal integration and intermodal passenger transport; enhancement of existing infrastructure assets; sustainable urban development. Within this framework, several lines of action are related to smart grids, essentially refocusing the mobility demand towards highly sustainable means of transport, promoting intermodal public and private transport, and improving the efficiency and technological upgrading of existing infrastructures.

Nowadays, the rapid social changes, connected with innovation in communication, require a deep rethinking of public and private mobility, responding with innovative approaches to emerging critical urban issues, in order to enable increasing sustainable mobility, fully integrated in the common aim of having smart and user-friendly cities.

The most promising path to ensure that citizens remain on board and actively engaged in the present urban mobility and digital transformation seems to be to promote new attitudes towards the interactive digitalization of mobility. Personal smartphones as well as highly connected cars and other mobility means, can allow predictive algorithms to calculate the expected duration of routes with further precision, elaborating traffic data from the connected users in real time on the basis of their movements and the GPS satellite they are connected with. The increasing popularity of social networks favors new mobility models, also allowing peer-to-peer interaction among moving users, showing that an intelligent integration of social media, dedicated apps and monitoring networks, is a remarkable source of dynamic data, enabling interesting future mobility scenarios, based on our behaviors and routines.

Bearing that in mind, we can highlight a few principles as relevant for the envisioned transformation. What is really needed are cities that are really Smart and able to offer, through networks, the relevant services for travel optimization, and more specifically to ensure the availability of flexible, sustainable, and customizable mass transport services for passengers and goods, such as car and bike sharing, responsive transport on demand, and city logistics for goods. This framework must include networking of services and their full availability, together with efficient and sustainable private traffic.

The most promising development, however, concerns the Internet of Things (IoT) as most modern vehicles can provide traffic data (Extended Floating Car Data) continuously and at low cost. They can also interact with each other and with overarching control infrastructures in order to increase safety, security and efficiency. Modern technologies, such as cloud computing and Big Data, are opening up new possibilities as they enable more appropriate and widespread management of transport networks, with limited cost and acceptable management difficulties.

The availability of accurate and timely information, together with information and communication technologies, makes possible the application of increasingly effective and comprehensive predictive and control models. Intelligent Transport Systems (ITS) are recognized as key tools to address transport safety, emissions, and congestion, and the integration of existing technologies can be important in boosting jobs and growth in the transport sector. Work is already underway to implement the next generation of ITS solutions through the development of Cooperative Intelligent Transport Systems (C-ITS).

C-ITS are systems able to share data through wireless technologies, connecting each other, as well as with road infrastructures or with other road users. These systems when able to realize full digital connectivity will be fundamental for improving road safety, traffic efficiency, and driving comfort. Connectivity, cooperation and automation, growing synergically and reinforcing each other, will in time reach full integration.

The potential benefits of a strategic approach to Smart Mobility are clear, but the real advantages for cities will be significant only if Smart Mobility involves all city mobility actors and infrastructures, as well as a large part of citizens' movements. In order to achieve positive results, it will be necessary to avoid 'experimental' approaches, based on demonstrative and sectorial projects, supporting instead fully comprehensive market-based ones. Also selecting basic digital applications having widely accepted standards is surely the most suitable option, accompanied by a serious and comprehensive reconsideration of the local normative framework, giving urban traffic planners as well as administrative decision makers the solutions most appropriate for their cities. It is fundamental to tailor the selected solutions based on a cost/benefit analysis and potential market needs, because the city must be large enough to justify the investment[15].

Information management systems for teleworking, e-teaching and e-learning and telemedicine

The present exponential growth of information technology infrastructures, mostly developed within urbanized areas through widespread employment of optical fiber for data transmission, is allowing a large-scale implementation of innovative approaches for teleworking, also in the health sector. The recent COVID-19 pandemic, with the forced acceleration of all digital processes, has suddenly brought teleworking, e-teaching and e-learning and experimental

[15] The future of such systems, which is already a reality in the US, is the so-called Wireless Emergency Alerts (WEA) formerly known as the Commercial Mobile Alert System (CMAS). This is an alert network designed to disseminate emergency alerts on mobile devices such as mobile phones and pagers. Authorities are able to disseminate and coordinate emergency alerts and warning messages through the WEA and other public systems via the Integrated Public Alert and Warning System. In Italy, there are similar experiments in the civil protection field, but they are strongly constrained by privacy regulations and require informed consent, i.e. they cannot indiscriminately reach anyone with a device suitable for receiving such messages. The US government issues three types of alerts through this system, namely: Alerts issued by the President of the United States; Alerts involving imminent threats to life safety, issued in two different categories: extreme threats and serious threats; and AMBER Alerts, involving child abduction.

telemedicine to be used widely every day. Smart (or flexible) working is a work modality characterized by the flexible organization of the working time and place, based on predefined objectives, shared and agreed between the employee and the employer. It is conceived as a methodology for helping the employee to better reconcile work and life times and improve his/her productivity. The Italian definition of smart working, as fixed in the national legislation[16], emphasizes organizational flexibility, stressing the importance of reaching mutual consent for establishing individual tailored agreements, and the use of personal digital equipment allowing remote working (such as laptops, tablets and smartphones), reaching the same results as by in presence activities.

Teleworking in general can be defined as work carried out in a distance modality, using advanced communication systems. Work from home carried out by connecting to a communications network allowing fast data transfer connects the employees to the headquarters. Performed essentially through the use of digital devices connected to a company's network by telephone lines or other data transfer systems, teleworking started to come into use during the last decade of the 20th century, especially in some of the more economically advanced countries and in particular in the USA[17].

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[16] State law n. 81 of 22 May 2017 *Measures for the protection of non-entrepreneurial self-employment and measures aimed at favoring flexible articulation of times and places for subordinate work.*

[17] The United States definition of 'telework' has been consolidated in the Telework Enhancement Act of 2010 as follows: "*[t]he term 'telework' or 'teleworking' refers to a work flexibility arrangement under which an employee performs the duties and responsibilities of such employee's*

One of the characteristic aspects of teleworking is that it can be carried out, from home, in a decentralized office, even in a digital center equipped for this purpose, and shared by the employees of one or more companies. In the offices of service companies that remotely provide services for other companies (Distant working enterprises) small units are linked virtually to constitute a global production system (Distributed business system). Such working structures may also involve foreign countries, different from the one where the company is based (offshore teleworking). Teleworking has certainly also been stimulated by some critical aspects of society such as containment of pollution due to workers commuting, as well as the need to be inclusive towards certain social groups[18]. All flexible and distance modalities of work registered an incredible boost in 2019 and 2020 all over the world, during the COVID-19 emergency. Still today, one year after the European outbreak of the pandemic, teleworking and flexible working is largely in use, in order to guarantee nearly regular working activities of public administrations and private companies during the periods of imposed lookdowns and becoming established as almost the sole tool for containing the spread of the virus, due to the risks in using public transportation.

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position, and other authorized activities, from an approved worksite other than the location from which the employee would otherwise work."

[18] Eurofound and the International Labour Office 2017, *Working anytime, anywhere: The effects on the world of work*, Publications Office of the European Union, Luxembourg, and the International Labour Office, Geneva.

According to a recent study of the EU commission[19], about 40% of EU workers started to telework fulltime as a consequence of the mobility restrictions due to the pandemic. The JRC COVID & Employment Working Group, in a 2020 study[20] stated that about 25% in the EU working force passed to some form of teleworking or flexible working, taking into account the sectors that allow such a way of working. Compared with the percentage of just 15/17 % of EU workers before the outbreak, the shift in working modalities due to the pandemic seems to constitute a powerful change in the EU's working landscape that will surely require further studies and research. Flexible working, or Smart working, can be seen as the evolution of Teleworking[21].

The main feature of Smart working is the large degree of autonomy that the worker has in deciding how, when, and where to carry out his or her work, and the possibility of organizing and controlling the progress of activities according to managers' objectives. As in the case of Teleworking, Smart working minimizes the demand for working mobility, thus reducing energy consumption, pollutant and greenhouse gas emissions, time and costs, and possible accidents linked to home-work journeys. Smart working, compared to Teleworking, allows different types of work activities in order to reduce or distribute differently the number of work-related trips.

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[19] Milasi S., González-Vázquez I., Fernández-Macías E. 2020, *Telework in the EU before and after the COVID-19: where we were, where we head to.*

[20] Fana M., Tolan S., Torrejón S., Urzi Brancati C., Fernández-Macías E. 2020, *The COVID confinement measures and EU labour markets*, EUR 30190 EN, Publications Office of the European Union, Luxembourg.

[21] Diritto 24, Il sole 24 ore 2014, *Smart Working: la nuova frontiera del telelavoro.*

Besides, the simplification of the workplace and its integration with co-working spaces makes it possible to decrease trips over a wider area, thus contributing to reducing commuter traffic congestion[22]. Smart working is conceived as allowing rigid constraints on working time and place to be eliminated, focusing on a more mature relationship with working duties, based on a "working for results" approach, and a better balance between company objectives and individual needs[23]. In Italy, the existing normative framework on working modalities, already mentioned, allows for a mixed format for employees:

> [...] working partly within the company premises and partly outside without a defined workspace, within the agreed working time limits, defined by law, and within the labor union agreements[24].

Between 2013 and 2019, the number of Smart Workers in Italy grew by more than 70% and more than 50% of the large companies have or are introducing initiatives aimed at increasing flexibility in the work organization, bringing benefits to both companies and workers[25]. A set of flexible work organization policies, such as Smart working, is being defined throughout Europe; in the many countries its diffusion as well as the terminology used for defining it varies. Among others, we find the terms Flexible working, Teleworking, Work 4.0, telecommuting working, Activity-based working, Mobile working, and New ways of

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[22] Penna M., Carrabba P., Felici B., Lucibello S., Oteri M.G., Padovani L.M. 2019, *Smart working x Smart cities*, ENEA Studies and Strategies Unit-project, Rome.

[23] Digital Agenda, *Smart Working, what it is in Italy and other European countries*.

[24] Law n. 81 of 22 May 2017, in Chapter II, Art. 18.

[25] Osservatori.net, Smart Working Observatory.

working. The implementation of those novel modes is affected not only by technological development but also by existing economic and cultural structures[26]. According to this framework, the European Parliament promoted a resolution in 13/9/2016 (general principle n. 48) endorsing flexible working and highlighting its potential to:

> […] support 'smart working' as an approach to organizing work through a combination of flexibility, autonomy and collaboration, which does not necessarily require the worker to be present in the workplace or in any pre-defined place and enables them to manage their own working hours, while nevertheless ensuring consistency with the maximum daily and weekly working hours laid down by law and collective agreements; underlines, therefore, the potential of smart working for a better work-life balance, in particular for parents returning to or entering the labor market after maternity or parental leave; rejects, however, a shift from a culture of presence to a culture of permanent availability; calls on the Commission, the Member States and the social partners, when developing smart working policies, to ensure that these do not impose an additional burden on the worker, but rather reinforce a healthy work-life balance and increase workers' well-being; stresses the need to focus on achieving job outcomes to prevent abuse of these new forms of work; calls on the Member States to promote the potential of technology such as digital data, high-speed internet, audio and video technology for smart (tele)working arrangements[27].

The benefits of teleworking entail a reduction of issues connected with commuting, for both workers and companies, giving workers greater autonomy and flexibility (spatial, temporal, and organizational), and

[26] Eurofound, *Op. cit.*
[27] European Parliament resolution of 13 September 2016 on creating labor market conditions favorable for work-life balance (2016/2017-INI).

establishing a better overall work-life balance, and higher productivity. Employers also benefit from teleworking, registering increased worker motivation and reduced turnover, increased productivity and efficiency, reduced costs related to office space and related costs.

One method of enhancing the positive effects of teleworking, and mitigating its negative effects, could be balancing and rationalizing the use of information and communication technologies, establishing part-time forms of teleworking with a well-regulated length of working hours. In addition, legislation on workers' health and safety at work should be implemented and telework policies should be dynamically adapted to the advancement of technologies, to workers' and employers' needs, and now to the new working landscape generated by the pandemic. Finally, in order to make the most of the potential of teleworking, specific and targeted training in the use of information and communication technologies is needed for both employers and workers[28].

A very significant scenario for the use of teleworking concerns all professional categories of the healthcare sectors. Doctors and patients can interact more efficiently now that technology has made it possible to overcome the constraints of physical distance: several concrete cases of Smart Working implementation are currently in use in the health professions and the COVID-19 pandemic has shown clearly the relevance of those new tools in support of distance health assistance.

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[28] Eurofound, *Op. cit.*

General practitioners are able to offer consultation services for clinical analyses to patients at home in Smart working, allowing them to receive the service while staying at home without having to go to the doctor's office. Remote working is presently also used for prescriptions for medications, blood tests, and medical examinations by specialists. The new e-medicine easily reaches patients with chronic diseases, who periodically repeat the same tests, or patients at low clinical risk, such as in the case of flu, minor traumas, and diseases suitable for remote treatment. In the meantime, the primary remote evaluation of COVID-19 cases, has played and still plays an important role in containing the risk of spreading the virus in case of suspected infection. The possibility of reaching the family doctor remotely is an important opportunity for elderly patients or people with reduced mobility, avoiding in many cases the need to go to hospitals. Using advanced telecommunication technologies for healthcare benefits National Health Systems in terms of reducing crowding and the risk of contagion, but also making more efficient use of emergency rooms, and projecting positive effects in general on urban environments.

Technological development related to telemedicine shows its usefulness as soon as it allows an increase in health and social-healthcare, contributing to ensure equity in access to care in remote/isolated areas, supporting chronic conditions management, ensuring easier access to highly specialized care, multidisciplinary comparison, and support for emergency-urgency services. The development and adoption of Telemedicine techniques and tools could be summarized as follows:

- **Equal access to and availability of qualified health care** in remote areas, including prisons, which otherwise entails extra inconvenience and additional costs, thanks to decentralization and flexibility of service provision through innovative forms of home care;
- **Improved quality and ensuring continuity of care.** Telemedicine aims to bring the doctor's service to the patient's home, without the need to physically travel, if it is not necessary;
- **Better treatment for chronic diseases**, with improvement in the quality of patients' life, thanks to self-management and remote monitoring solutions;
- **Improved effectiveness**, efficiency, and appropriateness, i.e. better use of the system supported by information and communication technology;
- **Improved communication** between stakeholders. This leads to the optimization of the use of available resources and the reduction of risks linked to complications, recourse to hospitalization and waiting times;
- **Optimal management of human, technological, and clinical resources** between different departments in the area[29].

Therefore, in a social context characterized by an aging population and increasing chronicity of pathologies, e-health can be synergistic with telemedicine interventions in prevention activities. E-Health is

[29] PA Forum, 2016, S@lute2016 – L'innovazione digitale e nuovi sistemi di logistica nella sanità pubblica in Italia (www.forumpa.it).

characterized by the possibility of interdisciplinarity, thus allowing better service thanks to faster availability of information on the state of each individual's health, allowing the optimization of the doctor's intervention[30].
At the regulatory level, the European Commission has highlighted the issue of Telemedicine with its 2008 Communication "Telemedicine for the benefit of patients, healthcare systems and society"[31]. With this document, the European Commission summarizes several actions, involving all levels of government within the EU and individual Member States, to promote greater and more effective integration of telemedicine services in clinical practice[32]. In Italy, following the European Commission, in 2012 the General Assembly of the *Consiglio Superiore di Sanità* (High council for health), approved the National Guidelines on Telemedicine, recommending that the Ministry of Health share the document with the regions and autonomous provinces to promote "a coordinated, harmonious and coherent development" of telemedicine within the National Health Service. In 2014, the State-Regions Conference reached an agreement on the shared text[33]. This is a very significant achievement given

[30] Ministry of Health 2011, *The National eHealth Information Strategy National context, state of implementation and best practices*, Rome and Ministry of Health 2014, Telemedicina. Linee di indirizzo nazionali, Rome.
[31] Communication from the Commission to the European parliament, the Council, the European economic and social committee and the committee of the regions 2008, COM(2008)689 final, *On telemedicine for the benefit of patients, healthcare systems and society*, Brussels.
[32] PA Forum, *cit*.
[33] Italian Government, Presidency of the Council of Ministers, State-Regions and Unified Conferences, Agreement between the Government, the Regions and the Autonomous Provinces of Trento and Bolzano 2003,

the need to review the organizational and structural model of the National Health Service[34]. On the specific sector of distance teaching and learning activities, in the political priorities of her candidature as president of the EU Commission, Ursula von der Leyen stated that:

> [...] my priority will be to get Europe up to speed on digital skills for both young people and adults by updating the Digital Education Action Plan. We need to rethink education by using the potential the internet provides to make learning material available to all, for example by the increased use of massive open online courses. Digital literacy has to be a foundation for everyone[35].

This clear indication given by President von der Leyen has been translated by the European Commission into the EU communication "Digital Education Action Plan 2021-2027"[36], published at the end of summer 2020 after the first dramatic pandemic wave. The plan is closely related to two other relevant Commission documents, namely the "European Skills Agenda for sustainable competitiveness, social fairness and resilience"[37] and the "The European

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Telemedicine. National Guidelines, Understanding pursuant to Article 8, paragraph 6, of Law n. 131 of 5 June.

[34] Ministry of Health 2011, *Telemedicine*.

[35] Leyen von der U. 2019, *A Union that strives for more. My agenda for Europe, Political Guidelines for the next European* Commission 2019-2024, Publications Office of the European Union, Luxembourg.

[36] European commission, COM(2020) 624, final Communication from the Commission to the European Parliament, the Council, the European economic and social Committee and the Committee of the regions, *Digital Education Action Plan 2021-2027 Resetting education and training for the digital age*, Brussels.

[37] Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the committee of the Regions, *European Skills Agenda for sustainable competitiveness, social fairness and resilience* , COM(2020) 274 final, Brussels.

Green Deal"[38], considered as a transversal policy for all EU activities. The three documents are designed to contribute to the implementation of the European Pillar of Social Rights promoted by president of the EU Commission Junker[39] in November 2017, specifically referring to Equal opportunities and access to the labour market, Fair working conditions and Social protection and inclusion. Preparation of the three fundamental documents started in early 2019, according to the political vision of President von der Leyen, however all of them also reflect the substantial impact of the COVID-19 pandemic on the European education systems. With regard to the impacts of COVID-19 on education, the 2019/2020 outbreak forced all education systems around the world to switch abruptly from in presence to digital technologies, in order to provide education and training. In Europe in particular,

> […] the digital transformation in education is being driven by advances in connectivity; the widespread use of devices and digital applications; the need for individual flexibility and the ever-increasing demand for digital skills. The COVID-19 crisis, which has heavily impacted education and training, has accelerated the change and provided a learning experience[40].

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[38] Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the committee of the Regions, *The European Green Deal*, COM(2019) 640 final Brussels.

[39] Jean-Claude Juncker (1954), is a Luxembourgish politician who served as the 23rd Prime Minister of Luxembourg from 1995 to 2013, as Minister for Finances from 1989 to 2009, and as President of the European Commission from 2014 to 2019.

[40] Communication, *Digital Education* 2020, p 1.

The world is still fighting in 2021 with the effects of the pandemic, and most of the measures regarding social distancing are still enforced in order to contain the spread of the virus, despite the on-going vaccination campaigns. The labor sector, as well as the health and education sectors, are still trying to respect their obligation to carry out their activities in remote form, struggling with network malfunctions and the 'digital divide'. As stated in the preamble of the Digital education plan:

> […] COVID-19 pandemic has accelerated the digital transition. While telework and distance learning have become a reality for millions of people in the EU, the limitations of our current digital preparedness were often also revealed. The pandemic has accentuated the digital skills gap that already existed and new inequalities are emerging as many people do not have the required level of digital skills or are in workplaces or schools lagging behind in digitalization[41].

What is clear from this picture is that the traditional in presence way to work, study and assist patients in the health sector, are not just temporarily changed. They are presently the subject of an insightful transformation, with long-term scenarios still difficult to foresee.

Internet of Things (IoT), home automation and Artificial Intelligence (AI)

Modern buildings, in general, still obey the three principles of architecture set out by Vitruvius in "De Architectura", namely *Firmitas*, *Utilitas* and *Venustas*[42].

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[41] Communication, *European Skills*, 2020. p. 1.

[42] *"Haec autem ita fieri debent, ut habeatur ratio firmitatis, utilitatis, venustatis"*. (In all things to be made, the aim must be solidity, usefulness and beauty...), Marcus Vitruvius Pollio, *De Architectura*, liber I, 2.

They are historically the privileged places where humans develop their social interactions. While Vitruvius' principles are still substantially valid today, the modern reinterpretation of the ancient idea of *Utilitas* forms the context of this book, where it is addressed in relation to the technological (and sometimes ethical) understanding of the functionalities of contemporary homes and cities.
Most of the built environment in modern cities[43] consists of physical walled spaces, where people spend most of their lifetime, whether in residential buildings or at their workplaces. These personal spaces are more than just physical residences; they often become the intimate safe dimension where citizens can live and rest, enclosed environments where modern technologies meet (and sometimes clash) with humanity, bringing to mind Le Corbusier's early twentieth-century definition of the house as "*…a machine to live in*"[44].
Today, however, new and groundbreaking elements are emerging. Houses, having increasingly improved support functions for the inhabitants and equipped with devices and instruments that expand their efficiency, are evolving towards a new stage of interactive technology.

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[43] The term 'built environment' appears in the 2014 essay *Moving forward for an Ageing Society: Bridging the Distances*, and it could be defined as the place where schools, hospitals, social services and healthcare facilities, and in general, highly specialized services, are available not far from residential areas, in order to improve citizens' quality of life, Cinquepalmi F., *et al.* 2014, *Moving forward for an Ageing Society: Bridging the Distances*, Palombi, Rome, p. 17.
[44] '*La maison est une machine à habiter*' Charles-Édouard Jeanneret-Gris, known as Le Corbusier 1923, *Vers une architecture*, les editions G. Cres et C. Paris, p. 83

Home automation or Domotics[45], houses that 'learn' how to interact directly with humans, are increasingly able to meet their needs and learn from their habits. Although most of the technologies concerned are well known separately and already in use, the real innovation lies in their combination and reorganization under the Domotics umbrella and in connection with Artificial intelligence. This will not mean increasing the technological complexity of houses by adding advanced technologies and devices, but rather transforming houses and buildings into technological-intelligent objects *per se*, able to elaborate tailored solutions according to their analysis of the behaviors of the human inhabitants, and gradually acquiring the ability to adapt to their needs and requests, even those unexpressed. A transformation is under way: from "*a machine to live in*", the house is becoming "*a machine to live with…and through*".

The first step was undoubtedly the integration of existing and well-tested home automation technologies into the domestic environment, but the real paradigm shift is being brought about by Artificial intelligence in its Machine Learning version. This could be considered a Darwinian evolutionary process in which housing units learn how to adapt to the needs of their inhabitants, supported by Artificial intelligence. Buildings equipped with advanced sensors and able to 'perceive' internal and surrounding conditions, could optimize energy

[45] Domotics (from the Latin word *Domus*, house) can be defined as the application of advanced information technologies, digitalization and artificial intelligence to houses and buildings, with the aim of increasing comfort and improving the quality of life within the domestic space.

consumption with positive effects on both family savings and the environment, while in the meantime also creating an optimized internal climate and protecting the home from unauthorized intrusions. Domotics interactions between residents and technical devices will enhance support especially for fragile categories, such as the elderly, children, and people with disabilities, in an increasingly comfortable and intelligent way, assuring an improved standard of care or appropriate human intervention.

The preconditions for realizing the new intelligent buildings are produced by the evolution of 'IoT' where the term 'Internet of Things' refers to all digital devices operating in the same networks on a global scale. Unlike traditional Internet, where individual people connect to a common network through personal devices, IoT comprises only intelligent sensors and other devices; its uses include the collection of operational data from remote sensors that can be used both for monitoring and control and for the implementation of devices and/or procedures.

The Internet of Things (IoT) for Smart Homes is presently growing in Italy, although it has not yet developed its full and real potential. In Italy this market sector reached €350 million in 2019, with a 55% growth compared to 2016. According to a survey from the Internet of Things Observatory of the School of Management of the Polytechnic University of Milan in collaboration with Doxa[46], Italians do not yet consider the Smart home

[46] Doxa is an opinion poll company operating in Italy since 1946.

setting a suitable option for their home improvement, preferring instead to invest in security and protection devices[47].

A Smart building is a domestic or working environment, equipped with the latest generation of sensors allowing the automatic 'detection' of relevant human and climatic data and information. IoT, Cloud, and mobile systems can store and transmit data to the building's owners and facility managers in order to improve the building's reliability and performance[48]. Smart buildings can be classified according to four categories of devices and technologies, those related to:

- **Energy**, concerning the production, management, and consumption of energy;
- **Entertainment**, dedicated to all audio-video multimedia equipment;
- **Security and Safety,** aimed at risk prevention and management;
- **Comfort,** concerning all connections, sensors and devices related to human physical presence.

However, we must bear in mind that an automated building is not necessarily also intelligent: the distinction depends on the fact that a building to be considered "intelligent" must not only be equipped with technologies and devices: these must also be interconnected and communicate constantly and automatically with a supervising control infrastructure. It is still perhaps

[47] Doxa, Smart Home, it's boom in 2017 (+35%).

[48] Hardwire Internet of Things solutions for industry, IoT and Smart Building: smart buildings, efficient buildings.

too ambitious to envisage a true symbiotic interaction between humans and advanced digital Domotics homes. Certainly, though, it is fascinating to imagine a possible evolutionary leap from machine learning towards some kind of consciousness that one day might be realized thanks to the fruitful collaboration achieved in home automation, and successively extended to other fields of application of Artificial intelligence[49]. We must keep an attentive eye on the technological evolution of buildings, always bearing in mind that human needs and desires must have absolute priority.

The present urban evolution related to digital technologies is aimed at digital integration not only of single houses and buildings, but also of infrastructures, roads, supplies and waste systems. The design of contemporary buildings and the integrated design of infrastructural systems are evolving with the best available technologies, in order to cope with societal challenges and perform in an increasingly 'intelligent' way.

In this picture, so-called Artificial intelligence (AI) is therefore the most promising additional tool for analyzing reality, developing different scenarios, and simulating something similar to human intelligence[50].

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[49] Cinquepalmi F., Carlino F. 2019, *Oiko-domotica: visioni di simbiosi abitative nel terzo millennio - Oiko-domotics: visions of living symbiosis in the third millennium*, *Architettura, Tecnica e Legislazione per Costruire*, Ponte 1, pp. 7-9.

[50] In a 2018 Communication, the European Commission defined Artificial Intelligence as "…*systems that exhibit intelligent behaviour by analysing their environment and performing actions, with some degree of autonomy, to achieve specific goals*", European Commission, COM 237 final, Brussels. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Artificial Intelligence for

AI systems use 'neural circuits' that can be described as computational systems, imitating some functions of the human nervous system in order to achieve automatic learning. Human operators monitor this learning process, correcting the programme when it fails and providing positive feedback when it works correctly. Artificial intelligence, applied to artificial vision, data analysis, and predictive data analysis, is able to radically change management and control procedures within urban functions. The potential fields of application in smart cities can be summarized as follows:

- traffic control and related applications;
- physical security and anti-intrusion systems;
- biometric recognition and people tracking;
- energy optimization of buildings and grids;
- satellite image analysis for land and soil management;
- monitoring of critical infrastructures;
- big data analysis for urban logistics optimization;
- public administration support systems;
- sustainable mobility with unmanned vehicles.

The fields of application that are already relevant on the global market concern the regulation of energy grids and home automation. The International Energy Agency (IEA) predicts that in the energy field AI will be decisive in the years to come and will deeply transform global energy production and transport systems, interconnecting them in a reliable and sustainable way. In the field of clean energy production and consumption, there are many issues that AI can help to solve, and many projects

Europe, swd(2018) 137 final, Brussels, p. 1.

are already launched based on this technology, namely in the field of renewable energy production, in order to cope with the uncertainty of weather conditions.
Photovoltaic or wind power energy production is notoriously risky because adverse weather conditions may make it necessary to compensate with traditional energy sources. AI could help to optimize production, transmission, and storage of energy from photovoltaic or wind systems scattered across the territory, integrating real-time weather satellite data, identifying recurring and seasonal patterns, maximizing efficiency grids also according to statistical peaks of consumption, while minimizing the risk of blackouts or burnouts.
At the Microgrid home level, AI applied to energy consumption and efficiency in single buildings is perhaps having an even more decisive impact. The household sector for AI represents the greatest potential as it is estimated that by 2040 there will be one billion 'smart' homes and 11 billion smart devices worldwide, and their optimization through Artificial intelligence would allow a decrease of more than 10% in household energy consumption. Even at present, interconnected grids and devices are already producing a massive amount of data, available for public and private utility companies, mainly used for tailored personal solutions for consumers.
Monitoring the use of household devices and local grids with AI tools could help estimating individual consumption, analyzing personal habits and daily use statistically, thus approximating the hypothetical monthly bill and allowing sustainable personal choices. Practically speaking, AI integrated within a household system detects

energy needs and intervenes actively, avoiding unnecessary consumption. In case solar energy reserves are not adequate, the AI guided home will be able to switch off unnecessary devices automatically, or to reduce their consumption when possible, sending appropriate warning messages to the householder. Present and future applications of AI are being continuously tested, mainly in the field of *Domestic Domotics*, and their evolution will certainly be greatly accelerated by the forthcoming spread of 5G telecommunication wireless technology, able to transfer an unprecedented flow of information and data to predictive systems, largely superior than the ones available at present.

Managing urban environments with Digital Twin models

At the beginning of the 4^{th} Industrial Revolution, the rise of digitalization, innovative technologies, and materials as well as the emergence of new construction techniques, transformed the way that infrastructures, real estate and building assets can be planned, designed, constructed, and made operational to create a more attractive, energy-efficient, comfortable, affordable, safe, and sustainable built environment. Developments in digital design, Artificial Intelligence, robotics, nanotechnology, and additive manufacturing, have finally started to move the construction industry – traditionally reluctant to innovate and slow to adopt new technologies – towards a new era.
In particular, the architecture, engineering and construction (AEC) sector is facing a rapid and considerable transformation given the diffusion of BIM (Building Information Modelling), which is consistently

modifying construction workflows. In such an innovative framework, even the innovations related to the Internet of Things (IoT) and Smart Cities in general are changing urban planning and development dramatically, improving urban 'intelligence' and sustainability[51].

The goal of digitization within the AEC sector is to build digital processes and ecosystems based on three-dimensional digital models, combining physical objects and components, and monitoring their interactions with reality, following the Digital Twin Model approach. According to Sue Weeks, a Digital Twin could be defined as the transposition of a real world object to a virtual/digital representation, aimed to evaluate its functionality and perfomance[52]. Digital Twins (DT) for building systems are designed as three-dimensional real-time databases, where data are encompassed within object-oriented models representing building components as well as their qualities and other useful information, aimed at simulating activities and real-time management of processes. The concept of DT implemented at urban environment scale gives rise to the concept of City Digital Twin (CDT), a virtual model which upgrades the single building approach to a higher and more complex level. The Digital Twin City is essentially able to improve and enrich the knowledge received through input data and signals coming from

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[51] Perera C., Zaslavsky A., Christen P., Georgakopoulos D., 2014, *Sensing as a service model for smart cities supported by the Internet of Things*. Transactions on Emerging Telecommunications Technologies, 25, pp. 81-93.

[52] Weekes S. 2019, *The rise of digital twins in smart cities*, SmartCities-World, on line platform (www.smartcitiesworld.net)

the continuous data flow obtained by the continuous monitoring of urban systems, namely by smart sensors, IoT, smart metering, personal mobile data and information. DT is progressively developing self-learning and predictive capabilities through Machine Learning, Artificial Intelligence, Deep Learning and Neural Networks[53].

Therefore, the development of a CDT usually moves from a Building Information Model (BIM), a three-dimensional database that communicates with data and sensors, acquiring some levels of self-learning using Artificial Intelligence algorithms, progressively developing predictive capabilities and allowing some level of autonomous decisions and actions based on the analyses performed[54].

The Digital Twin of an urban environment can therefore be a key tool for organized data collection, storage, analysis and visualization for the daily management of urban life, and for the integrated use of Geographic Information Systems (GIS) and Building Information Modelling (BIM), expanding the information data management and processing from single buildings to territorial scale. Since the building sector remains the

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[53] In the field of machine learning, an artificial neural network (abbreviated as ANN or also as NN) is a computational model composed of artificial "neurons" inspired by the simplification of a biological neural network. Such mathematical models are used to attempt to solve artificial intelligence engineering problems such as those of technological fields (in electronics, computer science, simulation, and other disciplines).

[54] ISO20944-1:2013: Information technology - Metadata Registries Interoperability and Bindings (MDR-IB) - Part 1: Framework, common vocabulary, and common provisions for conformance. Standard, International Organization for Standardization, Geneva.

largest end-energy consumer (up to 40% globally), all the Information and Communication Technologies (ICT) mentioned have been identified as playing an important role in reducing the energy intensity and increasing the energy efficiency of the building stock.

The amount of information to be processed must be managed with ICT methodologies and solutions through an integration process that requires a "wide-scale" vision and design method: from Satellite-Land scale to the "vertical" BIM.

The main approach is that of management continuity between building related representation and information and, thanks to Artificial Intelligence (AI), building systems are becoming able to integrate autonomously the data flow derived from domestic IoT devices and occupant behavior for improving performance and environmental efficiency. When AI is integrated with building systems and IoT devices, it has the potential to improve occupant experience, increase operational efficiency and optimize space and asset utilization. A vast array of information from digital devices furnishes insights about the operativity, use and conditions of a building's infrastructure, physical internal microclimate, external climate, water, and energy use, providing dwellers with a better living experience and greater satisfaction.

IoT and platforms embedded with Artificial Intelligence and machine learning make it possible to develop innovative new services for engaging with building occupants[55]. These systems have the potential to radically

[55] Guillemin P., Friess, P. 2009, *Internet of things strategic research*

reduce costs through automation and optimization of operations. By taking advantage of powerful analytics and Artificial Intelligence, for example, building owners can significantly cut energy consumption and achieve ambitious cost-saving targets. After equipment performance, information is collected through sensors and smart meters, a library of benchmark data is applied, analytics are performed, and potential operational improvements are identified. Advanced analytics tools can be also used to prevent energy waste by isolating inefficient energy use.

Sensor-controlled systems can monitor water distribution and use, cognitive maintenance systems can help preserve the proper functioning of critical building equipment and assets, anticipating possible failures and guiding timely maintenance interventions. A comprehensive building optimization system leverages all aspects of building and facility management.

Taking these monitoring activities one step further, building equipment data collected from IoT sensors tagged by location or asset type and associated with business rules can trigger algorithms to not only detect but also predict and respond to anomalies. For instance, data transmitted from connected assets, such as boilers, pumps, air conditioning systems and elevators, are analyzed and enriched to identify anomalies, such as equipment operating outside of normal registered parameters, standardized in order to be evaluated not only

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roadmap. The Cluster of European Research Projects, Technical report, European Commission - Information Society and Media DG, Brussels.

on the basis of the operative conditions provided by the manufacturer when newly installed, but also after some years of use. Devices automatically receive instructions to take corrective actions, and building AI memorizes the intervention results in order to improve the accuracy of detection and resolution for future occurrences.

In the meantime, these optimized ecosystems of building technologies identify further opportunities for efficiency controls through predictive maintenance[56], and building DT identifies possible inner causes, not necessarily depending on the malfunctioning of a single device, thus helping to improve the entire interconnected system, and sending appropriate communications to human maintenance teams, to the building administrator and to the landlord. AI is also able to capture data from day-by-day building operations, enabling new levels of real-time automation, giving to the buildings the capacity to "think," engage and learn, autonomously monitoring and predicting self-maintenance needs[57].

The integration of cognitive analytic sensors can also significantly improve dwellers' living experience. IoT sensors are constantly monitoring movements, indoor air quality, temperature, and other human related parameters[58], switching lights on and off, adjusting

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[56] Anvari-Moghaddam A., Monsef H., Rahimi-Kian A. 2015, *Optimal Smart Home Energy Management Considering Energy Saving and a Comfortable Lifestyle*, «IEEE Trans. Smart Grid», vol. 6, n. 1, pp. 324–332.

[57] Vastamäki R., Sinkkonen I., Leinonen C. 2005, *A Behavioural Model of Temperature Controller Usage and Energy Saving*, «Personal and Ubiquitous Computing», pp. 250-259.

[58] ISO16678:2014: *Guidelines for interoperable object identification and related authentication systems to deter counterfeiting and illicit trade*.

restroom water flow, obeying voice commands, learning and adapting to the tone of voice of occupants. Even breaths are monitored for carbon dioxide concentration and corrected with appropriate airflow adjustments.

This kind of approach to problem-solving is related to real-time simulation modeling, which aims at reproducing the behavior of a non-linear dynamic system in a virtual environment. It serves as a digital testbed to evaluate ex-ante different strategies over a simulated time-horizon.

Digital Twins can therefore involve Artificial Intelligence but also Machine learning (ML), enabling the DT system to learn from data rather than through programming on purpose. ML is a form of self-learning data model, comparable to children's learning, driven by progressive "experience". Data-models are incrementally refined, through data gathering, supplying "machine-learning" algorithms, where the quality referred to the algorithm is a direct function of data quality[59].

Machine Learning (ML) techniques are essentially divided into two main categories: *Supervised learning* or *Unsupervised learning*. Given a sample of data and a desired output, *Supervised Learning* is based on the so called 'ground truth'[60] and its goal is learning on the basis of the function that best estimate expected outputs, as determined from clearly known inputs, using acceptable

Standard, International Organization for Standardization, Geneva.

[59] Martínez-Prieto M. A., Cuesta C. E., Arias M., Fernández J. D. 2015, *The Solid Architecture for Real-time Management of Big Semantic Data*, «Future Generation Computer System», 47, pp. 62-79.

[60] The term 'Ground truthing' in Machine Learning refers to the process of gathering a proper provable ideal expected result.

approximation and statistical experience. On the other hand, *Unsupervised Learning* does not have clearly identified outputs (tagged data), and the algorithm in this case self organizes data, with the aim of guiding the input data charge (non-tagged data), according to a self-constructed internal classification.

ML in fact is typically related to classification of data (input and output tagged data) or regression of data (relating input to a continuous output)[61]. In both regression and classification, the goal of machine learning is to find specific relationships in the input data that make it possible to produce correct outputs, where model complexity refers to the complexity of the learning function; the appropriate level of algorithm model complexity is defined by the nature/structure of the data acquired during the machine's training.

In fact, a high-complexity model, if used on a small/limited quantity of data, will overload the function (overfitting)[62], reducing the algorithm's capacity to generalize other self-elaborated data. In this case the learning process can produce training data, without acquiring a structure in the data able to lead to a meaningful output.

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[61] All algorithms for Machine learning are divided into two families: algorithms of classification (AoC) and algorithms of regression (AoR). AoC essentially classify the data; AoR interpolate data. This implies that the output of a Classification model results in a class, and the output of a Regression model gives a number.

[62] Overfitting happens when a model learns too much detail in the training data. This kind of "noise" negatively impacts the performance of the model on new data, since noise or random fluctuation confuse the learning process and the Machine is unable to distinguish relevant from non-relevant data, negatively impacting on the algorithms' ability to generalize through regression.

The machine learning specifically related to computers is also called Deep learning[63], a form of machine learning enabling computers to learn from experience, self-hierarchizing concepts. Such a hierarchy of concepts allows the computer to learn complicated notions, relating them to other simpler ones already stored in its memory. Deep learning techniques are the ground basis of digital applications such as: natural language processing; speech recognition; computer vision and related digital image recognition; online recommendation systems; bioinformatics, and videogames.

In conclusion, today major progress in Artificial Intelligence is taking place through systems combining representation learning[64], developed through specific and customized algorithms and rule-based systems.

European cities from space: the EU Copernicus programme

In Europe the importance of Earth observation and related services was officially recognized on 19 May 1998, when the *Baveno Manifesto*, a declaration creating the Global Monitoring for Environment and Security

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[63] Scientifically, Deep Learning is the learning of data not provided by humans but learned through the use of statistical computing algorithms. These algorithms have the purpose of understanding how the human brain works and manages to interpret images and language. The learning process has the form of a pyramid: the highest concepts are learned from the lowest levels. Deep learning techniques are widely used by practitioners in industry, including deep feedforward networks, regularization, optimization algorithms, convolutional networks, sequence modeling, and practical methodology.

[64] Bengio Y., Courville A., Vincent P. 2013, *Representation Learning: A Review and New Perspectives*, «IEEE Transactions on Pattern Analysis and Machine Intelligence», vol. 35, n. 8, pp. 1798-1828.

(GMES) program, was signed[65]. On that occasion, all institutions involved in the development of space activities in Europe expressed, through the Manifesto, their long-term commitment to developing a space-based environmental monitoring service, relying on European expertise and technologies[66]. This initial Earth observation programme was essentially aimed at the implementation of environmental and security information services, with in-situ or in-atmosphere data collection[67], combining the

[65] European Commission, Regulation (EU) n. 911/2010 of the European parliament and of the Council of 22 September 2010 on the European earth monitoring programme (GMES) and its initial operations (2011 to 2013) Official Journal of the European Union, Brussels.

[66] Alberti F. 2008, *La nuova iniziativa europea per lo spazio: Global Monitoring for Environment and Security*, «Quaderni IAI - Istituto Affari Internazionali», n. 32 Roma, p. 7.

[67] Italy is one of the countries in the Union with the most effective infrastructure in the space sector with the San Marco Project, a bilateral collaboration programme that saw Italy and the United States engaged in scientific research and experimentation on aerospace issues between 1962 and 1980. The project marked the beginning of the Italian space age with the launch of the first San Marco 1 satellite on 15 December 1964, making Italy the fifth nation to design and put into orbit an artificial satellite, after the Soviet Union, the United States, the United Kingdom and Canada. Today, Italy, in addition to being a founding country of the European Space Agency (ESA), is one of the most effective EU countries in this sector, thanks both to its own Italian Space Agency (ASI) and to its network of ground and atmospheric services.
Law n. 7 of 11 January 2018 "*Measures for the coordination of space and aerospace policy and provisions concerning the organisation and functioning of the Italian Space Agency*" gives the President of the Council of Ministers general political responsibility and policy coordination of the Ministries relating to space programmes. It establishes the "Comitato interministeriale per le politiche relative allo spazio e all'aerospazio" (COMINT), in which 12 Ministers and the President of the Conference of Regions participate, with the task of defining the Government's guidelines for space and aerospace, directing and supporting the Italian Space Agency (ASI), approving the Strategic Document for National Space Policy (DSPSN), and identifying the priorities for participation in the European programmes of the European Space Agency (ESA). Furthermore, COMINT promotes the development of space and

existing space and satellite assets of the Member States to collect and elaborate environmental data, and make it available to end-users. In the meantime, EU Member States also committed to a specific intergovernmental agreement in order to provide the European Union with an autonomous capacity of earth and atmosphere observation through the development of the first six EU satellites, named *Sentinels*[68].

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aerospace programmes and related sectors, involving all aspects of national security and protection, including dual (civil-military) aspects, also to support and incentivise the transfer of knowledge from the research sector to the public utility services.

[68] **Sentinel-1** is a polar-orbiting mission that acquires SAR images, and is capable of operating even in cloud cover and at night. It is used in particular by land and ocean services. Sentinel-1A was launched on 3 April 2014 and Sentinel-1B on 25 April 2016.

Sentinel-2 is a polar-orbiting mission that acquires high-resolution multispectral images. It is used for land monitoring to provide, for example, information on vegetation, land cover, water status, and coastal areas. Sentinel-2A was launched on 23 June 2015 and Sentinel-2B followed on 7 March 2017.

Sentinel-3 is a multi-instrument mission that measures sea surface topography, sea surface and land surface temperature, ocean colour and land colour with high accuracy and reliability, at a sufficiently large spatial scale and at least daily frequency. The mission supports ocean and land forecasting systems as well as environmental and climate monitoring. Sentinel-3A was launched on 16 February 2016 and Sentinel-3B on 25 April 2018.

Sentinel-4 and Sentinel-5 are two instruments dedicated to monitoring the composition of the atmosphere, in support of Copernicus Atmosphere Services, and will be hosted by meteorological satellites operated by Eumetsat.

Sentinel-5 was preceded by Sentinel-5 Precursor (Sentinel-5P). It is capable of collecting data on a multitude of gases and aerosols that affect air quality and climate. Sentinel-5P has been in orbit since 13 October 2017.

Sentinel-6 is equipped with a radar altimeter to measure the global height of the sea surface. Its main use is for operational oceanography and climate studies. The Sentinel family will be enriched by other missions, whose development is currently under the supervision of the European Space Agency.

Recognizing the strategic importance of joint actions in the field of Earth observation and emergency management, in 2014 the European Commission launched a renewed Earth observation program, called the Copernicus program[69], considered the natural evolution of the previous GMES program. The decision to replace the GMES acronym with the name Copernicus was essentially aimed at

> […] facilitating communication with the general public[70], linking the European Earth observation program and related services to the figure of Nicolaus Copernicus[71].

Today, the Copernicus program provides the European Union and its Member States with global, continuous, autonomous, high quality, wide-area Earth and Atmosphere observation. Copernicus links space observations to ground-based and atmospheric data collection and processing, provides operational services in the fields of environment, ground infrastructures, civil protection and civil security[72],

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[69] European Commission 2014, Regulation (EU) n. 377/2014 of the European Parliament and of the Council of 3 April 2014 establishing the Copernicus Programme and repealing Regulation (EU) n. 911/2010 Text with EEA relevance, Official Journal of the European Union, Brussels.

[70] *Ibidem*, p. 1.

[71] Nicolaus Copernicus (1473 - 1543) was a Polish astronomer and mathematician, who graduated in canon law from the University of Ferrara in 1503. He is famous for having advocated, defended and eventually definitively promoted heliocentrism against the geocentrism that had hitherto been held in the Christian world. Although he was not the first to formulate this theory, he was the scientist who most rigorously demonstrated it using mathematical procedures (Copernican Revolution).

[72] The programme is user-led through the Copernicus Committee and the Copernicus User Forum, bodies recognised by the European Commission and the Presidency of the Council of Ministers. The

and supports the implementation of a large number of sectorial and transversal European public policies. Copernicus' objectives include ensuring Europe's independence in gathering a large range of data and information on the state of the planet, helping decision makers at all levels, making possible the continuous tracking of land, seas, and human infrastructures with the *Sentinel* satellites. Copernicus' services are organized in six thematic macro-areas, namely: soil (Land monitoring service), sea (Marine Environment Monitoring Service), atmosphere (Atmosphere monitoring Service), climate change (Climate Change Service), emergency management (Emergency Management Service) and security (Security Service). Observation and ground monitoring of the European urban systems lies in the first thematic area of the Land monitoring service[73].

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programme, to be funded under the 2021/2027 eu Multiannual Financial Framework (MFF) at €5.8 billion, aims to achieve a global, continuous, autonomous, high-quality, wide-area Earth observation capability and to provide accurate, timely and easily accessible information to improve environmental management, understand and mitigate the effects of climate change and ensure civil security, using big data from satellites and ground, airborne and marine measurement systems. Information processing, service management and the timely and high-quality processing of knowledge in the fields of environment and security at global level aim to help service providers, public authorities and other international organizations to improve the quality of life of European citizens.

[73] Copernicus products within the Land monitoring service thematic area are: Very High Resolution Mosaics (general soil mapping) CORINE Land Cover (CLC, which provides biophysical features on the ground), Riparian Zones (which monitors transition zones along rivers and lakes), Natura 2000 (N2K which monitors nature protected habitats), Urban Atlas (first service to create harmonised land cover and land use maps over several hundred cities in both the EU and European Free Trade Association countries, (Norway, Iceland, Liechtenstein and Switzerland), EU Digital Elevation Model (EU-DEM, combining data from different

Each Sentinel mission is composed of two satellites, necessary to meet the time and space coverage requirements established by the Copernicus services. These missions utilize a wide range of observational technologies, divided in active technologies, such as synthetic aperture radar (SAR), and passive technologies, such as a number of instruments operating through the optical observation tools needed for monitoring earth surface, oceans, and atmosphere. All the satellites are used for emergency and security services as well as for collecting data enabling climate change evaluations.
Even though the deep understanding of the functioning of urban systems is a key factor for improving the quality of life at all levels, urban development is still poorly monitored globally, and reliable and comparable satellite urban data across countries is still limited, slowing down international comparative research.
This also because of the difficulty to agree on a fully shared administrative and territorial definition of a city, on what should properly be considered "urban" and on the logical and scientific categories to be used as descriptors.
In 2011, the OECD and the European Commission attempted to resolve this issue by developing a standardized methodology for defining appropriately and comparing urban areas more accurately. In contrast to the traditional definitions based on administrative boundaries, the joint OECD/EC work focused on the economic function of cities, to improve existing

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sources into a single homogeneous data and information system), EU-Hydro (provides river basin monitoring) and Global systematic & hot spot monitoring.

analytical tools and allow a more accurate comparison of the economic and social performance of cities located in different countries. The initial database used by the OECD/EC[74] includes over 1 100 urban areas from 28 OECD countries, divided into coherent clusters and essentially classified in four categories: large metropolitan areas, metropolitan areas, medium-sized urban areas, and small urban areas. Using this database, the Regional Focus edited by Dijkstra and Poelman in 2012[75] considered 828 cities with an urban center of at least 50 000 inhabitants, distributed across the EU, and including Switzerland, Croatia[76], Iceland and Norway. Half the European cities considered are relatively small, with a population between 50 000 and 100 000 inhabitants. Only two of them are considered to be global cities (London and Paris), and in total the cities considered are home to about 40% of the EU population; the study did not include smaller cities and suburbs, which host another 30% of the EU population.

The methodology proposed by the OECD/EC research is based on a harmonized definition, referenced to a 1 square kilometer grid, which identifies urban areas as functional economic units. Using population density[77]

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[74] OECD 2012, *Redefining 'Urban': A New Way to Measure Metropolitan Areas*, OECD Publishing.

[75] Dijkstra L., Poelman H. 2012, *Cities in Europe, the new OECD-EC definition Regional Focus*, A series of short papers on regional research and indicators produced by the Directorate-General for Regional and Urban Policy.

[76] Croatia concluded accession negotiations as EU Member State on 30 June 2011, and signed the Treaty of Accession on 9 December 2011.

[77] The source of the population grid data for European countries is the disaggregated population density with the Corine Land Cover dataset,

and work mobility flows as key information, urban areas can be described as densely populated 'urban centers' surrounded by 'hinterlands', highly interconnected with the cores by the movement of commuting population. The definition of urban areas as functional economic units, based on the differentiation between the dense 'urban center' and the functionally connected outskirts of the 'city', is well described by Dijkstra and Poelman[78] in four basic steps, namely:

- All grid cells having a population density greater than 1 500 inhabitants per square kilometer are selected;
- Contiguous high-density cells are then clustered, empty spaces are filled and only clusters with a minimum population of 50 000 inhabitants are retained as 'urban centers';
- All municipalities (Local Administrative Units level 2 or LAU2) with at least half of their population within the urban center are selected as candidates to become part of the 'city' surroundings.
- The perimeter of the city is then established ensuring that a) there is a link at the political level, b) at least 50% of the population lives in the 'urban center' and c) at least 75% of the population of the 'urban center' lives in a 'city'.

The methodology constructed by the OECD/EC, although based on a purely quantitative assessment of urban perimeters and urban "entities", has built a fundamental standard of comparison

produced by the Joint Research Centre for the European Environmental Agency (EEA).

[78] Dijkstra L., *Op. cit.*

for the development of statistically consistent research and comparisons of urban areas across different countries, linked to satellite data sources. In this perspective, the Copernicus program, allowing a global, continuous, autonomous, high quality and wide-ranging monitoring of the state of the atmosphere, soils and a large number of related parameters, could allow further refinement of this methodology, linking observations and quantitative definitions, and contributing to the collection and processing of data. This would allow the construction of an accurate and up-to-date database on the state of health of our cities and surrounding environments, providing research materials simply inconceivable only a few decades ago.

Copernicus satellites contribute in a variety of ways to our knowledge of urban areas. For example, the SAR[79] of Sentinel 1 allows the monitoring of ground, buildings, and infrastructures movements with millimetric precision; while the huge data sets acquired until now by Sentinel 1 and Sentinel 2 allow monitoring of land use, land cover, urban growth, and infrastructures. The *Urban Atlas*[80], collecting data from Land monitoring services and specifically dedicated to monitoring urban areas, can be used as a basis for several further uses, such as monitoring air quality over the cities as well as evaluation of the prior and post conditions of buildings

[79] Synthetic-aperture radar (SAR) is a radar used to create two-dimensional or even three-dimensional images of ground located objects, or landscapes features. The advantage with respect to optical sensors is that SAR reads the ground surface also with cloudy weather.
[80] https://land.copernicus.eu/local/urban-atlas.

and infrastructure after disastrous events (earthquakes or extreme climatic events)[81].

An interesting initiative for the academic world is the establishment in 2018 of the "Copernicus Academy" an European academic and scientific network, promoted by EU Commission, currently involving some of the most relevant Italian universities, representing the Italian academic community on the network, as well as other subjects, both public and private. The aim of the Copernicus academy is to promote the interest of the academic community, as well as of the entire educational chain, towards all themes related to Earth observation. Also indirectly to increase the awareness of European citizens towards the importance of EU and Member states' investments in the Space Economy sector, showing the opportunities deriving from Copernicus services, for both the welfare and security of the whole European Union[82].

Risk management and insurance tools for urban resilience*

As clearly reported in other sections of the present chapter, fragilities of urban systems are increased

[81] Cinquepalmi F. 2019, *The Copernicus programme: Europe's eye on urban areas*, in Dwelling on Earth Gangemi, International, supplement, 2, n. 51, pp. 12-15.

[82] The Italian National Delegation to the European Copernicus Committee decided in September 2018 to create a National Copernicus Academy Network, currently involving the main Italian universities, representative of the academic community as well as other subjects, both public and private, in order to define, support and implement a National Action Plan.

* This subsection has been written with the technical contribution of Giulia De Toma (M.Arch.), senior expert on risk management for building insurance

at present by extreme events such as earthquakes, floods, volcanic eruptions, hurricanes, and fires, multiplied by the effects of climate change. Italy, due to its geomorphology is one of the most vulnerable countries in Europe in that sense[83]. Bearing this in mind, it seems especially important to identify the potential vulnerabilities of the built environment in order to define strategies aimed at enhancing urban resilience. The evaluation of vulnerability, from that of a single building on up to an urban scale, is based on the combined analysis of descriptive factors (materials, construction techniques, age) of the building itself and of the surrounding environment (location, geomorphological and seismic risk, potential exposure to meteo-climatic effects). Increasing knowledge of the peculiarities of buildings and their related territories and an enhanced culture of prevention, maintenance, and risk management, are key factors for ensuring sustainable conservation of public and private real estate. A useful supporting tool for urban management is the proper use of insurance contracts[84] that help cope with the risk

[83] This claim is supported by data from the Germanwatch Global Climate Risk Index, an analysis based on one of the most reliable data sets available on the impacts of extreme weather events and associated socio-economic data. The annual study by Germanwatch calculates the extent to which countries around the world have been affected by extreme weather events and ranks them according to their vulnerability. In the report, Italy is ranked 21st in the world for impacts from extreme climate events in 2018 and 26th for loss of life due to climate change. Eckstein D., Künzel V., Schäfer L., Winges M. 2019, *Global Climate Risk Index 2020. Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2018 and 1999 to 2018*, Germanwatch e.V, Berlin, Germany.
[84] That is 'insurance policies', i.e. the documents proving and regulating the insurance.

of property damage[85]. According to Article 1882 of the Italian Civil Code, an insurance policy is:

> […] the contract by which the insurer, in return for the payment of a premium, undertakes to reimburse the insured for damages incurred, on the basis of a claim and within agreed limits, or even to reimburse the corresponding capital or, in case of a life-threatening event, paying an insurance annuity"[86].

According to Professor Mark Richard Greene[87], Insurance can be defined as:

> […] a system under which the insurer, for a consideration usually agreed upon in advance, promises to reimburse the insured or to render services to the insured in the event that certain accidental occurrences result in losses during a given period. It thus is a method of coping with risk. Its primary function is to substitute certainty for uncertainty as regards the economic cost of loss-producing events[88].

In case of unexpected critical events that affect properties covered by a policy, insurers commit to covering financially the response to the damage, either by restoring the pre-damage state of the asset, or by paying a reimbursement on agreed terms.

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85 "*We could say that Risk Management is basically nothing more than the replacement of pure risk costs with other costs implemented on the condition that the latter are lower than the former*", Misani N., 1994, *Introduction to Risk Management*, E.G.E.A. S.p.A. Milan, p. 18.

86 Each country defines the insurance policy not only with its own code, but also with its own insurance estimation practices: 'When in Rome, do as the Romans do', Cavadini M., Licetto G. 2014, *Risk Management conoscenze e competenze di un unico processo*, Cacucci Editori, Bari, p. 53.

87 Prof. Mark Richard Greene (1923 - 2012) Distinguished Professor Emeritus of Insurance, University of Georgia, and Athens. Coauthor of *Risk and Insurance*, South-Western Publishing Co., U.S. 1973.

88 Greene M.R. 2019, *Insurance*, in Encyclopedia Britannica.

The existing literature dealing with criteria for risk assessment and risk management strategies in general approaches the topic of insurance from the financial and economic side, even though the entire insurance sector largely relies on the usual established practices[89].

The purpose of this paragraph is to approach the insurance sector from a technological- and building-related point of view, applying the innovative methodologies for investigating and evaluating buildings and materials already described

Modern insurance policies are fundamentally based on contracts governed by a country's civil code.

However, despite general rules and normative frameworks, the insurance sector remains strongly regulated *de facto* by "established practice". Insurance policies are essentially contracts based on the general principle of never fully covering the possible damage[90], compensating only direct disruptions or in some cases restoring the previous state of the asset insured, according to an agreed evaluation stated at the moment the policy was signed, and before the harmful event occurs[91].

The constraints on contracts currently offered on the insurance market, based on the principle of zero *Risk-unsustainability*[92], are outside the scope of our analysis.

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[89] Borghesi A. 1985, *La gestione dei rischi di azienda. Economia e Organizzazione. Teoria e Pratica*, CEDAM, Padova.

[90] Policies are offered to policyholders by agents who, in the case of large risks or specific risks, become brokers who, by detailing specific requests, propose to companies extensions on standard policies placed on the market.

[91] Obligations to update regulations are not covered, unless there is a specific clause, which is rare and always limited to small percentages of the indemnifiable sum.

[92] The concept of zero risk no longer defines a risk-free action, but rather

Our focus is on how building values are defined according to insurance terms, i.e. of the risk transferred[93], and policyholders' lack of knowledge of the rules applied. This implies that the best insurance contract is based on a compromise between the insurance premium and the limits imposed by the rigid conditions of the contract itself[94]. Unfortunately, policyholders are often unaware of the potential misunderstandings connected with the procedures of damage evaluation, underestimating the importance of hiring an expert in the field who is able to deal with the difficulties of technical insurance language during the claims process[95].

In the event of damage to an insured property, the policy is activated by written communication from the

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a risk that cannot be associated with an economic value and is therefore considered irreparable. Comandé G. 2006, *Gli strumenti della precauzione: nuovi rischi, assicurazione e responsabilità*, Giuffrè Editore, Milano.

[93] "*In risk identification, an important aspect is the ability to identify the causal link between a potential hazard, i.e. the occurrence of an event and the consequences that may result from it, taking into account all the logistical implications (necessary and/or sufficient) for a risk scenario to occur or not to occur (as well as possible Propagating and Reducing Factors)*", Cavadini A. M., Licetto G. 2014, *Risk Management knowledge and skills in a single process*, p. 102.

[94] "*There are many combinations of cover and policy cost, and they tend to increase as more modern products appear. Moreover, the offer of the various operators is not homogeneous. The bad risk manager refuses to compare his insurer's service with that of others and tends to flatten himself on the solutions he is offered, without a serious evaluation of the policy alternatives. This means that the full potential of insurance is not exploited in the first place. In this regard, it is legitimate to suspect that part of the emphasis given in recent times to everything that in Risk Management is not insurance hides a certain inability to do good insurance management first and foremost*", Misani N.1994, *Introduction to Risk management*, edizioni giuridiche economiche e aziendali, E.G.E.A. S.p.A. Milano p. 175.

[95] This benefit is an expense recognized in the policy, not only for those with significant assets.

policyholder, opening the claim. This starts an internal company procedure for the evaluation of the damage according to the conditions in the policy. An insurance assessor is appointed for the damage evaluation procedure that, in the case of positive assessment, will lead to an indemnity based on the estimated damage.

Experts on building construction and management, such as architects and engineers, suitably equipped with the necessary knowledge in the insurance sector, would be able to maximize the insurance contract value, taking carefully into account both policy conditions and what is necessary for the restoration/reconstruction of the insured building, with full satisfaction of both parties[96].

These professional figures could also have a useful role in mediating during the activation phase, finding the most suitable insurance policy, guiding policyholders towards more informed choices, with better definition of the risk to be insured and faster resolution of claims, therefore shortening reimbursement procedures.

An accurate and thorough description of the true state of the properties is certainly a necessary tool for estimating the previous insurance value[97], both for the stipulation of the insurance policy and for the management of possible damage, leading to a better definition of the contractual conditions.

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96 "*One general aspect that we must always consider is that crises and projects have many things in common, for example, both are not repetitive activities and their management requires the expertise and experience of people from different worlds and specializations, whether we like it or not*", Cavadini, Op. cit., p.22.

97 The so-called 'preventive expertise', a concept that already exists in insurance technical language.

This will enable more aware risk management based more accurately on the property's fragilities, evidencing the 'uninsurable uncertainties' and allowing programmed maintenance, in order to optimize the management of future claims, reducing uncertainties related to the previous conditions of the property. The lack of a culture of programmed maintenance is a substantial source of fragility and loss of value of real estate.

We must bear in mind that insurance is based on a "value as new" reconstruction cost of the insured property, without considering real estate or historical value, and further reducing the insurance value in proportion to the deterioration due to age and lack of maintenance, called "value in use"[98]. Based on similar reconstruction/restoration values, well-maintained proprieties will receive compensation for the value in use, recognizing the value difference between "value as new" and "value in use"[99] or even the strategic commitment to complete planned maintenance that has not yet been started.

Summing up, to avoid the hidden deficiencies of the current insurance system for risk management, taking as a given the impossibility of changing the legal form of the policies, it is necessary to increase the policyholder's

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[98] Insurance companies pay for the state of use of the property by reducing the compensation by a percentage according to age. The percentage depreciation due to old age of an unmaintained asset will result in a lower compensation, i.e. proportionate to the state of deterioration of the asset at the time of the claim

[99] This condition rarely occurs due to a variety of factors, but these can be handled by risk management, such as by the requirement for regulatory or structural updates that normally insurance companies do not recognize, or a commitment to start refurbishment works not planned or impossible to do in a short period of time.

awareness about the appropriate evaluation of the risk to be insured, and of what will inevitably be left uncovered. The development of indicators supporting correct risk assessment will raise policyholders' awareness about the "value in use" of a property, so that they will preserve and increase that value over time through appropriate maintenance.

The dynamic nature of risks, especially related to climate change or extreme events, also requires constantly updated data analysis, becoming a shared asset for the benefit of both policyholders and insurance companies.

Digitalization tools such as BIM, GIS, IoT sensors and satellite data offered by platforms like Copernicus provide valuable support for the construction and building management sectors. Those digital tools allow the creation of predictive models for risk evaluation and management, integrating the assessment of the structural conditions of buildings with geomorphological and climatic risks. This framework moreover underlines the importance of a new generation of architectural and engineering professionals, linking their traditional knowledge of the building and project-related sectors with advanced digital technologies, as well as with the specifics of the insurance sector.

IGNORANCE
MORE FREQUENTLY
BEGETS CONFIDENCE
THAN DOES KNOWLEDGE:
IT IS THOSE WHO KNOW
LITTLE, AND NOT THOSE
WHO KNOW MUCH, WHO
SO POSITIVELY ASSERT
THAT THIS OR THAT
PROBLEM WILL NEVER BE
SOLVED BY SCIENCE.

Charles Darwin*
1871, *The descent of man, and selection in relation to sex,*

In order to analyze and understand the contemporary human condition, with specific reference to the *Homo urbanus*, we must first clarify the limits we are dealing with. Both very modern and very ancient, those limits are related to the complexities of contemporary cities, but on the other hand, also linked with our ancestral perception of reality and relationship to other people.

We must consider different scenarios at different latitudes: most cities in the southern hemisphere are defined by exponential, irregular, and uncontrolled growth that devours landscape and natural resources. Those located in the northern hemisphere are mostly evolving internally rather than expanding, but they share with the southern-ones the tendency to consume goods and services directly and indirectly at an unsustainable rate. All urban areas of the world have brutally destructive urban metabolic cycles that produce abnormal ecological footprints, which the global ecosystem will certainly be unable to sustain in the medium-long term.

* Charles Robert Darwin (1809 - 1882) was an English naturalist, geologist and biologist, well known for his contributions to the science of evolution, father of the theory of the natural selection. Considered one of the most influential figures of modern history science, he was honored by burial in Westminster Abbey.

Any urban system is by definition characterized by transformative processes, considering its continuous adaptation to environmental, social and cultural conditions, conditions that are also permanently evolving. Those synergical transformations appear to be evolving at feverish speed, but often also in a seemingly casual manner, without any clear governance, able at least to address if not to guide those changes.
It is as if humankind were being forced through a revolving door, where the different elements and factors are continually entering and getting on a merry-go-round or carousel -- and humanity or rather the citizens, who must also get on, do not seem to be having fun at all.
The transformation of the living conditions of urban populations, linked to the transformation of cities and the malfunctioning of their metabolism, produces deleterious effects which, combined, lead to problems ranging from daily difficulties and more or less serious annoyances, to completely unacceptable living urban conditions that end up abandoning citizens to their struggles. These processes, which we might define "evolutionary", borrowing the Darwinian term, are not necessarily caused by the increasing dimension of the cities, considering that what is mainly increasing is functional complexity, resulting in growing entropy of poorly governed cities.
The urbanisation of mankind seems to be an overwhelming trend, justified by the need to achieve better social or economic conditions, ultimately in view of personal attempts to improve quality of life. Unfortunately, this legitimate aspiration is often frustrated by the harsh

reality of contemporary urban systems, and their so-called "urbanization" most often leads to overcrowded slums. The urban systems affected by those conditions, far from being "smart" or "digital", are better described as "in-volving" cities, with increasing degradation, growing and worsening management issues, evolving naturally towards social degradation and discomfort.

Among all the aspects to be taken into account in contemporary cities, the loss of identity is perhaps the most insidious. The continuous social and demographic changes, together with structural, climatic, and now also health issues, exacerbated by changing and uncertain immigration laws and practices, means that new citizens do not feel like "citizens" at all. Far from finding reasons for 'urban' cohabitation, they end up disaffected, outsiders in their urban environment: they tend to form closed micro-communities, or even worse isolate themselves, contributing a wider ranging sense of marginalization, of being physically or culturally on the outskirts of society.

Etymologically speaking, the English noun "outskirt" – defining suburban and outlying districts – is one of the most interesting terms related to the urban glossary. Formed by the adverb "out" (meaning something external, with a negative sense), and the noun "skirt" (referring to a piece of women's clothing), it indicates the edge, or the final and extreme part of something. The use of "outskirt" for suburb suggests a city seen as a protective mother, under whose mantle citizens seek protection, almost an earthly translation of the Virgin of Mercy image (the *Schutzmantelmadonna* of German countries), under whose cloak human beings can find shelter[1]. Suburbs do not enjoy the same protection as the inner part of the city, and thus are described as being outside the protective skirt (Fig. 1). This same perspective, connected to the conditions of marginalization of perpheries was expressed by Pope Francis[2] in the first apostolic exhortation of his pontificate, where he affirms that:

> […] Going out to others in order to reach the fringes of humanity does not mean rushing out aimlessly into the world. Often it is better simply to slow down, to put aside our eagerness in order to see and listen to others, to stop rushing from one thing to another and to remain with someone who has faltered along the way[3].

The concept of "fringes of humanity", which conveys the idea of isolation, in the original borrows the term "peripheries" from the urban vocabulary as an expression describing the human condition of distress. These human peripheries or outskirts are the result of a lack of integration, an alienation arising from poor understanding, both cultural and linguistic, as well as

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[1] The Virgin of Mercy refers directly to the oldest of Christian exhortations, from a papyrus in Greek found in Alexandria and dating from the 3rd century, currently in the possession of the John Rylands Library in Manchester. The text corresponds to the prayer *Sub tuum praesidium confugimus* (Under your protection we find refuge).

[2] Jorge Mario Bergoglio (1936) has been the 266th Supreme Pontiff of the Catholic Church and Bishop of Rome since 13 March 2013, with the pontifical name of H.H. Pope Francis, 8th sovereign of the Vatican City State, Primate of Italy, in addition to the other titles proper to the Roman Pontiff. Of Argentine nationality, he is the first Pope born in the American continent.

[3] Bergoglio F. 2013, A*postolic exhortation Evangelii Gaudium of the Holy Father Francis, to the bishops, clergy, consecrated persons and the lay faithful on the proclamation of the gospel in today's world*, Vatican City, chapter V (46) p. 39.

Fig. 1 Madonna della Misericordia (Our Lady of Mercy) Unidentified sculptor c. 1345, bas-relief on Istrian stone (138 x 170 cm) located on the left exterior side of the church of San Tomà, in Venice. The Holy Virgin is represented in the classical position of sheltering praying people under her mantle, recalling the medieval tradition of the "protection of the mantle", a protection that noble ladies had the privilege to accord for poor people seeking refuge (Source: Didier Descouens - Wikimedia Commons 2013 ®).

from the historical, social and cultural circumstances that shaped the city. Losing its original meaning, the city becomes something else, its social connective tissue is torn apart, and having abandoned their original cultural references, its inhabitants are unable to find new reference points. Trapped in physical or cultural ghettos, they become unable to interact positively with the rest of the social/urban environment.

In order to answer these social issues, the (R)evolving city overcomes the current boundaries of 'smartness'.

It is technologically well equipped to face climatic, health, and geomorphological conditions that surround

and condition the city. Strongly rooted in the circular economy and the principles of citizens' wellbeing, it consumes without destroying, recycles while metabolizing, and mitigates the negative effects of its ecological footprint.
The (R)evolving city guides its inhabitants in a kindly and maternal manner towards a new idea of citizenship. Its citizens, proactive agents of the 21st century evolution of urban systems, leave behind their predatory approach, evolving towards a higher level of awareness, integrating into the ecosystem and respecting mutual relationships.
It is a "polite" city, inhabited by consciously polite citizens, educated in the principles of sustainable development as the basis for contemporary civil coexistence. They are well aware of the need to establish a new balance between human and social development, and environmental sustainability, carefully harmonizing present and future decisions. The relation between the city of tomorrow and its inhabitants will be significantly different: it will be based on a new and rational approach to land and soil management, reclaiming deteriorated neighborhoods, and in the meantime involving citizens in daily decisions, taking into account their ongoing needs. The COVID-19 pandemic has created very interesting examples of how digital devices and networks can support social activities in an urban context. Ensuring the continuity of education, public administration, healthcare, security, as well as of the supply of goods and services has been an incredible real-life stress test for digital urban services, giving a new sense to their role in supporting societal functions.

In this complex but promising scenario, the real obstacle is ignorance, the root cause of the lethargic and narrow-minded indifference we often find in contemporary human society.

Short sighted and rather uninterested in the future of mankind, modern *Homo sapiens* often seems to prefer to ignore that, from the ecosystemic perspective, he is just one of the infinite species that populate the Earth.

If humankind disappears, the Planet will soon find new equilibria: new species will arise as happened at the Anthropocene dawn.

Among all the concerns related to present global changes, we must recall that the most dangerous one remains Ignorance.

Showing supreme indifference towards the tens of thousands of years it has taken our species to build our patrimony of knowledge and culture, using our natural human intelligence and initiative, Ignorance grows day by day, becoming a catastrophic tsunami, more dangerous than any climatic or pandemic challenge. If not contained, it will convert in an overwhelming wave, able to submerge our civilisation more than any climatic disaster, a true “perfect storm”, leaving no chance for shelter, devastating the world we know for many years to come, causing the collapse of our societies and plunging humankind into a new dark age.

This new “Age of anxiety”[4] is the harsh lesson left by COVID-19. It tells us that we must understand our failures and improve, but above all it must not prevent us from progressing: the direction we take may no longer be the one we thought was unquestioned, but crises generate new opportunities and paths not previously considered[5]”. The (R)evolving city, as we have portrayed it in this book, can help to avoid the mentioned dangers, bearing in mind that the evolutionary leaps in human societies have always resulted from crises, challenging previous models and creating new ones. The fall of Constantinople in 1453, and with it the end of the last vestiges of the Roman Empire brought a whole generation of Byzantine scholars to western Europe, and with them entire libraries of ancient classics came to the west, especially to Italy.

[4] *The Age of Anxiety: A Baroque Eclogue* (1947; first published in Great Britain in 1948) is a poetic composition in six parts by W. H. Auden. The symphony No. 2 for Piano and Orchestra by American composer Leonard Bernstein, also entitled *The Age of Anxiety*, is inspired by this literary work. The title in both compositions refers to the uncertainty and fragility of the balance of the 20th Century. Auden, W.H., *The Age of Anxiety: A Baroque Eclogue*, New York: Random House, ©1947

[5] Cinquepalmi F. 2020, *The Age of the Anxiety: mobilità e università ai tempi del Coronavirus*, in «Condividere», a cura di Paola Gribaudo, disegnodiverso, Torino. p. 34-35

Along with the rebuilding of the economy and society after the Black Death, these immigrants and refugees, who fled with their books, were among the driving forces behind Humanism. Our hope is that the current crisis, combined with a deeper and more aware reflection on digitalization, can serve to mark the path of mankind towards a new Renaissance[6].

[6] *I salti evolutivi delle società umane sono sempre scaturiti da crisi più o meno gravi, che hanno messo in discussione i modelli di sviluppo precedenti per crearne di nuovi. La caduta di Costantinopoli nel 1453, e con essa l'eclissi delle ultime vestigia della romanità, portò in occidente una intera generazione di sapienti bizantini, uno per tutti il Cardinal Bessarione, che recarono soprattutto in Italia intere biblioteche di classici antichi. Tali profughi, fuggiti con i loro libri, sono stati il motore dell'Umanesimo; non resta da augurarsi che la crisi attuale, coniugata ad una più consapevole riflessione sulla comunicazione digitale, servano a segnare il cammino dell'umanità verso la ricerca di un nuovo Rinascimento*. Cinquepalmi, F. *Alla ricerca del Rinascimento*, in *L'università che verrà. Verso un nuovo ecosistema della Conoscenza*, in Mecca S., Cianfanelli E., Cinquepalmi F., Condotta M., Giorgi D., Giretti A.,Trombadore A., Zambelli M., Firenze: DIDA press, ISBN: 9788833380995, p. 13-18.

INSIGHTS

Carlo Pisano

BRUSSELS AND PARIS: THE APPLICATION OF THE METABOLIC APPROACH

Urban metabolism and material flow analysis have become widely recognised tools in the academic world and are employed to monitor and assess resource use, understand its environmental impact, and propose appropriate policies accordingly. Industrial ecology and spatial metabolism are considered two of the actions that can be used to trigger the transition from the current linear economic development model to a circular one, i.e. one capable of (re)generating the material and energy resources society needs to thrive, ensuring an acceptable and equitable standard of living for all. The application of the metabolic approach to urban systems was first introduced by engineer Abel Wolman, who was also the first to propose the notion of urban metabolism in his 1965 book *The metabolism of cities*. Wolman calculated the input and output of energy, water, and materials for a hypothetical American city of one million inhabitants, using national production and consumption data from the United States (Fig. 1).

Through this assessment, he developed a detailed analysis of the main urban metabolic flows, investigating the present and future sustainability of each of them and

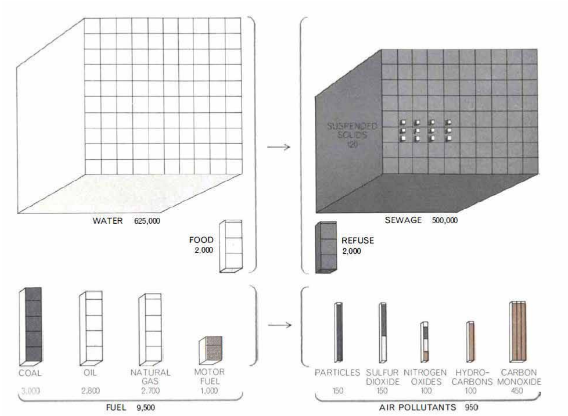


Fig. 1 Input and output flows calculated by Wolman.
Source: The metabolism of cities.

hypothesising corrective actions and virtuous regulatory scenarios to make the typical American city more sustainable.

The first application of urban metabolism to a real city was carried out for the city of Brussels by Duvigneaud and Denayer-De Smet (1977). The aim of this study was to understand the functioning of the urban ecosystem and its subsystems. The two scholars proposed the results of their research on the Brussels case study, analysed between 1970 and 1975, in an infographic (Fig. 2). The various flows taken into account were shown: the natural energy balance (highlighted in yellow) and the subsidiary energy balance comprising the inputs of coal, fuel, petrol and natural gas, electricity, and food (in orange), the water

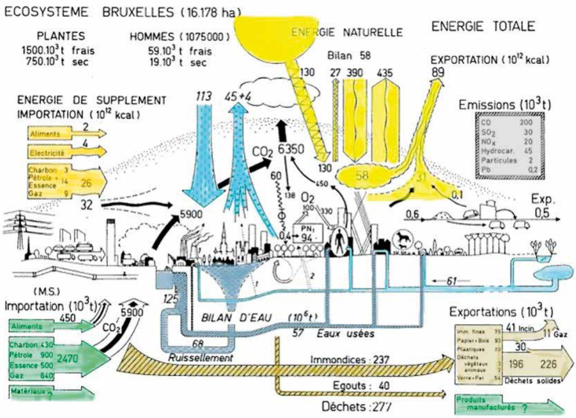


Fig. 2 Diagram of metabolic flows in the city of Brussels in 1970-1975. Source: Duvigneaud and Denayer-De Smet (1977).

(yellow)	energie naturelle	natural energy sources
(orange-yellow)	energie de supplement	supplementary energies
(blue / grey)	bilan d'eau	water balance of rainwaters and wastewaters
(light grey)	emission	emissions in atmosphere
(green)	importations	raw materials, food supply and fossil fuels
(brown)	exportations	waste disposal

balance relating to rainfall and wastewater (in shades of blue), material flows (in green) and the production of pollutants and waste (in grey and brown respectively). Although this is the best known representation of the Brussels ecosystem study, other versions have been published more recently under the auspices of the metropolitan city. Notably, in 2015 the Brussels Institute for Environmental Management (IBGE) commissioned and funded major research and design studies as part of the startup of the collective construction of the regional circular economy programme "Be Circular, Be

Brussels". This programme, which is expected to guide future government planning arrangements, contains in particular an in-depth study on the metabolism of material flows within the city boundaries (Danneels, 2018).

In fact, this study of the metabolism of the Brussels-Capital Region (BCR) aimed not only at establishing a metabolic balance, as had been done in the past, but also at proposing lines of action in a circular economic perspective, including activities of recovery, reuse, recycling of material flows and promotion of ecodesign (Ecores *et a*l., 2015). In the final report, several methods found in the literature to assess urban metabolism were examined in order to choose the most appropriate one for Brussels. These included the Eurostat method[1] (Eurostat, 2001), the Brunner-Baccini method[2] (Baccini and Brunner, 1991), or the Brunner-Rechberger method[3] (Brunner and Rechberger, 2004)

[1] This method was developed by the European Statistical Office Eurostat in 2001. Its objective is to make national or even continental assessments of the use of all-natural resources by the economic system in terms of the physical mass of materials moved in, moved within the system and moved out. Physical indicators are monitored on an annual basis, in the same way as economic indicators.

[2] This method was developed, by Peter Baccini and Paul H. Brunner, for regional and local approaches and has already been applied to several agglomerations and/or regions including Vienna and more recently Geneva. The method takes into account a group of elements and their interactions within the geographical boundaries of the system under investigation and, in most cases, has a time frame of one year. The material flows analysed are linked to four main human activities, considered a synthesis of human material needs: feeding, cleaning, living and working, transport and communication.

[3] Material flow analysis (MFA) by Brunner and Rechberger is a systematic assessment of material and stock flows within a system, defined in space and time, applicable to various fields such as environmental, water quality, resource and waste management. In general, a MFA starts with the definition of the problem and the objectives of the study and

and the Climatecon method[4] (Minx *et al*. 2011). The review showed that most studies use the Eurostat method and that this methodology is adapted according to the available data, and even enriched with new indicators. In the case of Brussels, a hybrid methodology based on the Eurostat method was used, employing the data available for the territory studied; each resource, such as energy, matter, and water, was described through the selection of the most appropriate values. The system considered in this study was the Brussels-Capital region and data for the years 2010, 2011, and 2012 was collected and used where possible. On 1 January 2011, the region had a population of 1 119 088 inhabitants. The region, with an area of 161 km², represents approximately 0.5% of the Belgian territory. As in many other capitals, the population density is very high, with 6 934 inhabitants per km² in 2011. The average household size was 2.08 persons in 2010. The

continues with the identification of the system boundaries, and the substances, processes and assets involved. The analysis of commodity flows and the concentrations of substances in these flows is then carried out. The results are presented in an appropriate manner in order to facilitate understanding and the implementation of goal-oriented decisions.

[4] The Climatecon method is the result of a study commissioned by the European Environment Agency and developed by researchers at TU Berlin to develop a pragmatic approach to assessing urban metabolism in Europe. The research defined urban metabolism as a systemic assessment of the environmental pressures generated by urban lifestyles. This systemic approach is characterised by the comprehensiveness of the description of metabolic flows and global system boundaries. Above all, imports of finished products and raw materials constitute global environmental pressures that must be taken into account. This method emphasises the need to understand how certain parameters – including the socio-economic fabric, urban form, lifestyles or the presence of certain infrastructures – lead to metabolic differences between cities, as knowledge of the quantity and composition of material flows alone does not provide sufficient support for local decision-making.

qualification and quantification of outgoing and incoming flows recorded in the BCR in 2011 are shown in Table 1. An analysis of the BCR metabolism shows that the region is highly dependent on external territories for raw materials and manufactured goods, but also for waste management and but also for managing its waste and absorbing its polluted air; it is also evident that about 20 times more energy is consumed than is produced. Internal flows account for only a fraction of incoming and outgoing flows. This assessment clearly highlights the need for targeted action to move towards a circular economy and reduce Brussels' environmental impact (Fig. 3).

Likewise, the City of Paris funded in 2007 a research project directed by Sabine Barles, a professor at the Pantheon-Sorbonne University, to identify and quantify metabolic flows for the territories of Paris, its suburbs, and the entire Île-de-France region. This choice makes it possible to compare the results obtained depending on whether a central city, a dense urban area, or an urban region is considered. The Eurostat method was also used in this case study. Based on the analysis of material flows (MFA) in (fuels, food, goods, raw materials) and out (various emissions, waste, finished or semi-finished products), it was possible to measure urban pressure on the environment. MFA is a prerequisite for the analysis of substance flows (SFA), such as carbon, nitrogen, phosphorus, heavy metals, etc., knowing the quantities of which is essential for assessing the environmental performance of cities. The aim of the work carried out by Prof. Barles was to characterise the metabolism of Paris

Typology and qualification of flows	Measured values
Energy import	20 838 GWh
Sum of water inflows including rainfall, rivers, distribution water and water to be treated from the Flemish region	349 106 m^3
International and interregional imported material flow	8 932 kt
Local primary energy production	1 150 GWh
These are respectively the quantity of water withdrawn in BCR and the quantity of wastewater treated.	2 106 m^3 e 130 106 m^3
Total amount of estimated material stock including residential, office and commercial buildings as well as different types of infrastructure and vehicles	184 921 kt
Waste treated by the incinerator (this value does not directly influence the balance of material flows as it is a reduction of the amount of waste leaving the system. However, waste from incineration is included in the waste output count)	448 kt
Addition to material stock	500 kt
GHG emissions in eq CO_2 in BCR in 2011	3 693 kt
Sum of water outflows	369 106 m^3
Sum of waste outflows including household and similar waste, construction and demolition waste, HoReCa waste (hotels, restaurants, bars), waste generated by sewage treatment plants, offices, industry and incineration, healthcare, retail, education and cleaning (some of this waste is sorted and subject to recycling)	1 312 kt
Material flows exported internationally and interregionally	6 770 kt

Tab. 1 Incoming and outgoing flows recorded in the BCR in 2011.

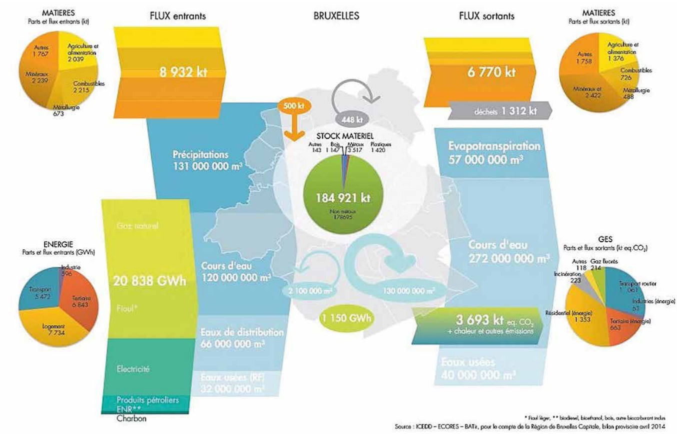


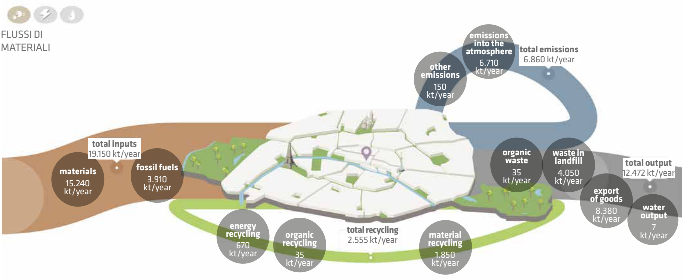
Fig. 3 Diagram of metabolic flows in the city of Brussels in 2011.
Source: Ecores, 2015.

and the Île-de-France from a macroscopic point of view, focusing not only on the results of this approach but also on the methodological issues it raises (Barles, 2007). The main difficulties encountered with the method of the European Statistical Office are, in fact, linked to the availability of data which is often non-existent or too outdated. Adapting the method to the local scale led to the introduction of a new indicator, TTN (Total to nature), to summarise total emissions into the environment, whether local or exported, as is often the case for solid waste and wastewater.

The study shows that the areas assessed exert high pressure on the environment in terms of both resource consumption and emissions and are highly dependent on imports of materials, estimated at 8.8 tonnes per inhabitant per year, of which 20% are fossil fuels in Paris, 11 tonnes per inhabitant per year in the suburbs and 12 tonnes per year in Île-de-France; total emissions into the environment reach 5 t/hab/year in Paris, 5.9 t/hab/year in the inner suburbs and 6.8 t/hab/year in Île-de-France. Agri-food products are among the resources most consumed in Paris as the tourism and catering sectors are particularly developed and very important for the city's economy. The amount of imported food is therefore proportionally higher in the capital than in the rest of the agglomeration or in other cities in France.

In terms of organic waste, 57 kg of food waste per Parisian was recorded in 2013, including 13 kg of unconsumed food. On the other hand, in Île-de-France construction materials are among the resources most imported and consumed; their recovery and recycling must be promoted. This highlights both the process of urban expansion and the importance of implementing sustainable housing and urban renewal projects to reduce anthropogenic pressure. Energy consumption is also particularly high in Paris at 35 680 GWh/an, but the share of renewable and recovered energy in its energy mix can still be significantly improved. The heat of the urban network is produced by an energy mix of which about 50% comes from energy recovery from waste. In terms of water, Paris has two supply networks (one for drinking water and one for non-drinking water) and a unitary network for collecting wastewater and rainwater.

At the end of 2014, the Urban Ecology Agency of the City of Paris created an online platform showing all the



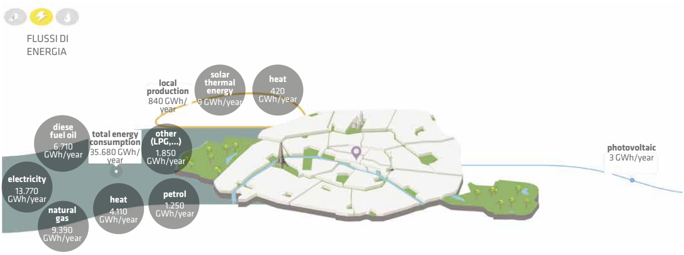


Fig. 4 Qualification and quantification of Paris energy flows. Source: http://metabolisme.paris.fr/#t/paris/water/2.

Fig. 5 Qualification and quantification of material flows in Paris. Source: http://metabolisme.paris.fr/#t/paris/matter/1.

Fig. 6 Qualification and quantification of Paris energy flows. Source: http://metabolisme.paris.fr/#t/paris/energy/2.

flows of energy, materials, and water moving in and out of the territory, as well as the impacts of projects developed between 2003 and 2015 (Figs. 4-6).

This platform has increased awareness and improved understanding of the strong and ongoing interactions between the city and its environment, allowing clear visualisation of how the physical extension of the city represents only a small portion of its ecological footprint on its surrounding territories.

Elisa Pennacchia

MICRO-SCALE ANALYSIS OF THE URBAN TERRITORY ACCORDING TO THE 'SUSTAINABLE CELLS' METHODOLOGY

The growth of the world's urban population strongly affects the management of urban areas, leading to heavy building pressure on peri-urban areas, with multiple consequences, both direct and indirect, on for example the environment, local climate, and quality of life. In an overall global assessment, it is impossible to ignore the potential value of cities. Indeed, cities are simultaneously the source of both the critical issues identified by detailed analysis and solutions for them. The management of complex systems is a difficult and delicate task and must focus primarily on optimising services, structures and networks, and the safety of citizens. It is clear that when the studied area is characterized by a significant urban complexity an inter- and/or trans-disciplinary approach is needed to identify the correlations between environmental and urban aspects and quality of life.

In the framework of a bilateral international research project called SoURCE (Sustainable URban CElls)[1],

[1] "SOURCE (Sustainable Urban Cells) is a major project approved and funded under the executive protocol of the scientific and technological cooperation agreement between the Italian Republic and the Kingdom of Sweden for the period 2010/2013.

carried out by Italy and Sweden, the research teams of the CITERA research centre in the Sapienza University of Rome and the KTH Royal Institute of in Stockholm have developed a methodology for micro-scale urban spatial analysis able to assess the main parameters that characterise a city's level of environmental sustainability. Shifting from analysing and intervening at the macro scale to the urban cell scale can enable local administrators to perceive and assess problems more accurately and respond more concretely to emerging needs.
The objective of this methodology was initially linked to sustainable management mainly from an energy perspective, which was to be achieved also by redesigning urban areas. The aim of this tool is fully in line with the objectives of the EU 2020 Directive, such as a 20% reduction in greenhouse gas emissions, a 20% increase in energy efficiency and a 20% increase in energy requirements from renewable sources[2].
The analysis, evaluation and management of interventions to optimise the use of renewable energy sources, and the containment and rationalisation of energy consumption, concern an elementary unit/module of territory, defined as the "urban cell". The cell is identified according to the number of inhabitants (between 1,000 and 2,500 citizens), the characteristics of the buildings and the use of the territory. An urban cell, therefore, constitutes an "elementary unit of territory", aggregating which a network or Smart grid can be created.

[2] Fabrizio Cumo "Sustainable Urban Cells" Edizioni Quintily, Ottobre 2011.

Topic	Indicator
WATER	Purification capacity Domestic consumption Network losses
BIODIVERSITY	Watersheds Local flora and fauna
LAND CONSUMPTION	Built environment
ENERGY CONSUMED	Electric and thermal consumption
ENERGY FROM RENEWABLE SOURCES	Energy produced
MOBILITY	Car motorization rate Motorbike motorization rate Public passenger transport Sustainable mobility Limited traffic zones
POPULATION	Number of inhabitants Average age
AIR QUALITY	Nitrogen dioxide (annual average) CO2 emissions Ozone (mobile average exceedance) Fine dust (annual average)
WASTE	Separate collection C&D waste produced Urban waste produced
URBAN GREEN	Pedestrian islands Usable urban green areas Total urban green Bicycle paths

Tab. 1 Themes and indicators for urban cell analysis

Energy, however, is only one of the urban metabolism flows that can be studied using this methodology; to this can be added economic flows, flows of people, materials and waste that can be analysed and modified, with a view to sustainability, through the identification and analysis of urban cells, to create Smart cities and increasingly

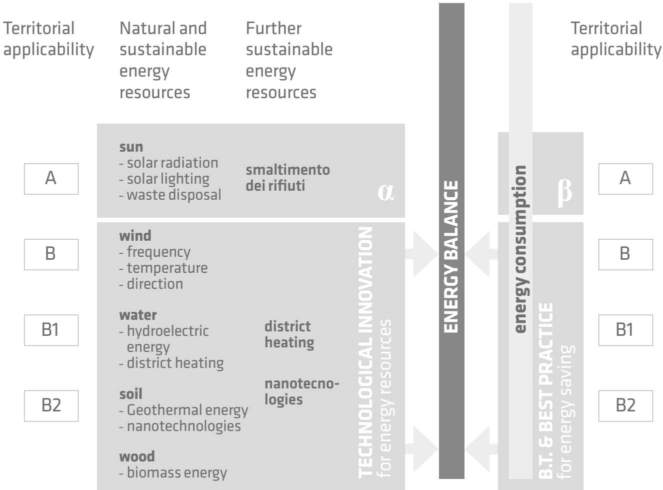


Fig. 1 The synoptic diagram shows the overall reference grid on which we worked to analyse the existing situation and propose corrective elements.

inclusive communities. The issues that constitute the key to understanding urban cells are, therefore: water; biodiversity; soil consumption; energy consumed; energy produced from renewable sources; mobility; air quality; waste and urban green (Table 1).

These themes constitute the reference grid through which it will be possible to analyse and 'read' an urban cell; a sort of x-ray with which it will be possible to elaborate, for each cell, a card for the reading the single urban systems and, subsequently, indicate possible corrective measures in order, finally, to be able to carry out a comparison, and networking, between the urban cells. With regard to energy, for example, the estimated consumption was assessed based on data provided by the municipal administration and on an estimated average of residential and tertiary consumption, taking into account both economic conditions and the objective conditions of degradation of individual buildings.

Subsequently, the potential of the territory of the single cell to produce clean energy from renewable sources was studied and an assessment carried out to ascertain whether there was a deficit or surplus of energy capable of determining a bidirectional flow of energy from the cell in question to neighbouring cells (Fig. 1).

This brief exposition serves to outline, albeit in broad terms, the framework of reference, highlighting the correlation of each of the potentially quantifiable themes with all the others to delineate a picture that illustrates the problem in critical terms and in a broad perspective. Indicators have been identified for each of these themes and a detailed description has been drawn up for each of them, both in terms of significance and ease of finding data, as well as the reliability or method of measurement of the collected data.

The final picture that emerged from the various case studies analysed – the cities of Sabaudia and Trevignano Romano in Italy and Lund in Sweden[3] – was the result of the selection of a series of indicators on which it was possible to intervene to make the necessary corrections, while also indicating the political, administrative,

[3] Fabrizio Cumo "Sustainable and Smart communities" edizioni Quintily, Novembre 2013.

regulatory and economic instruments with which to intervene to change them 'for the better'.

The methodology illustrated privileges the energy theme so much as to identify a sort of energy urban cell, but it is also transferred to the other themes in such a way as to configure, for example, the water urban cell, the waste urban cell and the biodiversity urban cell, thus structuring different thematic layers of reading, analysis and management of the territory, which, superimposed on each other, would contribute to a more complete configuration of the sustainable urban cell.

It should be underlined that the methodological structure adopted, in allowing to work simultaneously on several scales, permits to adopt and constantly compare a series of disciplines such as those of urban planning and landscape when working at territorial scale, those of technology (building and plant engineering) when working at the scale of the building, those of design present to varying degrees in all scales of intervention. On this basis we can conclude that the possibility of further verification of the complementarity between different disciplines and, consequently, once this has been verified, of the validity of the method of intervening simultaneously on several scales. From this point of view, the potentialities and criticalities in the use of an urban cell for the planning of the territory and/or for its recomposition must be identified.

As mentioned above, a series of urban cells can be aggregated according to different logics; the first and simplest one is quantitatively correlated to the balance between production and consumption. Another one which is certainly more significant, should be correlated to the context (in the broadest sense) taken into consideration from time to time; in this way 'city cells' having all the potential and all the criticalities of a single urban cell will be obtained. However, it should be stressed that operating on a small urban cell (even when it is added to others) seems to go against the dominant o which the larger the metropolitan area, the more highly it is considered due to the greater number of services, the more numerous alternatives, better infrastructures and, lastly, the rationalisation of costs and consumption that it offers.

In the opinion of the authors of the research, however, a division of the territory into smaller modules (one or more urban cells) facilitates the necessary social and interpersonal relationships, promotes forms of adequate participation by encouraging greater awareness of citizens and can therefore be a stimulus and a tool for those who administer them while combining the principles of environmental sustainability with the much desired 'quality'.

Elisa Pennacchia

INTEGRATED DIGITAL SYSTEMS FOR BUILDING AND URBAN PROCESSES: THE INTEGRATION OF ADVANCED DIGITAL TECHNOLOGIES

The design approach and methodologies for managing development processes are currently undergoing a phase of profound growth based on innovative principles of progressive computerisation and digitalisation. The technological evolution today makes it possible to revisit the phases of the building process in a digital key, identifying tools, methodologies and approaches oriented towards the introduction and application of increasingly computerised systems aimed at translating traditional approaches by exploiting the potential and advantages of technology.

The next step in this digital evolution will be the creation of systems that replicate urban reality and are in continuous connection with it through data flow, thus being able to support or surrogate city managers in the immediate response to a disruptive event, working with machine learning algorithms.

This then is the rapidly changing scenario of the evolutionary opportunities offered by Industry 4.0, which sees digitalisation as a strategic choice, but also as an increasingly pressing need, as dictated by the regulations currently in force. The European Union

Public Procurement Directive 2014/24/EU (EUPPD) in this sense modernises the procedures concerning public procurement and is implemented in Italy through the "Public Contracts Code" (Legislative Decree 50/2016) and Decree no. 560/2017[1], which describes the introduction of digital methods, approaches and tools, as well as how and how fast it will become compulsory for administrations, contracting stations and economic operators in all phases of the building life cycle, from conception and design to construction and future management.

Even the digital city system is obviously involved in this digital revolution thanks to the application of methodologies and approaches that supplant the traditional methods of managing the built environment, as well as urban areas, configuring digital models as spatial indices of information previously collected in differentiated databases.

The so-called Building Information Modeling (BIM) is the methodology that today promotes the digital approach in the construction sector, placing at the centre of the process the univocity, transparency and coherence of the data during all the phases of the process, defining a database structured by parametric objects, characterised qualitatively and quantitatively, and contextually integrating the various disciplines. The result is a fundamental and univocal multi-dimensional tool to support integrated design, in which the players

[1] Ministerial Decree No 560 of 2017, implementing Article 23(13) of Legislative Decree No 50 of 18 April 2016.

in the process collaborate within the same digital environment to improve the quality of the product obtained, experiencing considerable advantages in terms of time and costs. Information modelling, therefore, offers considerable added value to the management systems of the development processes, which can be traced back to the possibility of reconstructing the building and its peculiar characteristics faithfully, implementing the digital objects with information regarding materials, performance, systems, components, etc.
In this panorama, therefore, the concept of information is subject to continuous evolution and it takes on a fundamental role in the digital era, where new methods and tools emerge to support the construction phase and are able to integrate, manage and monitor data from the real world. It is enough to think of an existing physical object that, thanks to the use of sensors, can become a digital entity capable of communicating in real-time, a database useful for carrying out specific activities, just as tools, machines and construction site equipment can be equipped with their own IoT (Internet of Things)[2] intelligence that transmits information and parameters to shared networks.
Therefore, the objective of the new data supply chain is to manage a heterogeneous wealth of information, elaborating semi-automatic analyses for the management

[2] The concept of IoT represents an evolution of the use of the Internet in which objects become recognisable and acquire intelligence by being able to communicate data about themselves and access aggregated information from others with the aim of giving an electronic identity to things and places in the physical environment.

of that large container of information today called Big Data, whose function is to be able to provide a descriptive and predictive analysis capable of integrating objects, materials, characteristics and processes starting from the vast amount of data available, to achieve the design objectives in a perspective of "project management 2.0".

With the integration of some existing construction management tools and platforms[3] still in increasing and progressive use due to the computerisation of the AEC (Architecture Engineering Construction) sector, it is possible to integrate these BIM systems aimed at describing the built environment at the micro-level of buildings with the GIS (Geographic Information System) which instead provides a large-scale representation of the territorial/urban context in which they are inserted. This makes it possible to obtain a digital reconstruction extended to the architectural and environmental entities of reference, thus allowing effective and integrated management of data and information that combine to form a solid and structured support system for decision-making processes. This allows a broader and deeper understanding of the process, having as a reference different levels of georeferenced and overlapping data, exploiting the technological potential of advanced tools such as the information made available by drones. These systems make it possible to rapidly acquire data gathered

[3] Those tools and platforms are widely used in field execution by contractors and construction project teams. They are cloud-based construction project management solutions able to connect project information and workflows, keeping the office and field teams in sync.

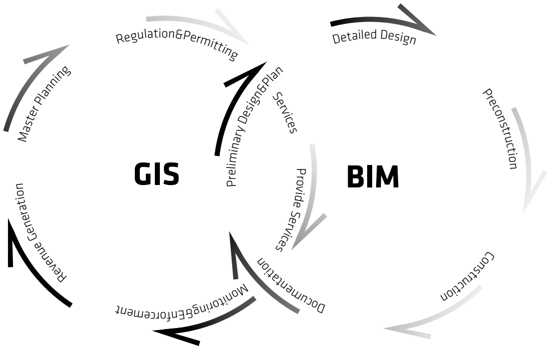


Fig. 1 Integrated data and information flow in the interaction between BIM and GIS systems. Graphic re-elaboration from source: Esri https://www.geospatialworld.net).

in the field, as well as to analyse spatial information that influences urban and territorial planning and programming, for which this approach change the paradigm.

Geographical information and data from GIS systems undoubtedly represent an important element in the decision-making process, allowing the stakeholders involved to gain greater awareness of the environmental and territorial context of interest, thus constituting digital information models, which can be visualised, allowing for immediate understanding of the impacts of design decisions before, during and after implementation.

The objective is, therefore, to manage the complexity of urban processes with greater efficiency and awareness, configuring what can essentially be defined as BIM/GIS as a powerful tool that can be used in different fields such as resource and asset management, environmental

BIM/GIS INTEGRATION AREAS	APPLICATION BENEFITS
INCREASING PRODUCTIVITY THROUGH DATA MAPPING	The automation of data increases the levels of efficiency and accuracy, making it possible to create specific thematic maps to serve a wide range of management needs.
OPTIMISING PRODUCTIVITY THROUGH ACCESS TO INFORMATION	Flow models in the management of the built environment, be it a single building or an entire urban system, require data that is as expensive to produce as it is to maintain and update. Driving these models and analysis models based on an integrated BIM/GIS database can lead to a significant economic advantage and an improvement in the quality of the analytical models themselves due to the robustness and reliability of the data used.
IMPROVING OPERATIONAL EFFICIENCY	The opportunity to improve the efficiency of the entire process generates significant time and cost savings and revolutionises traditional planning and workflow organisation techniques.

Tab. 1 Summary of the main benefits that can be obtained from the application of an operational flow based on integrated digital systems (A. Osello et al. Building Information Modelling, Geographic Information System, Augmented Reality for Facility Management).

impact analysis, scientific and archaeological investigations, as well as for the support of urban planning or conservation and restoration interventions, multicriteria analysis on a territorial scale and so on. Therefore, to realise an integrated workflow through BIM and GIS systems (Fig. 1) means to allow a concrete interaction between the data contained in the digital models and the geographical/territorial ones, using the specific potentialities of the tools and technologies that guarantee optimal transfer between different applications, exploiting the basic principles of software interoperability through specific data interchange formats (IFC-Industry Foundation Classes)[4].
BIM and GIS are therefore increasingly complementary methodologies that must be configured as a continuum in the field of digital infrastructures, and whose application has a positive impact on production levels, with benefits in the areas summarised in Table 1.

[4] Industry Foundation Classes is an open data format, created to facilitate interoperability between different operators with the aim of enabling the interchange of an information model without loss or distortion of data or information.

Sofia Agostinelli

COGNITIVE DIGITAL TWIN FOR BUILDING MANAGEMENT SYSTEMS: A CASE STUDY IN ROME

The concept of "digital twin" is moving beyond manufacturing and industrial sectors configuring virtual models and ICT (Information Comunication Technology) systems for improved real-time data-driven management of physical assets, developing data-centric[2] processes to support the design, construction, and operation phases.

The configuration of Digital Twins is gradually becoming useful even in the AEC (Architecture, Engineering, Construction) sector, connecting physical objects such as buildings and their digital equivalent through ICT systems. In fact, thanks to the so-called Key Enabling Technologies (KET)[3] of Industry 4.0 and their progressive

[1] CITERA Interdepartmental Research Centre for Territory, Construction, Restoration and Environment - Sapienza University of Rome.

[2] According to B. Combemale, et al. data-centric approaches refer to the implementation of digital processes where data are collected and processed by predictive and prescriptive models in order to adapt the system handling the evolving data.

[3] According to the definition given by the European Commission, Key Enabling Technologies are "knowledge-intensive technologies associated with high R&D intensity, rapid innovation cycles, substantial investment costs and highly qualified employments". They have systemic relevance as they feed the value chain of the production system by

evolution (i.e. Cloud, BIM, GIS, Big Data, Internet of Things, High-speed Networking, Advanced Analytics, Robotics and Automation, Artificial Intelligence, Cybersecurity, Augmented and Mixed Reality etc.), the effective exchange of data from virtual to physical assets becomes possible.

In particular, the configuration of digital ecosystems for the built environment leads to the creation of three-dimensional information models with BIM (Building Information Modeling) approaches aiming at real-time management and monitoring of the interactions between digitized objects and their physical equivalent, creating new scenarios for efficient digital processes.

According to the UK Center for Digital Built Britain, Digital Twins are useful for assets, processes or technical systems in a built or natural environment, and if combined with machine learning methods, they may lead to predictive analytics resulting in digital decision-making support systems optimizing and automating processes.

Digital Twin information systems and workflows in fact involve the use of computing technologies in building processes, applying lean construction[4] approaches to the management of the entire lifecycle, prioritizing the achievement of smooth production flows, minimizing the variation and waste of resources[5].

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innovating processes, products and services in all economic sectors of human activity.

[4] Lean construction paradigms refer to modern management techniques in building processes which prioritize the achievement of smooth production flows with minimal variation and thus minimal waste of resources.

[5] Forbes L.H. and Ahmed S.M. (2011) *Modern Construction: Lean*

Consequently, by introducing the increasing potential of Artificial Intelligence and Machine Learning systems in a Digital Twin-based construction process, it becomes possible to optimize and automate the operation and maintenance phases with the acquisition and continuous processing of data streams from different sources, allowing to perform analysis, evaluating alternative scenarios using what-if analysis approaches[6] and promptly responding to unexpected events in an increasingly accurate way over time[7].

From a technological point of view, it can be pointed out that commercial applications of monitoring technologies are still involved in the construction process but often for specific purposes, such as laser scanning for 3D Reality Capture[8] and construction status recording, computer vision with video and 360° images for safety/security or production progress monitoring, as well as smart sensors for indoor air quality or safety monitoring.

In this framework, it seems relevant to underline the absolute need to achieve an integrated holistic approach

Project Delivery and Integrated Practices. CRC Press, Boca Raton, FL, USA; Forbes L.H. and Ahmed S.M. (2011) *Modern Construction: Lean Project Delivery and Integrated Practices*. CRC Press, Boca Raton, FL, USA.

[6] What-if analysis is the basic level of data-driven predictive analytics. as a tool able to elaborate different scenarios to offer multiple possible results. In contrast to advanced predictive analysis, *what-if analysis* has the advantage of requiring only a few input data to be processed.

[7] Koskela L (1992) *Application of the New Production Philosophy to Construction* (Technical Report # 72). Center for Integrated. Facility Engineering, Department of Civil Engineering, Stanford University, Stanford, CA, USA.

[8] 3D Reality Capture is the process of scanning and capturing sites, plants, buildings, into a 3D digital model, combining measurements and visual information.

Frequency of monitoring	ICT-based approach	Enabling technologies
REAL-TIME MONITORING	Remote sensing for real-time and predictive monitoring	BIM, GIS, Cloud computing, Laser scanning, GPS, computer vision, IoT devices, WiFi ultra-wideband, machine learning.
DAILY PERFORMANCE MONITORING	AI software for early detection	
PERIODIC (WEEKLY-MONTHLY) ANALYSIS	Agent-based simulations	
LONG-TERM/PROJECT DURATION PLANNING	Machine learning improving future scenarios	

Tab. 1 Enabling technologies for building monitoring systems.

combining different technologies and merging data from multiples sources with a consistent project database, as a useful support system for delivering specific actions and implementing efficient management strategies[9]. From this perspective, table 1 lists various ICT approaches to monitoring, according to type and frequency, all of which correspond to the enabling technologies.

Cyber-Physical systems for facility management and construction monitoring

The effective value of such "data-centric" monitoring systems for construction and facility management consists of the production of relevant awareness about Building

[9] Seo J., Han S., Lee S. and Kim H. (2015) *Computer vision techniques for construction safety and health monitoring*. Advanced Engineering Informatics 29(2), 239–251; Fang W., Ding L., Zhong B., Love P.E. and Luo H. (2018) *Automated detection of workers and heavy equipment on construction sites: a convolutional neural network approach*. Advanced Engineering Informatics 37, 139–149.

Managers activities, making construction and facility management processes gradually more proactive than reactive[10].

In fact, Digital Twins must virtually contain and represent physical information in both predicted and real states, reflecting physical reality as it evolves over time. When occurring a change in the physical world, real-time updates are needed to re-monitoring or re-measuring, as the virtual replica of physical information will no longer represent the actual physical reality.

If Machine and Deep Learning[11] techniques combined with automatic reasoning mechanisms are involved in the Digital Twin-based building management process, they allow to strategically leverage such a large amount of real-time available information through features for the elaboration of heterogeneous data streams, including:

- Prediction of phenomena, particularly of failures;
- Profiling of users' behaviors and operating states of machinery;
- Optimized planning of material supplies and processing shifts;
- Real-time monitoring of systems and infrastructures;
- Multidimensional analysis of information.

Production management as well as supply chain performances, construction safety and labour productivity

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[10] Sacks R., Brilakis I., Pikas E., Xie H. S., Girolami M. (2020) *Construction with digital twin information systems*. Data-Centric Engineering.

[11] *Machine learning* is the domain of Artificial Intelligence that investigates automatic learning capacity of a system basing on data inputs analysis. *Deep learning* is a specific form of machine learning involving the use of artificial neural networks to process information in a non-linear manner, simulating the cellular behaviour of the human brain.

are also enriched by the use of Digital Twins thanks to the availability of large-scale, reliable and accessible databases representing a complete evolution of proactive building management systems, where data are contained in Digital Twin Models (DTM), along with associated performance simulation results. Thanks to artificial intelligence systems DTMs can be used as a knowledge-based predictive system, providing a source of labelled (tagged) data supporting machine learning application training, leading to learning and classification[12] processes.

Digital Twin and Artificial Intelligence for predictive maintenance: a residential district in Rome

The project developed in 2020 by the CITERA Interdepartmental Center for Territory, Construction, Restoration and Environment of the Sapienza University of Rome explores the application of digital tools and methods in order to obtain a three-dimensional information district-model integrated with Artificial Intelligence (AI) systems, defining predictive maintenance approaches for Building Management.

These potentials are examined in relation to a residential area called Rione Rinascimento III[13] consisting of a total

[12] *Classification* is a Machine Learning technique based on predicting the "class" (called targets/labels) of given data points. Classification predictive modelling is the approximation of a mapping function finding specific relationships in the input data that make it possible to produce correct outputs.

[13] Rinascimento III in Rome is configured as a building intervention characterizing an energetically almost self-sufficient (nZEB) new portion of the city, integrated as much as possible with the surrounding areas in terms of urban planning and services. The total area is about 85,000 m^2 consisting of 16 eight-floor buildings with 911 apartment units and 2,500

of 40 units, built in 2008 and located in the Monte Sacro district in Rome, next to a large public park.

Predictive maintenance is a methodology based on condition-monitoring techniques to track performance levels during the operations, aiming at identifying and resolve anomalies in a timely way before they give rise to failures. In comparison, with corrective/reactive maintenance, repairs are carried out only after a malfunction or failure has occurred, and preventive or scheduled maintenance interventions are implemented on the basis of the time or intensity of use of a given asset.

In addition to the ability to reduce downtimes and improve productivity, predictive maintenance can be used to extend the lifecycle of assets, reducing the costs and complexity of repairs, optimizing inventories of materials and spare parts, and complying with relevant regulations and compliance standards.

Thus, the development of Digital Twins for predictive maintenance of the built environment begins from the configuration of a building information model connecting three-dimensional objects (Figure 1) to specific information about the planned maintenance of individual components, as well as collecting input data from different sources (IoT, alarm systems, operators data sheets etc.), gradually powering self-learning capabilities with artificial intelligence and machine learning techniques, analysing data and comparing expected and unexpected rates of maintenance interventions.

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inhabitants.

Fig. 1. Rinascimento III BIM digital information model.

The configured BIM-AI integrated model is based on an automatic reasoning system, allowing the digital control of scheduled maintenance activities through the dynamic definition of rule-based algorithms for the recognition of malfunctioning scenarios, aiming at the progressive reduction of breakdown interventions.

As defined, the BIM model is the core-system of the DTM-based predictive maintenance process, combining machine learning systems and rule-based methods (such as data mining and association rule mining[14]) with the 3D physical/spatial information model containing operation and maintenance data layers, optimizing specific activities and interventions on such a complex building system thanks to the as-built geometric virtual representation provided by the BIM model.

Based on the collected data, Digital Twin-based building predictive models are structured to allow the optimization

[14] Data mining is a set of techniques and methodologies aimed at extracting useful information from large amounts of data through automatic or semi-automatic methods. In data mining, association rules are one of the methods to extract hidden relationships between data.

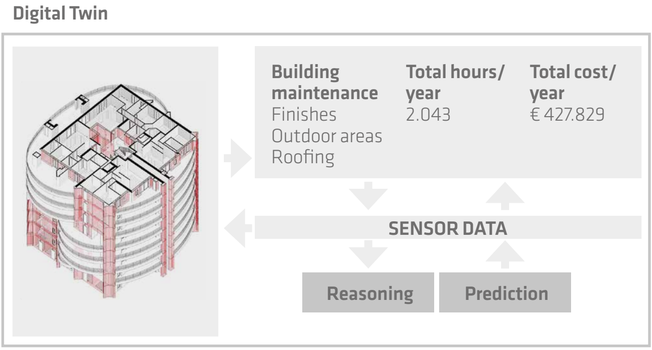

Fig. 2. Digital Twin-based machine learning system for predictive maintenance

of maintenance strategies (Figure 2) through the interaction of AI and data coming from sensors with 3D objects containing data layers about specific maintenance activities in terms of (a) type of activity, (b) description of activities for each phase (verification, restoration, repair), (c) total consistencies, (d) frequency, (e) employees, (f) time employed to perform the planned activities.

Then, the BIM functional/spatial data model combined with data coming from sensors and integrated with artificial intelligence systems becomes the control and monitoring centre for the operations and maintenance phases on building systems as well as on mechanical, electrical, and HVAC plants, supporting decision-making processes.

In fact, Digital Twin Models for predictive maintenance may indicate both that the current programs and practices are ideal and do not need to be changed, or that there is the urgent need to avoid a breakdown, even postponing a costly intervention if the component does not need it.

Thus, integrating Artificial Intelligence systems into Facility Management processes implies the use of software to make decisions and solve problems autonomously through deduction and reasoning processes, thanks to the collection and analysis of large amounts of real-time data supporting decisions and providing in-depth information, even identifying and eliminating routine and repetitive tasks that could be easily automated.
Therefore, Facility Management using AI-systems takes advantages of automating activities such as scheduled maintenance and critical inspections, achieving greater efficiency as machine learning makes the system capable to learn autonomously and become smarter gradually over time, as it increases amount of data analyzed.
Leveraging the advantage offered by AI as well as the support of information and data for decision-making, it is also essential to manage resources more efficiently, operating in a strategic and optimized integrated way.
In fact, the progressive diffusion of IoT (Internet of Things) devices and applications, together with the availability of advanced analytical tools using Artificial Intelligence and machine learning technologies, now make it possible to integrate different kind of sensors into industrial machinery, connecting such equipment to a structured network, in order to continuously monitor its operating status.
In this perspective, the more data is captured from sensors, the more machine learning algorithms can learn about the history and condition of building systems and machines, continuously improving maintenance methodologies.

The configuration of such a Building Management system aimed at optimizing the maintenance activities allows therefore considerable savings on the operating costs to be charged to the single owner, providing the opportunity to identify a fixed fee for the annual maintenance program according to the real needs and conditions of the assets.

In addition, through the identification of tasks and activities that could be potentially assigned to advanced TVCC sensors, the use of computer vision for image recognition[15] analysis with drones and video-surveillance systems provides a significant optimization of costs and resources for maintenance activities.

In fact, with regard to the security requirements of the building complex, cameras could take day and night images even in closed or inaccessible areas, and they could represent a source of useful data for a machine learning/computer vision system, processing and comparing the variation of chromatic ranges, as well as decreases in the performance of lighting fixtures, or the state of conservation of elements/components (roofs, facade elements, etc.) even for operation and maintenance purposes.

In this perspective, drones and advanced cameras implemented in the district for high-performance security

[15] Computer vision, or artificial vision, is an interdisciplinary research field that deals with the study of computer processing, understanding how digital systems can reproduce processes and functions of the human visual apparatus. Therefore, it is not only referred to acquiring static or moving images (even beyond the spectrum of natural light), but also to their identification and recognition, extracting useful information to make decisions. Image Recognition is in fact only a part of computer vision, which is mainly based on neural networks able to identify, classify and recognize images.

levels could be used even for operation and maintenance control and monitoring activities using computer vision and image recognition systems on external areas as well as for monitoring the state of conservation of building finishes.

The configuration of such a DTM-AI-based construction and urban digital management ecosystem aims at optimizing decision-making processes integrating technologies for different purposes, implementing predictive tailor-made strategies based on the analyses performed, configuring a scalable and replicable methodological approach for different contexts from industrial to building assets.

Riccardo Maria Pulselli

EVOLUTIONARY CITIES: FROM THEORY TO PRACTICE

Approaching cities theoretically, taking inspiration from scientific disciplines such as thermodynamics and evolutionary physics, brings clear benefits. First, it allows for a deeper understanding of sustainability in the light of the second principle of thermodynamics and the concept of entropy; for instance, it becomes clearer that living organisms perform more efficiently than anthropic systems in terms of resource use and waste production. Second, it lays the basis for a common language that can be shared horizontally by experts with different backgrounds and thus encourage transdisciplinary cooperation; in order to face the closely interrelated environmental, social and economic problems, architects, biologists, geologists, engineers, environmental scientists, and other specialists are called upon to join their competences in a coordinated action and discover coherent practical solutions for building increasingly integrated and sustainable systems. Third, it shows the limits of the most commonly used planning and management approaches that focus prevalently on spatial and structural issues; rather it highlights the need for systemic views, exploring internal and external interactions, flows and dynamic processes. To give an example, typical Master Plans are considered largely obsolete tools, unable to handle the emerging needs of local communities due to quick social and climate change or technological innovation in our connected world. As proved by thermodynamic laws, time, more than space, is the crucial variable and increases the need for integrated planning practices that embed multiple parallel activities, widely shared policy-making with long term perspectives, inclusive programs and actions engaging multiple actors at all stages, from design to execution and management.

Ilya Prigogine, theorist of evolutionary physics, explained the general behaviour of complex dynamic systems such as living organisms and ecosystems, as well as economic and social systems, through thermodynamics. He defined these systems as *dissipative structures* for their capacity to structure themselves into coherent ordered forms depending on the capacity of the system to capture the energy and material inflows from the external environment and, contextually, to generate entropic outflows in the form of waste, heat and other emissions. Dissipative structures have the capacity to self-organize, making "order out of chaos", adapting and interacting with the surrounding environment, and behave as coherent systems, each with its own identity, that is more than the sum of its parts. Prigogine himself, together with Isabelle Stengers[1], stated that the simplest example of a dissipative structure that could be evoked

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[1] Prigogine I & Stengers I. *La Nouvelle Alliance. Métamorphose de la Science*. Gallimard, Paris 1979.

by analogy is the city. Cities therefore can be interpreted as ordered structures with their functions, dynamics and metabolism.

In the book titled *City out of Chaos*, which explores new approaches to the knowledge and management of urban systems interpreted as dissipative structures, Pulselli and Tiezzi[2] highlight the importance of the models and diagnostic tools that make it possible to visualise and quantify the dynamic processes that take place in cities and their evolution in time. The graphical language for system modelling used by Howard Odum[3] is one example. It allows representing real systems by visualizing interactions among main components and energy and material sources.

Representation in a diagram provides a synthetic description of stocks of resources and their flows throughout the transformation processes occurring within an observed boundary. In particular, Figure 1 shows a vision at a glance of the dynamics of a wide urban system. Sectors of activity, such as nature-based systems (bullet-shaped: agriculture including forestry and animal husbandry) and anthropic systems (rectangles: industry including electricity generation and manufacturing; cities including settlements and infrastructures), are indicated as crucial processes supported by a set of sources classified as natural (circles in the left side: sunlight, wind, rain), market-based (circles at the top: energy, materials, food

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[2] Pulselli R M, Tiezzi E. *City Out of Chaos. Urban Self-organization and Sustainability*. WITpress, Southampton UK 2009.

[3] Odum H T. *Environment, power and society*. Wiley, New York 1971; Odum H T. *Systems ecology*. Wiley, New York 1983.

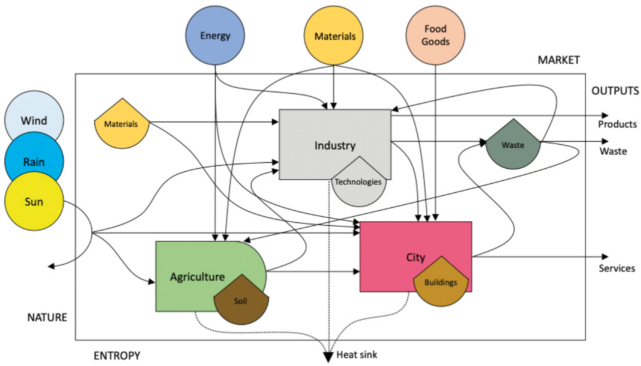

Fig. 1. Energy system diagram of a generic urban system based on the graphical language by Howard Odum.

and goods) and stocks, being quantities stored within the system (stock symbols: materials from quarries and mines; soil; technologies; buildings). Energy and material flows are defined by arrows. The arrows that point down, converging towards an entropic sink, indicate that, with each transformation, part of the energy is degraded in the form of heat, following the second principle of thermodynamics. This "macroscopic" vision clearly shows cities as a combination of connected processes that ultimately depend on resources directly deriving from the environment (left side). The city's autonomy is based upon the recognition of this inescapable dependence.
The simulation diagram gives a coherent representation of the various elements of an urban system and describes the general functioning of a city in the light of the thermodynamics of dissipative structures. The formation

and subsistence of the whole, services and urban functions that generate general outputs (namely society, economy, culture), are processes that absorb resources from the external environment and dissipate entropy, in the form of heat, waste, refluent water, and atmospheric emissions. Once the importance of these dynamic processes as crucial factors in urban management is proved, it is clear that it is desirable to use innovative methodologies and tools to collect data, estimate quantities, elaborate indicators and inform urban design practices based on deeper knowledge and increased awareness.

Quickly moving from theory to practice, one representative example of a tool that has been used for this purpose is the carbon accounting framework tested by the *Ecodynamics Group* at the University of Siena[4]. The basic greenhouse gas inventory methodology has been applied to cities and city neighbourhoods to evaluate the intensity of emissions (a form of entropy) generated by the urban functions. The added value consists in the opportunity to tackle multiple variables including energy demand, waste production, water use and material flows for different sectors of activity and, through specific emission factors, express impacts in the common unit of tons of equivalent carbon dioxide (CO_2eq).

The carbon accounting framework has been used to show the impact of energy and material processing in cities and neighbourhoods and is used to inform urban policies and

[4] Pulselli R M, Marchi M, Neri E, Marchettini N, Bastianoni S. "Carbon accounting framework for decarbonisation of European city neighborhoods". *Journal of Cleaner Production* 208 (2019) 850-868.

design, for example for implementing mitigation measures in the various sectors of activities to avoid emissions and achieve a low carbon society. Although this monitoring tool is partial and not exhaustive, it helps to guarantee the robust scientific coherence of planning and design practices by focusing on dynamic processes and their measurements; moreover, it can support awareness-raising initiatives targeting citizens and stakeholders engaged in participative processes. The outcomes concern many urban design issues operating at different scales, from that of the community to the individual level, and promoting different strategies, from structural and technological solutions to policymaking and behavioural changes. In the framework of the European project CityZen, a series of participatory workshops were carried out in ten sample cities. The travelling workshop involved an international team of academics, specialists in urban design, energy transition and environmental accounting. During the course of each workshop, each of which had a designated location, the team of experts visited the urban area under study and interacted with administrators and citizens to gather their concerns and identify their main needs and aspirations. At the end of several study and co-design sessions, the team produced a plan for the radical transformation of the city in a medium- to long-term perspective. In practice, the outcome of each workshop was the vision of a desirable sustainable, energy self-sufficient and carbon-neutral city by 2050; to this end, each action in the plan was measured and sized according to the actual feasibility of the interventions and the expected mitigation effects.

There is extensive documentation on the results obtained during CityZen roadshows[5]. One of the most significant experiences was carried out in Roeselare[6], Belgium, a city that has been working on an innovative urban climate plan for some time and to which the administration has dedicated a specific office. During the five days of the workshop, the action of monitoring emissions served first to guide and then to verify the activities of sustainable urban planning and energy transition.

Starting with a collection of site-specific data, the first step concerned the estimate of the city's overall impact in its current state, taking into account the main sources of emissions: energy consumption for residential use and urban mobility, waste management and water resources (it is understood that this estimate is partial and overlooks other important factors that contribute to determining the carbon footprint of an urban system, such as food supply, consumption of goods acquired from the market, the costs of facilities and infrastructure, industrial, craft and agricultural activities). For the

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[5] van den Dobbelsteen A, Martin CL, Keeffe G, Pulselli RM, Vandevyvere H. From Problems to Potentials—The Urban Energy Transition of Gruž, Dubrovnik. Energies 2018, 11, 922. Pulselli RM, Maccanti M, Marrero M, van den Dobbelsteen, Martin C, Marchettini M. Energy transition for decarbonisation of urban neighbourhoods. A case study in Sevilla. In Passerini G. Sustainable Development and Planning X 893-901 2018. Pulselli RM, Maccanti M, Neri E, Patrizi N. Planning neighbourhood decarbonisation in Mediterranean cities. Quaderni di Urbanistica 3. 20, 2020 15-22.

[6] Pulselli R M, Broersma S, Martin C L, Keeffe G, Bastianoni S, van den Dobbelsteen A 2020. "Future City Visions. The Energy Transition Towards Carbon-Neutrality: lessons learned from the case of Roeselare, Belgium". *Renewable & Sustainable Energy Reviews* 137 (2021) 110612.

city of Roeselare, with more than 61000 inhabitants, the emissions measured correspond to approximately 320000 t CO_2eq on an annual basis. In addition to the measurement of the emission value, which would be puzzling for a non-expert audience, the communication of the results played an important role in the entire participatory process. In order to make the measured carbon footprint understandable and accessible to all, the emission value was expressed in spatial terms, representing a virtual forest area that could absorb an equivalent amount of CO_2. The virtual forest offsetting Roeselare's emissions corresponds to 23700 hectares, four times larger than the area of the municipality itself (6000 hectares).

The representation in Figure 2 shows the proportions of this equivalent forest area in relation to the size of the municipality and the shares allocated to the various emission sources. This image is the result of a simplification of a more complex calculation model in order to deliver a very clear message: the set of processes within the selected sectors of activity has significant environmental impacts and the equivalent forest area represents in an effective way the current challenge to be faced in order to reach the objective of a carbon neutral society by 2050, as expected by Europe. The second step of the process is therefore to determine every possible measure to reduce the extent of the equivalent forest, i.e. the amount of greenhouse gases emitted. The final outcome of the workshop is a sequence of actions for decarbonisation, for each of which the effects in terms of emissions avoided are visualized and appreciated.

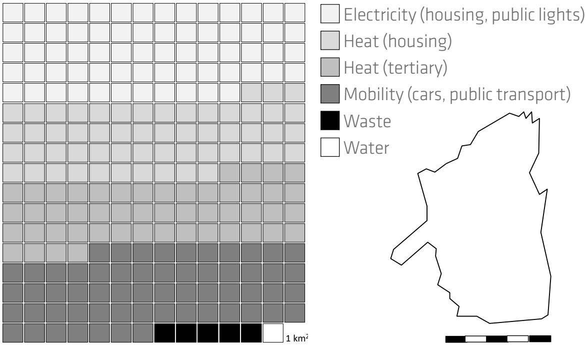

Fig. 2 Representation of the virtual forest offsetting greenhouse gas emissions of the municipality of Roeselare (Belgium), compared to the administrative boundaries, and the corresponding emission sources.

The mitigation actions discussed and then approved in Roeselare cover various possible solutions. Information and awareness-raising campaigns were planned to induce changes in individual behaviour regarding energy (energy savings in homes and workplaces), mobility (reduced use of private cars) and waste (reduction, reuse, differentiation), but also shared community policies on urban regeneration, circular economy, and community-based agriculture. Other measures concern the implementation of technological solutions from the scale of the individual building (energy saving, passive ventilation, nature-based solutions, renewable energy sources and storage systems, rainwater recovery), to that of the neighborhood or the whole city (smart grids and district heating networks powered by various renewable sources, integrated sustainable mobility systems, nature-based solutions at urban scale, integrated waste and waste water management systems). A further long-term scenario assumed a complete transition to electric power (air conditioning of buildings with heat pumps; electric mobility) considering, in addition to the benefits of a definitive abandonment of fossil fuels, the need to meet a greater demand for electricity consumption through new generation plants from renewable sources and integrated smart grids capable of supporting intermittent production and consumption. For every single action envisaged in this decarbonisation plan, potential benefits were estimated, quantified in terms of emissions avoided and therefore of portions of forest area progressively subtracted from the initial equivalent forest area, until its extension is reduced to zero. A clear observation arises from the experience of Roeselare: the scenario that emerges implies the creation of a new way of functioning and a new landscape of the urban system in which the combination of individual behaviour and new technologies profoundly changes how the city is perceived and experienced. Above all, the integrated approach shows that the energy transition is not merely a technological or infrastructural issue. For example, electric mobility can never be achieved through a complete replacement of the existing fleet of cars, but to be sustainable it will require a radical change in the mobility system towards integrated networks, intermodal exchanges, public transport and shared vehicles, bicycle and pedestrian infrastructures and limited mobility for private vehicles; in short, social and business models completely different from the current ones will have to be hypothesised, with a radical reduction in private mobility in favour of a widespread and capillary organisation of integrated transport.

The experience of the CityZen roadshows has shown how urban planning and programming practices must have a multiple value, not limited to the regulation of homogeneous spaces and zones as in current Structural Plans. From now on, it will be crucial to integrate different competences, e.g. combining design actions with assessment in order to predict the effects of proposed measures and assess their feasibility. In addition, participatory and civic involvement practices will play a crucial role, which in turn will be able to draw on the contributions of experts and specialists provided that simple and straightforward communication is developed. It is conceivable that, in the future, all planning will be the subject of coordinated and shared action by multiple actors within an articulated process of comparison and verification.

Accounting frameworks, monitoring methodologies, and mediation models are examples of tools that drive the transdisciplinary work of more scientifically oriented planning and design processes. These are needed to face the challenges and achieve the objectives of the Agenda 2030 of the United Nations (i.e. Sustainable Development Goals) or the European Green Deal. It is certainly to be hoped that, in the future, monitoring operations will be structured in an increasingly efficient manner, and that we may reach deeper knowledge of the processes that take place within an urban system and of the quantities of energy and material that they involve. The analogy between urban systems and living organisms that we have identified brings us to this conclusion; it underlines the importance of overcoming the emphasis on structural and spatial aspects and turning our attention more to the *metabolism*, rather than to the *anatomy*, of urban systems.

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Towards (R)evolving Cities: Urban fragilities and prospects in the 21st century first questions how we perceive the 'intelligence' of a city. The *New Frontier* of development for urban civilisations certainly includes digital and technological evolution, but it does not consider technology to be the final answer to all contemporary cities' problems. The formidable challenges of the COVID-19 pandemic have thrown existing urban fragilities into stark relief. At the same time however they have highlighted the potential of digital solutions for reaching a new level of interconnected civility.

(R)evolving cities evolve by adopting the principles of the circular economy in the higher interest of their citizens' well-being: they consume therefore without devouring, recycle as much as possible what they metabolize, limit the effects of their ecological footprint and ultimately lead their inhabitants, with maternal guidance and care, to a new idea of citizenship.

As protagonists of this evolutionary leap, the citizens of (R)evolving cities will abandon their predatory approach, reaching a higher stage of integration in the ecosystem and becoming more respectful of reciprocal relationships. (R)evolving cities are above all 'polite' cities, or rather cities whose citizens are consciously educated in the principles of sustainable development, the essential basis for contemporary civil coexistence.

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