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Review

Resource management as a key factor for sustainable urban planning

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ABSTRACT

Due to fast urbanization and increasing living standards, the environmental sustainability of our global society becomes more and more questionable. In this historical review we investigate the role of resources management (RM) and urban planning (UP) and propose ways for integration in sustainable development (SD). RM follows the principle of circular causation, and we reflect on to what extent RM has been an element for urban planning. Since the existence of the first settlements, a close relationship between RM, urbanization and technological development has been present. RM followed the demand for urban resources like water, energy, and food. In history, RM has been fostered by innovation and technology developments and has driven population growth and urbanization. Recent massive resource demand, especially in relation to energy and material flows, has altered natural ecosystems and has resulted in environmental degradation. UP has developed separately in response to different questions. UP followed the demand for improved living conditions, often associated to safety, good manufacturing and trading conditions and appropriate sanitation and waste management. In history UP has been a developing research area, especially since the industrial era and the related strong urbanization at the end of the 18th century. UP responded to new emerging problems in urban areas and became increasingly complex. Nowadays, UP has to address many objectives that are often conflicting, including, the urban sustainability. Our current urban un-sustainability is rooted in massive resource consumption and waste production beyond natural limits, and the absence of flows from waste to resources. Therefore, sustainable urban development requires integration of RM into UP. We propose new ways to this integration.

1. Introduction

For the first time in history, more than half of the world population, which is 3.5 billion people, are living in urban areas. This urban fraction will increase to almost 60% by 2030 and 70% by 2050 (ESA-UN, 2007). This large-scale urbanization requires large amounts of resources[1] – energy and materials – to build, feed and fuel cities (Girardet, 2003).

Cities are complex dynamic systems in a continuous state of change. They evolve in complex ways due to their size, social structures, economic systems, geopolitical settings, and the evolution of technology (Kennedy et al., 2007). Moreover, they require vast amounts of resources to function, displaying diverse patterns, agglomeration and intense competition for space with other land uses (Batty, 2008).

In the past, the depletion of the nearest and most accessible resources may have become a constraint on the growth of cities (Tainter, 2000). However, technological and infrastructural innovations have driven the increments on urban inputs and outputs (Kennedy et al., 2007; Krausmann et al., 2008, 2009; Monstadt, 2009). On a global scale and especially over the past two centuries, resources pressures have increased due to industrialism, rapid growth of the world population, urbanization (Tarr, 2002) and technological development. For instance, because of the development of advanced transport systems, resources can be imported from far away, which has led to a world-wide and complex resources network. Currently, cities are highly dependent on other cities and hinterlands to supply resources and dispose waste (Bai, 2007). Hence, the environmental

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[1] In this paper resources refer to energy and materials. Therefore, "resources" and "energy and materials" are used interchangeably. Materials and energy are two different aspects of the same processs. Regarding materials, earth is a closed system, meanwhile for energy it is an open system due to solar energy input. To understand the metabolism of a society it is necessary to consider both because many interdependencies exist between them e.g. energy can be used to increase the availability of materials and materials can be used to reduce energy flows. Additionally, production of energy for example nuclear power can generate hazardous radioactive material (Haberl, 2001; Lior, 2010).

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impacts are spread, thus enlarging the ecological (global) footprint of cities (McNeill, 2000; Monstadt, 2009; Rees, 1999).

Cities have direct and indirect global impacts on the atmosphere, hydrosphere, geosphere and biosphere by extracting large quantities of natural resources, in some cases leading to depletion, and disposing of urban waste (Mills, 2007). Global resource extraction has been grown steadily, from 40 billion metric tons (Gt) in 1980 to 59 Gt in 2006 (SERI, 2010). And global primary energy use has increased from 256 Exa-Joules (EJ) in 1973 to 514 EJ in 2008, 81% of that from non-renewable fossils fuels (IEA, 2010). Since the industrial revolution, we have paid less and less attention to the carrying capacity of the global ecosystem. Diamond (2005) and Ponting (2007) described how the consequences of irreversible damage to the environment can cause the collapse of ecosystems and societies. A famous case is Easter Island, where a human society was based in the period 900–1700 AD[2]. Massive environmental degradation due to indiscriminate deforestation of the island resulted in lack of essential materials not only for cooking, heating and building dwellings, but also to build canoes and nets for fishing. In addition to this, the quality of the soil also deteriorated due to erosion. All these factors brought the Easter Island civilization to a collapse. The current global human impact is unprecedented. In the past decade became widely accepted that continued growth with current utilization rates is unsustainable (Arrow et al., 2004). As humankind, we have to realize that the earth, like Easter Island, does not has unlimited resources to support human society and its demands (Ponting, 2007).

In a world of cities, it is becoming more and more clear that sustainable urban development is a crucial challenge (Girardet, 2003) and is maybe the most significant current and future environmental issue (McDonald and Patterson, 2007). To tackle this challenge, it is imperative to understand how urban metabolic systems function (Decker et al., 2000; Girardet, 2003). We can affirm that towards sustainable cities, it is crucial to manage available resources strategically. Isolated technical solutions are insufficient to deal with the complex problems we face today (Pahl-Wostl, 2007). As such, Resource Management (RM), as stated in the title, is a key factor for Sustainable Development (SD).

Recently, SD is increasingly being used to guide Urban Planning (UP). However, its implementation is not immediately apparent, because there has been no general agreement on how the concept should be translated into practice (Berke and Conroy, 2000; Jepson, 2001). UP and SD seem to be parallel activities with the common goal of sustainable cities. Both UP and SD refer to future. However, as stated by Hjorth and Bagheri (2006, p. 78) “Managing the future is a ‘wicked’ problem, meaning that it has no definitive formulation and no conclusively ‘best’ solutions and, furthermore, that the problem is constantly shifting”. Nevertheless, RM is an essential aspect that should be part of both, UP and SD.

The link between UP and SD is currently not strong. There is a significant number of articles approaching UP and sustainability in a broader sense and not becoming concrete and specific (Jepson, 2001). By investigating urban history, we aim to understand which factors have shaped RM and UP. It is important to highlight that UP and RM are different among regions; this paper refers mainly to UP and RM in the developed world: Europe and North America. This paper explored the relationship between urbanization, UP and RM reflecting on to what extent RM has been an element for UP. It gives an overview of past UP and RM practices, while taking into account the changes that cities have experienced over time. In the discussion, the paper also elaborates on the importance of urban RM as a key consideration for UP towards SD and how this could be achieved.

[2] There is considerably uncertainty about the date that Easter Island was occupied (Diamond, 2005).

2. Defining RM, UP and SD

Let us start by defining RM, UP and SD in some more detail. As yet, there is no formal definition of RM, although definitions for “natural resources management” and “integrated resources management” are available. Within the scope of this paper, RM refers to the conscious handling of natural resources – energy and materials – and the utilization of infrastructure and technology to meet human needs; including extraction, transformation, consumption or use and disposal of resources. Hence, RM includes natural resources and man-made products.

Planning, in general, aims to achieve an objective, and it proceeds by assembling actions into some orderly sequence (Hall, 2002). However, UP has multiple definitions. “UP refers to a planning with a spatial or geographical component, in which the general objective is to provide for a spatial structure of activities which in some way is better than the pattern that would exist without planning” (Hall, 2002, p. 3). Davidson (1996, p. 457) states that “UP is (or should be) a tool of urban management that helps to answer the questions what?, where?, when?, by whom?, and how?, urban development should take place”. Moreover, “UP has been continuously in a state of flux, reacting against what are seen as problems in the previous system” (Davidson, 1996, p. 452). Thus, although “UP is most often concerned with managing land development at the urban and regional scales, the field has broadened enormously since its origins, and now can be said to encompass the act of planning for desired future conditions at all scales of endeavor, within public and private sectors” (Wheeler, 2004, p. 11). In this paper UP is defined as the sequence of activities aimed to manage spatial development at urban and regional scales considering sociological, economic, political, technological and environmental aspects.

Likewise, SD has many definitions. Sustainability is a concept with many claims and definitions, but it is very difficult to translate into concrete terms (Gunder, 2006; Sahely et al., 2005). A major obstacle to the achievement of SD is lack of agreement of the conceptual basis. There is an inherent ambiguity of the terms: and the question that arises is what can be sustained and developed at the same time? Moreover, for different parties, the direct object of sustainability has different meanings (Seiffert and Loch, 2005). Parkin (2000) refers to more than two hundred definitions of sustainable development. The most accepted definition comes from the World Commission on Environment and Development (WCED) “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987, p. 8). Within this paper we interpret SD as RM that guarantee reliable resource provision for current and future generations, taking into account all potential tradeoffs and different scales in space and time (Pahl-Wostl, 2007). And we recognize that SD is not a fixed state of harmony, but a process of change (Reid, 1995).

The relationships between RM, UP and SD is shown in Fig. 1. Although, there is not unanimity of definitions of UP and SD, both activities are concerned with improving the future. Over history UP and RM have evolved over time and adapted to restrictions given by the changing state of cities. Increasing RM has caused increments of urban impact in the hinterland. We identify RM as a key factor within UP towards SD. The following paragraphs will identify the main factors within RM and UP along city development over history.

3. RM and UP over city history

3.1. The beginning of RM and emergence of settlements (8000 BC – 3000 BC)

The relationship between humans and their environment and natural resources has been in continuous change over the years. At

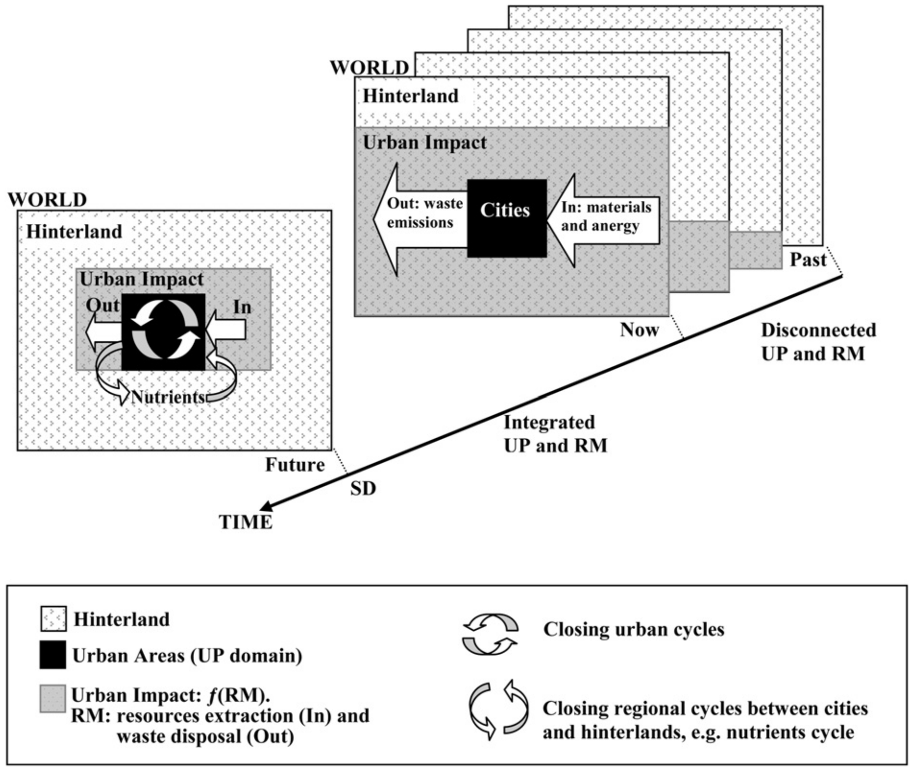

Fig. 1. Relationship between UP, RM and SD, and transition from a linear extraction-disposal based RM (now) towards closed cycles based RM (future).

the beginning, nomadic communities were basically hunters and gatherers. They collected resources in different places, migrating when resources became scarce. The energetic metabolism of hunters and gatherers has been described as an 'uncontrolled solar energy system' (Krausmann et al., 2008).

The first milestone in organized, large-scale RM started with the invention of agriculture, about 10000 years ago (Grübler, 1998; McNeill, 2000; Ponting, 2007). Ponting (2007) refers to agriculture as the most important transition in human history. Many societies changed from hunters and gatherers to an agrarian mode of subsistence. Adoption of agriculture had two major consequences – settled communities and a steadily rising population. Domestication[3] of plants and animals was a key factor on human domination on earth. Domestication and trade of agricultural products enabled division of labor, specialization, and faster technological change, which in turn led to further domestication (Grübler, 1998; McNeill, 2000). Domestication also affected social dynamics because since then, land resources and food were generally seen as a property (Ponting, 2007).

Agriculture also increased human pressure on the environment. Agrarian societies are fueled by solar energy and rely on the energy conversion provided by plant biomass (Krausmann et al., 2008). Compared with hunter and gatherer societies, the metabolism per capita of agrarian societies increased in terms of energy four to six fold and in terms of materials four fold (Fischer-Kowalski and Haberl, 1997). With agricultural development - plowing, fertilizing, flooding and irrigating - and feeding of animals, humankind caused ecological irreversible effects, because domestication improved productivity but involved tradeoffs, causing disturbances of natural cycles (Ehrlich, 2009; Kareiva et al., 2007; Mays et al., 2007).

3.2. *The rise of the cities and empires (3000 BC – 18th century)*

Agricultural production surpluses were a fundamental condition for the emergence of cities. Cities can be seen as a human strategy for survival. Cities concentrate population and resources, provide opportunities, e.g. jobs and services, but also concentrate problems, e.g. pollution (Bugliarello, 2006). With growing population, further RM developments were required, settled societies have to transport resources from their vicinities to survive. Consequently, complex social and infrastructural systems developed to deliver resources and services to more densely populated areas (Lee, 2006). As a result, early civilizations[4] appeared about 3000 BC in Mesopotamia and Egypt, and few hundred years later in the Indus Valley, a millennium later in China and another two millennia later in the Americas. In Mesopotamia, Uruk became the first city[5] in the world (Ponting, 2007).

The rise of the first empires, the steady but slow increase in the population and the development of trade led to the development of "pre-industrial" cities. They were characterized by a surrounded wall, not only for defense but also for political and economic control; they also developed water management techniques to guarantee survival (Ponting, 2007). Although, there were no formal UP principles at this time, many ancient cities were planned,

[3] "Domestication involves the selection of traits that fundamentally alter wild species to become more useful to us" (Kareiva et al., 2007 p. 1866).

[4] Civilizations are societies that became cohesive states and created organizations, institutions and culture (Ponting, 2007).

[5] Childe (1950) described the following conditions to identify cities from earlier settlements: extensive areas densely populated; with specialized division of labor; and social stratification with centralized power, therefore, leaders - priests, civil and military leaders and officials - will control surpluses by taxes and regular foreign trade. To symbolize the concentration of the social surplus monumental buildings were built. And development of writing, early scientific disciplines: arithmetic, geometry and astronomy. And finally the state organization based now on residence rather than kinship.

meaning that, their existence and their location were laid down consciously (Hall, 2002). Smith (2009) described a combination of planned central zones and unplanned residential neighborhoods as the most widespread principle of spatial organization in the ancient world. In addition, urban hydraulic systems, such as wells, baths and rainwater harvesting, were developed during the Bronze Age in the Indus valley and Mesopotamia (ca.2800–2100 BC), later it extended to Greece and finally to the Romans who inherited and improved these technologies (Mays et al., 2007).

During the following centuries, between 1000 BC and 1000 AD, various states and empires rose and fell. For example, in southern Mesopotamia, irrigating the desert soils brought prosperity and fostered population growth. However, after a few years of over irrigating, saline groundwater rose and ruined the soil; yields declined and after some attempts the dynasty finally collapsed (Tainter, 2000). The Indus valley civilization collapsed due to soil salinization but also due to deforestation. Deforestation has been, as well, a common problem in China, Japan, Greece, Italy, among others in different points of history (Ponting, 2007). They are examples of societies and its destructive impact on the environment, leading to their own collapse (Ponting, 2007). They demonstrate the relevance of RM to guarantee sustainability. Population growth and resources availability are an old concern, Greeks were aware that a city should balance its population with its resources, and Plato recommended zero population growth for his utopian republic (Harrison, 1993).

The creation of the Roman Empire increased the pressure on the environment due to a large food demand (Ponting, 2007). Romans developed complex and large water supply systems (Mays et al., 2007) and also consumed enormous quantities of water supplies. They also developed a large paved road network system. And the city of Rome even developed problems of traffic congestion (Hall, 2002). Unfortunately, after the decay of the Roman Empire their knowledge was lost. Therefore, water supply systems, water sanitation and public health declined in Europe, low hygienic conditions were common and minimum improvements were present regarding city livability. In Europe, this period is known as the dark ages (Mays et al., 2007). And it was not until the eighteenth century, that formal UP emerged (Hall, 2002).

3.3. *The industrial and urban revolution (18th and 19th century) – strong urbanization and the need for planning*

“Historical evidence suggests that industrialization is a transition process allowing populations to overcome scarcity and the sustainability problems of the agrarian sociometabolic regime” (Krausmann et al., 2008, p. 642). Industrialization caused changes in RM because the constraints from the controlled solar energy system became abolished. With fossil fuels and their associated technologies, energy became an abundant resource, productivity increased, transportation was fostered, and larger populations could be sustained, triggering an extraordinary growth of urban agglomerations.

Even though at the end of the 18th century, not more than three per cent of the world’s population lived in cities (Ponting, 2007), concern for increasing scarcity of resources was already raised. In his ‘Essay on the Principle of Population’, Malthus (1798) pointed out the unbalance between exponential human population growth and the linear food production growth. Some decades later, Jevons (1865) described the circular causation of RM, stating that economically justified energy-efficiency improvements will increase rather than reduce energy consumption. Additionally in 1885 to create awareness of the massive flows of resources in cities, Geddes used the concept of urban metabolism and established an urban energy and material budget in physical input–output terms (Geddes, 1885). Unfortunately, Geddes’ approach was not sound at that time (McDonald and Patterson, 2007).

Initially, the technological development – inventions in textiles and iron making - caused by the Industrial Revolution seemed to disperse industries out of the towns and into the open countryside. However, when coal became a principal raw material of industry, industry was concentrated where coal supplies were available (Wheeler, 2004). Consequently, industrial towns were developed across Europe to provide the energy source for the industrialization (Ponting, 2007). However, due to the fast development, growing and overcrowding of these towns did not include UP principles.

Early in the 19th century, in European cities, human excrements were collected in cesspools, emptied periodically and reused in agricultural fields (Barles, 2007). However, during the industrial revolution and the rapid growth of cities, environmental problems related to human excreta overwhelmed city governments. This rapid growth resulted in increments on density because public transport systems were nonexistent. Therefore, houses were located within walking distance to the work place (Hall, 2002). In addition to the removal of human excrements, the procurement of adequate drinking water was one of the most important concerns. Due to city growth and overcrowding, the limited water supplies became more and more contaminated with sewage and waste. The simplest RM approach – dumping wastes in the nearest watercourse and drinking from it too – worked only where people were few and water plentiful (McNeill, 2000). Additionally, greater mobility induced by trade facilitated the spread of epidemics like Cholera across the world (Hall, 2002).

Before the industrial revolution, RM and economic systems were primarily local and regional. With the industrial revolution, technological advances in transportation and communication established a global economy. In this economy, the main actors were Great Britain, Germany and the United states. Consequently, they were the most affected by urbanization. As a response to the problems caused by urbanization, formal UP schools were developed in these countries (Goff et al., 1994).

Hence, UP emerged as a very direct response and as a critique of unhealthy and polluted living conditions caused by the urbanization and industrialization (Fainstein, 2005; Watson, 2009). For example, in Britain, after the cholera epidemics of 1831 and 1854, British politicians established requirements for the construction of new housing from the 1870s onwards. The regulations stated that “streets should have a uniform minimum width to guarantee a modicum of air and light; each house originally should have a separate external lavatory, with access to a back alley running parallel to the street” (Hall, 2002, p. 17). The same regulations also posed restrictions to the maximal urban density (Hall, 2002).

The Industrial Revolution dramatically changed RM (McNeill, 2000). The expansion of industrial production required large amounts of natural resources. At the same time, new technologies facilitated the discovery of new resource deposits and improved accessibility and recoverability of the existing resources (Grübler, 1998). In the early 19th century, the massive use of coal made large quantities of manufactured steel available, which in turn fostered mining, industrial production, building construction, transport and warfare. These developments also gave an unprecedented access to the earth’s stores of resources (Girardet, 2003).

The exploitation of the earth’s vast, seemingly unlimited, stocks of fossil fuels led to a great transition in our societies which became highly dependent on energy use. Before, all the forms of energy used by human societies were renewable – human and animal power, water, wind and wood (McNeill, 2000; Ponting, 2007). Our current urban metabolic problems stem from the industrial revolution which brought about a shift in the use of materials from the organic to the inorganic and the change from a solar fueled economy to a fossil fuel based economy (White, 2002). Additionally, industrial societies use three to five times as much energy and materials as did agrarian ones (Krausmann et al., 2008).

In cities, further RM was fostered by infrastructure. Infrastructure was designed to extract, transform, transport, supply and dispose resource. Consequently, an interactive relationship between cities and environment was established, with cities having massive effects on the natural environment and the natural environment influencing urban configurations (Tarr, 2002). This development of urban infrastructure had two major implications. First, infrastructure was and is a driving force for development. Second, infrastructure development may in time lead to path dependency[6].

UP and in particular networking the city was not only a technical task. The implementation of these networks also generated a social and cultural process of adaptation. Infrastructure development led to fundamental changes in behavioral patterns of urban residents regarding RM, in both, their use of resources and disposal of waste. It favored the growth of resources use and caused a complete dematerialization of resources use, from which the only sensitive issue remaining is the price (Schott, 2004). This also implies that, towards an urban SD, a transition of existing infrastructures should take place (Monstadt, 2009).

3.4. The 20th and 21st century: Rapid urban changes

During the 20th century, the human population quadrupled to almost six billion. Resources consumption increased further and for every increase in production there was a corresponding increase in the excretion of entropic waste and eco-degradation. By the end of the twentieth century, half the world's land mass had been directly modified for human purposes and people were using half the accessible fresh water (McNeill, 2000). Fast urbanization and consequent land use change had altered ecosystems, destroyed wildlife habitats, changed regional climates and released large amounts of carbon into the atmosphere (Grübler, 1998).

As the world industrializes and urbanizes, the global flows of energy and materials were and are still increasing, (Decker et al., 2000; Goff et al., 1994), and a growing mismatch between human demand patterns and the capacity of the planet to supply resources and absorb wastes has emerged. In addition, during the twentieth century, human action put more harmful gases into the atmosphere. One major source of pollution was and is the mining, melting, refining, and use of heavy metals. When these pollutants become present in soils, they easily enter the food chain. In addition to heavy metals, industrialization also generated many other types of toxic wastes. Man-made chemicals became into existence after the mid-19th century but they only acquired environmental significance after the mid-20th (McNeill, 2000). Moreover, improvements in food production and preservation combined with decreasing of transport costs of the railway and steamship era allowed an unprecedented expansion of agricultural trade (Grübler, 1998). Between 1950 and 1985, "the world population doubled and the global food production almost tripled" (Goff et al., 1994 p. 285).

During the 20th century, crude oil and natural gas became the dominant energy sources. And cities became highly dependent on electricity, not only because of the spread of electric motors for different uses but also because electricity provided light and heat. In the late 20th century and early 21st century, several carriers, including nuclear energy, and modern renewable sources have risen in importance and are expected to play an important role in the energy mix of the future (Marcotullio and Lee, 2003; McNeill, 2000).

3.4.1. 1901 – 1960: fertilizers, automobiles and the search for the ideal city

Early agricultural techniques included a basic RM strategy by recycling of organic wastes and minerals in the form of manure and planting nitrogen-fixing legumes to preserve soil fertility (Grübler, 1998). Around 1900, the invention of chemical fertilizers allowed for tremendous increments in the agriculture production and fostered population growth. The impact of chemical fertilizers strongly influenced the choice of crops in and after the 1950s. Those crops that responded well to fertilizers spread far and wide, replacing those that did not. By chemical fertilizer use, food production became dependent on fossil fuels that are needed for fertilizer production. Moreover, fertilizers became water pollutants. Some estimates indicate that more than 50% of chemical fertilizers applied end up in nearby waters (McNeill, 2000).

The spread of the automobile strongly influenced the structure of modern cities, which led to large investments in road infrastructure and to the development of suburbs and less dense cities. New philosophies of road design emerged in the United States and Britain in the early 20th century (Hall, 2002). However, making room for cars took a lot of space and had a negative impact on urban environment as reflected by lead emissions (McNeill, 2000).

Some of the pioneers of UP pursued to design the "ideal city". To mention some, in the Anglo-American tradition, one of the most influential thinkers was Ebenezer Howard. His "Garden city" concept was proposed in 1898 and reappeared in 1902 in "Garden Cities of To-morrow" (Howard, 1902). The garden city concept took the regional polycentrist view and included self-contained, self-sufficient communities surrounded by greenbelts. Howard's vision influenced several generations of urban designers in Europe and the United States, including contemporary new urbanism movements (Berke, 2008; Miller, 2002). A new milestone in UP was made by Patrick Geddes, whose book "Cities in Evolution" appeared in 1915. He described how technology development and RM in cities influenced changes of cities (Geddes, 1915). His main contribution was to include human geography as basis of planning and giving planning a logical structure. His method became part of the standard sequence of planning: first, the preparation of a survey of the region, its characteristics and trends; secondly, an analysis of the survey and thirdly, the development of the actual plan (Hall, 2002). Geddes' approach illustrates that diversity of the local context was already acknowledged in UP in the early 20th century.

Also architects like Frank Lloyd Wright in the United States, Raymond Unwin in England, and Le Corbusier in France moved far beyond design of individual structures to design entire communities and societies (LeGates, 2003). In the early 1930s, Le Corbusier's "Radiant City" took a centrist urban perspective. Le Corbusier developed the idea of a city with high local concentrations of people in tall buildings, which would preserve open ground space. Uniformity was to be the basis of improving public health and livability. Frank Lloyd Wright's "Broadacre City" took a decentrist suburban view. His idea of decentralization was motivated by technological developments like the automobile and electricity. In his opinion with these technologies, there was no need of being concentrated in urban areas (Berke, 2008).

3.4.2. 1960–1990 UP diversification and RM concern

Up to the 1960s, UP was a local government task focused on exercising control over private land use and building design practices, and guiding spatial design of capital improvements such as streets, water pipes and sewers (Berke, 2002). During the 1960s, it was argued that UP should focus on broad principles rather than on

[6] Path dependency means that choices for certain key technologies and systems can limit the future room of maneuver for municipal policies and urban development. Changes in the system will imply great expenses, inhibiting changes of direction in how cities manage their resources (Schott, 2004), i.e. become a restriction for further development and innovation because infrastructure is extremely slow to change (Tarr, 1984).

details. Moreover, it should stress the process to reach the goal, rather than present the desired end state in detail (Hall, 2002). Between the 1960s and 1970s, cities in the USA and Europe faced poverty, racism, and high pollution levels. These problems questioned the efficacy of the classic view on UP (Berke, 2002). Moreover, critiques also argued that UP theories did not really affect the practice of urban architects and engineers (Hamlin, 2007).

In that same period, RM became high on the public agenda due to problems related to environmental degradation and resources scarcity. In 1962, when Rachel Carson published her book "Silent Spring", environmental degradation called the attention of the public and of politicians (McNeill, 2000). In 1965 Wolman revised the concept of urban metabolism, proposed by Geddes in 1885. In his study 'A Typical American City' (Wolman, 1965), Wolman called for attention towards the large resources consumption of cities. In 1969, McHarg published the book "Design with Nature", in which, he argued that cities should be planned as an integral part of natural systems. He proposed to use ecology to understand interactions between people and their environment and to use these as guiding principles for UP (McHarg, 1969). In 1968, Hardin published a warning statement on resources management in his "Tragedy of the commons" and concluded that "Freedom in a commons brings ruin to all" (Hardin, 1968, p. 1244). Also modern Malthusians ideologies reappeared, as in for instance, "The population bomb" (Ehrlich, 1968) and the report "Limits to Growth" (Meadows et al., 1972). Both sources basically concluded that continuation of the growth trends of the 1970s would lead to a collapse of human society because of scarcity of essential resources and food. According to the Club of Rome, this collapse could be avoided by establishing a condition of ecological and economic stability that should be sustainable far into the future (Meadows et al., 1972).

From the 1970s, in UP new urban forms were promoted as a response to environmental concerns. Within these approaches urban planners and designers also strived for a greater sense of place and identity. One example is the "compact city concept" that aims for a more efficient design by building high densities and mixed uses, especially considering energy for transportation. Also containment policies to limit urban growth encouraged densification and protection of surrounding natural resources (Watson, 2009). In the 1980s, communities set out on different development paths as a reaction on unified planning approaches. As described by Allmendinger, (2002) the development of UP theories has been in a hyperactive state since the early 1980s. These theories showed developments in a number of fields, including neo-liberal and public choice perspectives, postmodern planning, neo-pragmatism, political economy approaches and collaborative planning. New urbanists have revived the pre-1960s' idea that UP is about big, visionary ideas (Berke, 2002). But, it is not until 1987, that the WCED and its report "Our common future" placed the issue of SD at the core of urban policy and UP.

3.4.3. 1990 – now: Managing cities and resources, methodologies and assessments

At the end of the 20th century, "empirical evidence suggests that resource consumption already exceeds the productive capacity of critical biophysical systems on every continent and waste production already breaches the assimilative capacity of many ecosystems at every scale" (Rees, 1999, p. 208). As stated by Vitousek et al. (1997, p. 498) "We are changing Earth more rapidly that we can understand it". The scale of pollution increasingly surpassed the thresholds at which waters could assimilate wastes. Dilution as water pollution control did not work anymore (McNeill, 2000) and growth of flows of urban resources caused great problems regarding solid waste.

Initially, RM has been focused on mainly controlling environment deteriorating emissions to water, soil and air, the so called end-of-pipe solutions. Later, pollution prevention and design for the environment with strategies such us dematerialization, material substitution and recycling have been implemented to minimize environmental impacts (Grübler, 1998; Mihelcic et al., 2003). A noteworthy result of this is the general decline in metal emissions after 1980, a consequence of environmental awareness and regulation, and of new technologies with better efficiencies in metal removal and reduced waste productions (McNeill, 2000).

Some of the current global issues related to RM are the availability of resources such as: oil, fresh water, phosphorus, metals; and the disruption of natural cycles, for instance the nitrogen and carbon-cycle (Gordon et al., 2006; Rockström et al., 2009). Moreover, energy and materials are intertwined, for instance fossil energy and agricultural yields, as modern agriculture relies heavily on energy-intensive products such as fertilizers, pesticides and machines (Chambers, 2008).

Recently, the relevance of RM within SD has been recognized. And different approaches have been developed to study urban complexity and its impacts. Some examples of those approaches are Environmental Impact Assessment (EIA), Life Cycle Assessment (LCA) and Ecological Footprint (EF). EIA is an environmental tool used to assess the potential environmental impact of an activity. It assesses the level of impacts and provides recommendations to minimize them (Dincer and Rosen, 2005). LCA is a tool for quantitative assessment of materials, energy flows and environmental impacts of products, services and technologies (Krozer and Vis, 1998). LCA examines products "from cradle-to-grave". EF is based on the fact that many material and energy flows can be converted into land-area equivalents. Thus, the EF of a specified population is the area of land required to produce the resources consumed, and to assimilate the wastes generated (Rees, 1999). However, all these approaches have drawbacks, such as the use of aggregation methods and the need for extensive data sets. Therefore, currently, combined and hybrid methods are being developed, e.g. ECO-LCA (Zhang et al., 2010).

From the late 1990s, the notion of SD required that environmental issues were addressed at the same time as economic and social issues, and UP was viewed as having a central role to play in achieving this (Watson, 2009). LeGates and Stout (2003) gave words to the UP complexity by naming some of the issues that planning theory and practice must confront in the twenty-first century. The issues he mentioned are: design, economic feasibility, decision-making theory, conflict resolution, advocacy, race, class and gender equity, and sustainability. Moreover, new agendas in UP are continuously emerging. In 2009, the journal "progress in planning" published two special issues about emerging agendas in UP, showing that UP is an evolving field that should adapt to the current cities' needs. Furthermore, environmental sustainability and climate change concerns have been a fundamental source of new ideas and approaches in UP over the last years (Watson, 2009).

4. Discussion: Outlook

Fig. 2 summarizes the findings of this paper and includes an overview of the development of cities over time, of RM, of innovations in technologies and UP and the debates on urban spatial planning. The paper showed that RM, innovation and technology diffusion are at the core of the historical changes. The agricultural revolution, an innovation in RM, in approximately 8000 BC favored the emergence of cities. The newly established cities required storage, transportation and distribution of food, water and goods, thus increasing the energy demand. Discovery of new energy carriers foster technological innovation that in turn, enhanced population growth, urbanization (Tarr, 1984) and domestication of entire

	BC							AD																	
	-20000	-8000	-3000	-2000	-1000	-500	0	1000	1200	1500	1700	1800	1850	1870	1890	1900	1920	1950	1960	1970	1980	1990	2000	2010	Future
World population (Millions)	-	-	-	-	-	-	300	310	400	500	790	1000	1200	-	-	1600	2000	2535	3032	3699	4451	5295	6124	6907	
% Urban	-	-	-	-	-	-	-	-	-	-	-	<3	-	-	-	13	-	29.1	32.9	36	39.1	43	46.4	50.6	
Biggest city Population (Millions)	Non existing	First settlement	Uruk 0.04		Thebes 0.12	Babylon 0.20	Rome 0.80	-	Baghdad 1.0	Beijing 1.0		Beijing 1.1	London 2.3	-	-	London 6.5	-	New York 12.5	-	Tokyo 21.0	-	-	Tokyo 34	-	
Main feature	Nomads	Agriculture	Empires	Trade & defense				Dark ages				Industrialization					Mass production and consumption				Pollution & Environmental concern				SD
RM – RM DRIVERS – Food	Hunters gatherers	Agriculture surplus		Small ploughs						Malnutrition due to growing population		Use of human excrement as fertilizer Worldwide diffusion of crops and animals				Chemical fertilizer Increasing livestock	Industrialization of agriculture	Pesticides Ovefishing	Improvements on food preservation Worldwide food web Green Revolution:genetic modification of species				Phosphorus availability concern Competing claims with energy crops		
RM – RM DRIVERS – Water			Irrigation, Sewer Pipes			Aqueducts								Sewer			Water pollution due to fertilizer use						Integrated Water Management		
RM – RM DRIVERS – Energy		Human and animal power								Water power Water mills	Wind, wood	Steam Coal					Oil Electricity				Gas	Nuclear	Renewable		
RM – RM DRIVERS – Materials	Wood Stone Bones			Metals: Copper & bronze	Iron					Textiles	New products from colonies brought to Europe		Mining, industrial production, building construction			Mining, smelting, refining Heavy metals		Petrochemicals, plastic, steel, aluminum		Electronic, recyclable and degradable					
RM – RM DRIVERS – Transport	Walking	Horses				Roads ("pikes") water Transportation (ships)					Canals Ports	Carriage Bicycle	Steamships Railways Paved roads				Car Roads	Subway Bus			Air transport				
RM – Approaches												Nature absobs human load Dilute			From organic to inorganic	Export products	Dump & export waste				Pollution control, environmental technology, disassembly and recycling		Dematerialization Material substitution, Cleaner production	Resource recovery	Integrating UP + RM = Low impact urban design RM towards closed cycles Local context specific models
RM – Bottlenecks						First description of traffic congestion Large water consumption						High densities, Pollution of water bodies, and epidemics				Water and soil pollution	Ecosystems alteration Toxic waste		Pollution due to man made chemicals		Environmental degradation and resources scarcity		Earth carrying capacity exceeded	Climate change Resource Scarcity Un-sustainable consumption	
RM – Thinkers														Geddes input-output analysis					Wolman: metabolism of a typical American city	Limits to growth	Our common future		EIA, LCA, Ecological footprint Cradle to Cradle		
UP – UP drivers	Cities developed close to water resources			Religious and political power: Palaces		Surrounded wall for defense and political and economical control						Public health	Formal UP						Regional economic development, indefinite expansion, decentralization Containtment		Environmental planning, sustainability Compact city			Planning for long term sustainability	
UP – Models			Planned central zones and unplanned residential neighborhoods			Timber frame-houses and earthworks constructed with timber and stone						Walking cities		Streets minimum width and maximum densities	Land use regulation: Zoning Transportation planning		Planning for cars	Master plan		Public participation	Environmental justice New urbanism	Smart growth			
UP – Bottlenecks			Cities developed close to water resources		Security							Rapid urban growth	Dense unplanned settlements				Space for cars		Critiques about UP theories not affecting the practice		Hyperactive state of UP theories		Difficulties to translate sustainability into practice		
UP – Thinkers						Plato: Zero population growth							Malthus: Unbalance between geometrical population growth and linear food production growth	Jevons' Paradox	Howard's: Garden City		Geddes' planning methodology Frank Lloyd Wright's Broacre city and Le Corbusier's Radiant city		McHarg: Design with nature						

Fig. 2. Historical overview of world population, changes on resources management (RM) and urban planning (UP). Note: Sources for population values are ESA-UN, 1999, 2005a, 2005b; Marcotullio and Lee, 2003; Modelski, 2003; UN-Habitat, 2008.

landscapes and ecosystems (Kareiva et al., 2007), by redistributing organisms, energy and materials flows (Alberti et al., 2003).

The historical overview in this paper shows that since the existence of the first settlements, a close relationship between RM, urbanization, technological development and some form of UP has always been present. The first cities usually had some form of road planning in order to facilitate transport. During and after the industrial revolution – an era of many new inventions, such as the steam engine, electricity, chemical fertilizer and the automobile – urban growth accelerated exponentially and resulted in poor living conditions. As a response, various UP schools started to develop in the 1850s. The paper showed that urban RM and UP have developed separately in response to different questions: the demand for urban resources versus the demand for improved living conditions in cities. UP has been a flexible research area since, changing according to new emerging problems in urban areas. It developed further with the increasing complexity of urban areas. Nowadays, the demands posed on UP are overwhelming with many objectives that are sometimes conflicting, including sustainability which has been added in recent years.

After the industrial revolution, RM increased and shifted to inorganic materials and to a fossil fuel based economy. It is very clear that our current urban un-sustainability is rooted in a massive resource consumption and waste production beyond natural supply and recycling limits. To guarantee urban sustainability, cities must be planned to foster strategic RM. Knowing that the spatial organization of a city and its infrastructure influence RM (Alberti et al., 2003), UP for SD needs to go beyond traditional planning and strategy making (Bagheri and Hjorth, 2007). As presented in section 2, RM is a key component of SD. From that perspective, it is also clear that if SD and UP are to be integrated, RM is an important element, if not the key element, to take along.

A remarkable aspect is that, UP pioneers in the 19th century were already thinking about the ideal shape of the city from the perspective of managing resources and providing high quality of life to inhabitants. Paradoxically, more than a century later, formal links are still missing between RM and UP. There is clearly a need to develop a holistic approach to evaluate our urban areas, integrating sustainable resources management and urban spatial planning.

Concluding, there is a need for a comprehensive framework that integrates RM and UP. Towards urban sustainability, RM becomes a formal and critical link between UP and SD. As stated by Rees (1999, p. 216), "Urban planning in the 21st Century should evolve towards an ecologically-oriented macro-architecture, fully integrating the design and location of energy-and material-efficient buildings and urban infrastructure with overall spatial planning further to minimize material throughput".

As a consequence of this, in the first place, planners need tools to understand cities and regions as environmental systems that are part of regional and global networks (Campbell, 1996). Such tools should be used by different stakeholders during UP processes and translated into effective decision-making. As stated by (Graedel and Klee, 2002, p. 528), "If we are indeed serious about sustainability…we can move forward only by converting that fuzzy concept to dependable, measurable metrics".

The authors of this article are currently working on an approach that is named 'urban harvest' which integrates urban resources management into an approach for urban spatial planning. The Urban Harvest Approach (UHA) based on the urban metabolism concept, aims for improved resources management by closing urban cycles, applying innovative technologies and harvesting urban resources. It is our opinion that only by using RM as a formal link to integrate UP and SD, we will achieve sustainable urban planning. Sustainable UP should aim for low impact cities by integrating RM and UP.

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