

## **Flows, drivers, services and functions and urban typologies: an integrated approach for the analysis of urban eco-systems**

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### **Abstract**

The unplanned and non-environmentally integrated growth of cities in the last decades implies problems and challenges related to environmental impacts, life quality, social cohesion and economic capacities and competences. Considering this situation, an integrated management regarding the aforesaid aspects is demanded in urban areas. This requirement has already arisen from the European Commission within the Thematic Strategy on Urban Environment. Furthermore, in May 2007, the European Member States stated so in the Leipzig Charta.

INCYDA EMAU is a project partially supported by the Spanish Ministry of Environment which aims to provide an integrated methodology for the assessment of urban system patterns and capacity of response and action with two objectives, a) avoiding the alteration of the ecological, social and economical conditions of the city, and also b) improving them, throughout a process of building new economic and social habits, by means of an urban ecosystem approach. The project encompasses four phases: 1) Characterization and comprehension of urban ecosystems 2) Assessment and diagnosis 3) Identification of critical nodes and 4) Definition of strategic actions. The methodology is being tested as a pilot case from the very early stages of the project. This paper focuses on the characterization phase.

*Keywords: urban eco-system, sustainability, urban flows, urban typologies, capacity of response, policy, strategic actions.*



## 1 Introduction

According to the urban and rural UN statistics, more than sixty percent of the world's population will live in urban areas by 2030 [1, 2]. Metropolitan areas and urban agglomerations are growing in an uncontrolled way and are also lacking well structured planning. Thus, it is a common and widespread situation to observe highly inhabited city centres alongside low density or newly developed peri-urban areas, often characterised by a strong rural nature. Additionally, this urban increase, both in density and in spatial surface [3], is often performed with no regard to the promotion of social cohesion and also, with no regard to the extremely necessary integration with neighbouring rural areas. Following the hypothesis that this is caused in some way by anthropogenic actions, it is possible to better adapt urban systems to our immediate challenges, being those primarily caused by the unstoppable population growth, climate change and life style [4].

Consequently, an integrated management is demanded in urban areas. This necessity has previously arisen from the European Commission within the Thematic Strategy on Urban Environment [5]. Furthermore, in May 2007, the European Member States stated so in the Leipzig Charta [6].

## 2 The urban metabolism analysis proposal

The proposed research lies in the development of an integrated methodology, designed in order to ease urban management and planning, throughout the identification of how, where and when new urban actions should take place. Furthermore, it aims to build know-how about sustainable integrated urban management, not only addressed to local authorities, but also to stakeholders and citizens.

The approach presented in this paper is based on the diagnosis of the 'urban metabolism' (which was first introduced by Abel Wolman in 1965 [8]) and uses results in order to draw a strategy for sustainable urban management.

The proposed methodology implies an analysis and quantification of the energy and matter flows in urban areas. The following diagnosis consists of the assessment of interactions, synergies and trade-offs between the physical and non-physical processes, flows etc., which interact in the system dynamic. Thus, it is possible to identify the critical nodes concerning impacts on the environment (those originated by use or consumption, generation, production and transport of energy and matter). Accordingly, this information is used as an input for the definition of strategic actions concerning housing, mobility, electricity and water supply and waste management, production and consumption habits which must be jointly analysed and considered. Defined actions will be drawn based on the capacity of response and action of the urban areas assessed, which will be identify, at case study level, through participatory processes.



### 3 Services and functions of urban systems

Actions towards sustainability require consideration of the urban region as an open system [7] (and not as an 'ecosystem' per se but containing a number of ecosystems and with strong interactions among its components and weak interactions across its boundaries).

Accordingly, following the approach defined for natural ecosystems developed by the *Millennium Ecosystem Assessment* (2005) [9], this study approaches the evaluation of urban systems as ecosystems intensively managed and modified by human beings. The project mainly focuses in the identification of existing or available services and functions in these systems, with the aim of defining, afterwards, variables to quantify them, which will constitute an input in the definition of urban typologies (see section 4).

INCYDA EMAU's approach assumes as key elements, the interactions and links among the human beings, together with the diverse processes and dynamics within the system. Therefore, it considers the variability in the human beings' circumstances as drivers that operate directly or indirectly over the urban systems, causing different effects in morphology, consumption, production and mobility, among others. As a result, and reciprocally, life style and social conditions are influenced by the above-mentioned changes in the urban systems.

Given the DPSIR approach (Drivers-Pressures-State-Impact-Response) developed by the European Environmental Agency (EEA) in 1999 [10] as an extension of the PSR model developed by OECD in 1998 [11], the comprehension and identification of the factors that may influence ecosystems and their services and functions, is essential, in order to design actions which enhance positive impacts and minimize negative ones [12, 13].

Therefore, for the understanding of the relationships between urban systems elements, importance should be given to both, the analysis of services and functions from the view-point of human and natural processes and the analysis of drivers and pressures over urban areas, since it can draw a picture of the urban processes performance giving evidences for following steps in assessment and diagnosis or urban flows.

It is plausible to distinguish between endogenous drivers, which can be influenced by managers and planners, and exogenous drivers, which are uncontrolled or hardly controlled. Parameters derived from system resilience and adaptability will allow the definition of threshold values [14], which, in the case of urban systems, are likely to be controlled and managed through the endogenous drivers.

The project INCYDA EMAU attempts to characterize services and functions provided by urban systems, from the natural ecosystems perspective, and throughout the identification of different types of functions: fundamental functions, distribution and supply function, consumption and production functions, self-development and regulation functions, and finally, cultural functions and services.

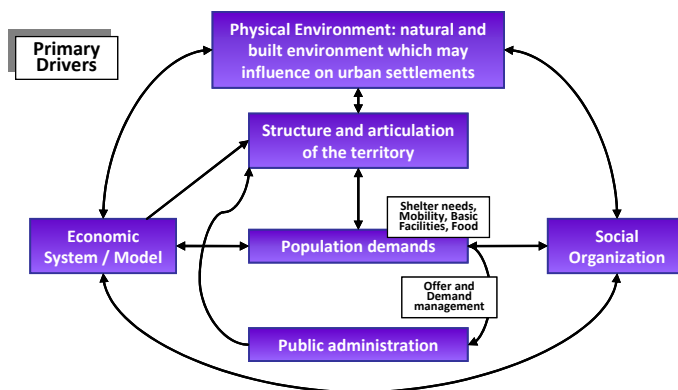


Figure 1: Drivers in urban systems.

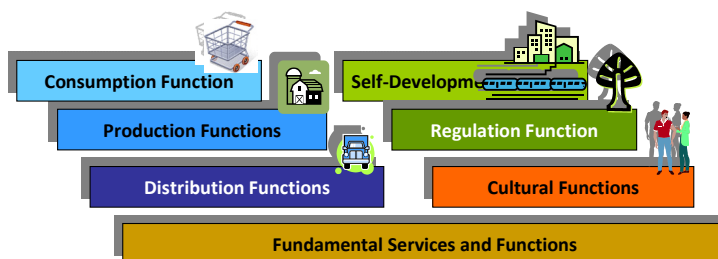


Figure 2: Services and functions of urban systems.

Services and functions of urban systems are those that intrinsically characterise the urban area from the perspective of aspects such as location and physical environment, policies, economic status, or historical experience and traditions.

Hence, which are those *Fundamental Functions or Services* in the urban system? In this project, the following have been defined:

- *Residence Service*: urban systems provide shelter for human beings.
- *Space for relationship service*: urban systems provide a space where relationships among human beings are promoted.
- *Function of space for trade and mobility of goods and services*: urban systems provide infrastructures that make possible the interchange of goods and services, and results in a population mobility and goods and services transportation.

The existence and combination of certain economic, historical, political and geographical factors allows the performance of these functions. Moreover, it determines a range of urban characteristics in relation to population, demand and offer of services and strategic location of these systems at regional, national or global level.

Cities can be suppliers or receptors of goods and services, such as raw or finished materials or products, food, telecommunications, post or mail services, energy generators, water consumers...Hence, *Consumption, Supply and Distribution and Production Functions* are defined.

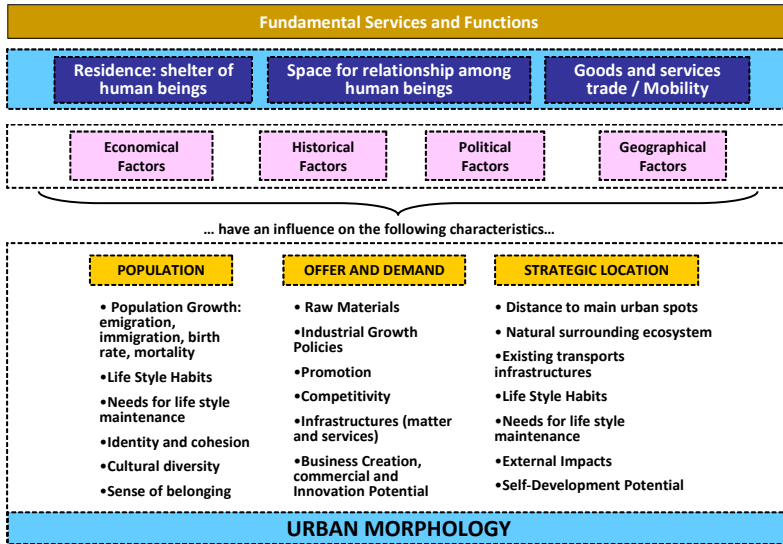


Figure 3: Fundamental services and functions.

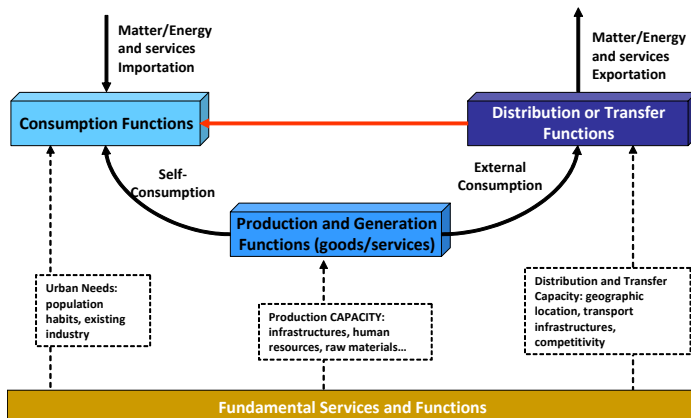


Figure 4: Consumption, production and distribution services and functions.

Cities can consume imported goods and services and/or other ones produced within its limits, which, additionally, can be exported. Consumption is determined by some aspects such as population needs, habits, existing industry... etc. The city's capacity to produce goods and services is, as well, determined by its infrastructures, the occupational training level of its population, the available raw matter... among others. This will be enhanced by the strategic opportunities of the city, that is, by its geographic location, its transport infrastructures, and as a whole, by its competitiveness level.

*Self-development Functions* are those that are strongly related to those transforming processes of functional and spatial sub-systems, within the self limits of the urban limits. These functions cover urban regeneration or rehabilitation (internal growth) and the external growth, that is, the urban sprawl.

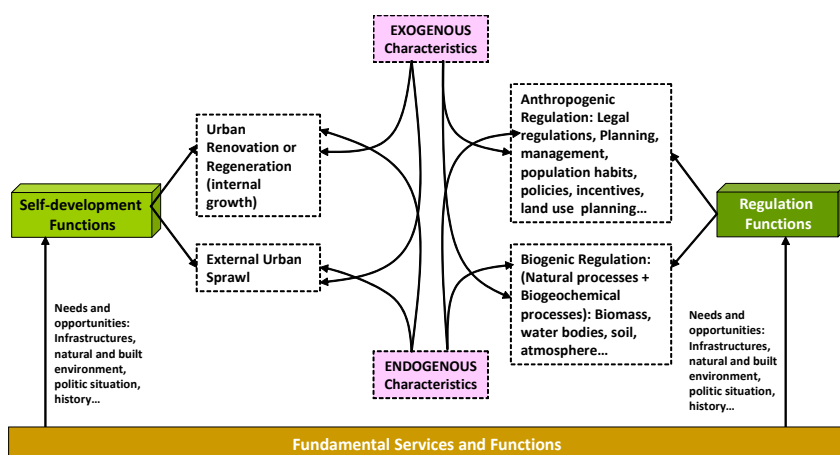


Figure 5: Self-development and regulation functions and services.

On the other hand, balance of urban systems is required. *Regulating Functions* (system 'protectors') are carried out by natural and biogeochemical processes among water bodies, soil, atmosphere, and biomass. Due to the inherent character of urban systems, a wide range of anthropogenic ways of control are also required, such as legislation, land use planning, urban management, population habits evolution, urban, regional and national policies, incentives... etc.

Finally, *Cultural Functions* are promoted by endogenous characteristics resulted from certain Fundamental Functions. These characteristics involve existing cultural diversity, education and knowledge, social relationships within the citizens, sense of belonging, social identity, the cultural heritage and traditions, and last, but not least relevant, the available natural ecosystem and physical environment, which implies certain behaviour patterns (i.e. traditional barbecues in open spaces around the city).

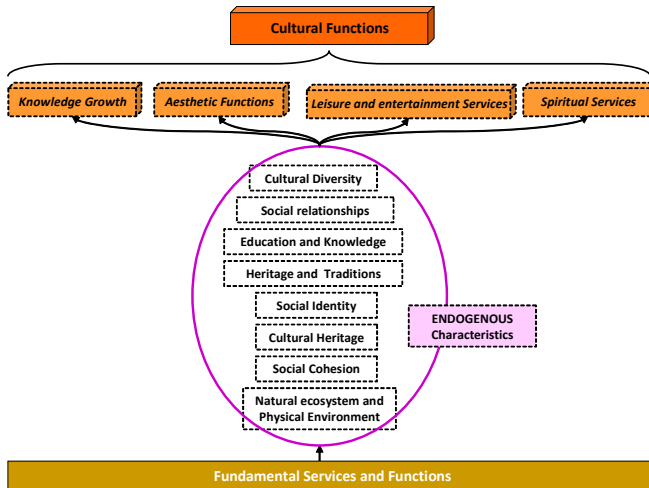


Figure 6: Cultural services and functions.

#### 4 Methodology for the definition of urban typologies based on urban morphology and dynamics

In order to get a better and detailed analysis of the performance of different urban processes, a study at district scale is proposed. Moreover, in order to make it applicable to any other urban area or municipality, a new definition of urban typologies is suggested. Urban typologies become the determining basics for thresholds selection in the identification of critical impacts of energy and matter flows.

Spatial units at 'district' scale are defined according to administrative and planning criteria already in place, to be used as analysis units. Each one of the spatial units classified within the same urban typology share with the others similar values for a group of variables measuring different elements of the urban morphology and its functional structure. In the context of the project this group of variables is called '*morpho-functional*' variables. Selection and definition of these variables arise from the characterization of the urban system's morphology. This characterization takes into account not only planning aspects but also the state of the physical environment, demographic dynamics, inter and intra-city's transport models, and eventually, resources and waste management models.

Certainly, services and functions provided by the urban system depend on each particular case. In addition, the urban system is divided in spatial units which can provide one or, more frequently, several of the above-mentioned services. This results in mono-functional or multi-functional typologies, respectively.

The definition of urban typologies is then undertaken by means of statistical techniques of *multivariant* analysis, where the subject or study cases are the

‘spatial units’ and the independent variables are the ‘morpho-functional’ variables that have been formerly selected. Therefore, it is plausible to obtain clusters in an exhaustive way for all units of analysis. Next step consists in the identification of key variables capable to provide critical information, both in quantity and in richness, for the differentiation of urban typologies.

A participative process involving local authorities, socio-economic stakeholders and general public, is carried out to characterize the definite urban typologies, taking into account the drivers and pressures operating in the study area. This process allows reconsideration of the ‘morpho-functional’ variables used in the classification of spatial units.

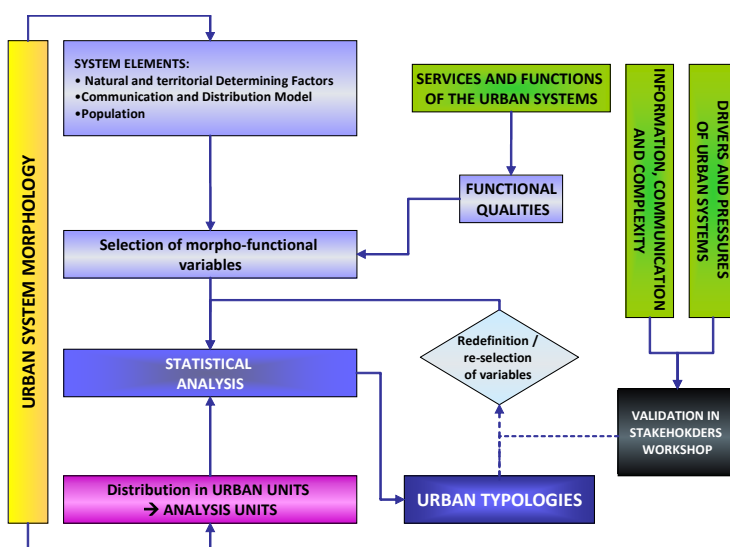


Figure 7: INCYDA EMAU's methodology for the definition of urban typologies.

## 5 Conceptual models for the characterization of urban flows

Eventually, the proposal implies a comprehension of urban systems' flows. Hence, it approaches an analysis of, what it is known as metabolism of a city. The analysis is achieved through what is generally called *conceptual* or *descriptive* models for each of the considered flows. These models allow the development of a graphic representation of the processes that operate in the urban area. The method followed in order to develop the descriptive models of urban flows, consists of:

- Defining *blocks*: place of sink or exit of flows. Quantity of matter or energy defined both by its physical, chemical or biological characteristics and by its limits or physical barriers. It has one input flow, or one output flow or both (i.e. lake, industry, household, landfill, logistics centre...).



- Defining *flows*: quantity of matter or energy transferred from one block to other based on the time needed for it.
- Defining *processes or activities*: physical, chemical or biological activity that generates a flow or promotes a change in its mass or in its chemical form (photosynthesis, materials transformation, fuel use, feeding...).
- Defining *cycles*: system with two or more blocks connected through different flows. They can be open or closed.

Descriptive models are developed based on the following flows which can be analysed separately: a) CO<sub>2</sub> and O<sub>2</sub> Balance, b) Food Flow, c) Water Flow, d) Materials Flow, and, e) Energy Flow. Figure 8 shows an example.

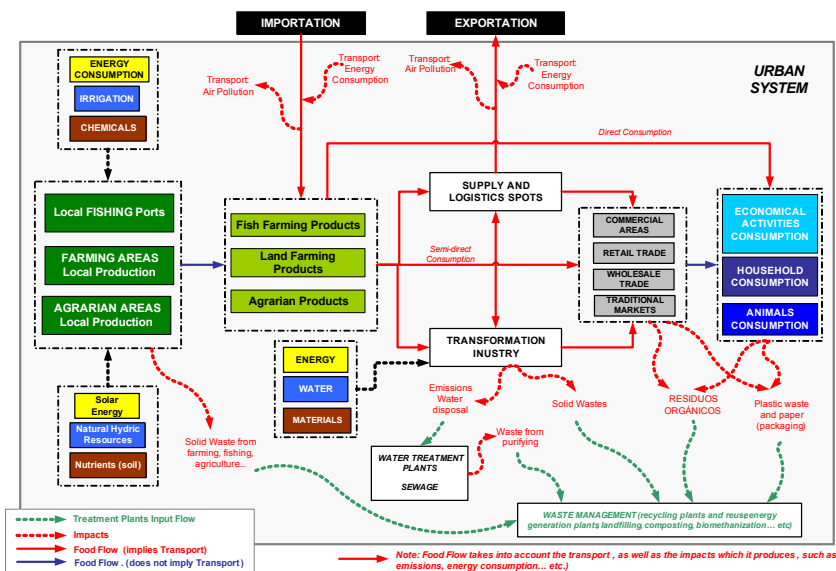


Figure 8: Food descriptive model.

## 6 Conclusions and future steps

The characterization of urban systems and the evaluation of its metabolism (in terms of energy, water, oxygen, carbon dioxide, materials and food) are one of the basis for the definition of strategic actions in order to implement the Strategy of Urban Environment in our cities and towns, still the final aim of the project.

Urban morphology, urban services and functions, and drivers and pressures of the urban system, are considered the main input for the definition of urban typologies. The qualitative modelling of urban flows together with the urban typologies definition, this will serve as a basis for the selection of indicators and thresholds, task which is being developed in Phase 2.

Insofar as complexity and size of urban areas increase, the natural and anthropogenic capacity of the system decreases regarding regulation of cycles and processes related to urban energy and matter flows. Urban metabolism

analysis is essential for an accurate assessment, thresholds definition and identification of critical nodes for action. It is a key point for the understating of the city's role and for the comprehension of its interaction with the surrounding environment.

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## References

- [1] United Nations publication (ST/ESA/SER.A/212), 2001. Urban and Rural Areas 2001.
- [2] United Nations publication (ST/ESA/SER.A/213), 2001. Urban Agglomerations 2001.
- [3] David Satterthwaite, 2007. The transition to a predominantly urban world and its underpinnings. Human Settlements Discussion Paper Series. Theme: Urban Change - 4. IIED.
- [4] European Commission, 2007. Future Research Areas in the field of Urban Sustainability. Work Package 3, URBAN-NET. Project funded under the 6th Framework Programme of the European Commission.
- [5] COM (2005). European Commission. Thematic Strategy on Urban Environment. Communication from the Commission to the Council and the European Parliament. Brussels, 11.1.2006.
- [6] European Member States, 2007. Leipzig Charta for Sustainable European Cities. Informal Meeting on Urban Development and Territorial Cohesion.
- [7] M. Alberti, 2008. Advances in urban ecology: integrating humans and ecological processes in urban ecosystems. Springer
- [8] Wolman A. (1965). The Metabolism of Cities. Scientific American, pp: 179-188.
- [9] Millennium Ecosystems Assessment, 2005. Ecosystems and Human Well-Being. Volume I Current State & Trends. Island Press.
- [10] EEA- European Environmental Agency, 1999. Environmental indicator: typology and overview. Report nr 25.
- [11] OECD, 1998. Towards Sustainable Development: Environmental Indicators, Paris, OECD.
- [12] Kremen C., 2005. Managing ecosystem services: What do we need to know about their ecology? Ecology Letters, 8: 468–479.
- [13] NRC (National Research Council), 2005. Valuing Ecosystem Services: Toward Better Environmental Decision-Making. Washington (DC): National Academies Press.
- [14] Farber SC, Costanza R, Wilson MA., 2002. Economic and ecological concepts for valuing ecosystem services. Ecological Economics, 41:375–392.

