Towards new design tools for integrating environmental criteria in the design process of architectural and urban projects in developing countries

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ABSTRACT

Cities are complex systems rapidly evolving in a context of strong interweaving between problems and solutions especially in developing countries. The architectural design and the city management processes are renewed by the eruption of sustainable development. These processes are multi-scale: new geographical, temporal and political scales are emerging, calling for new tools for monitoring architectural and urban environmental changes, for implementing comprehensive plans, or for communicating between practitioners. Number of communities in developing countries has taken initiatives to develop tools based on sets of sustainability indicators. But are these tools really helpful during the architectural design or the urban management processes characterized by complexity, fussy or lacunar data, various time and space scales and multi-actors decisions? We will demonstrate in this paper, that these systems, aiming at "a posteriori" diagnosis, cannot be used directly during these fuzzy processes, especially during their early phases very critical with respect to solutions. By adjoining them multicriteria decision support techniques, they may become powerful tools for decision support. Architectural and urban designs may be evaluated using a set of weighted environmental criteria and methods to aggregate the various dimensions involved. Some Electre methods based on the comparison between pairs of solutions have been successfully used in that sense. A step further away may be performed from decision to evaluation support tools, by comparing ongoing urban designs against convolutions of systems of practitioners' values. This "value focused" approach, combined with the Electre-Tri method has been successfully integrated for evaluating the performance of urban projects, according to their distance to various user-defined systems of values.

INTRODUCTION

The urban development is characterized by various changes and mutations. The environmental impacts of urban designs may be numerous, diverse and sometimes conflicting. The magnitude of the relationship between these different impacts shows potential dangers from decisions related to a family of impacts: solving a problem often creates another.

In this context, a large number of communities have taken initiatives to develop a new understanding of how urban systems work and how they interact with their environment. These tools are mostly based on sets of sustainability indicators (Mori 2012). They are supposed to help urban practitioners to design and to implement comprehensive plans (Alberti, 1996; Briassoulis, 2001; Brandon, 2005). At the same time, specific international programs have been created to develop and

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harmonize urban indicators worldwide, such as UNCSD (Stiglitz, 2009), OECD (OECD, 2011), (UNU, 2012).

Simultaneously, the urban decision is renewed by the eruption of sustainable development, and virtually all communities share concerns for the state of their environment.

The architectural design and urban planning processes are critical to global sustainability, but there is no consensus on how to model this sustainability (Owens 1986; Newman and Kenworthy 1989; Adolphe 1995; Tanguay, 2010). During these processes, practitioners are looking for solutions based on “reasonable compromise” between non-homogenous constraints instead of collecting optimal but partial answers: a new culture of the consensus that aims at "un-optimizing" urban decisions.

A rising information level characterizes this process. In the early stages, the information available is low because it is impossible to apply straightfully all the constraints: design is a wicked problem (Conklin, 2005). Indeed, the early design stages of these processes have a hegemonic weight related with fundamental architecture, urban and technical choices. At the beginning of the process, the importance of design choices is maximum; at the end, it is minimum. This context of problem solving has been baptized “the paradox of the architectural or urban design process” (Adolphe, 1995) - see figure1.

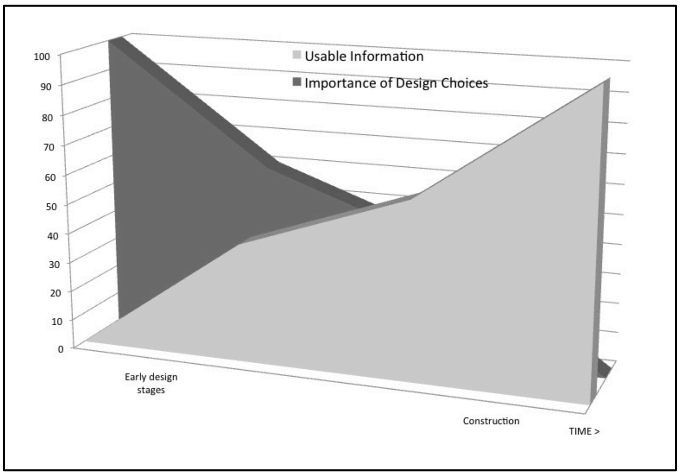

Figure 1 The paradox of architectural and urban design (Adolphe, 1995)

Therefore, the potential consequences of design support tools are highest in the early stages. They should rely on simplified but robust information on the design. The architectural design and urban planning processes are lacking for decision or evaluation support tools, especially during the critical configuration phases for the modeling process of cities. One of the main difficulties on building these tools rises with the simplification needed for modeling various urban elements and their relationships. In that sense, new research approaches have recently tried to fill this gap by improving validation on test cases, by integrating ranking between architectural variations in real practices (Adolphe, 1995; Fontenelle, 2012), or by a better integration of demand side management (Dubois, 2013). Therefore, it is necessary to develop assessment tools based on simplified models compatible with the level of information available during the various stages of the design process.

SYSTEMS OF INDICATORS FOR THE SUSTAINABLE DEVELOPMENT OF SETTLEMENTS

In this context, the most promising family of urban evaluation tools are based on systems of indicators able to integrate a wide variety of problems and the complexity of their interrelations in the space and the time (Adolphe, 2001; Josza, 2005 ; Adolphe, 2008; Adelle, 2009). The sets of urban indicators contribute to the building of systems in which development and environment are completely integrated. But currentlythese sets of indicators still remain very heterogeneous in terms of purposes as well as content.

But what is an indicator? Generally, indicators quantify information by aggregating different and multiple data. In short, “indicators simplify information that can help reveal complex phenomena”

(TERM, 2001). Compared to raw data used for example in the urban databases, single indicators are used to model the reality into decision support tools. These indicators would provide a representative picture of environmental conditions; being scientifically sound; being simple and easy to interpret; providing a basis for comparisons at various scales; integrating a target or threshold against which to compare environmental quality and performance (Alberti, 1999).

Therefore, how to build proper systems of indicators that exceed thematic, alphabetic, or just concatenated lists? How to interconnect indicators in systemic approaches characterized by strong interactions between subsystems?

Some characteristics of these systems are fundamental: 1) an indicator means nothing out of a system: there are strong links between indicators in a system; 2) a system means nothing elsewhere refering to fundamental issues. It is therefore necessary to build different systems for regulation compliance, decision support, simulation and evaluation; 3) a system means nothing without mixing physical, social, political scopes: each geographic scale or each actor may develop a specific system of indicators.

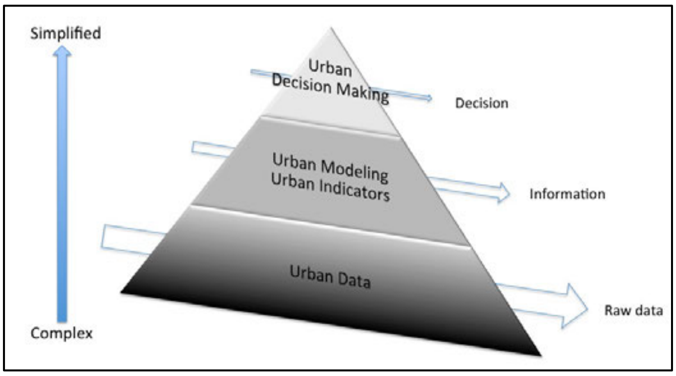

Figure 2 : Decision pyramid , from raw and complex data corresponding to real world, to simplified and abstract models useful in the decision process.

The first stage of building these tools is typically a structural stage. Some models have been developed to structure these systems: the PSR model "Pressure, State, Response" (RESPECT 2000) ; the DPSIR model : "Driving forces, Pressure, State, Impact, Response" (TERM, 2001); the DPSEER model : "Driving forces, Pressure, State, Exposure, Effect on Humans, Response" (Webster, 1996).

The second stage of constructing these indicators sets may rely on the aggregation of indicators into single index or composite indices. In the context of the sustainable development, one can say that this aggregation makes it possible: 1) simplifying, by reducing complexity, or simply reducing a great number of data into a smaller number of useful information for the evaluation; 2) quantifying, by modeling, simulating, and by building a comprehension of the phenomena and stakes; 3) communicating, by helping the decision makers to give their own opinion within the framework of a negotiation, an equitable exchange.

As a conclusion, the indicators are now popular and widely used in all organizations working on sustainable development. A consensus appears at least on the general characteristics of indicators. A good indicator needs to condense meaningful information into simplified, relevant, reliable, transparent, workable, synthetic, robust and correctly interpreted at the appropriate geographical scale. However, construction of current indicator systems suffers from serious methodological flaws.

The most important limitation of the current systems may be related to their construction method: these systems are based on a bottom-up approach, starting from the available data, without a global reflection about the goals to achieve. As a result, their gain to improve sustainability performance has been often limited (Alshuwaikhat, 2002; Seabroke, 2004).

The implementation of exhaustive top down approaches, starting from the fundamental concerns of the users of the system, to format and select the indicators could solve this problem. However, it should then iteratively combine with operational bottom-up approaches to reach a good compromise.

FROM SYSTEM OF URBAN INDICATORS TOWARDS DECISION SUPPORT TOOLS

To answer to this combined approach, we have moved off from this classical exercise of indicators concatenation, and to propose real decision support tools of the sustainable evaluation for urban projects, within an innovating morphologic and structural framework. This framework is based on the implementation, of multicriteria aggregation techniques. These tools allow to compare "the non-comparable", while implementing non-commensurable criteria or criteria which can get into conflict.

The main methods of multicriteria aggregation are primarily interested in alternatives or actions (Roy, 1985). They aim at putting forward the one or the better decisions to be taken, in comparison with the preferences of the decision-maker. These decision support tools are based therefore on a relative assessment: projects are compared to other ones in terms of sustainability performances. Some approaches are based on ELECTRE type methods, for ELimination and ChoicE Corresponding To Reality (Roy, 1993), and pairwise comparisons made without trying to bring the various criteria on the same scale value. They are able to manipulate complex concepts such as indifference, preference or veto thresholds to cope real-life decision context (Rousval, 2005; Fontenelle, 2012).

The multicriteria evaluation contributes to an exhaustive and synthetic census of information, while clarifying the results produced by the collections of indicators specific to each family of themes. The multicriteria evaluation is composed thus of two essential and indistinguishable aspects: the structuring model of information on the one hand and, the relative weighting of these criteria on the other (Adolphe, 2006).

The methods of partial aggregation are different from global aggregation ones mainly due to the three following aspects:

1) Data: evaluations of the indicators must be clear, probabilistic or fuzzy.

2) Operators of aggregation: the comparison of the evaluations of the criteria for each action can be performed by simple or complex fuzzy function (probabilistic or fuzzy evaluations). The over-ranking relationship between actions is established when a majority of criteria is better for an action than its competitor. The relations of indifference and incomparableness are also defined. The whole preference relations correspond to the criterion of over-ranking which constitutes the value of homogenization. Each preference relation represents the direction and the intensity of the preference between two actions.

3) Systems of preference: the decision makers define the weighting coefficients for the families of sustainability criteria.

This approach has been successfully used to evaluate the urban sustainability performance of urban designs at the district scale, in the SAGACITE Project (Adolphe, 2002). This project addresses the environmental influence of urban morphology at the neighbourhood scale. This work puts into perspective, objective indicators built from in situ measurements and environmental modelling, and subjective indicators related the perception of the users. The project is based on the simultaneous consideration of three concurrent areas: building, vegetation and transport. This resulted in the production of a decision support tool based on a Geographic Information System (GIS). This computing platform permits monitoring of existing urban projects (an “environmental dashboard”), comparison (intra or inter-urban) between sites, and scenario for urban spaces, taking into account environmental issues.

But the main limitations of this family of decision support tool are linked to the fact that they are based on relative assessment linked to partial two by two evaluations of actions. For most of the architectural and urban projects, practitioners are more obviously looking forward to compare their project with generic goals linked for example to its sustainability: this represents the shift between decision and evaluation support tools.

FROM DECISION TO EVALUATION SUPPORT TOOLS

"*The evaluation process aims at quantifying and/or qualifying a system, thanks to all necessary information for building criteria allowing to attain the objectives concerning this system and pertinent in the framework of a wider activity but previously identified". Therefore the evaluation consists of "an assessment using criteria for achieving objectives or the degree of proximity of a project compared to a norm*" (Abernot, 1996). Therefore, we distinguish the *decision*, for which we will compare several projects, based on a "relative" comparison (Roy, 1993) and the *evaluation* for which we will compare a project to goals or user's value systems, based on "absolute" comparison (Keeney, 1996).

The main motivations of these value focused approach are: 1) building a system of values as a reference for the evaluation; 2) knowing the reference system to understand the result of the evaluation; 3) explaining the system of values to justify the result of the evaluation; 4) communicating the system of values to build a consensus; 5) encouraging debate around the result of an evaluation; 6) monitoring the evolutions of the reference system for understanding the evolution of the evaluation.

In a first stage, we give privilege to the top-down approach, by defining the decision-makers' preoccupations for structuring the system of indicators, and by using a formal reconstruction system for the indicators selection.

When the object represents a major issue for the decision-maker concerning his position, it is a final objective, as opposed to the objective as a mean, which does not represent an end by itself for the decision-maker, but a means to reach a final objective. A strategic objective is a final objective that has the characteristic to be invariant during the time. A final objective can be decomposed; a means objective can be linked to various other ones (Fig.3-4). It is therefore possible to construct a structure (or hierarchy) of objectives for each decision-maker. To build the most exhaustive possible body of objectives, it is necessary to interview people representing each user group (Fig.5).

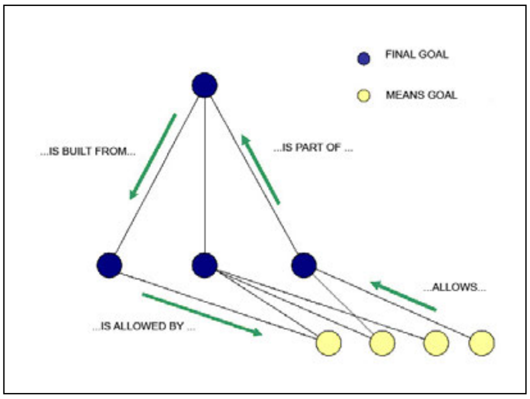

Figure 3 Relation between final and means objectives

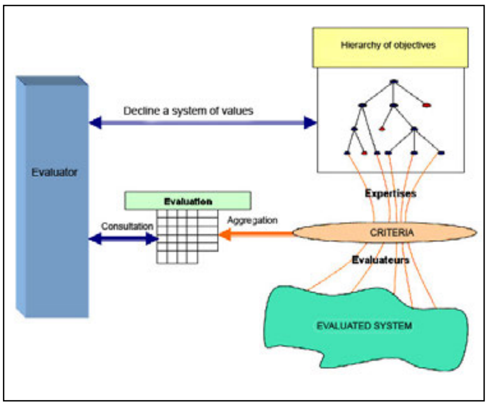

Figure 4 Application of the Value focused approach to our project (from Rousval 2005)

This value focused approach offers numerous advantages. It allows an interdisciplinary approach where the definition and the ranking of objectives structure the construction of the indicators system. It allows balancing objectives by propagating the weight in the hierarchy. Non-experts may use it to question and to structure the problems. At last it is easily applicable to wider contexts, such as sustainable development. The interviews are conduced in two stages. The first stage aims to define a first body of objectives. One lets the interviewee speak while asking non-directive questions. Taking some notes allows, then, to do a first census of objectives that appears along the interviewee speech. The second stage aims to explore the objectives that emerged from the interviews in the first phase. Thus, one can relate a means objective to an end objective while asking the question "Why this objective?". From a final objective, one can construct his superior hierarchy (bottom-up). To explore in depth the tree of the final objectives (top-down), one may ask "why this objective is important?" or "which facets of this objective are important?" (see Figure 5).

The last but not least advantage of the value focused approach is "the union" of several hierarchies, into a generic structure, while using a specific algebra (Keeney, 1992). One can thus structure the design of the system of common indicators for a population of decision-makers (Figure 6).

At last, we take into account the preferences of the decision-makers while using a multicriteria support method, the Electre-tri method (Yu, 2003). By using this method, it is proposed an ordinal evaluation of each objective.

- To master the environment
  - At the planetary scale
    - To preserve an environment in favor of human life
      - To limit the greenhouse effect
      - To limit the climatic change
      - To protect the ozone layer
    - To preserve the natural resources
      - To limit the extinction of natural types
      - To limit the extinction of natural environments
      - To limit the consumption of energy
    - To limit maritime pollution
    - To limit the production of persistent losses
  - At the local scale
    - Concerning natural environments
      - To limit impoverishment of landscapes
      - To limit the mineralization
    - Concerning human environments
      - Concerning public health
        - To limit the effects of the pollution of the air:
          - Of the peaks of pollution
          - Of mean pollution
          - To limit the effects of the accidents
        - To limit the effects of the noise on health
      - Concerning the life quality
        - To limit discomfort :
          - Due to noises
          - Due to smokes
          - Due to the odors
        - To improve the landscape
      - To improve cultural inheritage
      - To improve neighborhoods
      - To preserve the habitats from dust...

Figure 5 – Reduced and filtered hierarchy of objectives (from Rousval, 2005)

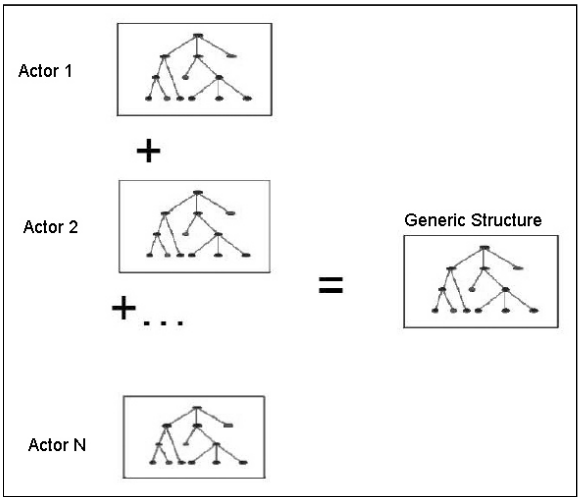

Figure 6: Union of deciders' hierarchies of goals into a generic structure (From Keeney, 1992).

This approach has been successfully used to evaluate the performance of urban sustainability of urban projects, in the PIE Project and to evaluation of sustainability of urban districts in developing countries (Adolphe, 2006). The "PIE" project aims to establish the specifications of a tool for the assessment of the environmental status of a geographical area selected in relation to the pressures (air, noise, water and soil pollution, impacts on space, on landscape, on fauna and flora, waste) enforced by the transport system. This tool for urban decision makers is based on sets of indicators structured by type of pollution. It enables a multi sectorial diagnosis from an aggregation of some (or all) of these indicators. These sets of indicators are based on two concurrent approaches: a top-down "back casting" approach based on concerns or objectives of decision-makers, and a bottom-up approach which starts from the operational constraints of the system. This tool uses multicriteria decision techniques allowing aggregation of basic indicators in sectorial indicators, and the construction of an operational approach for aggregating preferences of users of the system. This tool allows comparing the environmental impacts of different transport modes, technologies and policies.

The interests of this approach as well are numerous: the possible use of thresholds to consider the inaccuracy/uncertainty, the adequacy with the sorting approach, the comparison of the alternatives to a stable reference, the modularity, and finally, the incomparableness and no-compensation. The disadvantages are a weak readability and the lack of transparency. Possible applications of this method are the creation of a "global sustainability indicator", the support of activity-based "participative democracy" and the evaluation of "local and personalized follow-up".

CONCLUSION

Our work proposes a methodological framework for the decision and evaluation support of sustainable architectural and urban projects. The opportunities to use decision and evaluation support tools in the design or in the management process of architectural or urban projects are numerous. By simplifying a vast amount of information into a simple form, they make it much easier to read and understand complex reality and to help a new understanding of how urban systems work and how they interact with sustainable development at various scales (Alberti, 1999).

In a context where urban policymakers are, more than ever, challenged by the task of redirecting urban mutations into a more sustainable way, these new approaches are very challenging because they allow a good integration of the cultural or social dimensions of development. There is no point in building highly efficient cities, if they are not appropriate by their users, or if the spaces created do not meet their expectations or the representations of such places. "Sustainability, at the community level, is perceived as a holistic concept and not simply the sum of the environment, economy, society, and culture. The links among these components are established by the people and expressed in terms of people needs and aspirations" (Alberti, 1999).

We think that introducing these techniques into the design management process of architectural or urban projects brings new opportunities such as: 1) Avoiding to "bury" the practitioners in a proliferation of often conflicting and specialized information and constraints: help them keep up controlling the process that they are expected to master, so forth avoiding a divorce between design and production; 2) switching to a strategy of design "optimization" to a strategy of "reasonable compromise" between various constraints.

On the contrary, the limits and threads of these approaches are mostly linked to the context of sustainable urban development process itself. The decision is very complex and strongly context-related. Each new project is for example leading to a new set of indicators (Tanguay, 2010), and new user defines its own system of values (Kahn, 2006). These new tools are not designed for an automatic design but rather as a decision support in a specific governance context (Litman, 2011).

We have successfully integrated these various techniques to evaluate the performance of urban projects in developing countries in terms of sustainable development (Adolphe, 2006). The next step is to interbreed various themes simultaneously, such as building and transportation (Santos, 2013). Another development envisioned is to focus on the robustness of these systems, by testing the resilience of the threshold measurements. Even though this assessment presents difficult tasks, it is an unavoidable step in order to translate that new knowledge into effective policies.

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