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LCA ENHANCEMENT PERSPECTIVES TO FACILITATE SCALING UP FROM BUILDING TO TERRITORY

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Abstract

Environmental performance considerations in the construction sector extend from buildings to neighbourhoods, cities and territory. This transition implies a Life Cycle Assessment (LCA) adaptation to efficiently treat such complex systems. Indeed, performing environmental performance evaluations has already been done over the past few years but the existing LCA tools have to be improved regarding their user-friendliness to allow everyday urban planning stakeholders to use them. Providing keys to help the practice is a main subject to spread the large scale LCA evaluation and ensure a better urban planning trending to sustainable solutions. This objective is also motivated by local, national and European policies, particularly within the context of Paris COP21.

The aim of this study is to explore enhancement perspectives to facilitate LCA scaling up from building to territory. This work is based on observations from case studies underlining operational issues due to the evaluation time consumption. The urban planning process is analysed to focus, at different stages, on operational responses that could be proposed considering objectives, stakeholders' needs and potential drivers. In particular, for early stage decision making, an approach introducing urban typo-morphologies has been adopted to facilitate the comparison of large scale evaluations and scenarios. Such typo-morphologies, representing elemental bricks at building or block scale to build neighbourhoods or larger, have been widely described in the past. However, this work concentrates on the applicability of the approach to integrate this sort of description for environmental evaluation based on a multi-component (buildings, energy, water, public spaces, transportation) description of the systems. Particularly, a focus has to be given to scaling up mechanism. Expert systems sets on heuristic rules could help exploiting a typo-morphologies database. This solution should ease the practice of urban environmental assessments.

Keywords:
Urban morphologies, Systemic approach, LCA

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1 INTRODUCTION

The world's population is continuously increasing and expected to reach 9.3 billion people by 2050 [1]. In addition to the fact that cities accommodated more than 50% of the world's population in 2009 [2], most of the increase is likely to be absorbed by urban areas. This implies expanding energy, water and resources demands, increasing waste production and greenhouse gas emission. In this context, the evaluation and characterization of urban areas become of first interest to ensure a sustainable development.

Environmental performance considerations in the construction sector extend from buildings to neighbourhoods, cities and territory. This transition implies a Life Cycle Assessment (LCA) adaptation to efficiently treat such complex systems. Indeed, performing environmental performance evaluations has already been done over the past few years but the existing LCA tools have to be improved regarding their user-friendliness to allow everyday urban planning stakeholders to use them. Providing keys to help the practice is a main subject to spread the large scale LCA evaluation and ensure a better urban planning trending to sustainable solutions. This objective is also motivated by local, national and European policies, particularly within the context of Paris COP21.

In this context, Efficacity [1] (research & development institute specializing in the field of urban energy efficiency) aims to equip decision-makers, communities and all other urban stakeholders with operational tools to evaluate the environmental performance of districts and cities. This is not only a matter of methodological development but also to find convenient solutions to adapt the description process, the project data collection and the granularity of environmental data to user needs. Such an adaptation shall lead to an appropriate practice considering user's constraints and furnish intelligible results.

To ease the practice of LCA from the well-known building scale to upper scale, the creation of knowledge on urban typo-morphologies will be highlighted as a possible answer. An urban typo-morphology is a qualitative and quantitative description of a representative sized part of a city. It can widely describe this system including all the different components or focus on some interesting elements considering the purpose. Many works have already been performed on building [4] or urban typo-morphologies. These works are often focused on a particular thematic, such as thermal comfort [5] or urban heat islands [6], solar access [7] and energy [4], [8]. Few of them are related to environmental performance subjects [9] or giving a multi-thematic vision [10], [11] and even fewer are proposed to be used for an environmental aLCA evaluation [12], [13].

We propose to expose reflections and perspectives to build an urban typo-morphologies library which would be a data support for urban LCA tools. Urban LCA tools are understood as software to quantify environmental performance taking into account the different components (building, public space [parks, sidewalks, street lighting], transportation infrastructure, energy and water utilities and associated mobility, energy, water and waste flows). The components need a simulation or simplified calculation system to be evaluated. The tool's flexibility shall allow the input of variable data granularity.

This paper will present interests and drawbacks of getting such a library by positioning our objectives and the problem to be solved, the in-test methodology and discussions about it. Even if this work is at its beginning, the discussions will give some foreseen enhancement perspectives.

2 CONTEXT, GOALS AND UNDERSTANDINGS

This section gives insight into the context motivating this work, the goals aimed by the future results. It should finally provide understandings of the interest of having a middle scale granularity to describe cities and urban projects.

2.1 Modelling urban system - Limitations

Our approach to assess an urban system's environmental performance is based on systemic LCA in order to get a global overview without neglecting parts of the system or interactions between them. LCA is a solid scientific-based methodology allowing the identification of hot spots in an environmental performance. Its life cycle vision and multicriteria aspect make it a decision support tool which enables to avoid pollution shifts. However, urban systems are highly complex to both describe and understand. So, despite, the strong capabilities, the method remains time-consuming and difficult, particularly for complex systems [14] such as urban projects and cities. This is due to:

- System description (high input number and information collection)
- Choice of appropriated environmental data

In fact, the description of each components of a district can consist in listing all constitutive parts. For example, a building needs to be descripted considering all construction products and equipment, and also, the different flows (energy, water, waste, etc.).

One way to go through this difficulty is to capitalize and create knowledge, translated in environmental data, to describe buildings, urban blocks or districts at a convenient granularity. Then, the description of the system will be reduced to fewer inputs representing the system

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(square floor area for each building typology, transport solution, energy systems, etc.) directly associated with this high-granularity data.

2.2 Objectives – An adaptation to user needs through a multi-scale database

As previously exposed, a possible way to overpass the presented limitations is to facilitate the description by adapting input data to the interesting question and the available system information.

In fact, conducting an urban project is a long and in constant evolution process in which the information to describe and the questions are changing.

As said previously, design district with high environmental performances is crucial. To achieve this, different studies point out that early decisions in the design process have the most influence. Despite this fact, current assessments of environmental or energy performances is mainly run quite lately in the project's design process.

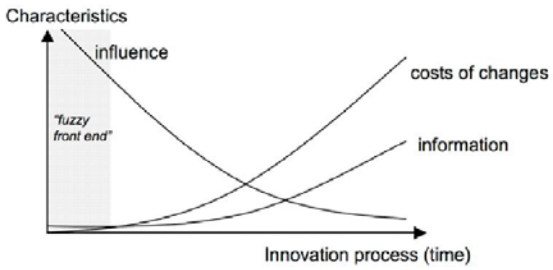

Fig. 1: Evolution of influence, costs of changes, and information during the innovation process (von Hippel [15], modified by Herstatt & Verworn [17]).

Then, it is of key interest to produce an environmental database at a different scale. In this way, the stakeholder can adapt the LCA granularity to his knowledge, question and available time. This database can be seen as a "Russian doll" system in which zoom in and out can be performed.

Potential applications of this library are multiple:

- Facilitate territorial diagnostic and community evaluation at larger scales without being too time consuming
- Give a first environmental performances estimation of specific urban projects in early stage through simplified LCA

We believed that it could also facilitate interactions between stakeholders and simplify the inputs.

3 METHODOLOGICAL PROPOSITIONS

Here is a proposition to construct the aimed database presented. This methodological process is currently being tested.

3.1 Global approach

The approach consists of defining types of urban morphologies classified by considering parameters that have to be linked to levers for decision-making (for example, footprint or constructive system depending on project, location, etc.). Those types have to offer, as much as possible, a systemic vision by taking into account not only building (as often done) but also public space (parks, sidewalks, streets lighting), transportation infrastructure, energy and water utilities and associated mobility, energy, water and waste flows.

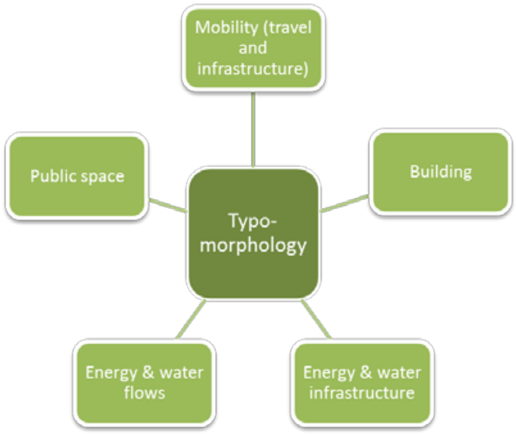

Fig. 2: Schematic representation of urban typo-morphology components.

Fig. 2 gives an illustration of the different components to consider. However, this schematic view is simplified and the systemic approach implies interactions and links between each component. As an example, energy flows need building thermal evaluation to be quantified.

To build a dataset including all these different aspects, detailed modelling of each one (building, public space, etc.) must be performed [15]. It is only the statistical analyses of large samples that can make the approach consistent. Representativeness and relevance of the obtained data are directly connected to the robustness of the samples and input data to evaluate each element. To overcome this time-consuming process, extrapolations can also be done to obtain values when statistical analyses are not achievable in the short-term. These values could further be consolidated/updated when more robust ones are obtained.

3.2 Data construction

To lead to an urban typo-morphologies library, several data, survey and information sources can be used:

- National survey
- Geographical Information System (GIS)
- Community and territory local survey and database
- Local stakeholders' knowledge and expertise

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The use of upstream data and information accessible on a large territory would make the methodology contextualization easier. For this reason, the above list is given in order of preference. It is then of major interest to prioritize the exploitation of national data in the model of input data to be used to evaluate the urban typo-morphology performance. In that way, it will make the applicability of the method much easier in every city.

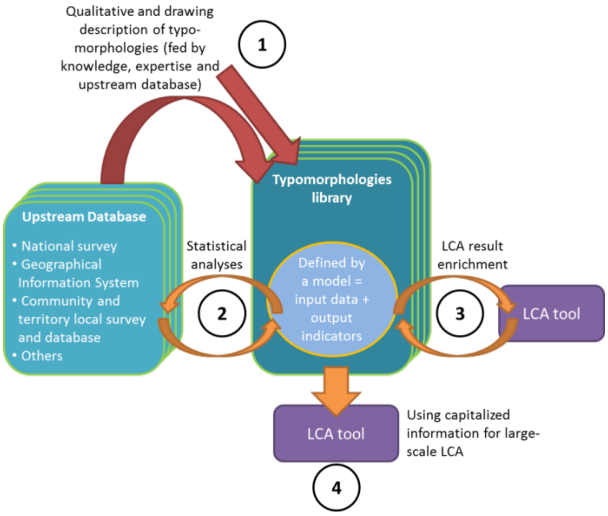

Fig. 3: Methodology scheme for urban typo-morphologies library elaboration and application.

Fig. 3 exposes the methodology to obtain the urban typo-morphologies library. The different steps are:

(i) Defining the urban typo-morphologies
(ii) Create input data for each typo-morphology which will be used in the next step
(iii) Evaluate the typo-morphology environmental performance
(iv) Use typo-morphology in LCA tool for large-scale (neighbourhood, city) evaluation

Step (i) can be completed by using statistical information from the different databases but also including knowledge and expertise from local stakeholders. In fact, people involved in territories often have much more information and a more operational view to describe urban typo-morphologies. The objective will be to characterize qualitatively and quantitatively representative cells of the city. As an example, a 200x200 m cell could be determined as:

- Representative of the city centre;
- With 90000 m² of multiple-dwelling built in 1975;
- With 10400 m² of commercial area built in 1975;
- With a mid-size roadway and access to tramway
- And 5000 m² of public spaces (parks, sidewalks)

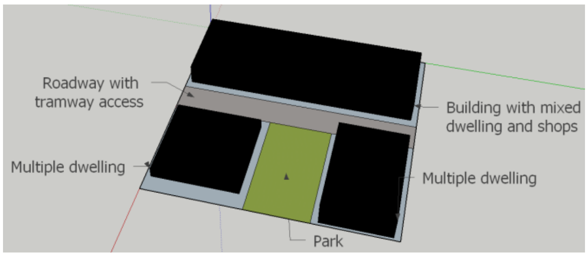

Fig. 4: Typo-morphology example in a 200x200m cell

Fig. 4 illustrates the previous description. This example is given as an illustration and could be less or more detailed, depending on the purpose. This description is closely linked to typologies for each component (building, public space, etc.). Examples for building typologies [18], [20] can be found to illustrate the purpose.

Step (ii) consists of collecting appropriate data to feed the simulation of the described system from Step (i). Then, Step (iii) is consecrated to the environmental performance evaluation throughout a LCA tool. It leads to a quantitative description for the considered typo-morphology including all sub-components (flows and materials). This performance is then considered as data which can feed an urban LCA calculation in Step (iv). Step (iv) can be performed with the same tool as Step (iii) but fed with this constructed database (then, allowing a different input granularity).

Among the different descriptions collected in Step (i), some could lead to a similar environmental performance. Consequently, identifying sensitive parameters will be a crucial part to adapt the library. Also, within this set of parameters, it will be necessary to recognize those related to the system location or not. In fact, if a parameter is location-related, it would be essential to run Step (iii) considering it to get an urban data adjusted to the location that could further be used for urban calculations. The modification of the location can be done between cities/communities or within a city to differentiate the centre and the suburbs for example.

The application of the presented method leads to a mixed-methodology of reference-families [19] (consisting in defining representative types in a location; for example, considering the period of urbanization) and statistical methods to build urban typo-morphology data.

3.3 Cell dimension

The cell dimension remains an unsolved intricate question at this point since this dimension adjustment is directly correlated to user needs, the system size and the aimed accuracy. For this reason, and as previously mentioned, an adapting scale system (similarly to "Russian

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dolls") could constitute the best answer. In this way, one can adjust the description to its needs. This adaptation is also necessary to fit with different contexts. In fact, from a city to another, the relevant size can differ. Commonly, the side dimension of the cell would be of a few ten or hundred meters depending on the distance between intersections (according to the country and city) and the expected representativeness. It is important to note that the methodology will remain the same whatever the cell dimension and that continuum between scales is necessary. This means that data at a higher scale (for example 500x500m if 250x250m is chosen in a first time [20]) can be obtained by aggregation of smaller ones.

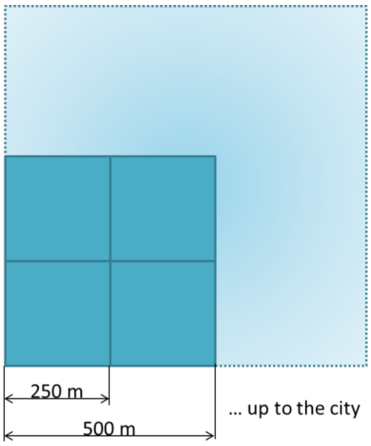

Fig. 4: Example of data granularity for houses.

Fig. 4 presents the aggregation concept to create higher scale data from smaller one. A key point will be to correctly consider interactions between the cells. In fact, some components can easily be aggregated by a simple additive principle when others are influenced by a near or more distant environment (in the meaning of context). For example, buildings can be approximated as additive and not much influence by surrounding cells (excepting some pooling of resources or modification [such as shading]) when mobility in a cell is highly influenced by its context (traffic or accessibility in a cell greatly influences its surroundings).

The interest in getting small cells is to increase the sensitivity and reach a more convenient scale to consider simplified evaluation of specific projects. In fact, the specific urban project's size (from a few hundreds of square meters to a few square kilometres) leads to the need of small cells to get the most representative as possible simplified results before switching to the most detailed simulation.

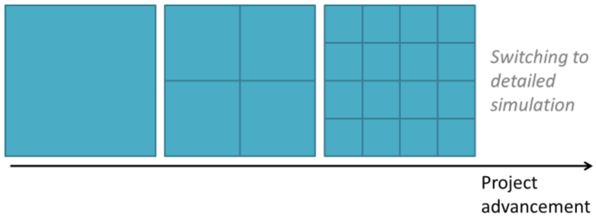

Fig. 5: Example of data granularity for houses.

Fig. 5 explains the need of reducing the cell dimension when typo-morphologies are used in specific project evaluations until the switch to detailed simulation. In early phases of the project, a large and quick assessment could be sufficient to get an order of magnitude of the likely-aimed performance. Then, the project evolution brings new information and description data which enable a thinner description making smaller cell dimension of interest.

3.4 Sensitive parameters

To define "types" (methodology Step 1), sensitive parameters have to be determined. For example, some key programming parameters could be listed:

- Building typology and morphology (volume and materials)
- Construction density (building, public space and mobility infrastructure)
- Constructive systems
- Mobility (network quality and accessibility)
- Energy performance

Many other parameters could be considered but this example set has been limited to ensure the applicability. In particular, the location should modulate the data as mentioned previously. It is necessary to focus in a first time on parameters:

- Of great influence on environmental performance
- Comfortably appreciable for stakeholders (designers, decision makers, etc.)
- Easily taken into LCA tools

All other parameters could further be implemented when knowledge and tools are constantly getting updated.

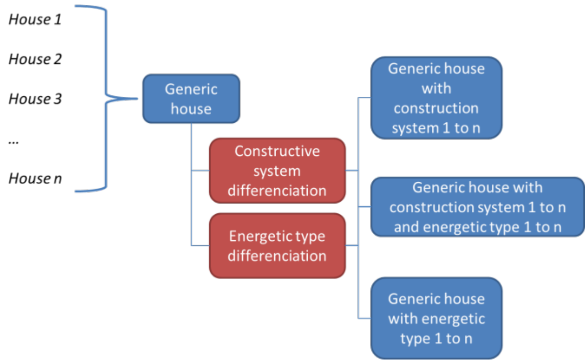

Fig. 6: Example of data granularity for houses.

Fig. 6 points out the room of manoeuvre existing to define types for the system components trough the example for houses. The granularity choice has to be adapted to needs and considered according to its influence on the results.

To solve this question, sensitivity studies must be performed on the considered parameters. Since the number of parameters could be very high, it is necessary to define priorities depending on the aspects of interest for stakeholders and applicability in LCA tools in the short and medium term.

According to the analyses that will be made by the sensitivity studies, the types will be defined by splitting or merging

4 DISCUSSION

The above propositions will lead to the definition of a contextualized typo-morphologies library. It will be a database to support LCA tools for territorial diagnostic and early-phase specific project evaluations. Beyond the contextualization aspect, the most convenient path to structure this library will be to aim a multi-scale system.

A first case study is being performed to validate the feasibility (some should be soon communicated). In particular, sensitive studies will give highlights about cell dimension and system's component data granularity questions. As presented, there is likely no best and unique answer since different relevant levels could exist according to user needs. For this reason, the case study is done in collaboration with a community to involve stakeholders in the methodology improvement and submit them alternatives. This process must lead to an operational solution responding to field considerations and helping the transfer to numerous current means objectives to a performance approach.

A key point mentioned in this paper is to take into account the interactions between cells. In fact, for some components, the performance within a typo-morphology can be greatly influenced by surrounding bricks. To evaluate the results' uncertainty due to this interaction when considered or not, it may be necessary to compare the aggregation of two cells and one bigger cell equivalent to the re-constitute one.

A lot of hypotheses or statistical data will have to be considered to evaluate each typo-morphology. Ideally, the results should illustrate scattering due to these different hypotheses and statistical distribution. In that way, it would give precious information to make a decision with a risk assessment.

5 CONCLUSION

This 1st version methodology describes the founding of the work being done and pursued objectives. The result should bring an innovative solution directly operational to run with LCA tools in order to facilitate territorial diagnostic and an early-phase specific project evaluation. Thanks to the flexibility to make it adaptable to the location and the scale of description, the library should readily be compatible with different purposes, questions and needs.

The different elements and recommendations exposed are still in experiment but based on bibliographical reviews to focus on the relevant conditions to link it with our needs in LCA tools.

Some discussed points may also greatly enhance its operability and consolidate its suitability for field stakeholders as a support for decision making.

We believe this approach to be of prime interest to help introduce environmental performance evaluation tools in the conception process. The solution will increase the user-friendliness of a still complex and time-consuming method and associated tools.

Further perspectives should finally consist in turning the approach to a global sustainability one. In fact, this paper only considers the environmental pillar of sustainability. The extension to economical and sociological matters may be the future step of this work.

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