Local Database as Crucial Factor of Sustainable Architecture
Linking Reality to Architectural Design Based on a Properly Modifiable Database

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Abstract
Preserving our environment has come to the forefront of our society's concerns and architects may not be indifferent. Sustainable architecture is seeking to minimize negative environmental impacts of buildings. Buildings should adapt to its environment both in shape and structure, and should reflect surroundings, providing maximum internal comfort and at the same time minimum harmful environmental impact. To achieve this goal the architectural design process must become more conscious based on holistic, performance based approach. Architects need to take into consideration full complexity of available data, while providing control over the decisions. Efficiency of design process depends on the adequacy of the data applied. Essential part is a properly modifiable Project-oriented Site-specific Database, continuously fitted to the project, consisting of real, up to date and comparable data.

Our research at Budapest University of Technology and Economics helps to discover how architects can capture locality, and how they can build databases to be used from the very first step of the design process. This research is always a multidisciplinary effort joining not only the various branches of architecture, but also involving IT specialists, meteorologists, civil engineers, economists, etc.

1. Introduction:
Problem Identification – Building and its environment

Shelter and comfort are basic needs for all human beings no matter where they live. We want a comfortable place to protect us against heat/cold, humidity, environmental diseases, dangerous animals, burglary and other possible threats. We want a comfortable environment where we can live a protected and healthy life.

The aim is to create a more comfortable and stable climate for our everyday existence. Nobody would feel well for an extended period at the extreme temperatures (e.g. -20 degree or +40 degree) if we could not generally somehow protect ourselves from the environment. Protection we get from our clothes and houses. We want to create a small "world" with a suitable climate we can control and regulate according to our needs. Fundamentally, function, arrangement and construction of the house is to set the framework for indoor climate, which is different from the outdoor climate. Thus, there is a close connection between the way we build our houses and the surrounding climate (Figure 1, [46, 47]).

For the several thousand years the houses were a part of the local eco-system. All over the world there were specific ways of relating to the climate. Whatever the general climate is - cold, hot, temperate, dry or humid - houses were built so that the local conditions are being utilized to a maximum. The first houses were built by hand out of local materials. This has been done by human beings since the beginning of time. Most old cultures had a good knowledge of the local resources (climate, materials) and understood how to utilize it instead of working against it (Figure 2, [48, 49]).

Development of society and industry has resulted with us to move away from the individual houses and to build uniform and anonymous houses located close to the factories. In the course of time, these houses have...
spread from the centre of the city to its enormous suburbs. Each individual person, therefore, no longer has influence or understanding on the relation between their house and its external environment. Recently indoor climate is mainly regulated by high-tech solutions. Houses are centrally heated, air-conditioned. Location of the house in relation to the natural conditions is not that important than before (Figure 3).
However, due to the increasing pressure on our energy resources we should again start to make use of experience and knowledge of natural resources. Widespread awareness of climate and other environmental change (decreasing natural resources, pollution of environment) together with huge amount of the technical opportunities have triggered professional demands for architects with advanced skills in design (Figure 4, [50, 51]).

Although most architectural practices claim “environmental, sustainable, green, energy efficient, holistic” as key elements of their design approach, few recent buildings have lived up the whole complexity to these targeted goals. Definition the exact meaning and content of terminology and methodology could help us to clarify the main aspects, demands, tools and techniques according to the challenges of changing nature, globalized society, economy, science and culture.

2. Tools and questions — Globalisation and digitalisation

Globalization refers to the increasing unification of the world’s economic. The goal is to increase material wealth, goods, and services through efficiencies catalyzed by international relations, specialization and competition. Globalization makes us familiar with new social, cultural habits, transfer huge amount of products and techniques. The question is how we could transmit and adapt solutions from all over the world in a given local situation. Is it enough to apply foreign ideas and products without changing to achieve an appropriate, sustainable variation on a local place? Is it appropriate to create the same buildings everywhere, despite the diversity of local condition? (Figure 5, [52, 53], Figure 6, [54, 55, 56]).
Architectural ideas have found new forms of digital representations, as information reconfigures into digital visualizations, and projects evolve further as digital fabrications. The new genre of "scripted, iterative, and indexical architecture" produces a proliferation of formal outcomes, leaving the designer the role of selection and increasing the possibilities in architectural design. Architects and engineers are able to push forward the boundaries of building design creating new forms of expression by taking advantage of the latest materials and construction methods. The computer aided architectural design opened new era for architects, but without awareness the basic human and material context of architecture the digitally generated forms are only nice pictures, but not real buildings (Figure 7, [57]).

Computer Analysis and simulation programs model environmental, technical and economic forces in order to quantify performance and enables us to analyze multiple design options. Computer aided design systems (CAD solutions) make the construction and drawing of building plans rapid and accurate. Projected physical dimensions and surfaces may be changed very easily. Architects – in theory - could have more control over the building design process, based on this freedom of shaping, modification through computer modelling, contemporary simulation, and calculation methods of reality.

Examples of Computer simulation programs:
- Physical simulations: Testing outside forces and stresses on the building.
- Wind and Turbulence Testing: Testing the turbulence patterns around the building.
- Lighting: Testing lighting of the building to find optimum solutions for natural lighting.

This technique does seem to be very accurate, but generally it is difficult to understand the calculation method. Separated simulation computer algorithms sometimes result with reductionism replacing the holistic approach, because measures of building construction are separated in independent processes and complex, comparative analysis of requirements and product performances in the context of the whole is missing. Reductionism in science says that a complex system can be explained by reduction to its fundamental parts. It could be problematic because of the interaction in between of the environmental impacts and material properties. For example we have computer algorithm for measurement of thermal quality of building envelope but it does not take into consideration possible contradiction in between of several evaluation fields, material performances (e.g. acoustical, thermal insulation quality and load bearing capacity) (Figure 8, [58, 59, 60]).

Every building project involves the choice of building materials. Selecting suitable building materials is a very complex process, being influenced and determined by numerous preconditions, decisions, and considerations [13, 14, 16, 20].

Database is the basic component of engineering calculation. The database information can be labelled according to data content, type of data affiliated in a computer program, the targeted group of stakeholders etc. Traditional database was an experience based system. Each stakeholders added their knowledge and information into the project. Elements of database were visible and accessible in documentations, maps, catalogues etc.
As part of globalization the building elements - materials and components - are arranged on internet through some product oriented building element basis. Clients may select from structures or materials as they compile its specification. These extensive catalogues are continually being updated with specifications covering most common products. Architects have difficulties in choosing the best product from these databases because of the huge amount of elements (one database division – e.g. thermal and moisture protection – could contain more than 10,000 enterprises with their several products!). Comparison the data of different products sometimes is problematic because of the different background (standards, measurement methods, units etc.). In these databases there is no information about whole complex application of structures and materials according to the local conditions (Figure 9. [61]).

The computer database programs through Database Management Systems (DBMSs) are a ubiquitous and critical component of modern computing. Given these various options, a typical DBMS needs to be compatible with many different connectivity protocols used by various client drivers. The structure of computer databases are hidden, the architect can use it through the Dialogue Boxes, windows. The storage and access of these data depends on the computer program so these are available only for those clients who have the appropriate software. These databases require the high level awareness of applied parameters (Figure 10, [62, 63, 64]).

Material selection is a complex and delicate task determined by the immense number of building material options. Likewise, multiple factors (cultural, economic, ecological etc.) should be often considered by the architect when evaluating the various categories of building materials. As a result, these sets of factors or variables often present trade-offs that make the decision process even more complex.

Nowadays we have thousands of new techniques, structures and products sold all over the world while the functions of our buildings have been changed and expanded. The question is how to take into consideration the whole complexity of important human attitudes, social, cultural, natural conditions together with integration of scientific results, computerization, challenging of the changed global, natural, economic situation in architectural design process? How can we use the results of controlling the behaviours of forms, structures and materials more effectively?

3. Conclusion
   Conscious design process, content and context

According to the new aspects and tools, the architectural design process must become more conscious. Recently our main task is not only to create new technical variations, but to define a really conscious, continuously controlled design process taking into consideration whole complexity of building requirements, performances and sustainable aspects, the way which we can follow step by step to achieve a sustainable optimum solution for the given design task.
As Michael Rice summarized “The new wave of awareness presents us with a pure principle anchor, a practical grounded philosophy based on simple measurable scientific principles, which apply in all life circumstances, because it is the way nature works - not a bad frame of reference if one wants to create a truly sustainable world.”

Definition of targeted goals is very important. We have to focus on the basic aspects of the architecture, like as human scale, safety, healthy, comfortable interior space, reflection of the surrounding nature. The complex building requirements generally are given in national building codes:

**Building Requirements**

Hungarian Regulation OTÉK 253/1997 (XII.20) recast 211/2012 (VII.30):

- Stability, mechanical strength,
- Fire protection,
- Noise and vibration protection,
- Safety and barrier free solutions,
- Life and wealth protection,
- Energy saving and heat protection,
- Health and environment protection,
- Sustainable consumption of natural resources.

These requirements must be fulfilled at the same time all together (Figure 11).

Widespread awareness of climate change together with technical requirements arising from new regulations such as the Directive on Energy Performance of Buildings have triggered professional demands for architects with advanced skills in sustainable design and energy efficiency.

**Sustainable environmental building design should**

- Take full account of the climate.
- Designed for durability.
- Use renewable local building materials wherever possible.
- Designed for increased efficiency in the use of materials, energy and other resources.
- Use life-cycle analysis in decision making about materials and construction techniques.
- Minimize the consumption of resources, especially non-renewable ones.
- Use materials with low embodied energy.
- Design buildings to use renewable energy.
- Minimize pollution of soil, air and water.
- Identify opportunities- and make easy for occupants to re-use and recycle waste.
- Identify opportunities for water conservation and re-use.
- Maintain or, where it has been disturbed, restore biodiversity.
- Reinforce and exemplify environmental responsiveness.
- Enhance appreciation and awareness of the environment.
- Be subordinate to and aesthetically sympathetic with the natural environment and cultural context.
- Take care of sewage treatment and waste treatment.

The surroundings, the location and orientation of the house are very important aspects for protection against weather. The way we build should reflect and be in dialogue with the local climatic conditions instead of working against them. Measures to improve building performances should take into account climatic and local conditions as well as indoor climate environment and cost-effectiveness. These measures should not affect other requirements concerning buildings such as accessibility, safety and the intended use of the building.

A comparative analysis based on the collected data of green vernacular buildings shows that there are significant changes in building performance across countries according to the specific natural and social circumstances, given their differences in building code restriction level in the use and mutual recognition of performance of materials, geographical and environmental conditions. How the building is oriented...
and located in its site is of major importance in its response to microclimate. The issues to consider are solar radiation, humidity and wind. To achieve the long-time appropriate structural solution during the whole life of the building we should take into consideration of the complex and interactive evaluation model, which consists of not only the single information but helps to recognize the coherencies as well.

The building can be interpreted only together with its surroundings. Every building and site is unique not just culturally and philosophically, but in terms of ‘technical solutions, energy performances etc. resulting from the unique locality (climate, terrain, shading, etc.) (Figure 12, [9, 65]).

This seems to suggest that there is a need for developing a systematic structural and material selection system that will enable architects identify and prioritize the relevant criteria to effectively and accurately evaluate the trade-offs between technical, environmental, economic and performance issues during the construction evaluation and selection processes. Therefore, to enable a structured and more comprehensive approach in the design-decision making process, in order to facilitate the processes of comparing and identifying the best material option(s) across different categories, it is important that the design-decision maker (architect, designer or expert) takes into account several material-selection factors or variables.

Analysis of the effects, requirements and structural, material performances on each stages of architectural design process can be the common ground of dialogue between the architect and the experts (Figure 13, [9]).

The design process should be the continuous development of architectural idea. It plays a very important role in architecture, not just aesthetically, but technically. By re-thinking the architectural design process as a coordinated set of stages, and sub-stages, replacing the traditional experience-related process by a more conscious, rational, and theory based approach; choices and solutions for specific design problems, traditionally taken base on experience or individual thinking, can be now taken base in technical awareness and attentive to potential alternatives (Figure 14, [9]).

In such a design process the architect can go back to his previous stages and improve his decisions. By “feedback” evaluation in between stages effect on each other the architects can develop the most appropriate solutions. The designers in their practice conclude the design process, while they finally choose a specific design form, technique and materials. The content of design stages does not depend on the design tools (e.g. manual or digital), but the connected real and complex database is essential factor.

Architects need to take into consideration the full complexity of available social, cultural, functional, economic, natural, structural, material and technological data, while providing control over the decisions of the design process. Each existing building requirements should be evaluated based on the real environmental, social, economic, material effects (impacts), requirements and performances database from the very first step of the design process (Figure 15, [65]).
Preventive and remedial measures and decisions should always be evaluated in the context of the whole. According to the holistic approach, a building should be thought of as a whole. The house should be approached as a complete system, with specific features and performance requirements, not as a collection of independent industrial engineering disciplines (electrical, mechanical, structural, and so on), as an integrated part of a process in dialog with the surroundings and its occupants. Holism (from ὅλος holos, a Greek word meaning all, whole, and entire, total) is the idea that all the properties of a given system (physical, biological, chemical, social, economic, mental, linguistic, etc.) cannot be determined or explained by its component parts alone. Instead, the system as a whole determines in an important way how the parts behave. The idea has ancient roots. The general principle of holism was concisely summarized by Aristotle in the Metaphysics: “The whole is different from the sum of its parts” (1045a10) (Figure 16, [9]).
Complex consideration the of available social, economic and natural data while providing control on the decisions of the design process may only be achieved through the use of a properly modifiable, database, continuously fitted to the project, consisting of real, up to date, and comparable data.

Efficiency of design process depends on the adequacy of the data applied. Architectural decisions can be correct only if they are based on a comprehensive, real, and up to date and appropriate Database. A Database is always unique and local. The essential part of the decision process is a properly modifiable Project-oriented Site-specific Database, continuously fitted to the project, consisting of real, up to date and comparable data (Figure 17, [4]).

In the Project Oriented Site-Specific Database system, the compilation of information - according to the project and site – starts at the beginning of the design process, with the collection of the basic data of social, cultural, functional, natural, structural, material, economical, technological information. This way, the first architectural and structural decisions may be made through the evaluation of real parameters and the complexity of the measurement will be more secure. The applied systemized parameters will be controlled and consciously selected. Each data type must be evaluated from the very first step of the project.

The choice of materials is the crucial part of the building value. The material performances should be appreciated on the knowledge of the whole by holistic performance based approach. First accomplishment of material during architectural design has essential effect on the final realization of the building. But the preliminary plans in scale 1.200 generally consist of only options of materials without structural evaluations according to the architectural envision supposed the choice is easily modifiable during later design phases. It is not true. As the attached figure shows the freedom of choice is the highest in the beginning, because later the decisions had been done earlier limit modifying of particular elements. As the project takes shape and becomes more detailed the degrees of freedom and the possibilities of choosing better alternatives are reduced.

I believe, that the architecture cannot be “global”. Every building should unique adapted to its real environment: both in shape and structure reflecting continuously on surroundings providing maximum internal comfort and at the same time minimum harmful environmental impact. The Holistic Performance Based design method responds on the surrounding conditions based on a properly modifiable Multilevel Project-oriented Site-specific Database, continuously fitted to the project, consisting of real, up to date, and comparable data. This method could be used not only in design practice, but in university curriculum as well.

This complex, holistic design process is very simple and adaptable all over the world together with the local database providing to fit the special conditions. During this design process the computer aided technologies can be only tools for architect, but not independent creative “intelligences” far from the human attitudes and real natural circumstances. The holistic analysis approach can be used for every aspect of design. The system can be applied on each field and level of the architecture, e.g. as Prof. Nicolas Pham (University of Applied Sciences of Western Switzerland, Geneva) told “Public building, public space are very complex corpus in which the relations that exist between the parts and the whole are more important, than the sum of the parts”.

By this way the architectural and structural decisions may be made through the evaluation of real parameters and the complexity of the measurement will be more secure. The applied systemized parameters will be controlled and consciously selected. Each data type must be evaluated from the very first step of the project (Figure 18).

Actually the difference is, how the designers interprets, synthesizes, and evaluates the collected data and techniques in their design process as result of all their perceptions, aims, convictions and skills.

The environmental work should be an integrated part of the designing process. It is worth emphasizing that it is important to start the environmental activities as early as possible in the course of the project. It is at the stage when the framework is established that it is possible to choose between different environmental alternatives. As the project takes shape and becomes more detailed the degrees of freedom and the possibilities of choosing better alternatives are reduced.
The architects have to pay close attention to possible environmental, structural and construction problems. Integration of whole complexity of design aspects and tools into complex architectural design process need to be provided from the very beginning of the design process (Figure 19).

4. Research — Perspective

Nowadays one of the most important task is to improve the energy quality of the buildings. The thermal insulation capability of the building envelope basically assigns the energy consumption of the whole building. The scope of the PhD research theme „Coherencies of the built-in thermal insulation’s material properties in residential buildings” (student Éva Keresztesy, supervisor: Zsuzsanna Fülöp Ph.D) at the Doctoral school of Budapest University of Technology and Economics, Faculty of Architecture, Department Building Construction is to define the real environmental and constructional parameters, the risk factors of applied thermal insulation materials. We have to explore those circumstances, which are crucial beside the thermal conductivity. A lot of factors affect the thermal insulation materials of the building envelope. These factors influence the thermal insulation capability and the energy value of the whole construction as well. At the calculation of the thermal transmittance standards attend to the declared value measured in laboratories despite of the fact that the insulation capability could significantly change in the completed construction depending on the environmental asset. If we are to design convenient thermal insulation constructions, we have to take jointly into consideration the real environmental impacts are effecting the given building, modifying material performances. Our PhD theme makes the performance-based approach closer to students. It attracts the attention, that the compliance of the building construction can be interpreted only in the knowledge of the environmental asset (Figure 20, [10]).

Our Scientific Student Competition (TDK) program at Budapest University of Technology and Economics (BME) provides possibility for students to improve their skills in a specific professional field. Topic „Aspects and examples of architectural and structural adaptation” helps our foreign students their acquired knowledge apply and transform at home.
One of study cases (Student: Aryan Choroomi, Teacher: Zsuzsanna Fülöp PhD) analyses students’ semester projects matching the site parameters, functional arrangements and shape according to the sustainability, energy efficiency aspects. His rating system allows him easily to recognize, analyse and compare design choices and their effects on the final performance of building, and that each requirement criteria has different priority in several design situations. (Figure 21, [11]).

At the Budapest University of Technology and Economics we concluded, that in order for architects to take the energy-consciousness seriously, they need precise local data and link the data to their plans. We have the data we need a tool to visualize it (architects tend to avoid dry numbers), and when we can visualize our data, we need to make this platform interactive and simple, so it’s easily accessible. So at the Budapest University of Technology and Economics, Department of Residential Design teachers (leader of research group: József Kolossa DLA) together with students and interdisciplinary partners we invented measuring equipment and software system – called DROID –, which provides site-specific and geometry-specific building energetic-data aiding architectural design. Based on the information retrieved from the database generated by the DROID, we can bring coherent and energy-consumption-conscious decisions already in the earliest design phase (Figure 22, [12]).

Figure 20. Changing of thermal insulation capacity on a façade after rain [10]

Figure 21. Aspects and examples of Architectural adaptation. Student’s Study Case BME [11]
The DROID consists of three parts:

- **The measuring unit**: a device designed and built, which logs the environmental impacts and data which are critical for building energetics on different planes and orientations.

- **The evaluation algorithm**: together with building energetics, students and meteorological measurement technology experts we have developed an evaluation algorithm, which clarifies how the data provided by the measuring unit can be applied to actual calculation, resulting an about 20% more accurate site specific dimensioning.

- **Visualization software**: a 3D visualization software has been developed that receives the measuring unit’s data, also reads the architect’s modelled building concept, and performs a simulation which shows, how the building would “behave” in terms of local environmental energy utilization if it was built on the actual site according to the concept. Thus, the architects design flow may become an energy-sensitive process as well, resulting a better “building-energetics DNA”.

References


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