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Building performance evaluation on "dynamical building" model – towards strategy for sustainable planning

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1 ABSTRACT

This paper presents the strategy for building performance evaluation according to principles of sustainability; based on interdisciplinary, life-cycle oriented planning process.

The issue of sustainability is one of the crucial issues the building industry is dealing with today - buildings count to the one of the main consumers of energy and primary resources.

However, in architecture and construction engineering, the terminus sustainability is still seen within sentimental context.

The application of the strategy enables the rationalisation of the sustainability potential, since the final result is expressed as an absolute value.

Keywords: sustainability, life-cycle approach, interdisciplinary planning

2 PROBLEM IDENTIFICATION

The new economic conditions, caused mainly by the rapid development of ICT (information and communication technology), seem to have set our world enterprise in the state of constant acceleration. Another important characteristic of our world is the scarceness of resources, where next to energy and material, time and space have also become tight resources. The acceleration of life brings the phenomena of constant change, and therefore of instability.

Our build environment, as one of the greatest resource-consumers, also underlies to process of constant change, due to economically technological development. The buildings, that used to referre to long duration once, therefore to constancy, stability, and in front of all to duration, are mutating in structures in persistent change.

The need for closer research of this change is urgent, since it is in close connection with saving of resources for future generations – sustainable development.

Architecture and construction: building industry of the new millennium has to fulfil new requirements – sustainability policy and regulations on the one hand as well as adaptability and flexibility on the other. However, the traditional planning process, that is phase oriented and with final horizon being completion of the building, cannot provide for such new requirements.

3 AIM

This paper is introducing a building performance evaluation strategy for support of decision-making process in planning and management of sustainable buildings throughout the lifecycle. The implementation of the strategy enables the quantification of the sustainability potential of a building or a project, the still rather vague and "irrational" term – sustainability - becomes tangible and easy to grasp, expressed through an absolute value.

This strategy will be applied to a conceptual model of a building; so called dynamoBsd model (dynamical building – under sustainable development) and should enable designing, planning and management of flexible, dynamical buildings, which are capable of absorbing different changes, guaranteeing social, economical and ecological optimum throughout the life cycle.

4 NECESSITY FOR SUSTAINABLE BUILDING

The buildings count to the one of the largest energy and material consumers of our society. The building process itself uses nature. During the last 40 years, it has been more built worldwide than in the past thousand years. Alone in Germany 100-120 ha of land is built over daily. 11 t of sand, gravel, stones and clay, 0,2 t of steel and steel products are used per capita inhabitant yearly for construction (Bomhard, 1998). Construction waste, building rubble and road decampment cause 1,2 t/per capita/year.

But not only are natural resources used for the manufacturing of buildings.

In the EU, 40% of total energy and material consumption is used for manufacturing and operation of the buildings. The ratio between the manufacturing-energy and building operation and maintenance energy consumption betrays 20% :80% - meaning that the largest consumption falls during the operation phase of the building life-path. Interestingly, the same ratio applies to the manufacturing vs. operation cost.

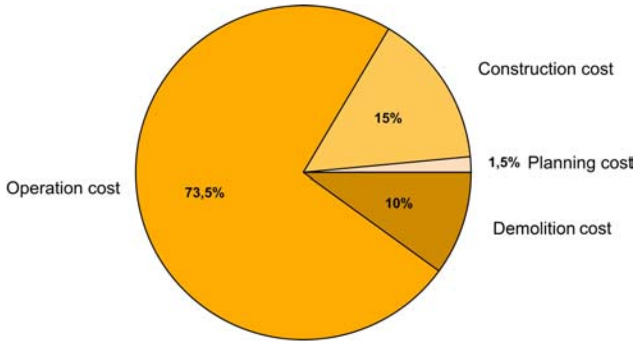

Figure 1: Cost development throughout life phases

5 SUSTAINABILITY IN BUILDING INDUSTRY

The terminus sustainability is often mistaken by solemnly satisfying the ecological issues. AGENDA 21 defines “triangle of sustainability” that coordinates the actions towards the sustainable development that lie upon satisfaction of economical, ecological and social issues (Renn et al, 1999), where Valentin (1999) introduces the fourth dimension of supervising institution. This concept corresponds to the holistic approach towards architecture, where buildings must not only fulfil the economical premises and ecological optimum; but also the original function of the shelter; further on as the container for certain social use (school, housing, etc.), representing the cultural expression of the society.

The rapid development of “new economy” and related so called “investor architecture” do not contribute to sustainable development – investors are interested in possibly lowest manufacturing/planning cost, and highest possible return of investment – future tenants will be coping with enormous operation costs and environmental load through out many years of building’s life duration.

The traditional planning process, with linear work flows on the time line: architectural concept first, then structural concept as the reaction to architecture and in the end the engineering as reaction to both previous concepts; results with over-installed buildings with illogical construction, wrong orientation, and an interior climate that is difficult to handle. As consequence: unsatisfied users, high life cycle costs, high environmental impact; all the factors that eventually lead to short economical life duration, soon vacation and demolishment; or in better scenario elaborate redevelopment and refurbishment – all again resulting in high following costs as well as environmental burden through resources consumption and waste production.

“The essence of sustainable building is thinking ahead” (RIDA, 2003), – therefore the life-cycle oriented interdisciplinary planning process from cradle to grave – from project development till demolition or reuse, is a precondition of actual sustainability.

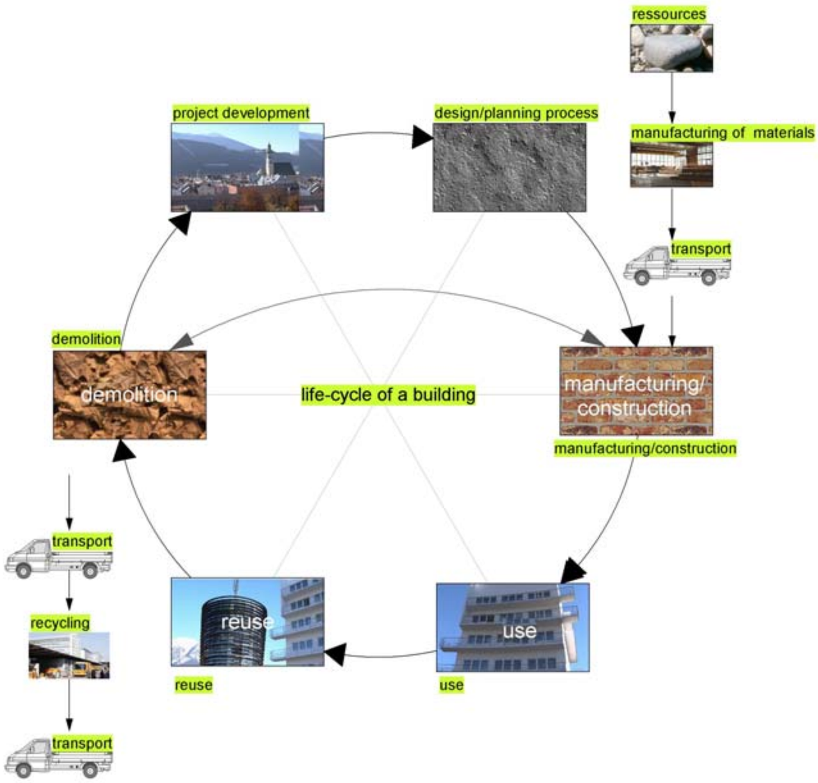

Figure 2: Life-cycle of a building

6 HYPOTHESIS

The basic hypothesis states, that building itself is not a stabile, static object but rather a dynamical system.

The current life duration of commercial real estates has been predicted by real estate investment management companies to lay somewhere around 50 years.(Schulte, 2002) Buildings change their original use two to three times throughout their lifecycle. The consumption of energy and resources is constantly progressing through building's lifecycle with its multiple changes and mutations. Therefore, the hypothesis develops a conceptual model of a building as permanent "project": as dynamical process – dynamoBsd model (dynamical building – under sustainable development).

6.1 dynamoBsd Model

dynamoBsd model is based upon the modernist approach of architecture as composition of form, function and construction. However, the modernist approach is expanded by:

- systemic concept – building as a system, set of micro and macro building elements
- temporal concept – building changing in time throughout its life cycle: dynamical system with life cycle approach
- sustainable concept – building interacting with its economical, social and finally natural environment: where eco-system represents the final system boundary, and is container of all sub-systems

The strategy for sustainable planning will be carried out upon dynamoBsd model .

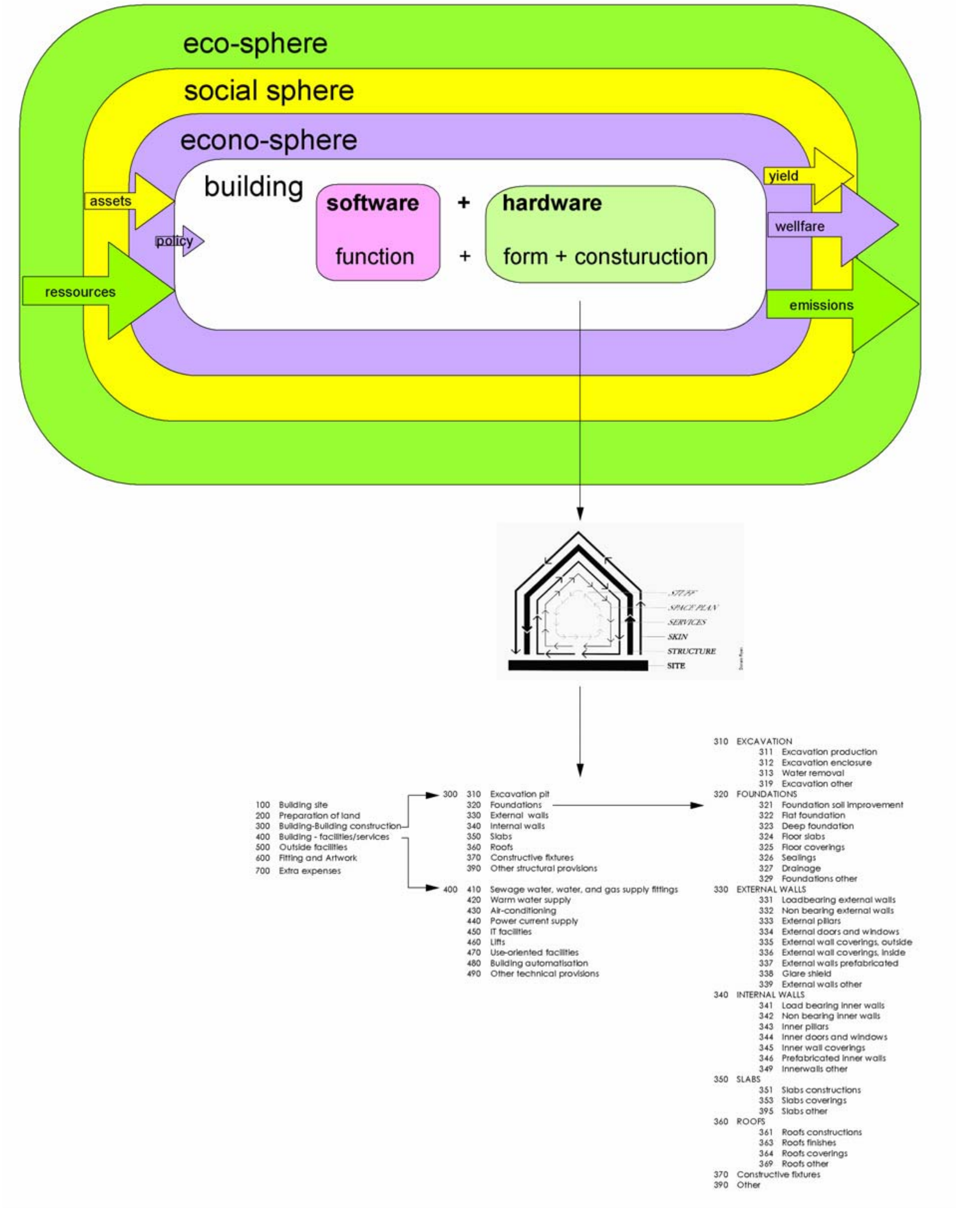

Figure 3: dynamBsd model

6.2 Flow analysis concept

To demonstrate the changes of building in time, the flow analysis concept developed by Kohler (1998) - to be referred to as Kohler Model - will be used. A building is represented through superposition of different flows taking place throughout its life-cycle: materials, energy, capital and information (Kohler, 1999). Moreover, different layers of building can be identified, according to their life-duration; which again experience different temporal changes: rhythms, cycles and phases. Brand (1994) proposes a "6s" building model, consisting of slow and long-lasting layers like site (eternal) and primary structure (50 - 60 yrs.), and fast and changing elements of short life duration such as skin (20 yrs.), services (7-15 yrs.), space plan (3 yrs.) and stuff-mobilia (monthly).

6.3 Tangible and intangible data

The ambivalent nature of a building as composition of "rationale" and "irrational" aspects brings problems for development of an evaluation strategy.

The tangible data are building's qualitative characteristics:

- ecological (consumption of resources and energy, emissions) and
- economic data (investments, life cycle cost),

The intangible data is expressed through quantitative characteristics:

- formal,
- cultural and
- functional aspects.

Both tangibles and intangibles have to be evaluated upon the same scheme.

For representation of tangible (qualitative) data the Kohler Model implemented in existing sirAdos-LEGEP (Hermann, 2000) Software is used – geometry and masses (materials) are calculated. Monetary flows, as well as inputs of energy and resources and outputs of emissions are modelled.

The intangible data will be represented using the method of sustainability indicators, that are adapted from the existing indicators of large scale-urban and regional planning (Steinhauer 2001) to the architectural scale of a single building (BVMBW 2001), and partially project-specifically defined.

7 THE EVALUATION STRATEGY

The building performace evaluation in terms of sustainability will be carried out upon the dynamoBsd through application of following STRATEGY:

1. Generation of project related indicators for sustainability indicator tables; which consist of ecological, economic and social aspects represented through relevant referential values
2. Building modelling through LEGEP-Software and developer calculation
3. Generation of data
4. Evaluation: Enrolment of the data into the indicator tables, relation to the referential values

7.1 Generation of indicator tables

The sustainability indicator parametric model is based on existing BMVBW (2001) model.

The parametric table reflects the "prism of sustainability" – containing aspects of: ecology, economy, and socio-cultural aspects; which are to be evaluated separately in own evaluation tables.

Some of typical aspect-indicators are:

a) Economy:

- economic competitiveness and sustainable management (yield, costs),
- economical aspect of ecology (water consumption cost in €/anno, heating kWh/m², maintenance cost inspection cost and operating cost €/m²),
- soft facts such as fungibility and flexibility, maintenance and creation of branch/business diversity

b) Ecology:

- Protection of natural resources (construction demand, land consumption)
- Protection of bio-diversity
- Protection of pollution rate/constraint of emissions: greenhouse gasses emissions (CO2 equivalent, Ethane equivalent), soil pollution
- Long life duration and easy dismantling (recycling of building materials)

- Rational energy consumption (U-Value, Substitution of fossil energy sources through regenerative energy sources),
- Water consumption, cleaning effort, maintenance effort (material flow in kg/anno), sewage water and waste (kg/anno)

c) Socio-cultural aspects:

- Social and spatial fairness: outer/inner appearance, barrier free building
- Creation of liveable urban identity
- Fulfilment of individual needs (Adequate provision of housing and living space, Accessibility of workplace, Accessibility of infrastructure and free time facilities of the higher level centre)
- Protection of social stability (Residence quality for all ages, Consideration of balanced income structure regarding working places, Integration foreign co-citizens)

The existing indicators have to be examined project specifically on their project relevance; new indicators have to be generated throughout careful basic research of a project.

The project-specific indicators are mostly complex interactions of different tangible and intangible aspects. In order to determine their project relevance, a tool of sustainablity cob-web diagram is used: the importance of the specific indicator-interaction is represented as an area within diagram.

Typical real-estate related indicator-interactions are e.g.:

- real estate image, sustainable rental incomes, higher yields depending on building easthetics
- cost-efficient and low maintenance, long life duration depending on construction-typology
- higher construction cost for lower life cycle cost, efficient energetic building performance
- urban identity, landmark charcter depending on formal aspects
- longer economic life duration depending on flexibility and fungibility

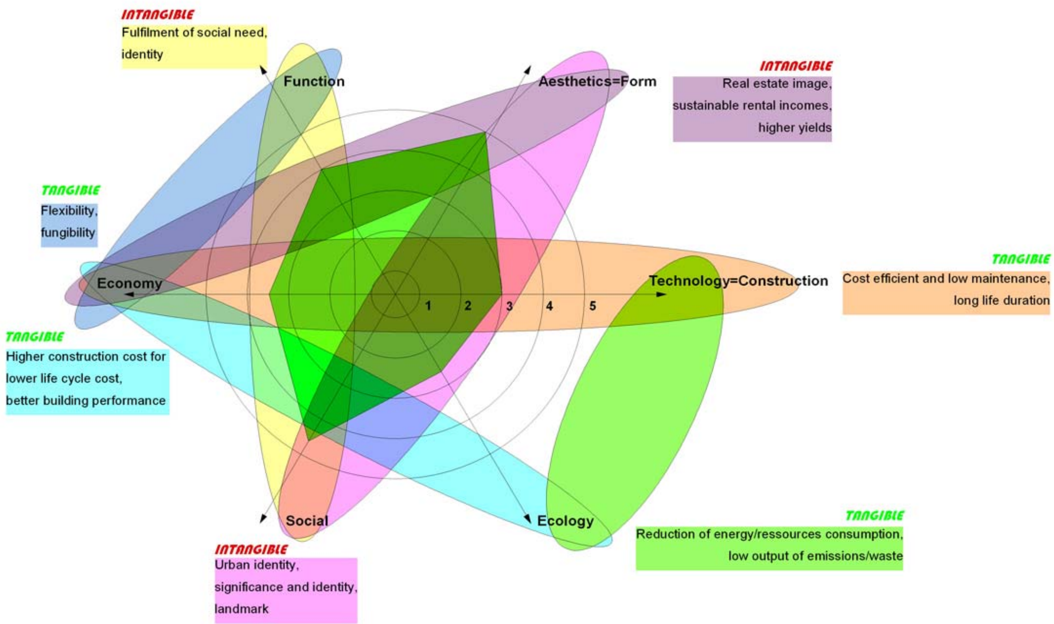

Figure 4: Cob-web diagram of interactions between tangible and intangible indicators

7.2 Data-generation:

Quantitative data will be modelled by the means of sirAdos-LEGEP-Software (2006) and developer calculation method (Achammer, 2003).

Qualitative data is legible from the plans, graphical representations, project specification, interviews etc. It will be evaluated by means of scale or simply yes/no answers.

7.2.1 The sirAdos-LEGEP

The sirAdos-LEGEP software performs a cost calculation by the means of macro-, gross- or fine building elements that define building construction. Each element is linked to its life cycle cost (consisting of maintenance, service, cleaning and demolishing cost) as well as to mass flow, emissions and energy consumption throughout its life cycle.

Following evaluation is carried out by LEGEP:

- Construction costs according to DIN 276 (1993):

100 – Building site

200 – Preparation of land

300 – Building construction

400 – Building facilities/services

500 – External facilities

600 – Fitting and artwork

700 – Extra expenses

Construction cost = ∑(200 – 600)

- Total price €/m² GFA (gross floor area) and Total price €/m³ GV (gross volume)
- Life cycle cost:
- cleaning, service/inspection, maintenance, operating cost, demolition: in total and €/m² GFA
- Energy consumption - U-Value calculation, transmission heath losses, energy costs for heating and warm water, electricity costs €/anno, water consumption in m³/anno and costs €/anno
- Ecology: mass flows and balances for life cycle or for single life cycle phase (construction, cleaning, maintenance): CO2 emissions, primary energy consumption, acidification, summer smog potential etc; waste mass flows (landfill, hazardous waste, underground landfill in kg)

7.2.2 Developer calculation method

The developer calculation method is employed to evaluate and/or to guarantee sustainable yields and incoming profits. It is basically based on cost calculation on the first cost group of building elements of DIN 276 (1993) Standard.

7.3 Evaluation

Both qualitative and quantitative data will be enrolled in the evaluation tables and compared to target values (quantitative data), graded on scale 1-5; and weighted by the factor of relevance for the project.

The target values are obtained from: referential projects, facility management companies, authorities or suppliers, LEGEP-Database.

Therefore, the determination of relevant indicators and their weighting should only be done upon well documented basic research in sense of project development, and remains in the realm of experience of evaluator.

Each aspect: ecology, economy, and socio-cultural is evaluated separately in own evaluation table, and becomes a grade – absolute value. The final result, so called factor of sustainability (Sd) is a mean value of the values of three aspects.

7.4 The factor of sustainability

The factor expresses the sustainability potential of a building or a project at given point in time (life cycle phase), and points out the weaknesses and potential future problems. Moreover, the concrete issues such as:

- identification of large cost originators throughout the lifecycle concerning cleaning, maintenance and demolition;
- peak years of expected great investments and reinvestments;
- development of following costs
- yields and revenues through alternative uses; etc.
- can be outlined.

8 CONCLUSION

The implementation of building performance evaluation tool dynamoBsd enables determination of the possible planning consequences already in the earliest stages of life cycle of the building: at the beginning of the planning process; in the pre-design phase.

This planning phase is crucial for the entire life cycle of the building; since at that early point the change potential is still almost infinite. This relatively short and fast phase determines however the future building features such as energy consumption; flexibility etc.; that will last over long period of time and will be hardly possible to correct in latter phases.

The evaluation tool can also be implemented at any later point in time: either in planning or operation, as the means of control or as means for redirecting of undesirable future developments – it serves as indicator of weaknesses but also strengths of a building; expressed in an absolute value.

The tool itself deals very well with tangible data that are clearly quantifiable, and can also be modelled for the future. However, more problematic are the intangible data because of their partially "irrational" and extreme temporal character.

To such data count in front of all the parameters of socio-cultural component; but of economical component as well – sustainable rents depend on future market developments or the future image of the site; these factors can hardly be foreseen and are extremely dependable on outer influences and indeterminist forces.

Therefore the implementation of the tool in the early phase of pre-design can only be seen as an indicator of sustainability; the re-evaluation and corrections in latter planning as well as in life cycle phases is necessary.

Some decisions concerning the potential user- or general public acceptance and image of the project within the urban context as well as the security of final economic success will always be escaping the rational evaluation methods, and will remain in the "irrational" judgement realm of experience, instinct, foreboding and talent of planner and developer.

The tool can find concrete and immediate application in the field of architectural competitions: in the EU-wide competitions the concepts and adherence of sustainable development gain increasingly on importance, however these concepts could hardly be objectively evaluated. The building performance evaluation strategy dynamoBsd gives a tool that enables the competition jury comparing of the projects based on tangible results – factors of sustainable development.

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