Integrated design with a focus on energy aspects

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Keywords

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Abstract

In the framework of the Solar Heating and Cooling (SHC) programme of the International Energy Agency (IEA) several European countries, USA, Japan and Canada developed an Integrated Design Process (IDP). The IDP-approach makes sure that energy efficiency, the use of renewable energy and wishes of the owner/user, the investors and other stakeholders, with respect to sustainability and lifecycle stability, are integrated in the design of buildings from the very first moment. In this way the effect is optimal and the overall cost impact is minimal.

The IDP-concept was put into practice in several demonstration projects. It has proven to be highly effective in realising high-energy performance and environmentally friendly buildings. An average increase in the energy efficiency of buildings of 20% seems realistic. Some demonstration projects even showed an energy performance improvement of over 30%, by just using the integrated design approach.

EBM-consult was one of the developers and is now working on the further implementation of the IDP-concept by making the knowledge and experiences accessible for practitioners and translating experiences into standards and codes. Local authorities (urban planners), investors and other stakeholders are involved in the process.

Introduction

In recent years it became clear that integrated design is an approach that can offer a very favourable perspective for the future of building design, especially in view of the increasingly strict performance requirements. Recent experiences show that integration in the design process lead to a better cost performance ratio of the final result, without extra expense for the design process.

Benefits are mainly to be gained by avoiding sub-optimisation of subsystems (building design, installations, functionality, etc). A pre-condition is that the market, especially the designing partners and the principals, has to assimilate this new approach. It is important to realise that this concerns not only the know-how, but especially skills. For the beginning this requires an extra effort of the parties involved. The economical benefits for the principals form an important driving force.

This paper is based on a five-year international research project (IEA-SHC Task 23) and implementation of the results in The Netherlands.

The Need for a Better Performance

The global drive towards sustainable development has resulted in an increasing level of pressure on building developers and designers to produce buildings with a markedly higher level of environmental performance. Although various experts have somewhat different interpretations, a consensus view is that such buildings must achieve measurably high performance, over the full life cycle, in the following areas:

- minimal consumption of non-renewable resources, including land, water, materials and fossil fuels;
- minimal atmospheric emissions related to global warming and acidification;
- minimal liquid effluents and solid waste;
- minimal negative impacts on site ecosystems;
- maximum quality of indoor environment, in the areas of air quality, thermal regime, illumination and acoustic/noise.

Some authorities in this rapidly developing field would add related issues such as adaptability, flexibility and operation costs as well as life-cycle cost.

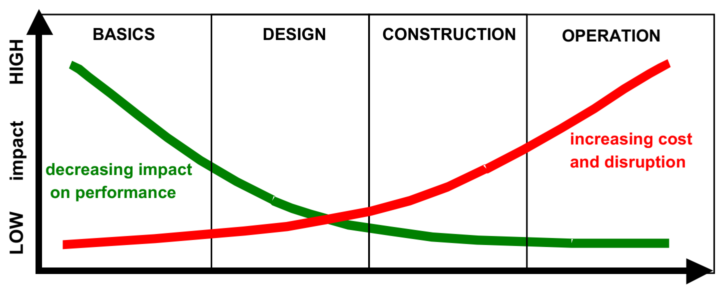
In addition to a new breadth of performance to be addressed, contemporary developers and designers are faced with more stringent performance requirements being imposed by markets or regulation, or both. Chief amongst these is energy performance, and this poses a definite challenge to designers, in terms of reducing purchased energy consumption and in the application of solar technologies, all within the constraints of minimal fees and the time pressure of the modern development process.

The Conventional Design Process

Although there are many exceptions, we can refer to a "traditional" design process as consisting of the following features:

- The architect and the client agree on a design concept, consisting of a general massing scheme, orientation, fenestration and, usually, the general exterior appearance as determined by these characteristics as well as basic materials;
- The mechanical and electrical engineers are then asked to implement the design and to suggest appropriate systems.

Although this is vastly oversimplified, such a process is one that is followed by the large majority of general-purpose design firms, and it generally limits the performance levels achievable to conventional levels. The traditional design process has a mainly linear structure due to the successive contributions of the members of the design team. There is a limited possibility of optimisation during the traditional process, while optimisation in the later stages of the process is often troublesome or even impossible.



Source: Solidar, Berlin Germany

Figure 1. *Impact on the process.*

Sub-optimal design solutions are the result of a design process that is not sufficiently taking into account the integration of different design disciplines (building structure, HVAC systems, functionality and architecture).

If the engineers involved in such a process are clever, they may suggest some very advanced and high-performance heating, cooling and lighting systems, but these may result in only marginal performance increases, combined with considerable capital cost increases. The underlying cause is that the introduction of high-performance systems late in the design process cannot overcome the handicaps imposed by the initial suboptimal design decisions.

In summary, the conventional design process is not generally capable of delivering the high levels of broad-spectrum performance that are required in many contemporary projects.

The Integrated Design Process

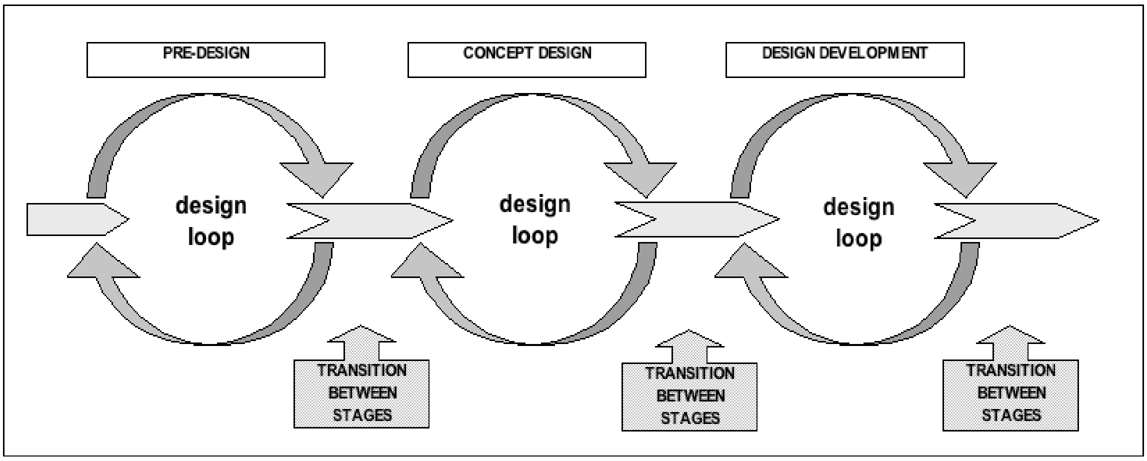
The Integrated Design Process (IDP) involves a different approach from the very early stages of design, and can result in a much better performance. In the simplest of terms, the IDP process requires a high level of skills and communication within the team, involves a synergy of skills and knowledge throughout the process, uses modern simulation tools, and leads to a high level of synergy and integration of systems. All of this can allow buildings to reach a very high level of performance and reduced operating costs, at very little extra capital cost.

The IDP process is based on the well-proven observation that changes and improvements in the design process are relatively easy to make at the beginning of the process, but become increasingly difficult and disruptive as the process unfolds. Changes or improvements to a building design when foundations are being poured, or even contract documents are in the process of being prepared, are likely to be very costly, extremely disruptive to the process, and are also likely to result in only modest gains in performance. In fact, this observation is applicable to a large number of processes beyond the building sector.

Although these observations are hardly novel, it is a fact that most clients and designers have not followed up on their implications. The methods and tools developed in IEA-SHC Task 23 provide a sound basis for implementation on national level.

THE IDP INCLUDES SOME TYPICAL ELEMENTS THAT ARE RELATED TO INTEGRATION:

- Inter-disciplinary work between architects, engineers, costing specialists, operations people and other relevant actors right from the beginning of the design process;
- Discussion of the relative importance of various performance issues and the establishment of a consensus on this matter between client and designers;
- Budget restrictions are applied at the whole-building level, and there is no strict separation of budgets for individual building systems, such as HVAC or the building



Source: Solidar, Berlin Germany

Figure 2. *Diagram Integrated Design Process.*

structure. This reflects the experience that extra expenditures for one system, e.g. for sun shading devices, may reduce costs in other systems, e.g. capital and operating costs for a cooling system;

- The addition of a specialist in the field of energy, comfort or sustainability;
- The testing of various design assumptions through the use of energy simulations throughout the process, to provide relatively objective information on this key aspect of performance;
- The addition of subject specialists (e.g. for daylighting, thermal storage etc.) for short consultations with the design team;
- A very clear articulation of performance targets and strategies right at the start of the design process in a much more explicit way than usual also addressing non technical expectations of the client like appearance of the building and the mutual importance of the different building performances. Throughout the design process a change of insight in the team may lead to modifications of the performance targets;
- In some cases, a Design Facilitator may be added to the team, to raise performance issues throughout the process and to bring specialised knowledge to the table.

Based on experience in Europe and North America, the overall characteristic of an IDP is the fact that it consists of a series of design loops per stage of the design process, separated by transitions with decisions about milestones. In each of the design loops the design team members relevant for that stage are participating in the process.

MULTI-CRITERIA DECISION-MAKING INSTRUMENT: MCDM 23

An important tool developed within IEA SHC Task 23 is MCDM-23. A multi-criteria decision support method.

This method provides the opportunity to validate the different performances of a building in their mutual coherence. This provides the possibility to mirror the design to the programme of requirements, or to compare the different design variations. Application of such a method to a architectural competition is evident.

The MCDM 23 is designed as software. It is possible to define building performances for a maximum of eight aspects, which can be chosen freely. Each of these eight performance fields can be divided into eight sub-performances. Both performances and sub-performances can be provided with weighings, to be decided upon by the design team or the client. Performance fields are e.g.: costs, environmental loading, indoor quality, architectural expression, functionality, etc.

After several performance fields have been compared to each other, a design can be judged by determining a score for each of the performances. For some performances this can be a number, e.g. for energy consumption or cost. For other performances the valuation will take place on a quality scale, ranging e.g. from 'excellent' to 'minimum requirement'. Based on this weighing and valuation we can subsequently show the performance of the building. These

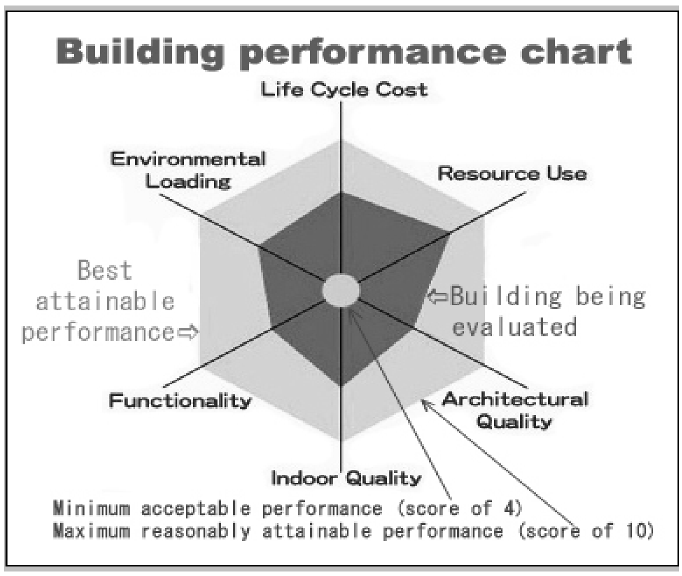
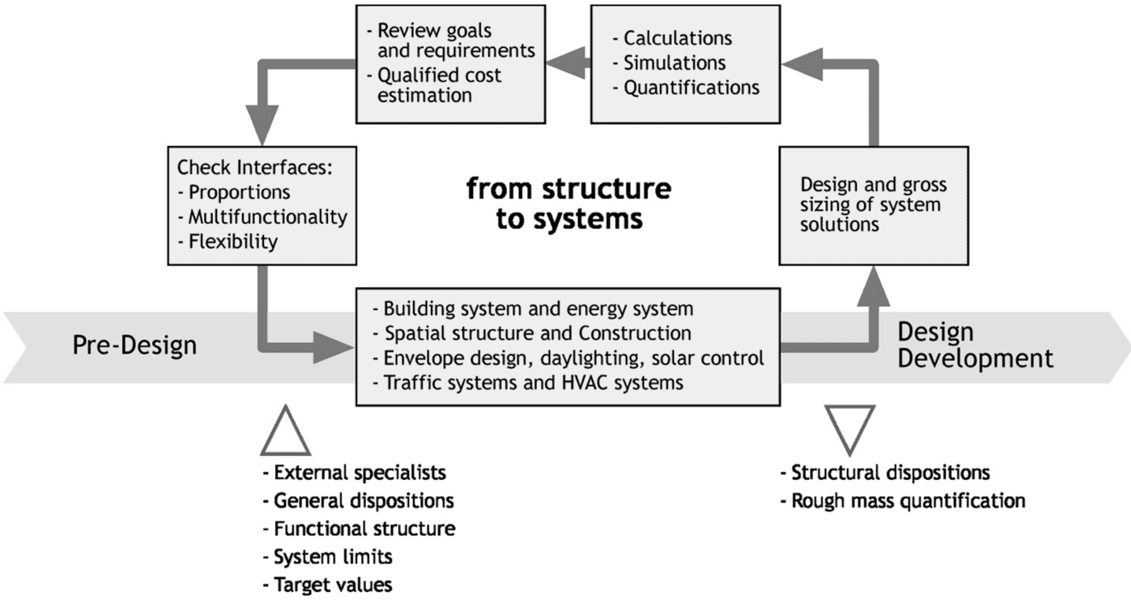


Figure 3. *Star diagram in MCDM 23.*



Source: Solidar, Berlin Germany

Figure 4. *The Integrated Design Process in the Concept Design Phase.*

results can be shown in marks and graphically in a star diagram as shown in figure 3.

This method does not lead to an ultimate assessment on the performance of the building; the strength of this method lies mainly in the fact that the design team can discuss the performance fields in a structural way – design choices are always put in a broader context. The method is very appropriate for validating the design in relation to the programme of requirement (the brief).

THE DESIGN PROCESS ITSELF EMPHASISES THE FOLLOWING SEQUENCE:

- Establish performance targets right at the beginning of the design process very explicitly for a broad range of parameters, and develop preliminary strategies to achieve these targets. This sounds obvious, but in the context of an IDP approach it creates a common understanding of the expectations of the client and the design task already in the conceptual phase, thereby helping the owner and architect to avoid becoming committed to a sub-optimal design solution;
- Then minimise heating and cooling loads and maximise daylighting potential through orientation, building configuration, an efficient building envelope and careful consideration of amount, type and location of fenestration;
- Meet these loads through the maximum use of solar and other renewable technologies and the use of efficient HVAC systems, while maintaining performance targets for indoor air quality, thermal comfort, illumination levels and quality, and noise control;
- Iterate the process to produce at least two, and preferably three, concept design alternatives, using energy simulations as a test of progress, and then select the most promising of these for further development.

As an example a more detailed description of the design loop during the concept design phase is pictured. The central issue in this phase is to define systems in a conceptual way, based on the structure/scheme of the building. In a loop several options are considered, paying attention to the integration in the building as a whole not just restricted to the technical aspects.

IDP Successful in Practice

Both in Europe and in North America design teams had positive experiences with the integrated design process regarding the aspects of energy and sustainability.

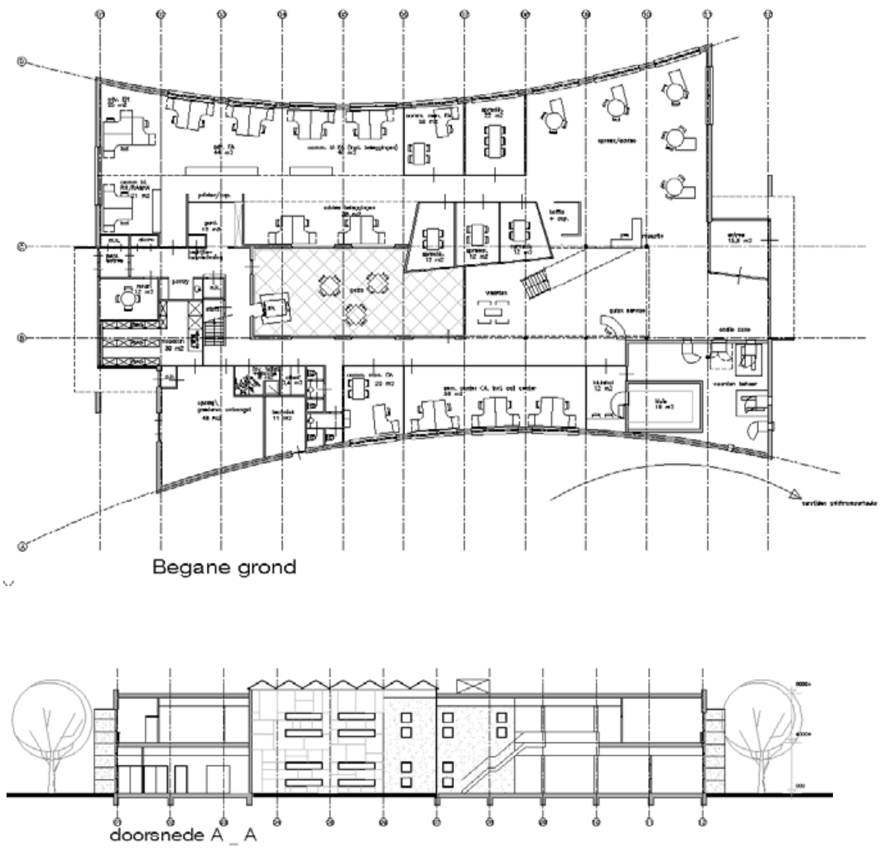
On an international scale several design processes and their resulting designs, based on the application of the principles of IDP were evaluated. In these projects the aspects of energy and sustainability were taken into account from the very early stages of the design process.

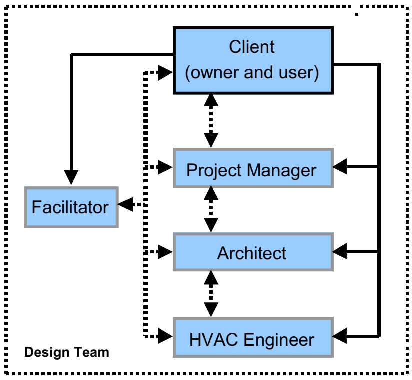
Regarding the aspect of energy, as an important component of sustainability, it is stated that by applying IDP a reduction of the primary energy use of 20% is possible, without additional cost for the building and the design process.

The need for methods and tools to be developed by IEA SHC Task 23 was defined on the basis of experiences in a number of projects characterised by a type of design process that was meant to facilitate integration. Two Dutch experiences will be highlighted, based on interviews with the actors involved in the IDP process.

RABOBANK IN ZIERIKZEE: SUSTAINABLE, FLEXIBLE AND COMFORTABLE

The Rabobank building in Zierikzee, the Netherlands was required in order to centralise the local activities of the bank in one new building. This building had to be sustainable and comfortable, within the financial targets (pay back time on energy measures up to seven years). The argument for





Source: Archikon – Goes

Figure 5. *Groundfloor Plan and Cross Section, Design Team.*

choosing an IDP was to create a more optimal and efficient building at no extra building cost.

Design Team. The Rabobank organisation was approached to initiate a demonstration project, aimed at the application of the integrated design process. Rabobank reacted enthusiastically and proposed the project in Zierikzee. A facilitator was appointed to guide the integrated design process and to support the application of the new design instruments/tools.

The users were represented by the Rabobank in the design team, supported by the project manager with a broad experience in participating in building and design teams. The project manager provided the necessary expertise on behalf of the Rabobank. He developed a high quality programme of requirements and chaired the meetings. The architect was the actual designer and joined the project team after the programme of requirements was established. Right from the beginning, the HVAC engineer was involved in the team.

Experiences. In the Zierikzee project the team decided to use the IDP method to achieve an optimal design without extra cost. At the start of the project all team members had positive expectations of this approach. The facilitator maintained efficiency during the design process and kept an eye on the integration of the different disciplines. This was an important factor to success, as the team members had no previous experience with IDP.

The kick-off meeting workshop at the start of the design process proved to be of great importance in order to make the design task explicit for all the actors involved. Tools used during the design process by the team were MCDM 23 and Energy 10, an energy simulation model developed in the USA. After completing the design process the members of the design team agreed that all tools had a positive contribution to the process.

Instruments/Tools. A kick-off workshop started the design process. The principle of integrated design was explained to the team members and the design brief was discussed in order to familiarise all with the requirements of the client. By using MCDM all criteria to be included in the design were presented. In a later stage of the process MCDM proved again it's value. The instrument showed the discrepancies between the programme of requirements and the preliminary design. These discrepancies formed the basis of a clarifying discussion, as it became evident that choices had to be made within conflicting requirements. The design team agreed that MCDM is a useful tool to portrait advantages and disadvantages of several designs in order to make a comparison. Furthermore the tool can be used as a checklist of assessment criteria.

Besides MCDM several other instruments were used. To make i.e. quick analysis of the energy consumption and the comfort aspects of the design Energy 10 was applied.

Results. The main result from IDP in this project is that building and HVAC concepts/ designs were optimally integrated. The building and the climate installation are an integrated system; the architect even stated that the building also functions as a part of the HVAC system. The approach lead to a decrease of the overall energy performance expressed in primary energy compared to the requirements set in the building code (see footnote below) of no less than 30%. Furthermore less piping was used (heating elements were positioned in the centre of the building and not along the facades) and space needed for installations was reduced by 50%.

The IDP approach resulted in a design in which the optimum was found considering cost, environmental loading and comfort for the user.

Project Details
Client: Rabobank Schouwen-Zierikzee.
Architect: Archikon bv, Goes.
Facilitator: EBM-consult bv, Arnhem.

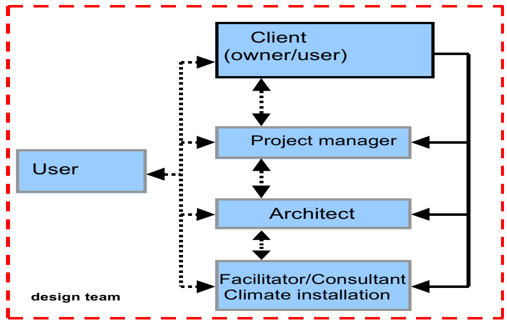


Figure 7. *Design Team.*

ONAFHANKELIJK TONEEL: SUSTAINABILITY AND CULTURE IN AN EXTRAORDINARY BUILDING

The Onafhankelijk Toneel (Independant Stage Company) was located in a characteristic building in Rotterdam (the Netherlands). The available space, however, did no longer meet the modern requirements: the premises had become too small. The client decided to build a new theatre adjacent to the old building. Sustainability and a flexible use of space were main issues. Eventually a extraordinary construction was chosen: a building within a building. A wooden theatre was situated within the exterior building with. The double envelope that was created provides a flexible use of the building and allows for several possibilities to simplify the installation.

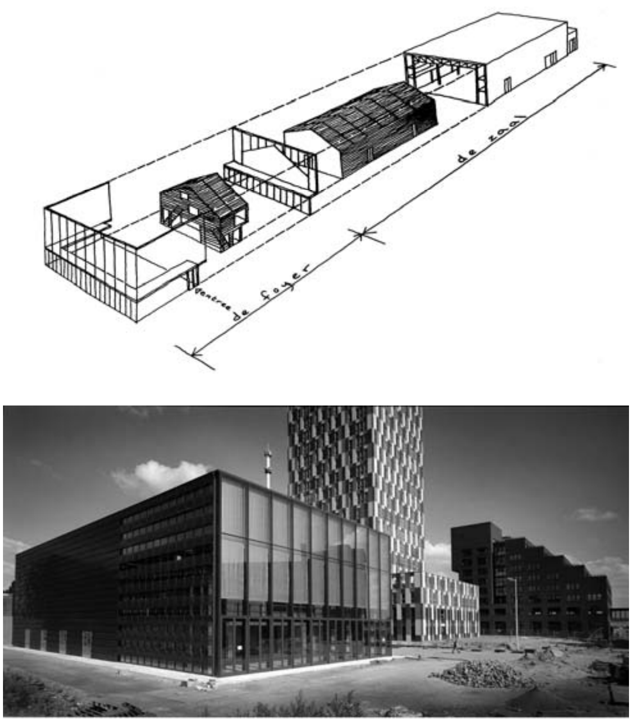


Figure 6. *Double Envelope.*
Source: Franz Ziegler, architect

Design Team. The decision to choose for an integrated design approach was made naturally. The integrated approach emerged from the manner in which the members of the design team experience their profession. The client and the energy consultant played an important part in the process. The energy consultant had extensive experience with IDP and the client immediately was very enthusiastic about this approach. The client had a substantive stimulating input in the team, right from the start of the project. This aspect, combined with the enthusiastic attitude of the other team members, was an important success factor, as the design could be exactly tuned to the requirements of the client.

Experiences. The design team was very motivated to realise a sustainable building with the possibility of flexible use. Besides it's function as a theatre, the outer building should be adaptable for use as an office in a later stage. Other important aspects were low energy consumption combined with a high level of functionality for the user (no fixed stage and audience section). IDP contributed substantially in achieving these goals. An optimal fine tuning between installations and building design was accomplished.

Instruments/tools. Energy 10 was mainly used during the design process. It helped to fine-tune the building structure and the installation design. The project team was very satisfied with the use of Energy 10 as it provided energy and comfort calculations that helped minimise the installation. Other instruments developed specially for in the integrated design process were only used on a small scale.

Results. The result of this design process is a building with low energy consumption, and suited for flexible use. Without extra costs a design was realised which resulted in a 35% decrease of the overall energy performance (expressed in primary energy) compared to the requirements set in the building code[1]. These energy savings were mainly achieved by fine tuning the building structure and installation components. The design was based on a minimal installation in which heating, ventilation and cooling are combined.

1. The **Energy Performance Coefficient** (EPC) in the Netherlands expresses the overall energy consumption of a building calculated under standard conditions, taking into account space heating cooling, lighting, DHW heating and electricity use for fans and pumps. This consumption is weighted with the size of the building. The conversion factors from natural gas and electricity to primary energy taken into account are 35,17 [MJ/m^3 gas] and 9,23 [MJ/kWh electricity].

Ventilation air at the required temperature is brought to the double envelope through the installation and transport to the theatre through vents in the walls of the internal building. Subsequently the air is mechanically exhausted from the theatre room and the heat of this air is used for heating the incoming ventilation air by means of a high efficiency heat exchanger.

All members of the design team are very satisfied with the Integrated Design Process and anticipate on incorporating this method in future projects.

Project details

Client: OntwikkelingsBedrijf Rotterdam, Rotterdam.
Architect: Bureau Franz Ziegler architectuur en stedenbouw, Rotterdam.
Facilitator and consultant: EBM-consult bv, Arnhem.

Lessons to be learned from the above examples

Both examples together with the other projects that were evaluated, show that integrated design offers great benefits. This approach enables the design team to implement and to weigh a broad range of aspects for the design from an early stage of the design process. The result is an optimal design that scores high marks both in the fields of energy and environment on the aspects of costs and comfort.

In order to succeed in an integrated design process it is important to meet a number of requirements. The first requirement is an open attitude and well-structured communication within the project team. Team members have to be willing to look beyond the boundaries of their expertise and actively co-operate, both practical and theoretical, from the early stages on. If a team has no experience with IDP it is useful to add a facilitator. A clear perception of the design task is an important starting point for a successful process. Important is not only to study the brief, but also to debate the task set by the client and the client's expectations.

Finally a flexible budget structure is of the essence. In an integrated design process decisions on design aspects are no longer linked to certain stages of the design. This means that budgets are disconnected from design stages, and preferably disconnected from design disciplines as well. In the next paragraphs some experiences regarding design team and design process from above mentioned examples are summarised.

If above mentioned requirements are met, the integrated design process offers an excellent opportunity to realise – against limited cost – an optimal design, in which energy efficiency and a high standard of comfort for the user are combined.

Projects show that integrated design can be a general approach for different design tasks within a variety of contexts. This means that integrated design can be applied in a wide variety of projects. It is important to understand that integrated design is no rigid approach, but needs to be customised to the specific circumstances of a project. Lessons learned from projects emphasise the importance of:

- adequate compilation and structure of the design team
- competent and well-motivated team members
- a clear design task
- a process structure which stimulates integration
- well-executed project management.

Conclusion

The overall conclusion is that the Integrated Design Process has been shown in many case studies to result in higher levels of energy performance and greatly reduced operating costs, without extra building costs. In order to achieve an integrated building in terms of performance and cost, a traditional design process is in many cases ineffective. Although there will always be individual designers who are able to design brilliant buildings in an individualistic way, the IDP approach will be of significant benefit to most designers and clients who are attempting to achieve excellence in building design.

OVERVIEW OF BENEFITS OF INTEGRATED DESIGN PROCESS

For the Client

- better building, more quality against the same cost in the fields of energy, environment and comfort
- more influence on the design process
- better control of the process in the fields of cost and building performance
- favourable design solutions in a flexible design process

For the Architect

- central role in the design process
- better tuning to the expectations of the client
- more efficient and effective process
- integration of form, functionality, cost, energy, environment and comfort.

References

IEA – Solar Heating & Cooling Programme – Task 23 – Optimization of Solar Energy Use in Large Buildings. (Publications below are part of this task and are available through website: www.iea.shc.org/task23)

Balcomb, Douglas, Inger Andresen, Anne Grete Hestnes, Søren Aggerholm. 2002. Multi-Criteria Decision-Making MCDM-23, A method for specifying and prioritising criteria and goals in design.

Cruchten, Gerelle van (ed.). 2000. Examples of Integrated Design, Five Low Energy Buildings Created Through Integrated Design.

Poel, Bart and Nils Larsson. 2002. Solar Low Energy Buildings and the Integrated Design Process – an Introduction.

Poel, Bart, Gerelle van Cruchten, Nils Larsson, Torben Esbensen and Matthias Schuler. 2002. The Integrated Design Process in Practice Demonstration Projects Evaluated.

Software (available through website)

- Integrated Design Process, A Guideline for Sustainable and Solar-optimised Building Design (www.iea-shc.org/task23)
- Navigator (www.iea-shc.org/task23)
- Multi-Criteria Decision-Making : MCDM 23 (www.iea-shc.org/task23)
- Energy 10 (www.sbicouncil.org/enTen)