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# Integral Design method to support nZEB design: an real project experiment

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## Abstract

*The increasing complexity of these sustainable buildings requires a design team of architect and engineers already from the conceptual design phase. In this phase the highest impact of changes for the lowest costs can be achieved. The more a design is developed the harder (and more expensive) it becomes to make adjustments. In this case the design task was a nearly zero energy building to be realized in the Netherlands. It was a real setting in practice in which the researchers could organize a workshop during the conceptual design phase of the project. A new design approach during the conceptual phase which was chosen in this study is the integral design methodology which makes use of morphological charts and overviews. The workshop started with a lecture about the Integral Design method in the context of nZEB design. After this, a design session was done, an exercise session about a nearly zero office building located in Utrecht to make the members familiar with the method so that they would be able to use it for the proposed new multifunctional nZEB building. Results showed that the morphological design methodology was a good way of showing the knowledge and influence of each design discipline/member. The design tool enabled an effective support for the design team during the conceptual design phase, but also to study the process within the design team and individual members in detail.*

*Keywords - component; formatting; style; styling; insert (key words)*

## Introduction

Future building regulations will require nearly Zero Energy Buildings in Europe [1]. The increasing complexity of sustainable buildings requires a design team of architect and engineers already from the conceptual design phase as in the early phases of a design process of a building the significant design decisions affecting Green House Gas emissions are made [2]. The earlier design stages are dominantly responsible for the latter building performance and especially conceptual design plays crucial role [3]. In this phase the highest impact of changes for the lowest costs can be achieved. The further a design is developed the harder (and more expensive) it

becomes to make adjustments. Integrated design process (IDP) has emerged as an approach to design low energy buildings, derived from the whole building design approach by Amory Lovins in 1992 [4,5,6]. Although the IDP has been fully developed in theory with clear and general descriptions, the practical applications of the IDP is often problematic [1]. According to RIBA president Jane Duncan, architects, engineers and builders must have a ‘frank debate’ why collaboration is still not happening across the supply chain [7]. As stated by Doug King [8] in order to do anything meaningful in terms of moving to a low carbon society, a consistent framework for the knowledge embodied in a design team is needed.

A new design approach during the conceptual phase which is chosen in this study is the integral design methodology. The design tool [9] enables an effective support for the design team during the conceptual design phase, but also to study the process within the design team and individual members in detail. In this case the design task was a nearly zero energy building to be realized in the Netherlands. On the 12th of December 2014 a workshop was organized for the design members. Two design sessions were done, where the first design task was a nZEB to make the members familiar with the method and the second design task was about a new multifunctional building itself.

## **2 Methodology**

This research is focusing on the conceptual design phase, where a team’s oriented design approach is used to improve the collaboration. Earlier research [9] showed that the following stakeholders/design disciplines should at least participate in this design team; an Architect, Structural Engineer, Building Physics consultant and a Building Services consultant. They are the most relevant in the conceptual design phase; other design disciplines can join the team in a later phase. The design method which is applied is called; integral design. It is used as support during the initial design period.

A program of requirements is examined by each team member, in this case a new multifunctional commercial nZEB. Then the morphological charts are formed as each designer decomposes the main goals of the design task for their design discipline into functions/aspects (step 1). These functions are listed on the first column of their morphological chart, see fig. 1. After listing these functions, solutions are proposed for each sub-function/aspect as the second step (step 2), see fig 1.

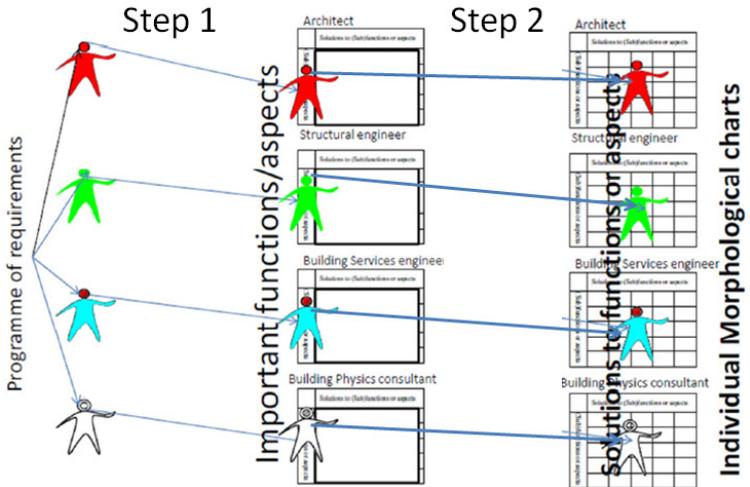


Fig. 1 Step 1 from program of requirements to functions/aspects and Step 2 from functions/aspects to part solutions

From this point the individual charts are filled and a group discussion will take place as the third step (step 3). This is an important step since here decisions are made, and influence of each discipline can be evaluated, about which functions are placed on the team's morphological overview. After this procedure solutions corresponding to the functions are discussed and placed into the row of a chosen function/aspect, see figure 2 and 3.

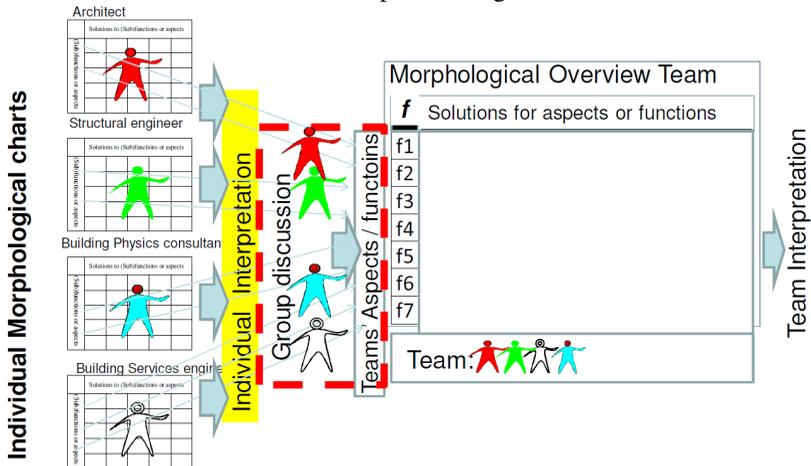


Fig. 2 Step 3: Team discussion to functions for Morphological Overview [11]

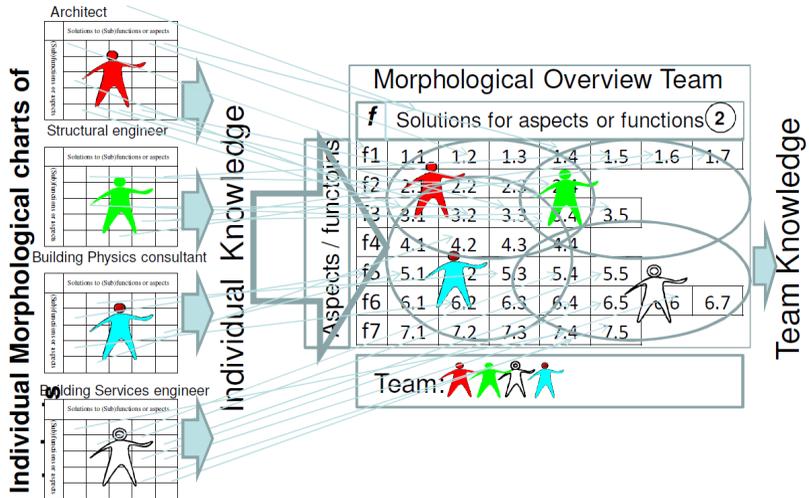


Fig. 3 Step 4: Solutions for aspects or functions in Morphological Overview [11]

An advantage of this methodology is that it can be used for a Team's mental model, 'the individual charts or each individual designer represent their active perception, their activate part of their memory [10], their individual knowledge used as well as their interpretation of the design needs'. By combining the individual charts to the morphological overview a representation of the design team interpretation/perception and activated memory/knowledge can be analyzed. This method was applied during an organized integral workshop for the design of the new multifunctional commercial building. With this workshop each team member can be assessed on actual knowledge and influence in the team. This process was analyzed.

### 3 Morphological Design Method

Morphological design methodology is a method applied during the conceptual design phase to give a good overview of different design solutions and enables to integrate the influence of each team member corresponding to their design discipline. This leads to a greater number of discussed aspects and functions and leads to a higher number of generated possible part solutions.

### 4 Workshop for professionals: an integral approach for a new nZEB

Designing a nZEB building requires a systematic design approach, during a workshop day the morphological design methodology is explained and applied. The goal of this workshop was a kick-off boost for a new

building to be realized in Netherlands. The workshop was organized in the following matter:

1. General introduction participants
2. Introduction integral design method
  - a. Morphologic design method
3. First integral design session; Kropman Utrecht building
4. Nearly Zero Energy Buildings in practice
  - a. Villa Flora Venlo, CBW Mitex, TnT office Hoofddorp
  - b. Example building (5a.) design solutions shown in morphological charts
5. Second integral design session TT-Plaza, Assen
6. Discussion

During this day the design following disciplines were participating; Architect, Building Physics & Services consultant, Building Services consultant, Contractor/builder and Project manager. The session was guided by experts from the Eindhoven University of Technology.

The first session was organized as a design exercise for the (for some of the participants) new design method. The design program comprised a new office building located in Utrecht, Papendorp. This plot is located in a business park where more offices are located. It should fulfil the central need of a pleasant and healthy working environment for employees. A sustainable and energy neutral building, where solar-energy can be promoted. 5.500m<sup>2</sup> gross floor area with a challenging budget of 16 million euro. Two groups were formed during the start of this first session, they are not influenced by each other since they were placed in two rooms. No discussion was allowed when completing the individual charts. An additional analysis is done for all the participants during the session, to show what their influence and knowledge is.

## **5 Workshop analysis: Session 1 new sustainable office**

Participants Team 1: 2 initiators, building services consultant and an architect. The individual charts and team's morphological overview (MO) from both teams are shown in Fig. 4. The real sketch and written charts were digitized and translated to English.

| Morphological Chart |   |        |                                  |           | TT Phase 1 (10/11/November 2014) Design Task 1 |  |  |  |  |
|---------------------|---|--------|----------------------------------|-----------|--|--|--|--|--|
| Initiators/Aspects  | Aspects   | Team 1 | Name                             | Component | Design/Description                             |  |  |  |  |
| Heat (energy)       | Water, water  |        | OSP                              |           |  |  |  |  |  |
| Electrical (energy) | Solar Panel<br>(SP in Back)<br>Solar Panel<br>(SP in Front) |        | OSP<br>SP in Back<br>SP in Front |           | Material<br>in D                               |  |  |  |  |
| Healthy Environment | Health, Health<br>(in Back)<br>Health, Health<br>(in Front) |        | OSP<br>SP in Back<br>SP in Front |           | Material<br>in D                               |  |  |  |  |
| Building            | Steel, Steel<br>(in Back)<br>Steel, Steel<br>(in Front)     |        | OSP<br>SP in Back<br>SP in Front |           | Material<br>in D                               |  |  |  |  |
| Cooling             | Water, water  |        | OSP                              |           |  |  |  |  |  |

| Morphological Chart     |   |        |                                  |           | TT Phase 1 (10/11/November 2014) Design Task 1 |  |  |  |  |
|-------------------------|---|--------|----------------------------------|-----------|--|--|--|--|--|
| Initiators/Aspects      | Aspects   | Team 1 | Name                             | Component | Design/Description                             |  |  |  |  |
| Healthy pleasant        | Water, water  |        | OSP                              |           |  |  |  |  |  |
| Sustainable / Energy    | Solar Panel<br>(SP in Back)<br>Solar Panel<br>(SP in Front) |        | OSP<br>SP in Back<br>SP in Front |           | Material<br>in D                               |  |  |  |  |
| Structure               | Steel, Steel<br>(in Back)<br>Steel, Steel<br>(in Front)     |        | OSP<br>SP in Back<br>SP in Front |           | Material<br>in D                               |  |  |  |  |
| Promote PV              | Solar Panel<br>(SP in Back)<br>Solar Panel<br>(SP in Front) |        | OSP<br>SP in Back<br>SP in Front |           | Material<br>in D                               |  |  |  |  |
| Go-out with material    | Steel, Steel<br>(in Back)<br>Steel, Steel<br>(in Front)     |        | OSP<br>SP in Back<br>SP in Front |           | Material<br>in D                               |  |  |  |  |
| Flexibility in building | Water, water  |        | OSP                              |           |  |  |  |  |  |
| Lightning               | Light, Light  |        | OSP                              |           |  |  |  |  |  |

| Morphological Chart     |              |        |      |           | TT Phase 1 (10/11/November 2014) Design Task 1 |  |  |  |  |
|-------------------------|--------------|--------|------|-----------|--|--|--|--|--|
| Initiators/Aspects      | Aspects      | Team 1 | Name | Component | Design/Description                             |  |  |  |  |
| Public building         | Water, water |        | OSP  |           |  |  |  |  |  |
| Transparent             | Water, water |        | OSP  |           |  |  |  |  |  |
| Technology              | Water, water |        | OSP  |           |  |  |  |  |  |
| Pleasure                | Water, water |        | OSP  |           |  |  |  |  |  |
| Environmental friendly  | Water, water |        | OSP  |           |  |  |  |  |  |
| Affordable for everyone | Water, water |        | OSP  |           |  |  |  |  |  |
| Off the Grid            | Water, water |        | OSP  |           |  |  |  |  |  |

| Morphological Chart |              |        |      |           | TT Phase 1 (10/11/November 2014) Design Task 1 |  |  |  |  |
|---------------------|--------------|--------|------|-----------|--|--|--|--|--|
| Initiators/Aspects  | Aspects      | Team 1 | Name | Component | Design/Description                             |  |  |  |  |
| Design              | Water, water |        | OSP  |           |  |  |  |  |  |
| Structure           | Water, water |        | OSP  |           |  |  |  |  |  |
| Technology          | Water, water |        | OSP  |           |  |  |  |  |  |
| Materials           | Water, water |        | OSP  |           |  |  |  |  |  |
| Climate             | Water, water |        | OSP  |           |  |  |  |  |  |
| Entrance            | Water, water |        | OSP  |           |  |  |  |  |  |
| Roof                | Water, water |        | OSP  |           |  |  |  |  |  |
| Lighting            | Water, water |        | OSP  |           |  |  |  |  |  |

| Morphological Chart |              |        |      |           | TT Phase 1 (10/11/November 2014) Design Task 1 |  |  |  |  |
|---------------------|--------------|--------|------|-----------|--|--|--|--|--|
| Initiators/Aspects  | Aspects      | Team 1 | Name | Component | Design/Description                             |  |  |  |  |
| Healthy Environment | Water, water |        | OSP  |           |  |  |  |  |  |
| Design              | Water, water |        | OSP  |           |  |  |  |  |  |
| Heat (energy)       | Water, water |        | OSP  |           |  |  |  |  |  |
| Cold (energy)       | Water, water |        | OSP  |           |  |  |  |  |  |
| Electrical (energy) | Water, water |        | OSP  |           |  |  |  |  |  |
| Materials           | Water, water |        | OSP  |           |  |  |  |  |  |
| Structure           | Water, water |        | OSP  |           |  |  |  |  |  |
| Lighting            | Water, water |        | OSP  |           |  |  |  |  |  |
| Solar Energy        | Water, water |        | OSP  |           |  |  |  |  |  |
| Flexibility         | Water, water |        | OSP  |           |  |  |  |  |  |

|                             | Initiator (PvdK) | Building services (PvdR) | Initiator (RI) | Architect (WS) | MC Average Team 1 | MO Team 1 |
|-----------------------------|------------------|--------------------------|----------------|----------------|-------------------|-----------|
| MC to MO Functions/ Aspects | 4 out of 5       | 4 out of 6               | 0 out of 8     | 5 out of 8     | 6.75              | 10        |
| MC to MO (sub) Solutions    | 8 out of 13      | 5 out of 21              | 2 out of 6     | 7 out of 25    | 16.25             | 28        |

**Workshop session 1**  
 Team 1: initiator (PvdK), building services (JvdV), initiator (RI), architect (WS)

Fig. 4 Results from the individual morphological charts and the team's morphological charts of team 1 session 1

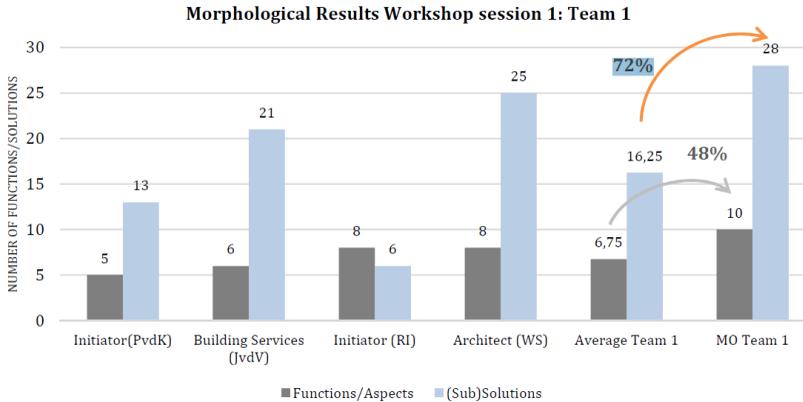


Fig. 5 Results individual morphological charts and team's morphological overview

The architect has the highest number of functions and solutions in the individual chart. Initiator (RI) has found the least solutions; the person even has fewer solutions than functions. After the completion of the individual charts (about 15 to 20 minutes) a discussion started about placing the individual functions into the morphological overview. Each member is analyzed shortly; mainly which functions/solutions are placed into the overview and some interesting which were not.

- 4 of the 5 functions (see also fig. 4) of Initiator (PvdK) are placed into the overview. Only the construction parts are not chosen. Functions are about building materials/physics/services.
- 4 of the 6 functions of Building Services (JvdV) are placed into the overview. Promotion PV, healthy environment, flexible building use and efficient use of lightning.
- No functions are directly used in the overview of initiator (RI), but two solutions from the individual charts are shown in the overview. There can be said that he has no influence during this integral design session.
- The influence of the Architect (WS) is big: 5 of the 8 functions mentioned by him are placed into the morphological overview. Here some esthetic design considerations are taken into account, but also healthy environment (climate) solutions are given.

The transformation from individual charts to the team's overview show a significant increase in functions and solutions as shown in table 2.

Table 2 Team 1, session 1: Member effectiveness

|                                  | <i>Initiator (PvdK)</i> | <i>Building Services (jvdV)</i> | <i>Initiator (RI)</i> | <i>Architect (WS)</i> | <i>Average</i> |
|----------------------------------|-------------------------|---------------------------------|-----------------------|-----------------------|----------------|
| Functions in individual chart    | 5                       | 6                               | 8                     | 8                     |                |
| In MO                            | 4                       | 4                               | 0                     | 5                     |                |
| Ratio of found functions in MO   | 80%                     | 67%                             | 0%                    | 63%                   | 52%            |
| <b>Effectiveness Functions</b>   | <b>40%</b>              | <b>40%</b>                      | <b>0%</b>             | <b>50%</b>            | <b>33%</b>     |
| (Sub)Solutions in individ. chart | 13                      | 21                              | 6                     | 25                    |                |
| In MO                            | 8                       | 5                               | 2                     | 7                     |                |
| Ratio of found solutions in MO   | 62%                     | 24%                             | 33%                   | 28%                   | 37%            |
| <b>Effectiveness Solutions</b>   | <b>29%</b>              | <b>18%</b>                      | <b>7%</b>             | <b>25%</b>            | <b>20%</b>     |

In the next step the effectiveness of each team member was examined. The effectiveness is defined as the number of mentioned functions in the morphological chart of a team member, in relation to the number of functions that were notated in the morphological overview of the design team. Based on these numbers the effectiveness of the members are defined in a percentage based on the number of functions mentioned by the member divided by the total number of functions mentioned in the morphological overview, see figure 6.

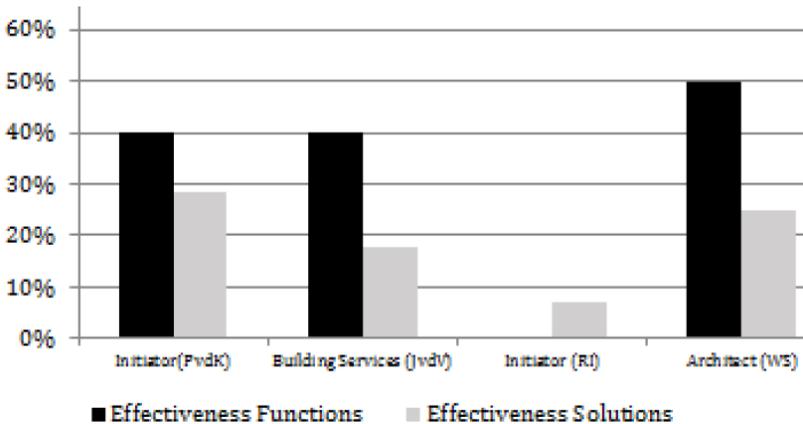


Fig. 6 Effectiveness members session 1

The architect was the leader and most effective in the number of functions found in the MO, the Initiator (RI) was the least effective. For the solutions the effectiveness of initiator (PvdK) was the highest with 29% and the architect was just a little lower with an effectiveness of 25%. The ratio of found functions and solutions in the MO was for the initiator the highest, which implies that most of his input on the individual morphological chart

was seen as important and useful. This ratio also indicates the power of a member. The effectiveness of all team members reveals that the building physics & services (JB) consultant was most effective and dominant. Thereafter the initiator (PvdK) and architect (WS), see fig. 6.

## 6 Discussion

Earlier research [9] showed that in all professional morphological design cases an increase of functions and solutions are generated after the team's discussion. A comparison of this research and workshop sessions for students (average of 98 students) is done in another research [12]. This was found from research with professionals in industry as well as from projects with students, see figure 7 .

For each function, solutions are given, and with the team knowledge and during discussions design solution tracks can be made. Different tracks for each program of goal, for instance; an energy plus building, energy neutral or conventional building. The results of the students and professionals are quite similar, there is only exception for the morphological chart (MC) where the students found 5.5 more solutions on average. Session 1, team 1 is performing approximately the same in the found solutions, also the mentioned functions/aspects are about the same number as compared to the outcome of earlier research.

Average students, professionals and workshop 12 december 2014

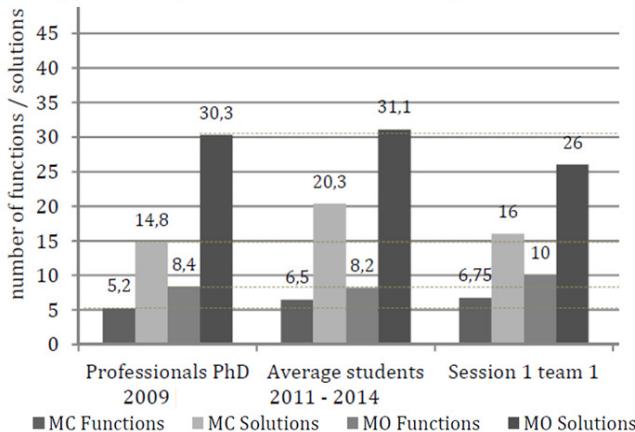


Fig. 7 Comparison between students, professionals and workshop session participants

## 7 Conclusion

A nearly zero energy building design approach is investigated with a 'new' design method. Using morphological charts during a conceptual design

phase is not new, but adding the morphological overview after a team discussion makes it a new design approach. Results of the organized workshop day show that the group interaction is of great importance during the conceptual design phase and has a positive effect on the number of functions and aspects discussed as well as on the number of generated part solutions. Results showed that the morphological design methodology was a good way of showing the knowledge and influence of each design discipline/member.

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