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Figure 1.
MFFD Zutphen, parking area integrated in flood defense (photo courtesy Mark Voorendt).

Figure 2.
MFFD Arnhem, flood defense incorporating city information building (photo courtesy Mark Voorendt).

Mark Voorendt

A METHOD FOR INTEGRATED AND SUSTAINABLE DESIGN

FIVE DESIGN STAGES

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Multifunctional flood defenses combine several functions into a single system. Therefore, several disciplines need to be combined to design such complex systems. An "integrated design" is a collaborative method that combines several disciplines for designing systems or structures, emphasizing a 'holistic' approach. Holism is the concept of considering systems and their properties as wholes, not just a collection of parts. The functioning of the entire system cannot be fully understood solely in terms of their component parts. A holistic, integrated approach is believed to be more cost-effective and sustainable.

Sustainable design could be defined as the philosophy of designing physical objects, the built environment, and services to comply with the principles of social, economic, and ecological sustainability (McLennan, 2004). This contains the three essential elements, or 'pillars' of sustainability: society, economy and environment.

The Roozenburg and Eekels design model (see figure 3) can provide an approach for integrated and sustainable design. According to Roozenburg and Eekels (1995), who were professors in the Industrial Design Faculty of Delft University of Technology, a design starts with specifying functions formulated at an abstract level, and ends in a concrete shape that fulfils the requirements. Another feature of the method is that it can be carried out at different levels of detail. Finally, the method distinguishes five main design stages, which enables designers to phase and organize their design process.

According to this method, a design consists of the following stages: analysis, synthesis, simulation, evaluation and decision (Figure 3). Although in theory these stages logically proceed from each other, in actual practice the process is iterative because insight into the problem, goal and functioning of the system under development only grows gradually. The main design stages are described below.

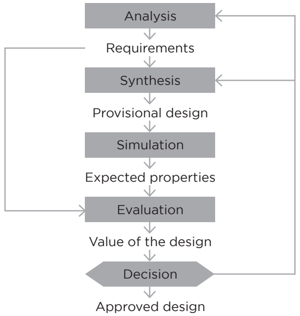

Figure 3. The Roozenburg and Eekels model of the design cycle (Roozenburg and Eekels, 1995)

1. Analysis
An inventory and analysis of the problem is made using given and found information (project file, informers, literature). This makes it clear exactly what the client wants to be accomplished. This results in a clear formulation of the problem, and an objective, solving the problem. The objective is formulated as fulfilling a certain function like protecting an area against flooding, which is still abstract. Requirements are then derived from the project objective to make it more specific. The designer needs to be restrained from jumping to specific solutions too quickly (generally

Figure 4.
MFFD Kampen, touristic walkway integrated in flood defense structure (photo courtesy Mark Voorendt)

familiar structures), because this would spoil the creative phase and likely lead to suboptimal solutions. The analysis phase includes an inventory of stakeholders, boundary conditions, prevailing laws and regulations, requirements, spatial aspects, and risks.

2. Synthesis
During this creative phase, alternatives are generated with brainstorm sessions or by drawing morphological maps. The solutions that are generated now use concrete materials and have concrete shapes. Reference projects can be searched for, to provide extra ideas. Possibilities for generating additional values can also be thought of at this stage, if the project would appear to be unaffordable without them.

3. Simulation
The proposed alternatives have to meet all the requirements and the system needs to adequately fulfil its function. The main dimensions of the structure or system are usually derived from this main function. Additional calculations can be performed to ensure that the structure meets the requirements regarding structural and user safety. Simulations can also be used to check requirements (e.g., bottlenecks in a transport system can be detected using a computer simulation). For multifunctional flood defenses, an important element of the simulation is determining the project's constructability. At this state, costs, planning and spatial restrictions need to be considered, as well as technical and logistical aspects.

4. Evaluation
Once it has been determined that they meet the requirements, the alternatives can be compared with the help of qualitative criteria. Requirements should not be included in the criteria, nor should the costs. Since not all criteria are equally important, they should be weighted. The alternatives get scores per criterion and the product of score and weight factor is calculated. The sum of these products is the value per alternative. To compare the alternatives, these values have to be divided by the costs. The higher the value-cost ratio, the better the alternative. This systematic method of comparing alternatives is called the Multi Criteria Evaluation (MCE).

5. Decision
The alternative with the highest value-cost ratio could possibly be enhanced by adding strong elements from other alternatives, and possibly by adding values. The optimal variant can now be proposed to the client. If the client approves, the 'winning' alternative can be detailed in another design loop, where more ideas, detailed calculations and drawings are generated.

If this method is applied to an integrated and sustainable design, several issues need to be addressed. First, the project goal should include all main design aspects. The design, after all, results in a program of requirements, which is used to verify the created solutions. If the design fails to include all the design aspects, the program of requirements will also be incomplete. In that case, there is no guarantee that the resulting system will be integrated and sustainable.

Merely including experts of various disciplines in the design team does not guarantee an integrated design. Specialists tend to design their own part or sub-system, resulting in a design that consists of separate mono-disciplinary solutions. So, having a multifunctional design team does not guarantee an integrated design. To achieve an integrated design, two or more disciplines need to work together on one design activity. An integrated design is about creating something new by crossing boundaries, and thinking across boundaries. To achieve that, the multi-disciplinary team has to cooperate intensively during the phases of project definition, generation of alternatives and evaluation, at least during the first design-loops. When it comes to a more detailed design, for instance the technical design of a reinforced concrete flood wall, multi-disciplinary cooperation is less important, and it is even desirable that this level design be carried out by a specialist.

It is important to remember that there is a difference between using the tools properly and using the proper tools: this is the difference between just doing calculations and making a design. The design work is typically suited for an integrated group approach, whereas design calculations are best conducted by individual specialists. Of course, to ensure that the final result is integrated, the outcome of detailed calculations will have to be integrated again into the overall design activity.