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# FLOOD CONTROL PLANNING AND EVALUATION WITH AN INFORMATION AND DECISION SUPPORT SYSTEM

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**ABSTRACT**: The INTERREG IIIB NWE funded 'nofdp' project promotes a nature-oriented approach towards flood damage prevention (www.nofdp.net). It addresses a combination of both technical and non-technical measures to reduce the risk of flood damage and to improve nature at the same time. One of the project's key deliverables is the interactive planning and communication software nofdp IDSS (**I**nformation and **D**ecision **S**upport **S**ystem) which is open source and free of charge for the user. The software is designed to assist water managers in the interactive and iterative process of developing and communicating alternative flood risk management strategies, which keep track with a balanced view on the often conflicting issues of spatial planning, flood damage prevention and ecological development.
Eight project partners from The Netherlands and Germany were directly involved in the development process. A consortium formed by Björnsen Consulting Engineers (GER) and WL | Delft Hydraulics (NL) implemented the descriptive concept that was developed by the nofdp project partners.
A first key functionality of interaction enables the user to position 22 different types of measures of flood control on a map within a GIS environment. At the same time, the user can assess existing and new spatial conflicts. Individual measures can be grouped to form variants and evaluated interactively. The nofdp IDSS provides four different methods of evaluation, ranging from very simple (Ranking) to more sophisticated methods (e.g. Value-Benefit Analysis).
This paper describes how the nofdp IDSS can interactively support the development of flood control plans. It demonstrates how measures can by positioned and how they can be composed and managed to arrive at alternative flood control strategies. Secondly, the assessment and evaluation methods will be presented. Using an example, the effect that the use of a specific evaluation method can have on the decision to be taken is demonstrated.

Key Words: Flood control planning; Flood protection; Decision Support Systems; Spatial Planning; Evaluation Flood-control storage.

## 1. INTRODUCTION

The INTERREG IIIB funded 'nofdp' project promotes a nature-oriented approach towards flood damage prevention. The INTERREG III B programme is an initiative of the European Commission promoting interregional co-operation within Europe. The aim of nofdp is to provide solutions supporting a balanced view on the issue of nature-oriented flood damage prevention. Still technical measures are often considered as the only way to achieve flood damage prevention, while impacts on ecology are often largely neglected in riverine management and spatial planning. One key deliverable of nofdp are four best-practice examples in the field of nature-oriented flood damage prevention – three of these measures are located in the Province of Noord Brabant (The Netherlands) and one measure is located in the Federal State of Hesse (Germany). A second key deliverable is the nofdp IDSS. It is an innovative concept for a Decision Support System (DSS) and will be introduced in this paper.

## 2. MAIN OBJECTIVE OF THE 'NOFDP IDSS' AND AIM OF THE PAPER

The main objective of the nofdp IDSS is to assist project managers in developing management strategies and measures, which in general comply with the requirements of integrated river basin management (IRBM) and in particular keep track with a balanced view on the often conflicting issues of spatial planning, water management and ecological development within river corridors. The acronym 'IDSS' stands for **I**nformation and **D**ecision **S**upport **S**ystem. We consider arriving at better informed decisions through interaction with relevant data and information as the resulting benefit when applying the nofdp IDSS in the stage of preliminary planning and strategy development. Key output of the nofdp IDSS is a number of alternative variants of measures. These have been evaluated and subsequently selected during an intermediated process involving technical staff, stakeholders and policy makers at the same time. The nofdp IDSS is based on a holistic concept, i.e. it is flexible in structure. Hence, it can be applied in any river basin across Northwest Europe. Furthermore, the software code is open source and free of charge for any user.

## 3. INTEGRATED RIVER BASIN MANAGEMENT AND DECISION SUPPORT SYSTEMS

Nowadays, it is commonly accepted that river basin management has to be fulfilled within an integrated framework. The key principle is a balanced view regarding the spatial issues of agricultural, urban, nature and riverine development and having flood risk as one focus of particular concern. More than 120 devastating floods with a total of 1.7 million people affected and damages amounting to 30 billion Euros within the last 10 years have impeded Europe's drive towards sustainable development (SAURÍ ET AL. 2003). Strategy development and subsequent planning and decision making are critical steps before taking action. These steps are subject to a wicked and unstructured problem framework. Hydrological, ecological and human issues in combination determine the complex functionality of river basins as the reference unit. There is a multitude of alternative technical measures and policy interventions to reach the defined goal. Often the goal itself must be considered as ill-defined and controversial. At the same time, for each alternative planning variant a multitude of pros and cons exist. To complicate matters further public policy demands and interest groups have a great influence on defining and negotiating these pros and cons as well as the definition of the overall goal. Therefore, IRBM is an ill-defined and iterative process which includes debate, feedback and improved planning proposals and incorporates a multitude of different actors: e.g. administrative bodies, policy makers, stakeholders, interest groups and the general public. There are significant differences concerning perspectives, the interests and intentions of taking action. It requires the development of new methodologies and conceptual approaches to overcome these opposites - also in the field of computer-based decision tools.

At this point the broad family of Decision Support Systems enters the field. DSS are designed to support project managers in the stage of preliminary planning or strategy development. A project manager refers to a person who is implementing a predetermined strategy by means of project development or developing new IRBM strategies. The main task of a DSS is to administer data generated by quantitative models, to select and interact with policy-relevant data, and to transform data into information which can be used for the purpose of communication and discussion with policy makers and stakeholders. The nofdp IDSS was developed having a strong emphasis on functionalities which are supporting interaction, evaluation and communication. These should improve the project manager's ability to discuss and communicate with actors.

Planning is an iterative process. Plans and strategies under development have to be discussed, evaluated and communicated in order to receive feedback and information for improved planning proposals. The IDSS supports this iterative process, by means of *a priori* preference articulation process, which is expandable to A Progressive Preferences Articulation in order to seek improvements for previously discarded solutions. The next chapter gives an overview on how and when decisions are taken and which method is support by the nofdp IDSS.

### *3.1 PROGRESSIVE DECISION MAKING*

So in many cases the Decision Maker (DM) is confronted with a set of solutions that must be considered as a compromise between multiple objectives and choices determined by the available alternatives. Thus, the decision outcome results from both solution search and decision processes. The decision process always includes the DM's preference articulation. In Decision Support Systems this preference articulation is mostly represented with a vector function, which assigns a weight to each objective and constitutes the multipliers for the value functions. Even though some authors define finer grades the authors (DEB 2001), (VAN VELDHUIZEN 1999) and (MUSCHALLA 2006) define three grades of the decision process. The final decision results from the DM's articulation of preferences, which is known before, *during*, or *after* the solution search process. This is more formally declared as follows:

**A Priori Preference Articulation**. *(Decide ⇒ Search)*
DM combines the differing objectives into a vector function.

**Progressive Preference Articulation**. *(Search ⇔ Decide)*
DM and solution search are intertwined. Partial preference information is provided upon which solution search occurs providing an "updated" set of solutions for the decision maker to consider.

**A Posteriori Preference Articulation**. *(Search ⇒ Decide)*
DM is presented with a set of candidate solutions and chooses from that set.

By the A Priori Preference Articulation the DM has to define the vector function. In this case the multi-criteria decision problem is transformed into a single-objective search problem. The principle process is shown in Figure 1, derived from (DEB 2001).

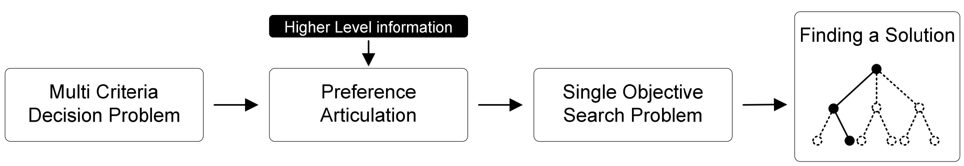


Figure 1: A Priori Preference Articulation.

The intertwined search and decision process by the Progressive Preference Articulation can be realized in manifold ways. In the case of the IDSS the Progressive Preference Articulation is an enhancement of the previously described A Priori Preference Articulation. The decision process is considered as an iterative process and in each cycle preferences can be modified and criteria can be added based on the experiences and feedback reactions gathered in the previous cycle. The principle process is depicted in Figure 2.

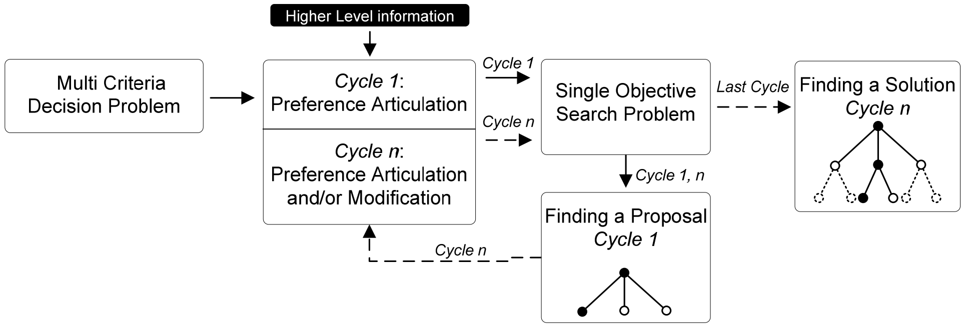


Figure 2: Progressive Preference Articulation

Decision making by means of A Posteriori Preference Articulation presupposes that the whole decision space is explored and all optimum solutions are found. Due to the small changes of the starting parameters a multitude of evaluation cycles are required. Therefore, the value assessment has to be fully automated. In this case criteria value assignment cannot be done manually. The principle process is depicted in Figure 3, derived from (DEB 2001).

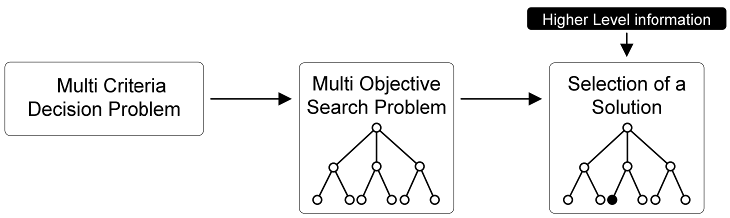


Figure 3: A Posteriori Preference Articulation

Multi-criteria optimization algorithms, for instance Multi-Criteria Evolution Strategy (MUSCHALLA 2006) or Multi Objective Genetic Algorithms (DEB 1999), are suitable for finding a set of best solutions for multi-criteria problems.

## 4. THE 'NOFDP IDSS' PLANNING AND COMMUNICATION TOOL

The increasing demand for integrated assessment and communication in the fields of flood damage prevention and nature development in river corridors sets the framework for developing the nofdp IDSS. Eight project partners from The Netherlands and Germany were directly involved in the concept development process. Beyond that nofdp carried out several interviews and workshops with potential European nofdp IDSS end-users to reflect on and improve the software concept under development. This comprehensive survey concluded that project managers working for water boards and regional authorities are potential nofdp IDSS end-users and demand software for bridging the gap between quantitative modeling and communicational needs in IRBM. Interaction comprises activities of developing, exploring and evaluating alternative variants of measures or of a strategy. Figure 4 shows the modular structure of the nofdp IDSS. The navigation tree guides the user through the current project under development. The workflow in the nofdp IDSS consists of fife main sections each including a number of modules. In July 2006 a consortium formed by Bjoernsen Consulting Engineers (GER) and WL | Delft Hydraulics (NL) started the implementation of the written concept that was developed in the period April 2004 to March 2006. The final, ready to use nofdp IDSS software is soon available under www.nofdp.net. You can also subscribe to the nofdp IDSS user community in order to receive latest information.

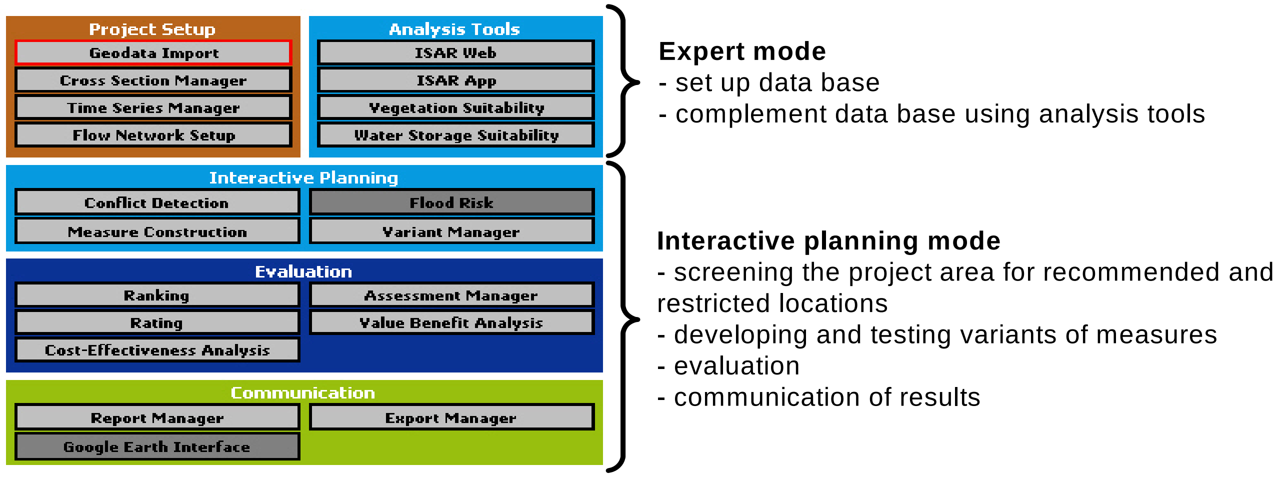


Figure 4: Navigation tree for operating the nofdp IDSS (prototype version 0.2)

In the sections ‘Project Setup’ and ‘Analysis tools’ the user compiles the data base using available geodata, cross-sections of river channels and time-series which altogether constitute a representation of the case study under consideration. The user is able to complement this data base by additionally generated data using the tools included in the section ‘Analysis Tools’. This section comprises a number of straightforward tools each having an ecological background to highlight nature as a particular focus of the assessment. The modules are described shortly in Table 1.

Table 1: Overview of the 22 typical measures implemented in the nofdp IDSS

| | **Sub-category** | **Measure** |
|---|---|---|
| **Category 1** Constructive measures | 1.1. Flood retention | 1.1.1. Polder |
| | | 1.1.2. Retarding basin (controlled and uncontrolled) |
| | | 1.1.3. Excavation works within floodplains |
| | | 1.1.4. Lowering floodplains |
| | 1.2. Hydraulic conveyance capacity | 1.2.1. Bank recession and –fill up |
| | | 1.2.2. Change of bottom slope or level |
| | | 1.2.3. Obstacles and line-structures on floodplains |
| | | 1.2.4. Diversion of flood discharge |
| | | 1.2.5. Weirs |
| | 1.3. Activation of retention area | 1.3.1. Relocation of dykes |
| | | 1.3.2. Earth walls in the valley |
| | 1.4. Flood protection | 1.4.1. Construction of dykes, increasing dyke height |
| | | 1.4.2. Mobile walls for local flood protection |
| **Category 2** Measures of nature conservancy and spatial planning | 2.1. Flood retention | 2.1.1. Ecological flooding of floodplains and polders |
| | 2.2. Hydraulic conveyance capacity | 2.2.1. Establishment of buffer strips with free vegetation succession on river banks |
| | | 2.2.2. Meandering of the river course (controlled and uncontrolled) |
| | 2.3. Activation of retention area | 2.3.1. Adapted forest management |
| | | 2.3.2. Forest development on floodplains (controlled and uncontrolled) |
| | | 2.3.3. Adapted cultivation on floodplains |
| | | 2.3.4. Zoning plan modifications |
| | 2.4. Flood protection | 2.4.1. Urban land use planning -precautionary measures against flood damage |

Land is the scarce resource and has a sustainable impact on the development of river corridors. In the event of flooding, the spatial extension of the water surface determines the hydrological demand for space, which mostly overlaps with urban and agricultural land use patterns. This conflict situation generates flood risk and can be shown by means of flood risk maps. Therefore, the nofdp IDSS includes the module ‘Flood Risk’ which in combination with an internal hydraulic model (Sobek from WL | Delft Hydraulics) enables the user to carry out a quick and preliminary flood risk assessment by means of generating flood risk maps.

The section ‘Evaluation’ includes the second group of functionalities. The nofdp IDSS provides four different methods of evaluation ranging from very simple (modules ‘Ranking’ and ‘Rating’) to more sophisticated methods (modules ‘Value-Benefit Analysis’ and ‘Cost-Effectiveness Analysis’). The module ‘Assessment Manager’ is the portal to the evaluation functionalities. Here, the user has direct access to the data base including the attributes of GIS layers and time series. And here the user defines evaluation criteria and assigns values to these criteria for each variant of measures - these variants were previously developed in the section ‘Interactive planning’. Manual input of values to the criteria is required and possible in case of qualitative values or estimates by personal judgment. It requires thinking in different spatial scales (local & regional) and across disciplines (human, water & ecology) to act in an integrated manner. Therefore, in order to prevent one-sided planning, the user must assign each evaluation criterion to a single category by means of a matrix (see Figure 5). This concept follows the idea of a layered approach, which has been well-established in Dutch spatial planning culture since more than ten years.

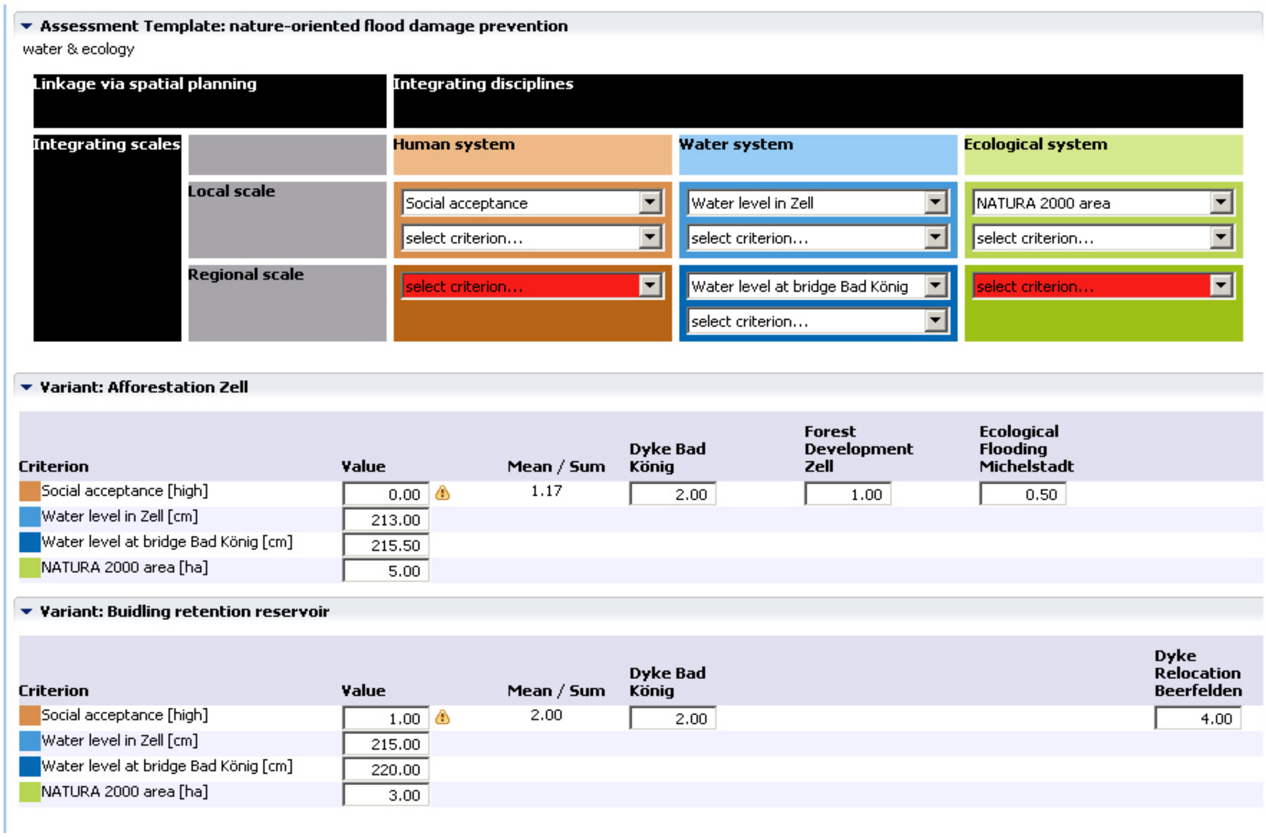


Figure 5: The module ‘Assessment Manager’

The final section ‘Communication’ includes a number of communication instruments. The main instrument is the interface to export geodata for 3-D visualization by means of Google Earth TM. 3-D visualization of data and information has a very high priority among project managers because it offers a high level of recognition of the spatial surrounding in the immediate vicinity of the project area. Furthermore, this section includes the modules ‘Export Manager’ and ‘Report Manager’. These provide data export functionalities and the possibility to generate a printed report including records of all actions and results achieved during the planning session.

## 5. CORNERSTONES OF SUITABILITY FOR DAILY USE

The nofdp IDSS is a new and innovative software concept. Therefore, one must demonstrate the suitability for daily use. This will significantly determine the future success of the nofdp IDSS. Already during the software development we relied on three cornerstones to ensure the suitability for daily use of the later nofdp IDSS. A broad project partnership is the first cornerstone. Hence, well validated and diverse types of software were available and could be used as a fundamental basis for the development of the nofdp IDSS. In particular, this refers to the sections 'Project Setup' and 'Analysis Tools'. Furthermore, a number of ongoing software projects in partner organizations are generating a considerable amount of synergy. For example, the partner organization German Federal Institute of Hydrology is currently implementing a DSS called 'INFORM DSS'. It is designed to evaluate the ecological impact of hydraulic-engineered measures on floodplain vegetation along waterways. Both systems - nofdp IDSS and INFORM DSS – use a similar module to support the interactive placing of measures within a GIS environment. This is the result of joint cooperation within the nofdp partnership. Another example is the ecological module 'Water Storage Suitability' which was developed under the synonym 'EcoDSS' in the framework of a transnational study coordinated by the Provincie of Noord Brabant. The aim of this study was to improve the cooperation between Dutch and Flemish water organizations in the catchments of the rivers Dommel and Mark. The transnational study was initiated and financed by the nofdp project and, therefore, was funded through the INTERREG IIIB programme.

The second cornerstone was the continuous involvement of potential end-users from different organizations, disciplines and Northwest European countries. For example, in November 2006 a workshop was organized to test the current nofdp IDSS prototype version. Feedback was the desired deliverable of the workshop in order to improve structure, content, design and functionality of the prototype. A workshop report summarizing the main conclusions is available for download under www.nofdp.net.

The third cornerstone is of a rather general nature and refers to the open source philosophy. In contrast to a software code with restricted access it enables the future user community to advance the nofdp IDSS or to modify individual modules according to their specific needs.

## 6. CONCLUSIONS

IRBM is an iterative process including discussion, conflicting interests, subjective valuation and feedback. Quantitative models do not cope with this kind of problem framework. They were developed as tools for environmental problem assessment. IRBM, however, requires tools which especially support project managers in their role as being an intermediator between science and policy. The nofdp IDSS is designed to assist project managers in the interactive development, testing and evaluation of alternative variants of measures in the field of nature-oriented flood damage prevention. The sustainable management of spatial conflicts on floodplains was identified as one key task in IRBM. The key outcome of the nofdp IDSS is a number of alternative variants of measures. These have been evaluated and subsequently selected during an intermediated process involving technical staff from water boards and regional authorities, stakeholders and policy makers at the same time.

In the nofdp IDSS, GIS and the data base itself constitute the basis and consequently, soft functionalities are used to modify and evaluate predominantly spatial information and impacts. This is because we consider spatial issues as prominent pro or contra arguments used by policy makers and interest groups. Obviously, applying the nofdp IDSS will contribute to a harmonized approach in shaping the riverscape within Northwest Europe considering both sustainable riverine ecology and demands for safe human living conditions.

## 7. ACKNOWLEDGEMENT

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## 8. REFERENCES

DEB, K. (1999): Multi-Objective Genetic Algorithms: Problem Difficulties and Construction of Test Problems. *Evolutionary Computation* 7, no. 3:205-230.

DEB, K. (2001): *Multi-Objective Optimization using Evolutionary Algorithms*. Chichester: John Wiley & Sons.

MUSCHALLA, D. (2006): Evolutionäre multikriterielle Optimierung komplexer wasserwirtschaftlicher Systeme. Technische Universität Darmstadt, .

SAURÍ, D. ET AL. (2003): Mapping the impacts of recent natural disasters and technological accidents in Europe. Environmental issue report no. 35. *European Environment Agency, Copenhagen, Denmark*.

VAN VELDHUIZEN, D.A. (1999): Multiobjective Evolutionary Algorithms: Classifications Analyses and New Innovations. Air University, Air Force Institute of Technology.