

# **FFI RAPPORT**

## **PROBLEM STRUCTURING METHODS A Survey and a Case Study**

GILLJAM Martin, LJØGODT Håkon

**FFI/RAPPORT-2005/00852**



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THESAURUS REFERENCE: 8) ABSTRACT <p>The main aim of the GOAL project at FFI is to increase the institute's competence on OR methods. This report contains an overview of six problem structuring methods and a description of a case study performed with the Soft Systems Methodology. The problem considered in the case study was: What must the OR community at FFI do in order to fulfil its vision?</p>				
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## PROBLEM STRUCTURING METHODS A Survey and a Case Study

### 1 INTRODUCTION

During the recent years, an increasing number of the projects at FFI have been concerned with analysing complex problems and working out alternative means of achieving some important objectives. The different phases of such analysis projects are illustrated in Figure 1.1. The initial phase of these projects has often been protracted as one has tried to define and delimit the problem to be solved. The need for a more methodical approach to this initial phase was a strong argument for conducting a study of Problem Structuring Methods (PSMs).

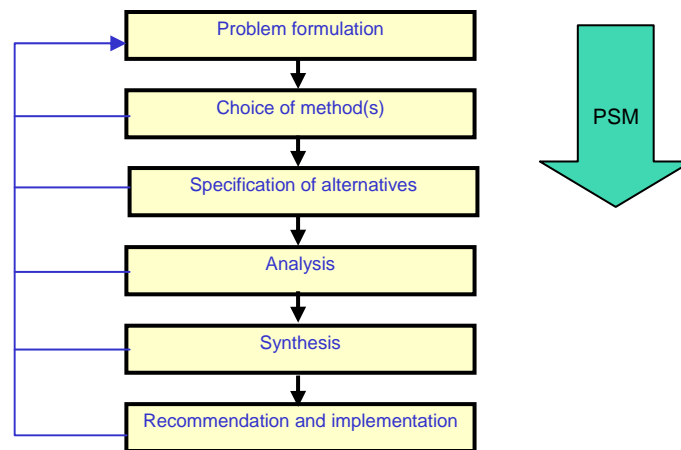


Figure 1.1 The different phases of an analysis project

The PSM study was conducted by project 1004 – GOAL at FFI. The main aim of GOAL is to further develop FFI's knowledge of methods of Operations Research (OR) including Soft OR methods. PSMs are included in the Soft OR methods. The aim of this report is to describe some PSMs and the application of one of them to a real case.

This report covers the PSM part of GOAL. Chapter 2 contains a short description of some of the more common PSMs. The selected methods emphasise one or more of the following topics: brainstorming, definition of system boundaries, real time decision making and general problem structuring. It was decided to study one of the methods in more detail to be able to apply it to real world problems. Soft Systems Methodology (SSM) was selected due to its reputation as the most well known and widely used of the soft OR methodologies.

It is difficult to learn PSMs only by reading – practice is also necessary. After some study and initial training, SSM was applied to a case looking at the task of organizing important aspects of the human resource development at the institute. The case and our experiences are described in Chapter 3.

## **2 PROBLEM STRUCTURING METHODS**

There is no succinct definition of a PSM. PSMs are, however, characterized by structuring problems rather than solving them. PSMs are suitable tools for addressing problems characterized by complexity, uncertainty and conflict, such as organizational decision problems with differing group interests. Most of the PSMs involve a facilitator for the workshop sessions that are held with the group of people holding stakes in the problem. Generally, PSMs give no single or correct answer/model. The facilitator may, however, by a systematic approach be able to obtain an agreed description/definition of the problem. PSMs may help to define sub problems that are suited for traditional OR methods.

The description of the methods in this chapter is mainly based on the books by Rosenhead and Mingers (1) and Ulrich (2). The exposition contains in addition the impressions of the authors. The intention of this partly superficial exposition is to give the reader an idea of the main scope of the methods and their main prerequisites. If the reader finds a particular method promising for her/his problem, further information must be sought in e.g. (1).

### **2.1 SSM – Soft Systems Methodology**

SSM was developed by Peter Checkland and his colleagues at the University of Lancaster. They started in the late 1960's and the methodology has evolved since then. A comprehensive exposition of the methodology and its history is found in Checkland (4). SSM seems to be the most applied of the PSMs. The focus of SSM is on structuring messy problem situations. SSM is a learning system that articulates a process of enquiry and leads to finding accommodations. Workshops are extensively used as an arena for a learning process. A consultant/facilitator is necessary if the participants of the workshop are not familiar with the method.

#### **2.1.1 Overview**

SSM was developed from systems engineering when it was recognized that this method failed in many management situations. Systems engineering failed when attempts were made to apply it to messy, changing and ill-defined problem situations within a management or social science context.

SSM can be described as a seven-stage process as illustrated in Figure 2.1

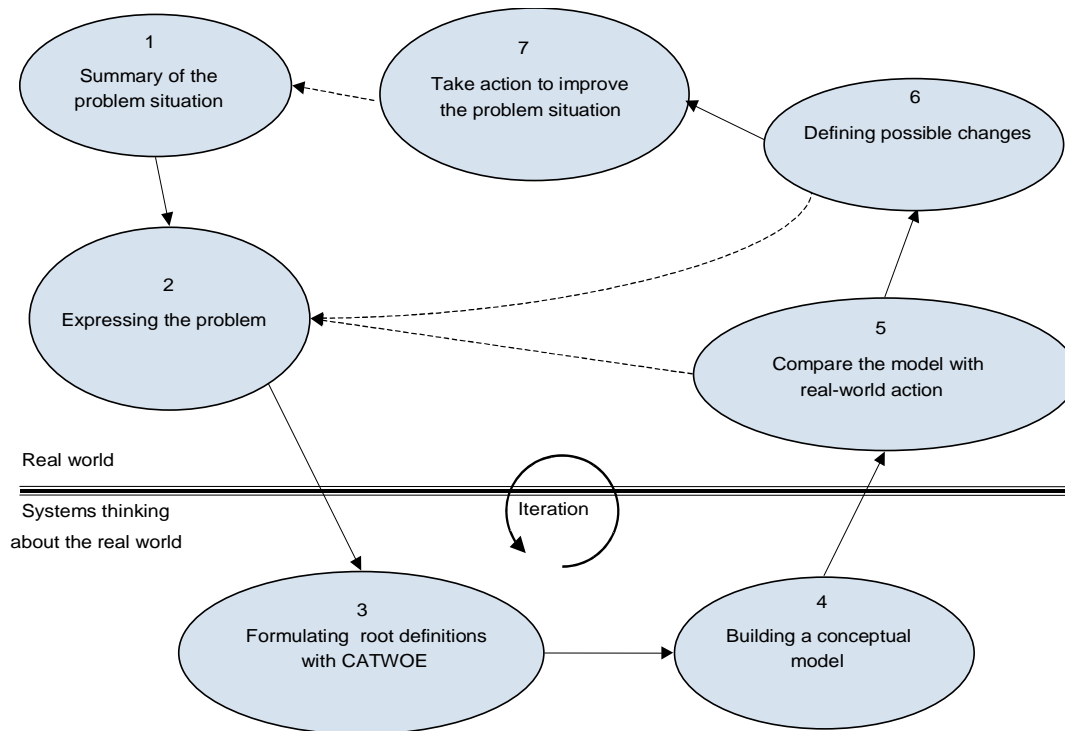


Figure 2.1 A flow diagram of Checkland's SSM .

A group of people representing the various stakeholders will have several meetings during their work through the stages of SSM.

- The aim of the first two stages is to assemble a summary or a rich picture (RP) of the problem situation. The RP should contain the main elements of structure and process as well as more informal information about the situation. An example of an RP is given in Figure 3.2. The word 'rich' refers to the wish to get a variety of alternatives and views of the problem. During these two stages the group is expected to gain a deeper, broader and more varied understanding of the problem.
- At stage three the group moves from the real world to the systems thinking about the real world. At this stage each alternative or theme is expressed by six short and unambiguous statements according to the mnemonic CATWOE. The owner (O) of the problem must be specified as well as the client/customer (C). The clients are the people being affected by the prime transformation (T) of the system. T defines what is transformed by this system by specifying the state before and after the transformation. The actors (A) will implement T with respect to environmental constraints (E). The owner's world view/Weltanschauung (W) make the T a meaningful activity. The root definition (RD) is a coherent formulation of the issues or tasks the system is supposed to deal with. There is a strong link between the CATWOE and the RD. It is usually possible to formulate several interesting root definitions from a rich picture.

- In stage four a conceptual model of the human activity system is build corresponding to the actual RD. The conceptual model is usually expressed in  $7 \pm 2$  activities. The verbs describing the activities are assembled and structured according to logical dependencies. Arrows show the logical relationships and the precedence sequence between these activities. The model should only be developed from the corresponding root definition and nothing else.
- Stage five brings us back to the real world and a comparison of the conceptual model with the real world situation. The emphasis should be on asking “what?” instead of “how?”, i.e. what activities are missing or problematic in the model?
- In stage six the “what” questions from stage five are discussed in the group of stakeholders. The aim is to come up with new ideas for change in the real world that are systemically desirable and culturally feasible.
- In stage seven the ideas that are agreed upon in stage six will be implemented.

As new insight is gained it is often useful to iterate back to one of the previous states to include omitted factors, as illustrated in Figure 2.1.

### 2.1.2 Example

In (1) the use of SSM is illustrated by its contribution to the creation of an information strategy for an acute hospital. Our application of SSM is described in Chapter 3.

### 2.1.3 Some impressions

SSM seems to be the most widely applied PSM. The role of the consultant/facilitator is not as prominent in SSM as in many of the other PSMs. The facilitator gives advice about what to do but leaves most of the execution to the group. As the stakeholders become really confident with the SSM process, the facilitator may become superfluous. SSM is comprehensive and it is time consuming to go through all seven stages.

## 2.2 Robustness Analysis

Robustness Analysis (RA) is a framework for planning under uncertainty. For a more comprehensive description, see (1), pp. 181–207. RA is typically applied in situations where it is possible to define a sequence of decisions in order to move from the present state to the desired end state. As all decisions are taken under uncertainty, they may later on appear unwise if the course of events takes a rather different direction than assumed. This is partly due to the ‘trumpet of uncertainty’, which is an illustration of the fact that the number of possible outcomes/states/futures increases with time.

The idea of RA is to split a single, comprehensive decision into a sequence of smaller

decisions stages in such a way that as many as possible of the attractive end states are kept open at each stage. Alternatively one can at each stage make decisions in order to close the possibility of the most undesirable end states.

### 2.2.1 An illustrating example

RA will be described by an illustrating example. Rosenhead (1) makes the following definition of a decision and a plan: A decision is a commitment of resources that transforms some aspect of the decision-maker's environment. A plan consists of a foreshadowing of a set of decisions which it is currently anticipated will be taken at some time or times in the future.

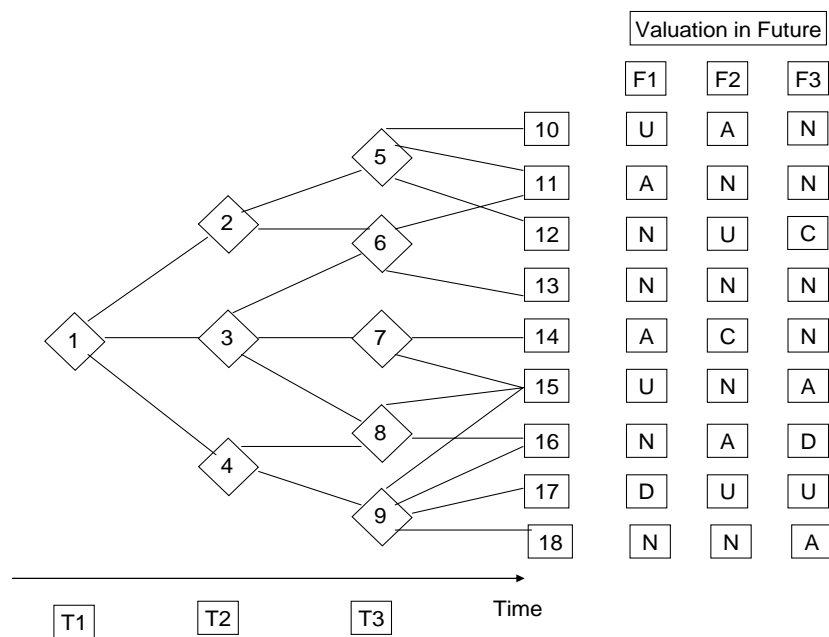


Figure 2.2 A three stage planning problem with three different futures. *D=desirable, A=acceptable, N=neutral, U=undesirable, C=catastrophic*

Figure 2.2 illustrates a situation where a sequence of decisions are to be made at times T1, T2 and T3. At T1 a decision is made leading to one of the three decisions 2, 3 or 4 at T2. Decisions are similarly made at T2 and T3 finally leading to end states 10–18. In columns F1 to F3 the end states 10–18 are evaluated with respect to the three different futures F1–F3. The end states may be roughly assessed by classifying each of them as acceptable or unacceptable. In the example each of the end states is placed in one of five categories: desirable (D), acceptable (A), neutral (N), undesirable (U) and catastrophic (C).

The robustness of any initial decision (with respect to the categories D and A) is defined as the number of end states marked with a D or an A that are reachable from the actual decision point, divided by the total number of end states marked with a D or an A in the considered future. The robustness of any initial decision with respect to category D or A is similarly defined. The complementary concept of robustness is called debility. The debility of any initial

decision (with respect to the categories U and C) is defined as the number of end states marked with a U or a C that are reachable from the actual decision point, divided by the total number of end states marked with a U or a C in the considered future.

The example in Figure 2.2 can be summarized in several ways. One way is by a table of preferred and non-preferred options left open by alternative decisions, see Table 2.1. Another way is by computing the robustness matrix and the debility matrix, see Table 2.2.

The results in Table 2.1 and Table 2.2 may be discussed in several ways. It is seen from Table 2.2 that the robustness values are equal for each initial decision within the future F2. It is further seen that the debility values are equal for each initial decision within the futures F1 and F2. However, in future F3 the initial decisions have different robustness and debility values. Initial decision 3 is preferable with respect to debility. Based on the robustness no definite conclusion can be drawn. If one regards future F3 as the most probable, the initial decision 4 is preferable. If the future F1 is the most probable, the initial decision 3 is preferable.

Initial decision	Options left open			
	D	A	U	C
Future F1				
2	0	1*	1	0
3	0	2	1*	0
4	1	0	1	0
Future F2				
2	0	1	1	0
3	0	1	0	1
4	0	1*	1	0
Future F3				
2	0	0	0	1
3	1	1*	0	0
4	1*	2	1	0

\* One option accessible by multiple routes

*Table 2.1 Number of preferred and non-preferred options left open by alternative decisions and futures*

Initial decision	Future				Future		
	F1	F2	F3		F1	F2	F3
2	1/3	1/2	0		1/2	1/3	1/2
3	2/3	1/2	2/3		1/2	1/3	0
4	1/3	1/2	1		1/2	1/3	1/2

Robustness matrix on categories D and A

Debility matrix on categories U and C

*Table 2.2 Robustness and debility matrices*

There is some supplementary information in Table 2.1. If the main priority is to avoid a catastrophic result, the initial decision 4 should be chosen. Initial decision 2 leads on the other hand to an inevitable catastrophe in future F3.

### 2.2.2 Some impressions

It is difficult to overestimate the richness of uncertainty. It will be impossible to describe all possible events, and the decision maker's preferences about the end states may change over time. One can, however, hope to be able to describe some quite different events/futures that will have a significant impact on the evaluation of the end states.

After the analysis is done the results may look quite unremarkable. The process may, however, be as important as the results. During the process the decision maker will obtain a better understanding of the problem situation and be able to make more informed choices. The focus of RA is to keep attractive options open. At the end there will thus be a need to evaluate the suggested solution with respect to additional criteria.

## 2.3 SODA – Strategic Option Development and Analysis

SODA was developed by Colin Eden and his colleagues from 1980 and onwards. References are found on page 40 in (1). The strength of SODA is the perception and structuring of a messy problem situation. The individual perceptions of each stakeholder are collected by the facilitator and merged into an aggregated model. As this is rather demanding, a skilled facilitator is required. SODA may be suitable for problem situations with a high level of conflict and where a decision has to be taken.

### 2.3.1 Overview

An important premise for applying SODA is the presence of an experienced facilitator that is skilled in managing the SODA process for the group. The group will have two to ten members who represent different views on the problems in the organization.

The SODA method is based on four interacting perspectives:

- **The individual perspective:** The basis consists of a body of psychological theory called cognitive theory. Individuals use language to express concepts and ideas. A cognitive map can capture an individual's perception of a problem situation.
- **The nature of organizations:** SODA regards that the purpose of an organization is defined in practice by its participants rather than by written documents. Change in organizations often occurs through management of conflict.
- **The nature of consulting practice:** The consultant plays a key role in designing and managing the negotiations trying to reach consensus and commitment.
- **Technology and technique:** The 'tools' used in SODA are cognitive mapping and dedicated computer software like Decision Explorer and Group Explorer.

The SODA process consists of four steps. A consultant runs the process with the aim of getting the group to commit itself to an agreed set of actions. The first step is an interview with each of the stakeholders involved. Based on these interviews the consultant will construct a cognitive map for each participant.

The second step consists of a discussion between the consultant and the owner of each cognitive map. They sort out ambiguities and contradictions and try to make the map as complete as possible. The process is meant to give each member of the group a good understanding of his own views and perceptions of the situation.

The third step is the responsibility of the consultant. He tries to merge the separate maps into a single strategic map. Substantial conflicts between the original maps may be highlighted by alternative paths in the strategic map. The interactive software Decision Explorer that has been designed at the Universities of Bath and Strathclyde may be used in the merging when there are many maps or many concepts in each map. Decision Explorer will also help identifying and analysing clusters.

The fourth step is the SODA workshop. The consultant presents the strategic map and points out core concepts and unresolved conflicts. The intention is that all group members will recognize their views as part of the greater picture. One or more clusters are then chosen for deeper analysis. Hopefully this will result in a shared view on actions and even goals. To obtain a positive result the consultant will try to bridge major differences in views and goals between stakeholders through negotiations.

### 2.3.2 Cognitive mapping

Cognitive mapping is a central technique in SODA. References are found in (1) on page 40. The product of cognitive mapping is called cognitive maps which are mental models also referred to as scripts, schema and frames of reference. Cognitive mapping aims to provide a tool for revealing peoples' subjective beliefs in a meaningful way so that they can be communicated to other individuals and groups. This is a way of entering valuable knowledge from different stakeholders into the decision-making process.

Cognitive mapping techniques do not aim to prescribe solutions. They aim instead to encourage the decision makers to reflect on their own perception of the problem and to appreciate the problem from other perspectives.

### 2.3.3 Example

Rosenhead (1) refers to a study done by SODA consultants for the National Audit Office. The task was to help H M Custom and Excise counter Value Added Tax (VAT) avoidance. Due to the sensitivity of the subject, the description is focused on the working process rather than the recommendations and results. It is pointed out that although SODA has been found effective on a number of occasions, each project is unique and demands various adaptations of the precepts of SODA. Due to time pressures the individual interviews using cognitive maps had



to be replaced by the faster Oval Mapping Technique (see 2.6.1) which is a method of structured brainstorming based on the use of oval PostIt stickers. The final result of the process was a statement of the objectives and a list of proposed actions which after a review was reduced to a shorter list with the detailed actions.

### 2.3.4 Some impressions

A common view on SODA is that there is likely to be disappointment with the first use. The main reason is that the method may look deceptively easy and that the beginner therefore believes that a cursory absorption of the principles will suffice. The consultant plays a critical role throughout the entire process. He needs to be a skilful interviewer, facilitator and negotiator in one person. The construction of cognitive maps for the stakeholders seems to be a useful technique for structuring and elucidation of the problem. In cases with conflicting interests it will be difficult for the facilitator to achieve agreement on even a short list of proposed actions. The process may however have given the owner of the problem sufficient insight to be able to take a decision.

## 2.4 CSH – Critical Systems Heuristics

The philosophic foundation of CSH is extensively described in the book “Critical Heuristics of Social planning” by Werner Ulrich (2). The first three hundred pages of the book contain a rendering and discussion of works of Jürgen Habermas, Immanuel Kant and Karl R Popper. The matter is not easily accessible and our description and comments are not based on a thorough reading. The main use of CSH seems to be in the initial phases of problem structuring and definition. CSH is a way of systematically rethinking the facts and values that are relevant for the stakeholders’ interpretation of the problem.

### 2.4.1 Overview

The core of Ulrich’s work is how to choose the boundaries for the system of interest and its environment. Ulrich asserts that methods such as General Systems Theory, RAND-systems analysis, systems engineering, managerial cybernetics, artificial intelligence, heuristic programming, MIS design, Management Science / Operations Research, incrementalist planning approaches, behaviourist learning theories, administrative and policy sciences *all suffer from a common inability to deal critically with the very social reality which they ought to improve.*

The guiding question for Ulrich is whether a system S is adequately designed to become a purposeful social system. To help answering that question and doing the assessment he asks:

- What kind of an inquiring system is S?
- What kind of an action system is S?
- What kind of valuation system is S?

To further elaborate these questions he recommends the planner of “Purposeful Systems” to ask:

- What is/ought to be the purpose of the system?
- Who is/ought to be the client?
- Who is/ought to be the decision maker?
- What is/ought to be the environment?
- What is/ought to be the guarantor?

Some of the main ideas of CSH have been partially incorporated into SSM by its use of central concepts like Client/Customer, Weltanschauung, Environment, and Owner.

#### 2.4.2 Example

In (2) the use of the method is illustrated by its application to a Health Systems Plan for an area in the state of Washington. The example starts with a thorough discussion of various definitions of health. The thoroughness is illustrated by the following proposal for an ideal task description to the Health Planning Council: “The level of public health corresponds to the degree to which the means and responsibility for coping with illness are distributed among the total population. This ability to cope can be enhanced but never replaced by medical intervention or by the hygienic characteristics of the environment. That society which can reduce professional intervention to a minimum will provide the best conditions for health. The greater the potential for autonomous adaptation to self, to others, and to the environment, the less management of adaptation will be needed or tolerated.”

#### 2.4.3 Some impressions

CHS seems to be useful at the initial phases of a project. By posing questions of the type mentioned above one may at an early stage be able to reveal conflicting views and ideas among the stakeholders in the planning and decision process.

### 2.5 SCA – Strategic Choice Approach

The SCA is an approach to planning under pressure as it combines a concern for complexity with an emphasis on real time decision making. SCA offers a procedure for handling the uncertainties associated with the imminent decisions. It has proved to be particularly appropriate and useful for contingency planning where the group participants represent stakeholder interests of several loosely connected organisations. A skilled consultant/facilitator is needed to manage the interactive workshop sessions. The development of SCA started in the 1960’s. For a more comprehensive description, see (1) page 115 and further.

#### 2.5.1 Overview

SCA regards the perception of three broad types of uncertainty as fundamental to the steering of a decision process. The first kind of uncertainty is about our working environment, UE. UE can be reduced by different actions like surveys, mathematical modelling or conversation with an expert.

The second kind of uncertainty is about our guiding values, UV. UV calls for more policy guidance from a higher authority.

The third kind of uncertainty is about choices on related agendas, UR. To reduce UR it is necessary to further explore the structural links between the decision currently in view and other related decisions with which it appears to be linked. It may be tempting to try hard to reduce all three kinds of uncertainty. The gain must, however, be compared to the costs and delays associated with the uncertainty reduction process.

The SCA can be described by four complementary modes of decision-making: *shaping*, *designing*, *comparing*, and *choosing*.

The starting point for the work of the shaping mode is the basic concept of the *decision area*. A decision area is an area of choice within which the decision makers have more than one possible course of action. The aim of the shaping mode is to define and select a manageable number of interrelated decision areas that constitute the problem focus. It is rarely advisable to select a focus of more than three or four decision areas.

The first step in the designing mode is to agree on a representative set of options within each decision area. Then pairs of options from different decision areas are examined to judge whether or not they constitute a feasible combination. The next step consists of performing Analysis of Interconnected Decision Areas (AIDA). AIDA checks the feasibility of the different combinations of one option from each of the decision areas. Such a feasible combination consisting of one option from each of the decision areas is called a feasible decision scheme. The incompatible combinations are discarded from further considerations.

In the comparing mode feasible decision schemes are compared within a set of comparison areas. It is difficult to cope with a simultaneous comparison of all decision schemes using the full set of comparison areas. It is common to start comparing pairs of alternatives among the more promising decision schemes. For each comparison area the two alternatives are compared and one of them is assessed to have extreme, considerable or marginal advantage to the other alternative. The judgement is represented by an interval on a line spanning from extreme advantage for one alternative to extreme advantage to the other alternative. Usually the mean position of the mid-points of the intervals from the comparison areas is computed as an indication of the result of the overall comparison.

The process ends with the choosing mode. During the process of shaping, designing and comparing one will have encountered one or more uncertainty areas. One such area may be the growth potential of the market. This is an example of uncertainty about the working environment, UE. Different values of growth may favour different decision schemes. For each uncertainty area it may be possible to reduce the uncertainty by some further exploratory option. In the case of growth potential of the market one may do an opinion poll or ask an

expert. To each exploratory option there are associated three comparison criteria: The *cost* of performing the exploration, the *delay* the pursuit of the option will involve and the *gain* in confidence expected through the reduction of uncertainty. For each exploratory option one somehow has to quantify the value of each of the criterion variables. There is no clear answer to the question of what to do next: Take a decision or delay the decision in order to perform one or more uncertainty reducing explorations.

It may be useful to rearrange the sequence of decision areas in the decision scheme in order to bring to the front the most urgent of these areas. The delay caused by performing the exploratory options may then be compared to the urgency of the most promising decision schemes found at the comparing stage. In a real situation the number of remaining alternatives and decisions will now usually be manageable.

### 2.5.2 Example

In (1) the use of SCA is illustrated by the development of a policy for the storage and distribution of Liquefied Petroleum Gas (LPG) in the Netherlands. The need for a carefully prepared policy became obvious after a disaster in Spain in 1978 where an LPG lorry crashed and exploded resulting in more than 200 dead. It gradually became apparent that it was difficult to satisfy all the different interests in combination, and the decision process got blocked. As the process reached a state of urgency it was decided to try SCA in order to get the process on track again. The SCA offered an essentially different way of thinking about uncertainties bringing UV and UR into consideration. Combining cyclic use of the SCA model and the work already done it became possible to agree upon a stepwise process solving the locked situation.

### 2.5.3 Some impressions

SCA seems to be suited for planning processes where the participants represent the interests of several organizations and where there is a strong pressure for decisions and commitment to action. SCA offers an opportunity to analyse the situation and find a suitable way to group decisions with mutual influence. As with most of the PSMs a skilled facilitator is needed to guide the group through the process in a constructive way.

## 2.6 Methods for structured brainstorming

The present description is mainly based on Eriksson (3). These methods for structured brainstorming are often called “PostIt” methods or “Yellow patch” methods with obvious reference to their extensive use of adhesive yellow patches. The main aim of these methods is to collect and structure the opinions and views of a group on important topics. Surveying of external factors influencing strategic choices and specification of strategic alternatives are typical topics. Usually 6–12 participants are involved in the groups, but the limits are not strict.

### 2.6.1 Overview

With the Oval Mapping Technique (OMT) the facilitator starts with a short presentation of the technique and the problem to be addressed. As a part of the problem presentation the facilitator often places roughly 10 ovals with written cues on the board. The participants are then asked to write down their own opinion on a number of ovals and place them on the board on a suitable place with respect to the already present cues.

The procedure with the “Tour de Table” technique is a bit different. Here each participant in rotation is asked to give his opinion and the facilitator writes down the short version on an oval and finds a suitable place for it on the board. For both methods this stage is finished when the group has no more important statements to put on the board. During the next stage the group, with assistance from the facilitator, tries to reorganize the ovals into clusters representing related ideas or alternatives.

A brainstorming session will normally constitute one of the initial steps in a decision process. The next step is usually the selection of the most promising alternatives from the brainstorming session for further elaboration. The selection process may be included in the brainstorming session and some voting/selection procedures are described in (3). In (3) Eriksson gives useful information about the many practical details associated with the facilitation of such brainstorming sessions.

### 2.6.2 Examples

An example of application mentioned in (3) is from Volvo where they posed the question: Is it right to sell our private car division to Ford? The aim of the brainstorming session was to come up with pros and cons. In an example described in (1), OMT was used at the start of a study on how H M Customs and Excise could counter VAT avoidance.

### 2.6.3 Some impressions

Structured brainstorming seems to be a well-established technique for the initial phases of complex decision processes. Structured brainstorming does not give the final result and follow-up activities are always needed if one is to gain benefit from the efforts.

## 2.7 Concluding remarks

The descriptions of the methods are not very precise and it is thus difficult to know whether or not a specific application is in accordance with the actual method. It is also problematic to evaluate the use of the methods because there seems to be no commonly accepted criteria of success. One way to cope with this problem is to regard the application of a method as a success if the group has talked together and agreed on what to do next. The actual decision may, however, not be the smartest one.

### 2.7.1 General role of PSMs

PSMs seem to have a role to play in the initial phase of solving complex problems. They help in a systematic way to involve stakeholders and to find their basic views. PSMs may also help to reveal disagreement. They are particularly valuable when the problem situation is messy. One may also get insight in the close relationship between the problem and the people involved. Most of the insight gained by using PSMs can in principle be obtained with more traditional practice. By using PSMs one will, however, speed up the process and reduce the danger of neglecting important factors.

### 2.7.2 Comparison

The book of Rosenhead (1) seems to be one of the most well known books describing the main PSMs. There is also a rich literature on the evaluation and comparison of different PSMs.

In an invited review in *The European Journal of Operational Research* in 2004 (5), Mingers and Rosenhead provide a review and evaluation of different PSMs in practice. A number of case studies are reported, both successful and less successful ones. They have collected a table showing published papers reporting practical applications of PSMs. The table shows the predominance of SSM as either a methodology by itself, or as one used in combination with other methods. This confirms the strong position of SSM shown in a previous survey by Mingers and Taylor (11). In that survey three hundred questionnaires were sent to OR and systems practitioners who were believed to have had some exposure to SSM. One of the findings was: "It was felt that considerable experience or training was necessary to use SSM successfully, and that its language could be off-putting for potential clients."

Regarding the choice of PSMs, Mingers and Rosenhead (5), address the problem on how to decide which one(s) to use in a particular situation. They point out several limitations in the existing framework for classifying different methods and end up with strong arguments for combining different PSMs in multi-methodology. A possible solution is to classify the problems and then associate suitable methods to the different problem categories. It is, however, difficult to define cells that the problems will fit neatly into. A simple two dimensional problem classification that has been tried is to use "nature of the problem" (simple/complex) and "degree of agreement among participants" as the dimensions.

In this chapter some of the most common problem structuring methods have been briefly described. They differ both in scope and aim. CSH and Structured Brainstorming methods are suited for the initial phase of the problem structuring and can be used to support the other methods mentioned.

SCA and RA are geared on the decision aspect of the problem after an initial structuring of the problem.

SSM and SODA have their focus on the structuring of messy problem situations. For SODA the main aim is to make the group of stakeholders develop a unified or merged view on the

problem. For SSM it is important to identify changes that can be made to improve the real world system and that the changes are regarded as systemically desirable and culturally feasible.

The facilitator plays an important role in all these approaches to problem structuring. The role is especially demanding in SODA where the facilitator is expected to produce a merged map based on the individual maps. A group knowing SSM well can, however, go through the process without the assistance of a facilitator.

### 2.7.3 Recommendations

Although several of the methods seemed promising for our case study, it was regarded necessary to select one method and concentrate on that one. An important reason for this is that a group of discussing people will grasp the different aspects of a soft method faster and easier than single individuals. SSM was considered as the most promising method for the problem structuring in our case study. The main reasons were:

- SSM seems to be the most widely applied of the PSMs.
- SSM has a relatively wide area of application and covers most phases of problem structuring.
- SSM is well suited for our problems as they tend to have a low level of conflict.
- The SSM process is stepwise and flexible.
- Application of SSM usually leads to proposed changes to the real world system.
- The role of the facilitator is less demanding than in e.g. SODA.

## 3 THE CASE STUDY

### 3.1 Objectives

Both Checkland (4), (6) and Rosenhead (1) emphasize that the only way to get a deeper understanding of problem structuring methods (PSM), is to acquire hands on experience. Ideally, that experience should include all the methods (and methodologies<sup>1</sup>) described above, and possibly other methods as well. However, gaining a *full understanding* of a single method would take more time than the lifespan of this project. According to his own books, Checkland is still learning and rewriting his methodology that was “invented” in 1975. The compromise then, is to obtain *some experience* from *one* method, and set up a case study with a problem formulation suited for studying this method. Hopefully, that will make us better prepared to evaluate the other PSMs as well.

The initial reason for conducting the case study was to obtain experience in facilitating SSM and gain a deeper understanding of problem structuring methods in general and soft systems methodology in particular. A second argument for the case study was to give the participants

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<sup>1</sup> A methodology is an assembly of different methods which have to be adapted to the particular situation

insight in SSM, which would make FFI (through the project members and participants to the case study) able to evaluate whether PSM is a branch of operational research worth focusing on in the future.

A third objective evolved from the problem formulation prior to the case. There had been a lot of discussions within FFI's recently established operations research group (Faggruppe OA, henceforth called FOA) concerning the groups goals and ambitions. Since senior researchers, as well as the management were involved, the case study of FOA could be interesting for the participants – which is very important in order to make the case study a success. The objective was to obtain a shared perception of the problem situation (or reveal differences), structure the problem situation and reach agreement for possible changes to the system. This third objective also defined the problem formulation for the case: *What should the operational research group do in order to reach its goals?*

The aim of this chapter is not to give a comprehensive and systematical description of how to use SSM in practice, but to share our experiences as first time users of the methodology. The problems first time users run into may be quite different from what long-time users are discussing in books and papers about SSM, thus a “naive” non-expert description can be valuable.

It is, however, mostly recommended to learn from more experienced facilitators of SSM (1), (4), (5), (8), (9), (10), which will provide a more thorough description of *SSM in practice*.

## 3.2 Preparations

### 3.2.1 Literature study

The whole project was involved in the preparation for the case study. Every project member studied broadly orientated literature (1), (4), (6), (7) on problem structuring methods and systems thinking, and a study group was formed to discuss promising methods. The result of these discussions was, as described in Chapter 2.7, the choice of SSM for the case study.

### 3.2.2 Pre-cases

After deciding upon SSM, there was a strong need to gain some experience on applying this methodology in practice before employing it on a group of stakeholders. Like all other PSMs, SSM is a learning methodology and it was never intended to be fully experienced before inviting to meetings with the expert-group. However, it was considered as a minimum requirement to know the basic steps of the methodology without having to confer with Checkland's book during the meetings, hence, two pre-cases were conducted.

#### *Pre-case I*

Checkland recommends being more situation-oriented than methodology-oriented when using SSM. However, in order to learn the methodology it was considered wise not to be too



engaged in discussions on the particular situation. It was feared that many strong views on the subject from all the project members would obscure the process of the methodology. When seeking a problem situation to practice SSM, the project chose an area about which none of the members had any in-depth knowledge, but everyone could relate to. This area had no relevance to the “real case”, and will therefore not be described further in this report.

This first pre-case was very valuable in order to learn about SSM. The most important lesson was that while the first four steps are quite straightforward and intuitive, it can be very difficult to converge all views into a useful outcome. This was one problem that could be attributed to too little experience, and with more focus on this in the next pre-case, it was believed that the problem would be eased. However, this was something that had to be experienced more than once, as the following chapters will show.

### *Pre-case II*

While the first pre-case was all about obtaining experience from the methodology (by being very methodology-oriented), it was just as important to have thought through the situation concerning the “real case”. By running a second pre-case, this time with the same problem formulation as in the actual case, the facilitator would have a much easier task facilitating the real case. It makes it easier to foresee the preferred end state of the case and thereby directing the participants in the right direction. Practical exercises like drawing a rich picture or generate a model, is very difficult if the facilitator is not familiar with the background and the problem situation of the case.

All the seven stages of SSM were carried through with all the project members present. One of the members was selected as facilitator for the actual case, and while everyone attended the meetings and prepared for them, the facilitator had the main responsibility.

## **3.3 Framework**

The first step of the SSM is to describe the situation that is considered problematic. As described previously, one of the objectives was to discuss what the operational research group should do in order to reach its goals. Having defined this as the problem situation it was easy to point out the participants of the expert group.

The expert group involved in the case study had to be persons that had in-depth knowledge of the situation and the authority to do something about it. Important participants were the division management and senior researchers that had been involved in the discussions about FOA. With these participants it was clear that both the owner(s) and some of the actors of the CATWOE would be involved in the meetings.

The case study was carried out during four weeks in March, and it was held a total of four meetings, with a combined duration of eight hours. This division into several shorter meetings instead of holding a one-day seminar, made it possible for the facilitator to get an overview of the situation between the SSM-steps and carefully plan the next session. In addition,

unfinished parts could be completed before meeting again, and the participants would be able to give feedback to already processed work – which was considered to be timesaving.

### 3.4 Implementation and results

This chapter will describe the implementation of the case study, as well as the results of the methodology (rich picture, root definition and the conceptual model), and how they were achieved.

It is of great importance that the results are evaluated for what they are. First of all, the results are not post processed after the end of the case study. In addition, they are in many cases ad hoc suggestions that are written down on the white board by the facilitator, and often they can be permanent even though no one is 100 % satisfied – as long as everyone agrees verbally about that. Finally, the results are not really important as such – they are only means to reach a higher goal (e.g. where the results can be part of a multi-methodology(1)). One thing the results *can* do, however, is providing an interesting illustration of SSM, linked to what should be familiar to most researchers at FFI.

As stated earlier, each step in SSM is a method in itself. Every SSM-step in the case study opened with the facilitator carefully explaining the concept of the particular step, including a short description of the method and why it is considered useful.

After every meeting, the facilitator and the rest of the project members discussed the results and the best way to process them at the subsequent meeting. Any changes should be loyal to the participants' inputs, but the unstructured results also had to be made easier for the participants to comprehend. As the facilitator was "producing" results between the meetings by "reading the participants minds", precious time was saved in the meetings.

#### 3.4.1 Summary of the problem situation

Included in the participants' notice for the meeting there was a short (two pages) description of the methodology and the projects' expectations for the case study. This notice also suggested a summary of the problem situation: *What should the operational research group do in order to reach its goals?* This suggestion was discussed at the first meeting, and since none of the participants had any strong feelings against this formulation, it was accepted as a summary of the problem situation.

#### 3.4.2 Expressing the problem situation (rich picture)

The drawing of the rich picture started with the facilitator inviting the expert group to identify three aspects: actors, processes and climate. Though Checkland might have chosen differently, the pre-cases had shown that separating the three aspects, and drawing the first cut of the rich picture consisting of just *actors*, makes the drawing much easier than trying to combine all at the same time. When the facilitator had written down the suggested actors on the whiteboard, it was relatively easy to make the connections between them. The same approach was employed



### Actors within FFI

Figure 3.2 shows the facilitators' interpretation of the participants' view of the situation concerning FOA. Not surprisingly, FOA has a central part in the rich picture. FOA is one of the FFI actors and part of the wider group FA (including OR, economy and security policy). It consists of members (whom they share with another group: M&S) and a coordinator. FFI scientists constitute the base of the different groups (FA, FOA, M&S) and the projects, and they are closely involved in most of the dependencies. The other important member of inside FFI-actors is the FFI management, represented by the managing director, the planning group (PLE) and the division management. The most vital connection between the scientists (including projects and FOA) and the management is the link between PLE and the leader of FA, as the leader of FA is part of both FA and PLE.

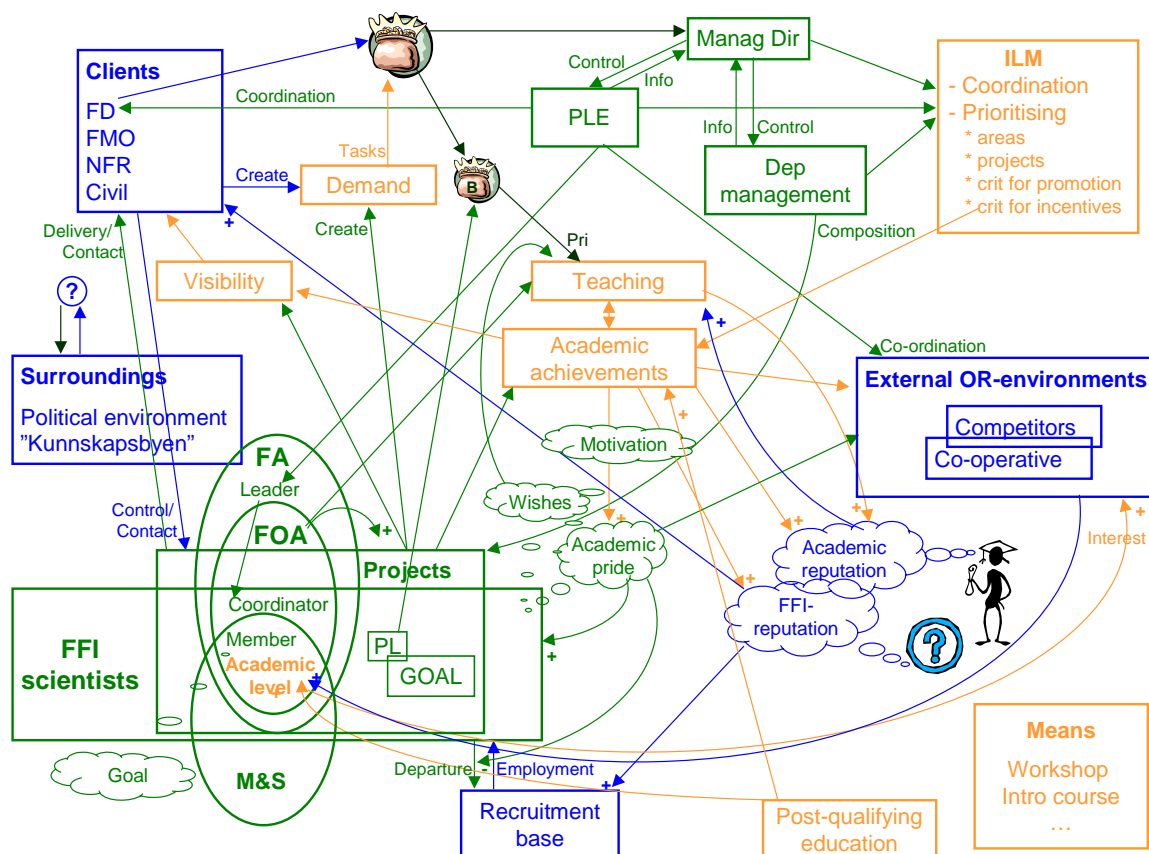


Figure 3.2 The result of the rich picture after the final meeting (colour codes described above)

### Actors outside FFI

The two most central actors outside FFI are the clients of FFI and external OR organizations, both partners and competitors. The clients were especially emphasized, which is made visible

by the many relations to other parts of the rich picture, with the most essential ones being customer relations, achieving assignments and (hence) bringing funding to FFI.

### *Processes*

There are several processes in Figure 3.2, and the most important to the situation regarding FOA is probably teaching, academic achievements and the last bullet point of ILM (meetings between the FFI-management): criteria for rewarding incentives. All three processes are closely connected, and influence several aspects of the rich picture.

### *Climates*

The climate illustrates other aspects of the actors and processes, and is by that contributing to a richer picture. The most significant climate-factors in Figure 3.2 are various thoughts of the FFI scientists (motivation, wishes, pride), the goal of FOA and the reputation of FFI. All these factors are important in order to understand how the system works and how the participants in the case study think about the system.

### 3.4.3 Formulating root definitions with CATWOE

The root definition, including the CATWOE, is the most formal part of the SSM, and its formal nature gives the facilitator a great responsibility to guide the participants through the root definition, as there is little room to improvise. On the other hand, a rigorous procedure provides useful help for a first time facilitator applying a generally fuzzy methodology. The SSM process encourages developing several root definitions, but with the time constraints in this case study it was not feasible to develop more than one.

#### *CATWOE*

The CATWOE mnemonic is a tool for remembering what to include in the root definition, and the facilitator started with the two most important letters in the mnemonic: T and W (Transformation and Weltanschauung). These are by far the most difficult to comprehend, but once these are sorted out, the rest is quite straightforward.

The final version of the CATWOE was not achieved at the first meeting where it was discussed, but was – like the rich picture – developed further at the consecutive meetings. The result of the discussions among the participant was as follows:

- Client/customer: The projects, FOA
- Actors: Various subgroups of FOA, division management
- Transformation: From: Today's FOA with its professional standard and profile  
To: FOA that has achieved a chosen professional standard and a chosen profile
- Weltanschauung: - A high professional standard will increase the motivation and the value added  
- It is important to be able to take some "short cuts" in order to get work done  
- Knowledge about the Norwegian Armed Forces is essential

- Strong focus on international recognition can affect the client in a negative way

**Owner:** Division management, PLE

**Environmental**

**constraints:** Resources (time, people, money), the regulations of FFI and the rest of the society

The transformation (T) is highly normative for the remaining letters in the CATWOE, and indeed for the whole SSM process. In this case study it was perhaps a little too vague and the T was really a paraphrase of the formulation of the problem situation from the opening of the case: “What should the operational research group do in order to reach its goals?”. The Weltanschauung (W) is not as normative as the transformation, as it is more the thoughts of the participants on different subjects – adding up to a Weltanschauung, or how they see the world. The list of W’s could have been even longer, but the important matter is that this is something that all the participants can agree upon.

#### *Root definition*

As described above, the root definition is a theme or vision expressed as a succinct unambiguous statement, and for ten persons to agree on that is quite complicated. This difficulty was solved by letting the facilitator receive input from the participants, and present a proposal for the root definition at the following meeting. Although there was a unanimous dissatisfaction with the suggested root definition (due to it being a little too vague), it was not altered during the case study.

The resulting root definition was: “A system that gives FOA a chosen professional standard, a chosen professional appliance and a chosen profile, and that over time will revise the choices and make necessary adjustments.”

#### 3.4.4 Building a conceptual model

Due to the time constraints, it was not possible to involve all the participants in the entire process of making a conceptual model. During *one* of the meetings the facilitator received feedback on the main activities that was to constitute the conceptual model, and a few aspects on their underlying concepts. The facilitator then used this feedback to construct the model together with the rest of the project members, and exposed the result for comments at the consecutive meeting.

The first cut from the facilitator was reviewed a number of times during the case study. While there still lacked accurate sub-activities in the final model, there was a general consensus about the main activities. However, the sub-models could have been richer, more accurate and containing action plans with a higher degree of measurability. Comments indicated that the model was too easy to agree upon. A more pinpointed model would have caused more debate and possibly a better model.

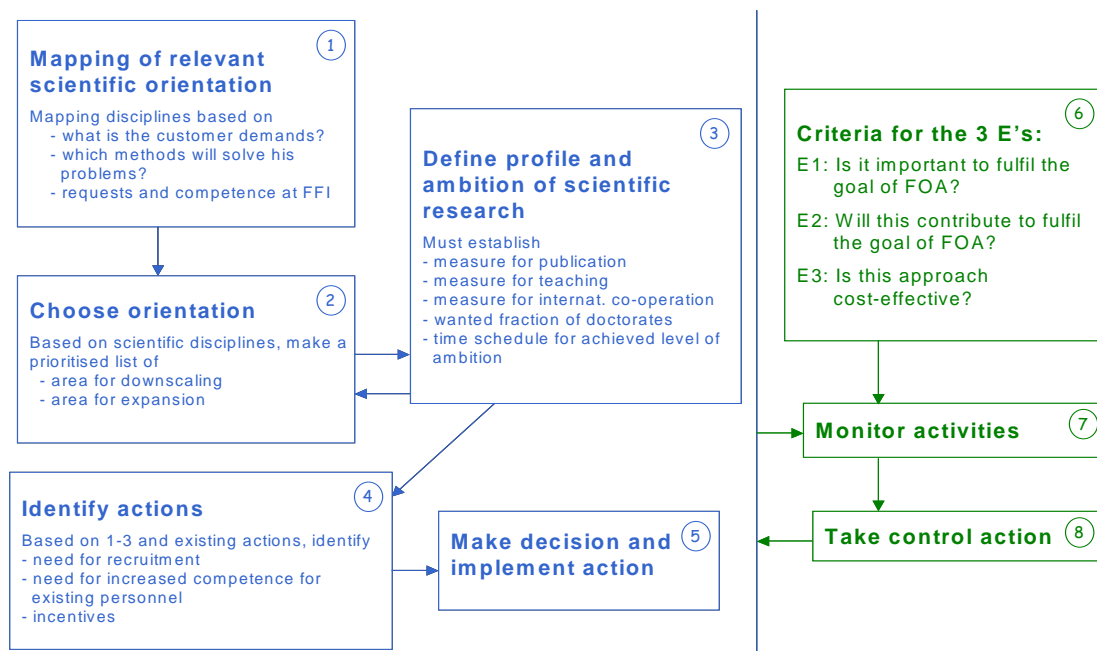


Figure 3.3 The results of the conceptual model after the final meeting

The result of the conceptual model is shown in Figure 3.3. The five activities demonstrate what is needed in order to make the root definition happen, while the sub-activities present a more detailed description of time schedule and involved personnel. Boxes numbered from six to eight is just a logical consequence of Checkland's description of this particular step in the SSM process.

### 3.4.5 Comparing the model with real-world action

The comparison of the conceptual model with the real-world situation was conducted by combining an informal approach with a more formal one. Firstly, the facilitator asked if the participants could see any divergence in the comparison – if the model contained errors or important aspects were missing. There were feedback on a few minor issues, and these were brought up for discussion and agreement was obtained.

A more formal approach was planned, which involved a development of 2–3 short scenarios concerning the problem situation, and comparing them with the real world. One should then be able to evaluate both the robustness of the model (Is the model valid in every scenario?) and the uncertainties in the real-world situation (the possibility for the scenario to occur, and the consequences for each one). Examples of such scenarios could be less funding and changes in the labour market. As feared, time constraints made this impossible, and this approach was skipped.

### 3.4.6 Defining possible changes and taking action

Unfortunately, there was no time for a thorough comparison of the model with the real world. Nevertheless, the discussion brought up a few possible changes. The debate then proceeded on

whether they were systemically desirable and culturally feasible, and – if *that* was the case – how these changes should materialize.

The first suggested change was a certification of scientists in the OR group, namely what sort of competence should be demanded of each individual in order to be labelled as an OR scientist. This could include credits from university, courses, experience, etc. The implementation of these changes is carried out by one of the sub-groups of FOA.

A review of the system for incentives and defining of criteria for choosing level of scientific ambition and orientation were proposed as possible changes, but were not discussed further due to time constraints.

### **3.5 Evaluation**

#### **3.5.1 Results from the case study**

What was the outcome from the case study – apart from the explicit SSM-results (rich picture, CATWOE and conceptual model)? The results can be classified into two different groups: Results in the FOA domain and results in the form of knowledge about SSM as a methodology.

Both the participants (including the project members) and the facilitator obtained a deeper understanding of the relations in and around FOA (however, this was much more evident for the participants that had not been deeply involved in the prior discussions about the function of this group). Even more significant was perhaps the shared view on important issues in this particular system. The discussions provoked different views to be shared, resulting in a debate. As a result, the participants either discovered that they actually had the same point of view, or at least appreciated the opposite stand – and agreed to disagree.

The changes identified in the sixth step of the SSM yielded ideas to improve the problem situation. These proposals were not new, but in this case study they were rooted in a forum of both decision makers and actors of the particular system. This gave the decision makers more confidence in having made the right decision, as well as it gave the process of implementation more credibility.

By taking part in this case study, the senior researchers and the division management acquired knowledge about SSM, which is important in itself. Their understanding of the methodology is vital when deciding whether SSM should be a part of the OR group's toolbox or not.

Last but not least, the project group obtained valuable experience in facilitating SSM. No soft OR method is fully understood until it has been tried out. There are many nuances in this kind of methods, and their value is not always evident until they have been experienced. Facilitating SSM is demanding in many ways. First of all it is important to know the methodology well to take part in a constructive manner. This requires that the facilitator is at least one step ahead of



the expert group with respect to the SSM process. Even though none of the project members are able to do that today, this case study was a step along the way of becoming a facilitator in SSM.

### 3.5.2 Comments from the participants

The participants were asked to give feedback on both the methodology and the facilitator's way of leading the process. Several important aspects of SSM were enlightened from this feedback.

Of course, the participants had little or no experience with SSM, so their basis of comparison was limited. The most evident comment on the facilitating was the expectation that the facilitator should “do magic” and turn the situation around – and by that make seemingly diffuse relations become clear. This particular wish can be attributed to the lack of convergence, as discussed in the next sub-chapter.

It was a unanimous opinion that a well-trained facilitator is a critical resource in SSM, and should SSM or another problem structuring method be used on a regular basis at FFI, there ought to be strong emphasis on educating facilitators. Some argued that appointing one or two persons to become the OR group's facilitators would be the way to go, and that this would provide time for them to fully understand the methodology and discover the various tricks that help “doing magic”.

The bottom line of the feedback to PSMs in general, and SSM in particular, was that this seems to be a useful tool for a number of tasks and definitely should be introduced to the OR group's toolbox. The main response regarding the methodology's use at FFI was that it is important to recognize the limitations of the methodology. It is not suited for *every project* at FFI and should not be used on *all categories of customers*.

Projects with a messy problem formulation may benefit from using a problem structuring method in its early phase, rather than ad hoc problem structuring. Scepticism from a particular type of customer towards this kind of methods and little time available for meetings are two strong showstoppers for introducing PSM. In addition, some participants argued that a client with a hidden agenda would not be interested in having it unveiled – which is exactly what SSM tries to do.

### 3.5.3 Lessons learned from facilitating

Bearing in mind the words of Eden and Ackermann (1) that “*a difficulty with [PSM], is that there is likely to be disappointment with first use*”, the overall feeling about the facilitating of the case study was very satisfactory. However, in every case study there should be several lessons learned, and this case study is no exception.

### *Time constraints*

Due to difficulties bringing together all the participants from the expert group, one meeting had to be omitted in order to finish in time. This tightened further an already tight time schedule and caused three explicit features to suffer. First of all, the rich picture should have included more informal processes to indicate how the system “really” works and who are pulling the strings. Second, time to build a more detailed conceptual model could have made the comparison with the real world situation easier and more fruitful. Finally, there was no time for making scenarios for the real world comparison, which could have made the comparison richer.

### *Choice of problem situation*

In retrospect, the choice of problem situation could have been different. The chosen topic had been debated within the expert group on a number of occasions before, which contributed to too much consensus within the group, making it fall back on old solutions. Deciding upon a problem situation is normative for the whole case study, and should probably have been treated with more emphasis in the group at the start of the SSM process.

### *Preparations*

The preparations ahead of the implementation of the methodology are vital for the result. This includes not only a thorough understanding of the methodology and how to use it, but just as important is knowledge about the problem situation. Although there is an expert group contributing to domain knowledge, it would be very difficult for a facilitator to ask the proper questions and guide the process in the right direction without knowledge about the domain. In addition, it is important for the facilitator to have an idea on where the process could end up, in order to converge the diverging inputs into a relevant result. The two pre-cases were very helpful, as they contributed to insight in both the methodology and the problem situation.

### *Drawing the rich picture*

The SSM methodology does not have a distinct procedure for collecting information from the expert group in order to produce the rich picture, which makes it hard for an inexperienced facilitator. The inclusion of methods like Structured Brainstorming or Oval Mapping Technique (Chapter 2.6) could have improved the drawing phase. These methods could ensure that all the members in the expert group have their view represented in the rich picture. These methods were not used in this particular case study, but should be considered in subsequent cases.

### *The facilitator role*

The role of the facilitator is a demanding one, both on a technical and personal level. Technically, it is important to know both the methodology and the problem domain. Only then one is able to vary the means to help the expert group reveal their thoughts about the system, and finally systematize them into a result that they will recognize. These are all demanding skills that are time-consuming to acquire, however, they are possible to learn.

The personality of the facilitator is more difficult to change. There are some personal characteristics that could be useful to possess. A key combination is to be both extroverted and introverted. On the one hand one should be comfortable talking to groups of possibly unacquainted people – and not be afraid of interrupting if the debate should derail. On the other hand being able to sit back and listen to the expert group without taking too much control until it is really necessary – and not putting yourself in the centre of attentions. At FFI, it could be an idea to appoint one or more scientists with this combination of personality and an interest in PSMs, to become experts in the long-term, rather than assigning the task to people “accidentally” working in a particular project suited for PSM.

One difficulty of becoming a well-educated facilitator is the prospect of practicing. As no one at FFI know the methodology well enough to use it on large problem areas with external expert groups, they will not be assigned to tasks like this and will consequently not develop as a facilitator. The solution for this is to start facilitating PSMs with internal participants and smaller problem situations or – if possible – assist a professional facilitator in a relevant case, to learn the small tricks that you cannot read in a book.

#### *Gathering participants*

Another lesson learned from the case study was the difficulties in bringing together all the participants for each meeting. From outside the project there were five members of the expert group, and the number could not have been much smaller without losing the different views necessary for fruitful discussions. The fact that most of them had very busy schedules was arguably the main reason that gathering as few as five experts turned out to be so difficult. It is not likely that external experts have less compact time schedules, but this will of course vary from client to client.

One possible way of solving the problem of participants not attending meetings, is to arrange fewer, but longer (preferably whole day) meetings. The advantage of the facilitator being able to work between the meetings will obviously be lost, and there is no guarantee that the participants will be able to book such long meetings. Nevertheless, once the meeting is booked, it will be much more difficult to cancel (in relation to this, it must be said that the cancelling of meetings in this particular case study had nothing to do with lack of commitment from the participants).

## **4 CONCLUSION**

The first two objectives in Chapter 3.1 were obtained as the project members clearly acquired a better understanding of SSM as well as experience in facilitating, although without becoming full-fledged. In addition, the expert group obtained insight in the SSM methodology.

During the case study, the participants did not gain many new ideas and insights regarding how the OR group should reach its goals, which was the third objective of the case study.

Despite the lack of new insight, the participants felt that they got a fair impression of the requirements and potential of the SSM methodology, and recommended a continued focus on problem structuring methods at FFI.

Apart from the lack of experience in facilitating SSM, time constraints were one of the major obstacles for reaching the third objective of the case study. Too little time will usually be an issue in SSM as the important stakeholders are often busy. The solution can therefore be to divide the methodology into several methods, and select the ones that suit the situation the best – therein lays one of the main advantages of the methodology. SSM has been used in combination with OMT on four occasions after the case study described in Chapter 3. On all occasions the time frame was tighter than in the referred case study. The seven stages of SSM, see Figure 2.1, were not completed on any of the occasions. A promising adaptation to the “time squeeze” is to go through only the initial three stages of SSM. If even less time is available one should at least apply the Oval Mapping Technique in order to identify some structure of the problem

The need for PSMs at FFI has been stated in Chapter 1. Our conclusion is that SSM or parts of SSM seem to be well suited for the initial phase of a number of our projects. The reasons for selecting SSM are mentioned in 2.7.3. The importance of an experienced facilitator cannot be overestimated, and if FFI decides to include SSM and OMT in its “toolbox”, there are two requirements that have to be satisfied. First of all, at least a couple of people must be carefully chosen according to personal characteristics suitable for being a facilitator. The selected persons must then be given sufficient training in SSM and OMT. Second, SSM and OMT should be applied several times every year until the knowledge of the method is firmly established.

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