MODELING MANAGEMENT OF RESEARCH AND EDUCATION NETWORKS

PROEFSCHRIFT

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Dedicated to my father

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Preface

Computer networks and their services have become an essential part of research and education. Nowadays every modern R&E institution must have a computer network and provide network services to its students and staff. In addition to its internal computer network, every R&E institution must have a connection with the computer networks of other institutions, and the Internet. Such connectivity is no longer a luxury, but a necessity. This is where the computer networks *among* the R&E organizations come in: these networks connect R&E organizations with each other and also with other networks, including the Internet. Such networks provide services to R&E organizations located within geographical areas of different sizes: a city, a region, a country, or a continent. They exist in many countries all over the world. Europe, North America and Eastern Asia are the main parts of the world where one finds the most well-developed computer networks among the R&E institutions.

This thesis discusses the issue of managing computer networks among R&E institutions. Such networks are here called *Research and Education Networks (RENs)*. Although the management of computer networks has received a lot of attention in the literature, the management of RENs was previously neglected by researchers.

The research presented here aims to fill this gap and to design a model which supports the management of RENs. The idea for this research was inspired by a project aimed at the creation of a national REN in Ukraine – the Ukrainian Research and Academic Network (URAN). The research described in this thesis initially started as an attempt to help building this REN in a systematic way rather than in a trial-and-error manner.

The research in this thesis was conducted as part of the research program of the Information Strategy and Management of Information Systems of the Delft University of Technology. It continues the line of the Doctoral projects conducted within this research program, which is related to the management of computer networks, namely "*Modelling change management of evolving heterogeneous networks*", "*Management of international networks*", and "*Management of networks with highly distributed international use*".

Chapter 1

Introduction

1.1 Background to the research

Every part of our society has been either transformed or influenced by computer networks importance of which in our daily lives is no longer questioned. Due to their unique ability to reduce the amount of time and computer power required to solve a problem, computer networks have undeniably demonstrated their benefits, and they are expected to have an even greater impact on the shaping of the future. The Internet as the most successful implementation of computer networking is developing and growing at an unprecedented pace, becoming a commodity similar to TV, telephone, gas or electric power.

1.1.1 Research and Education Networks (RENs)

Computer networks have become an indispensable tool for research and education. Internal computer networks of R&E organizations – also called intranets or campus networks – are an important platform for the automation of organizations' business processes. Core information systems of a university such as, for example, student administration, personnel administration, and library systems are very dependent on the university's intranet. Campus networks are also an important element in the delivery of Internet access, E-mail and other services to end users: teachers, students, and researchers.

In addition to networks *within* R&E organizations, there are also networks *among* R&E organizations: networks that connect R&E organizations with each other and also with other networks, including the Internet. Such networks, called *Research and Education Networks (RENs)*, provide services to R&E organizations located within geographical areas of different sizes: a city, a region, a country, or a continent. Most RENs have the national size and these are therefore called *National Research and Education Networks (NRENs).*

The fundamental goal of RENs is to provide network services to support high quality education and research, and to extend of the benefits of networking to other sectors of society such as industry, commerce, culture, and the government.

The importance of RENs for society has long been recognized in many countries. By providing services to the research and education communities, RENs perform an important mission and bring many benefits to society such as ([McC91, p. 37]):

- enhancing competitiveness of a country possessing such a network in the global economy, because an REN facilitates the country's leadership in science and technology and improve the productivity and quality of its national research community;
- providing access to supercomputers, which means not only that they provide supercomputing power to users, but also that they reduce the number of sites needed for the physical presence of supercomputers, and some other benefits associated with the possibility of such access, like, for example, powerful distributed computing;
- increasing collaboration among researchers due to increased communication possibilities, which encourage researchers to communicate more often with a broader range of individuals;
- increasing the rate of knowledge and technology transfer due to the increased speed of data exchange, and easier and broader dissemination of research findings.

Due to the highly innovative character of the R&E community, computer networks are not only a platform for the provision of various production services but also an important playground for the development, testing and introduction of new network services and applications. This leads to the second meaning of the research- part of the name of RENs: such networks are not only a tool for but also a *subject of* research.

RENs exist in many countries all over the world (see Figure 1.1). Europe, North America and Eastern Asia are the main parts of the world where the most developed RENs can be found. The NRENs of most European countries are interconnected via the international REN called GÉANT. NORDUNET is another international REN in Europe, which interconnects the NRENs of Sweden, Norway, Finland, Denmark, and Iceland.

In the USA, the NREN has become a major issue in national politics and a priority agenda item for the R&E community ([Par90]). The High-Performance Computing Act – the first legislative basis for the NREN in the USA – passed both houses of Congress in November 1991. According to [USn00], nearly 80% of all the states of the USA have statewide RENs (see Figure 1.1). Each statewide REN is connected to a nationwide REN vBNS or Abilene.

Developing RENs versus developed RENs

There is a gap between the developed and developing countries with regard to computer networking for research and education. Most countries in Africa, South America, Asia, and the Middle East either do not have RENs or just start building them.

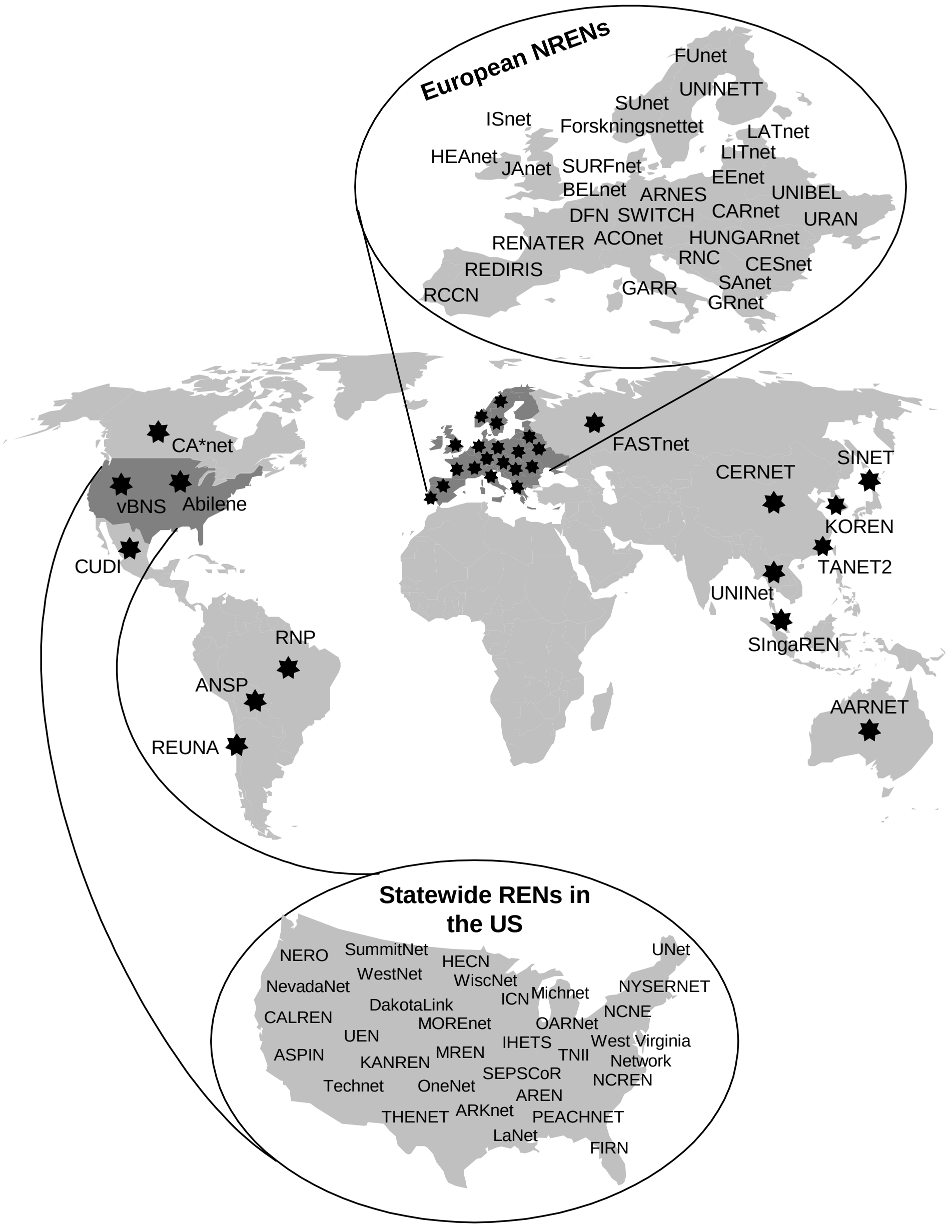

Figure 1.1: Research and Education Networks (RENs) worldwide.

Networks in such countries are often far behind the networks in developed countries in size and in the range and quality of services provided. For example, nowadays RENs in Western Europe and the US have links with gigabit capacities, while in many developing countries RENs still have links with kilobit capacities.

The following model[1] introduced in [Hal92] is used to illustrate the gap between the RENs of developing and developed countries. In this model, four stages in the development of an REN are distinguished: initiation, growth, control, and maturity. The horizontal axis of the graph in Figure 1.2 represents the time, and the vertical axis represents the size of an REN, which can be expressed using different indicators such as the number of users (both institutional users and end users), the capacity of communication links, the traffic volume, the network budget, or a combination of mentioned indicators. Every REN has its own lifetime, which starts from its creation in the initiation stage and continues while the network grows and develops, to reach the next stage in its development.

This model is similar to the first form of the Nolan curve – one of the most used models reflecting the evolution of the use of computers in organizations [NG74]. The S-shaped curve of Nolan shows budget for computing versus time. It is divided into four stages, namely Initiation, Contagion, Control, and Integration.

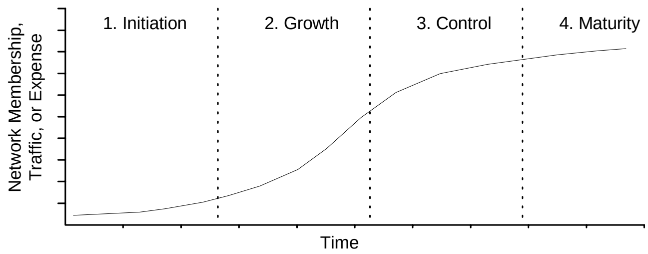

Figure 1.2: Four stages of the REN growth (source: [Hal92]).

Figure 1.3 graphically demonstrates growth curves for three different RENs[2]. At a given point in time (indicated by a vertical dotted line) the three networks are in different stages and have different sizes. The first network is an example of the developed network, having quite a long history and large size, while the third network is an example of the developing network.

1.1.2 Management of RENs

Research and education networks, like any other computer network, must be properly managed in order to be a successful platform for the services they provide. They need continuous support during their entire lifetime since they cannot survive on

[1]This model is used here merely as a graphical illustration, having the aim to give a general idea about the development process of an REN. It is not considered here in detail.

[2]Figure 2.2 on page 30 gives an example of such a growth curve for the Austrian NREN ACONET.

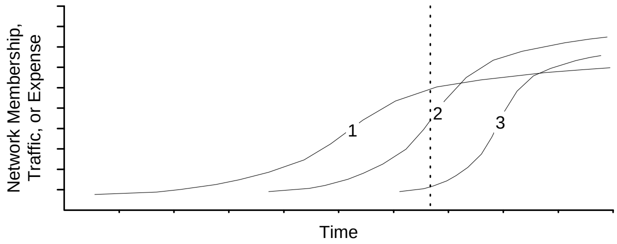

Figure 1.3: Examples of growth curves for three RENs.

their own[3]: faults and failures appear, performance degrades, hardware and software needs to be installed and maintained.

Management of RENs includes a broad range of activities such as monitoring performance, resolving faults and failures, billing and charging users, maintaining hardware and software, recruiting staff, securing funds, developing prices, marketing and promoting services, negotiating with suppliers, and developing policy documents. Therefore, it requires various types of knowledge such as technical, administrative, organizational, financial/ economical, and legal knowledge. Although most of attention is often devoted to the technical knowledge, other types of knowledge are also vital.

Management is a continuous process covering all stages in the development of RENs (see Figure 1.2) and it is particularly crucial at the initiation stage, where significant efforts are necessary to ensure the future growth and development of the REN. Examples of such efforts are administration of investments, development of the regulatory basis and policy documents, bulk purchase and installation of hardware and software, order of communication links, design of the organizational model, and staff recruitment.

A number of issues have to be taken into account in order to ensure the effectiveness and efficiency of the management, like the networks' governing structures, funding models, charging schemes, usage policies, capacities and technologies of communication links, network traffic, characteristics of hardware and software, range and quality of services, staff, and help desk.

The volume and complexity of these and other matters make management of RENs a big challenge which becomes even more complicated by the fact that there are many parties involved such as government authorities, donors, user organizations, network operators, software and hardware vendors, and Internet service providers. There are many issues that are related to the responsibilities of these parties and the relationships among them.

[3]Computer networks and systems of the future will probably be able to "live" on their own, like, for example, the androids from science fiction.

1.2 Research gap

1.2.1 Unacceptability of the trial-and-error manner of management

The traditional way in which RENs are managed is very much practically oriented and event driven, which implies that people responsible for the management perform it in a trial-and-error manner, without the use of models or methodologies ([Kah92], [Pop99], [Fre96]). McClure, for example, called the style in which many RENs in the US were managed "anarchic", as many management decisions at all levels are made by mutual agreement and peer contact [McC91].

Proper management is particularly important for developing RENs, which must progress at a faster pace, moving at a revolutionary rather than an evolutionary pace in order to catch up with the developed RENs. For developing RENs one should avoid the trial-and-error manner of management and its consequences such as the waste of vital resources and waste of time. The efficient and effective use of resources is a very important issue for developing countries, which experience a constant lack of such resources. The wastes could be avoided by using the knowledge on how to manage RENs in the most efficient and effective way.

1.2.2 Fragmented approaches to present the knowledge about RENs

The knowledge about RENs and their management is usually presented by a number of descriptions of particular experiences and existing practices. Many such descriptions can be found in the proceedings of various conferences and workshops, such as the Internet Society's INET Conferences (www.isoc.org), and the Joint European Networking Conferences. Particularly reach collection of descriptions of many European NRENs can be found in [Pop99].

Benbasat et al. noted in [IB87, p. 370] that the outcomes of such descriptions are almost always successful and the authors provide a list of "dos" and "don't's" for similar implementations. The different authors producing such descriptions – typically practitioners – usually try to successfully implement a specific system for a given assignment. If someone tries to discover the best way of managing RENs by reading and comparing such descriptions, he will not get far. Various approaches used by their authors and strong emphasis on a technical point of view make it difficult for readers to make comparisons and extract knowledge. Success stories presented in such descriptions may incite others to follow suit but they cannot guarantee success in situations other than the specific situation described in such stories.

Several initiatives with the aim to study the existing knowledge about RENs and their management were carried out, namely COSINE ([RAR88]), PHARE R&D Networking Programme, ARENA (Advanced Research and Education Network Atlas, arena.internet2.edu), and TERENA Compendium of NRENs in Europe ([NRE00]). All initiatives had similar objectives: to collect and to present various data about RENs such as the connectivity, topology, contact information, capacities, traffic volumes, services, budget, and user populations. Although these initiatives produced some valuable outcome and enriched the knowledge, they were practically oriented and did not have a scientific background. The fragmented approaches that were employed cannot be the basis for an objective and qualitative representation of the knowledge on the management of RENs.

Concluding, there are no effective ways in which the knowledge can be exchanged or transferred, for example, from developed RENs to developing RENs. As a result, the knowledge is typically concentrated only at the places (RENs) where it was initially obtained.

1.2.3 Lack of previous studies on the management of RENs

The management of RENs was previously neglected by researchers. Several studies described in [McC91], [Par90], [Kah92], and [Wei92] concerned management of RENs only partially, concentrating on a broad range of issues related to RENs. Because these studies were specifically concerned with RENs in the US, they could not be applied to other locations, for example, Europe or Asia. Moreover, the studies are already outdated and, therefore, it is arguable if their results are still applicable nowadays, considering the rapid progress in the field of computer networking during the last ten years.

Van Hemmen concluded in [Hem97] that the existing models supporting network management focus predominantly on the technical aspects of network management, leaving out financial, organizational and policy aspects. These aspects are ultimately important for RENs. For example, RENs typically have complex organizational structures: user organizations are usually united in associations, which often make strategic management decisions together with governmental authorities and donors.

Scientific research having the aim to study the knowledge about the management of RENs was not located. This fact inspires investigation of a research area which appears to be previously unexplored.

Conclusion There is a need for a model that would formalize the knowledge about management of RENs. The idea to develop such a model and to carry out this research was also inspired by a project aimed at the creation of an NREN in Ukraine, namely the Ukrainian Research and Academic Network (URAN). The research described in this thesis initially started as an attempt to help building this NREN in a systematic rather than a trial-and-error manner.

1.3 Research problem and questions

The previous sections presented the background of the need to learn more about the management of RENs. Based on what is said in the previous sections, the following research problem is formulated:

Research problem *How can the knowledge about RENs and their management be formalized in a model that is able to support such management?*

The following statement expressed by Christenson in [Chr76] reflects well the core idea of this research:

> "the trial-and-error process in which practitioners are engaged is necessary for knowledge to accumulate. It is incumbent upon the scientists to formalize this knowledge and proceed to a testing stage." [Chr76]

This research aims to apply a systematic approach to management of RENs. A theoretical foundation for the management of RENs must be developed rather than a collection of descriptions of success stories intended to encourage others to follow suit. The intention of this research is to provide a framework to overcome the fragmented perception of the management of RENs and to give a complete overview of all aspects of such management.

Therefore, the research problem is solved by first studying the knowledge about the management of RENs, then developing a model, and then testing this model in practical situations. For this purpose, three research questions are posed:

Research question 1 *What are the relevant topics associated with RENs and their management?*

Research question 2 *How can we build a model that can be used to support management of both developed and developing RENs?*

Research question 3 *How can the developed model be validated in practical situations?*

Because the term "knowledge" has a very broad and ambiguous nature, it would be too ambitious to declare that we try to study all the existing knowledge related to the management of RENs. Therefore, in the formulation of the first research question, this term is replaced by a more concrete term, namely "topics associated with management of RENs". These topics are meant to represent the most significant parts of the whole body of knowledge.

The validation of the model is defined here as the process of testing it against its objectives, or, in other words, the process of checking to which extent the model's objectives are met in the real situation of a REN. Similar interpretations of the validation were also used by Hendriks and Klompe: "validation is needed to check whether a system actually behaves as expected" [Hen03, p.215], "as the proof of the pudding is in the eating, we will now apply the method in practice to see whether it brings about the desired results" [Klo03, p.113].

The objectives of the model

The main objectives of the model are defined as follows. Firstly, the model has to provide a framework for producing a description of a real-life situation: a REN and its management. Secondly, it has to facilitate the identification of gaps in the real-life situation. Thirdly, it has to assist in developing useful recommendations that could make it possible to fill the gaps and to improve the real-life situation.

The model also has several *additional objectives*. The model should be capable of (1) raising the awareness of stakeholders[4], (2) facilitating communication among

[4]Stakeholders are those parties which are expected to be interested in the results of this research. For example, people directly involved in the management of RENs, parties providing financial and political support to RENs, and representatives of the user organizations of RENs.

stakeholders, (3) improving the effectiveness and the efficiency of management, (4) providing guidelines for building new RENs, (5) assisting in compiling project proposals, (6) facilitating the transfer of knowledge, and (7) promoting the use of scientific approaches in the management of RENs.

1.4 Research approach and methodology

The research approach consists of five phases as shown in Figure 1.4. Each phase, except for Phase 2 and Phase 5, consists of two or more steps. The three research questions are approached consecutively; each research question is answered during Phase 2, Phase 3 or Phase 4 correspondingly. Figure 1.4 also shows the connection of phases and steps with the chapters.

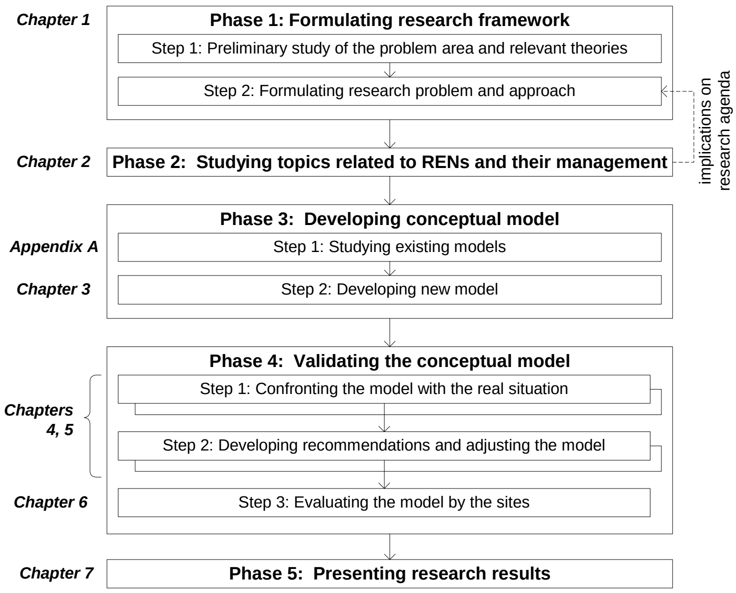

Figure 1.4: The research approach.

Let us briefly outline the content of each phase. *Phase 1* is aimed at familiarization with the problem area and the formulation of the research framework, which includes research problem, questions, and methodology. *Phase 2* is aimed at studying the knowledge about the management of RENs by conducting a historical analysis of a number of European NRENs. *Phase 3* is aimed at the development of the conceptual model that can be used to support the management of RENs. This phase begins with a literature study on the existing models supporting network management, and is then followed by the development of a new model. *Phase 4* is aimed at validating the developed conceptual model using two RENs. *Phase 5* is aimed at analyzing and presenting the research answers and conclusions.

1.4.1 Phase 1: Formulating research framework

Step 1: Preliminary study of the problem area and relevant theories

This step is necessary to get familiar with the subject of the research, and with major theoretical models and approaches employed by the researchers in this field. Because every research is usually performed within the research programme of the home university, faculty, and department, it is also important to get familiar with this research programme and the most important theories that are used. Since this research started within the research programme on Management, Control and Maintenance of Information Systems (MCM of IS), it was necessary to study main constructs of this programme, such as the management paradigm, the extended state model, and the triple model of management (see [Loo98], [Loo00]).

Step 2: Formulating research problem and approach

Every research should be based on a framework which consists of a research problem and a research approach [Ver91]. The research problem states the reasons why the research is performed; it is further specified by the research questions, which tell us what exactly is considered in the research. Yin mentioned in [Yin84, p. 19] that "defining the research questions is probably the most important step to be taken in a research study, so patience and sufficient time should be allowed for this task". The research approach regulates how the research is performed and what methodologies are employed to solve the research problem and to answer the research questions.

The research framework might have to be adjusted and refined as the result of some new information discovered at the next phases of the research. This is because an in-depth study of the problem area performed during Phase 2 may influence the initial construction of the research framework (see the dotted arrow in Figure 1.4).

1.4.2 Phase 2: Studying topics related to RENs and their management

The goal of Phase 2 is to study the existing knowledge about RENs and their management. Such knowledge is seen as the collection of topics associated with the management of RENs which include data about practical experience, problems, issues and challenges surrounding the management of such networks.

Because each particular site (REN) may possess a unique piece of knowledge which cannot be found at other sites, it was necessary to cover as many sites as possible in order to get an exhaustive picture of the existing knowledge. Time constraints and also limitations to financial resources made visits to the many sites hardly feasible. Therefore, a study of existing sources of information seemed to be the only way to cover many sites in a short period of time and within the strict budget of the research project. It was important to find sources that were based on the surveys already performed by others. Such an approach guarantees not only that the coverage is wide-ranging, but also in-depth.

The exploration of the problem area could be based predominantly on the secondary sources of information. We expected that conducting a large-scale questionnaire about many RENs would be unsuccessful because the respondents of such questionnaires are normally high-placed officials and it is quite difficult to get their active cooperations.

Yin pointed out that "the form of the research question provides an important clue regarding the appropriate research strategy to be used". Since the first research question is a 'what' question having an exploratory nature, "virtually any strategy can be employed" [Yin84, p. 19].

The methodology employed for seeking an answer to the first research question is the historical study. The historical study is the preferred strategy for this phase, because, firstly there is virtually no access to the sites in terms of direct communication with people involved in the management of the RENs. Secondly, the researcher does not have any control over actual events; he cannot influence any decisions regarding management of particular RENs. Therefore, he must rely on various documents and artifacts as the main source of evidence. The historical study also allows one to get a picture of the knowledge at different moments in time and at various stages of the development of RENs[5], instead of only knowledge about contemporary events at a current stage.

In this research the main source of evidence for the historical study was the literature, which involved all kinds of documents in both printed and electronic form. Web sites were an important source of the electronic documents used[6]. The study of the literature allowed us to cover many RENs by reading about the history and the progress of RENs in various countries. Such stories gave a good insight into the topics associated with RENs and their management.

During Phase 2, the site of URAN acted as a training ground for the researcher. His participation in various activities of URAN helped him to get a better understanding of and greater involvement into the problem area. The long collaboration with the people responsible for the management of this REN allowed him to gain experience in matters related to RENs and their management.

1.4.3 Phase 3: Developing conceptual model

Step 1: Studying existing models

This step is necessary to find out if there are existing models that can be effectively used to represent the knowledge about the management of RENs. Several models supporting network management were studied, namely the Looijen framework, the OSI Management framework, the Terplan framework, the TMN framework, the TeleManagement Forum models, and IT Infrastructure Library.

For each model it was analyzed if it could represent the knowledge about the management of RENs. This was accomplished by confronting each model with topics associated with the management of RENs. We analyzed to which extent each model covered topics which were studied during Phase 2.

[5] Recall the discussion of REN growth stages on page 2 and in Figure 1.2 that accompanies this discussion.

[6] Besides many benefits such as the speed and the ease of finding necessary data, the use of the web sites may create some difficulties, namely the lingual diversity of some websites, and the outdated character of information they might contain.

The conclusion of this analysis was that the existing models are not appropriate and, therefore, a new model had to be developed. This model is further referred to as the conceptual model.

Step 2: Developing new model

The conceptual model was developed using two fundamental frameworks, namely the management paradigm and the entity-relationship approach.

The management paradigm was chosen to be the basis for the conceptual model because it is a core element of the research programme on the management of information systems within the department of ICT management of the Delft University of Technology – the home department of this research project. The paradigm has proven its applicability in a number of practical situations because it uses a very generic approach which is suitable for any situation where the management of information systems is the main research topic.

The management paradigm considered in case of RENs was decomposed into a number of entities and relationships using the entity-relationship approach. Those entities and relationships represent the knowledge about the management of RENs. They become the main elements of the conceptual model.

1.4.4 Phase 4: Validating the conceptual model

The validation of the model relies on the case study strategy in its test form. According to Yin, "a test case study applies models that were developed. Its main objective is to test the relationships suggested by those models and to create ideas for the improvement of these models" [Yin84, p.125].

Since the model aims at supporting the management of both developing and developed RENs, it must be validated using cases which represent both kinds of RENs. Two sites were selected: the developing REN "Ukrainian Research and Academic Network (URAN)", and the developed REN "Swedish University Network (SUNET)".

Phase 4 consists of three steps described below. Step 1 and Step 2 were executed for each site. After completing these steps, Step 3 was executed for both sites.

Step 1: Bidirectional confrontation between the model and the real situation

In Step 1, the model is applied to compile the site's description. The entities and relationships comprising the model are filled with the actual data from the site. This is necessary to test whether the model meets its first objective: to provide a framework for producing a description of the real situation.

During this compilation of the description, it might turn out that the real situation does not include certain elements of the model (entities, relationships, or attributes), or that these elements have been developed improperly. Such missing elements are referred to as *gaps in the real situation*, see Figure 1.5. The search for such gaps is a part of checking whether the model meets its second objective: to facilitate the identification of gaps in the real situation.

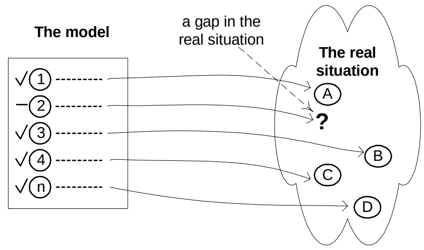

Figure 1.5: Visual interpretation of gaps in the real situation.

During the compilation of the description, it may also be found that the model cannot reflect certain aspects of the real situation, or, in other words, that these aspects do not match any of the model's entities, attributes, or relationships. Such aspects are referred to as *gaps in the model*, see Figure 1.6.

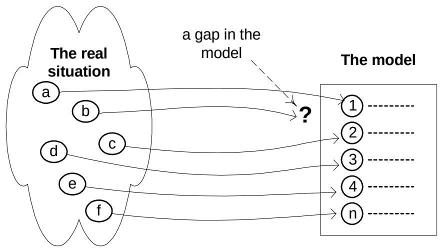

Figure 1.6: Visual interpretation of gaps in the conceptual model.

Step 2: Adjustment of the model and development of recommendations

Step 2 demonstrates in which way the model and the real situation can benefit from each other. The model provides the real situation with recommendations on how to fill gaps in the real situation. The real situation indicates how the model must be adjusted in order to fill the gaps in it. Figure 1.7 visually demonstrates these mutual benefits.

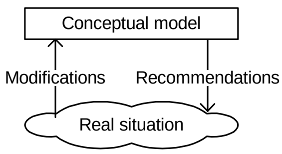

Figure 1.7: Visual interpretation of Phase 4, Step 2 "Adjustment of the model and development of recommendations".

As the result of gaps in the real situation, recommendations on how to fill these gaps can be developed. These recommendations result from the use of the model, and

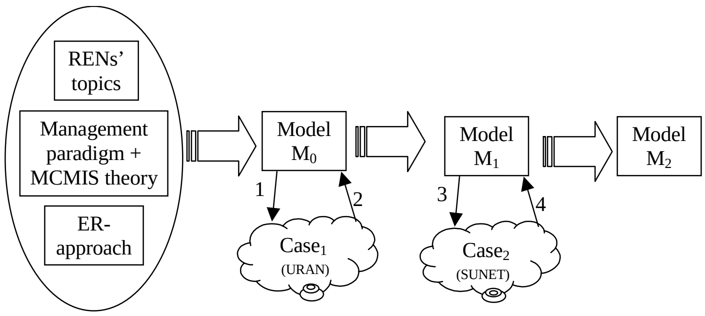

Figure 1.8: Visual interpretation of the iterative process of the model's improvement.

are based solely on own judgments of the researcher: no other people are involved. The development of recommendations corresponds to the model's third objective.

It is important to understand that the recommendations are not developed at the same time as the model is modified: these are two independent events that occur in sequence. On the one hand, the model has to improve the management of a REN. Therefore, the model is designed in such a way that it produces a number of recommendations for the improvement of the site. On the other hand, the model itself is to be improved as well, by confronting it with the validation sites (URAN and SUNET), and by analyzing the feedback coming from representatives of these sites.

This can be seen as an iterative process, depicted in Figure 1.8, in which the initial model M_0 is applied in $Case_1$ (arrow 1), then it is modified as result of the confrontation with this case (arrow 2). The resulting model is M_1, which is then applied in $Case_2$ (arrow 3), and is again adjusted as result of the confrontation with this case (arrow 4). The resulting model is M_2. The initial model M_0 has no rights without the validation sites. Only after it has been validated and, if necessary, adjusted, it can be claimed to be useful.

Step 3: Evaluation of the model by the sites

Step 3 concludes the validation of the model. It's purpose is to evaluate the quality of the model according to the people who are involved in the management of URAN and SUNET. Since these people represent the intended users of the model, they can provide the best input for judging on the model's quality. Here, the model is considered to be a product that can be used by these people.

1.4.5 Phase 5: Presenting research results

Phase 5 is dedicated to presenting and analyzing research results (findings) obtained as an outcome of activities carried out at previous phases. The results should give answers to the research questions defined in section 1.3.

The criteria for accepting the results of the research described in this thesis is not their theoretical soundness or theoretical completeness, instead the results are accepted on their empirical adequacy [Fra80]. This pragmatic view was summed up by Van Frasen as follows:

> "In so far as they [pragmatic views] go beyond consistency, empirical adequacy, and empirical strength, they do not concern the relation between the theory and the world, but rather the use and *the usefulness of the theory*; they provide reasons to prefer the theory independently of questions of truth" [Fra80, p.88]

Therefore, the acceptance of the research results depends on their usefulness for the practical situations in which the conceptual model is applied (URAN and SUNET).

Additionally, Phase 5 is devoted to presenting the directions for future research. Recommendations for further research activities are developed during this phase and some challenging research areas are outlined.

1.5 Definitions and delimitations

Definitions adopted by researchers are often not uniform, so key terms should be defined to establish positions taken in a research. In this research such a key term is *the research and education network*, which is the main object of our research. Because previous scientific research on this object was not found, it was necessary to formalize its definition. The first definition of RENs was already introduced in section 1.1.1 – this section presents the formal definition. It also presents some delimitations – boundaries put by the researcher on the types of RENs that are in the scope of this research.

The definition of an REN depends on its geographical coverage. One can distinguish several scales covered by RENs geographically: a campus, a city, a region, a state, a country, a continent, several continents, or the entire world[7]. The given list reflects not only the geographical but also the political and the administrative divisions of the entire world. Each country often uses its own terminology to refer to various levels of its administrative division.

This research distinguishes the following four types of RENs: campus, regional, national and international. Let us give the definition of each type and its relevance to this research.

Definition 1 ***A campus REN*** *is an internal computer network of an R&E institution, often also called 'intranet'.*

Campus RENs are an important platform for the automation of business processes of corresponding R&E organizations. Core information systems of an R&E organization such as, for example, student administration, personnel administration, and library systems are very dependent on the organization's intranet. Campus RENs are also an important element in the delivery of Internet access, E-mail and other services to end users: teachers, students, and researchers.

[7] Given list reflects not only the geographical but also the political and the administrative divisions of the entire world. Each country often uses its own terminology to refer to various levels of its administrative division.

Campus RENs might have very different sizes depending on the size of the R&E establishments they serve. The campus REN of a small R&E establishment might be a single LAN connecting several PCs within a building. The campus REN of a big university might consist of several LANs interconnected via routers; the number of PCs in such a campus REN might be counted in hundreds or even thousands, and the geographical scale may span the distances of tens of kilometers. Each LAN in such a case represents the computer network of a faculty or a department.

Definition 2 ***A regional REN*** *is a computer network on the scale of a city, a region, or a state*[8] *which interconnects campus networks of R&E institutions with each other and with other networks (including the Internet), and provides network services to those R&E institutions.*

If regional RENs are considered on the scale of a city they are usually called metropolitan RENs. For example, in the UK there are a number of regional RENs such as Aberdeen MAN, Cumbria & North Lancashire MAN, Edinburgh and Stirling MAN, Kentish MAN, Midlands MAN (MidMAN), North Wales MAN, Northern Ireland MAN, South Wales MAN, South West England Regional Network, and Yorkshire & Humberside MAN. According to this definition, statewide RENs in the US are also regional RENs (see Figure 1.1 on page 3).

Examples of network services are data transmission services, Internet access, E-mail, and Usenet news.

Definition 3 ***A National REN (NREN)*** *is a computer network on the scale of a country (nation) which* ***either***

1. *interconnects campus networks of R&E institutions with each other and with other networks (including the Internet), and provides network services to those institutions,* ***or***

2. *interconnects regional RENs with each other and with other networks (including the Internet), and provides network services to those regional RENs.*

Most of European NRENs belong to the first category (they directly interconnect campus networks of R&E institutions). NRENs in the UK (JANET), France (RENATER) and Poland (POL-34) belong to the second category and have the level of regional RENs. Due to the recursive definition of NRENs of the second category, they can also be viewed as networks connecting R&E institutions (more precisely campus networks of those institutions).

Definition 4 ***An international REN*** *is a computer network which interconnects NRENs with each other and with other networks (the Internet), and provides network services to those NRENs.*

At present there are only two international RENs: GÉANT (formerly TEN-155) and NORDUNET. GÉANT is the pan-European REN which interconnects 28 European NRENs and provides various network services to the R&E community. At

[8] State here means a part of a country (for example, the USA).

present GÉANT interconnects more than 3000 research and education institutions in 32 countries. The key objectives of this international REN are gigabit speeds, geographical expansion, global connectivity, and guaranteed quality of services. NORDUNET is the Nordic Internet highway to the NRENs in Denmark, Finland, Iceland, Norway and Sweden, providing the Nordic backbone to the Global Internet. It is the result of the programme financed by the Nordic Council of Ministers.

Let's now make a demarcation regarding the types of RENs which will be considered in this research. Regional RENs and NRENs are primarily in the scope of current project. Campus RENs and international RENs are outside the consideration of our research.

The definitions of the four types of RENs are graphically presented in Figure 1.9. Arrows should be read as "provide network services to", "interconnect", and "connect to other networks". The gray boxes indicate types of RENs that are in the scope of this research.

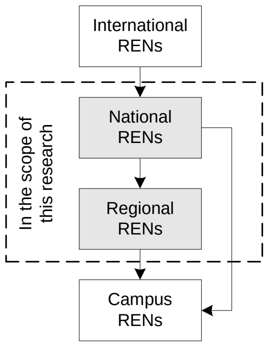

Figure 1.9: The hierarchy of research and education networks and the scope of this research.

1.6 Summary

This chapter laid the foundations for the research. It introduced the research problem and three research questions. Then the research was justified and several reasons for performing it were given. Finally, the research approach was described including phasing of the research and different research methodologies that are used at each phase.

On these foundations, the thesis can proceed further with a detailed description of the research. The outline of the following chapters of this thesis was already presented in the section 1.4 as part of the description of the research approach and its phases.

Chapter 2

REN topics

2.1 Introduction

In this chapter the existing knowledge about RENs and their management will be studied in depth. This chapter seeks an answer to the first research question *"What are the relevant topics associated with RENs and their management?"*. It corresponds to Phase 2 of the research approach which was described in Chapter 1. The information obtained will form the basis for the following phases of the research: the development of the conceptual model, and the validation of this model in real-life situations. We need to answer this research question in order to obtain the knowledge and experience necessary later on for creating the conceptual model.

The geographical coverage of the study described in this chapter predominantly includes European countries and their NRENs. Figure 2.1 demonstrates the geography of European NRENs that were included in the study. Additionally, some non-European RENs were also analyzed such as SInet and IMnet (Japan), CA*net (Canada), CERnet (China), ULAKnet (Turkey), and REUNA (Chile).

Although in the majority of countries there is only one single NREN, there are some countries where the research community has one computer network and the education community has another, where both networks operate on a national scale. Therefore, there could be more than one NREN in a country[1]. The examples of countries having more than one NREN are Greece, Denmark, and Japan. In Greece, there is the university network GUnet and the research network GRnet. In Denmark, there is the research network Forskningsnettet and the education network SEKTOR-net. In Japan, there is the inter-ministry research information network IMnet and the scientific network SInet.

2.1.1 Outline of the chapter

Each section of this chapter gives an overview of the topics associated with RENs and their management.

[1] In this case, it would be more correct to use the abbreviations NRN (National Research Network) or NEN (National Education Network). But because the abbreviation NREN is commonly accepted, it is used to refer to all kinds of nation-wide networks for R&E.

Figure 2.1: Geographical coverage of the study: European NRENs that were analyzed.

Section 2.2 presents various topics related to users of RENs. Both institutional (user organizations) and individual users (end users) are discussed in this section. It classifies of both types of users and indicates user volumes for a number of RENs.

Section 2.3 presents a classification and a brief description of communication links which RENs are based upon. The capacity of the links is considered to be the most important topic. The capacity growth of communication links is treated and their underlying transmission technology.

Section 2.4 classifies and briefly describes the services provided by RENs. The classification of these services is based on the four categories to which they belong, namely the operational services, the user support services, the security services and the information services.

Section 2.5 presents an overview of various topics related to the usage of RENs. The issue of acceptable usage of RENs is presented here and particular attention is paid to the analysis of usage. It is demonstrated that RENs are used not only as a network providing services to users, but also as a test bed for new technologies and applications.

Sections 2.6 and 2.7 present RENs from an organizational point of view. Section 2.6 gives an overview of the various entities comprising the organizational structure of RENs. Section 2.7 presents various financial topics, namely expenditure items, funding models, and charging models.

The description of topics ends with section 2.8. Various topics related to the external environment are presented here, namely the characteristics of telecommunication services and the Internet access service, the prices of hardware and software, the technological developments, the domestic Internet, and the regulatory framework.

Section 2.9 concludes the chapter and puts its results in the framework of further research activities, namely the development of the model supporting the management of RENs.

2.1.2 Description of data sources

In order to answer the question which topics are associated with RENs and their management we studied a number of data sources:

1. NREN websites[2]
2. The proceedings of conferences and workshops:
   (a) Internet Society INET conferences (www.isoc.org)
   (b) JENC and TNC conferences organized by TERENA [3]
   (c) [Pop99]
3. Books (particularly [Kah92])
4. Various reports and publications

[2]Usually the web address of a NREN consists of its abbreviated title/name (e.g. DFN for Germany), followed by the two-letter ISO country code (e.g. DE for Germany). Thus, the web address of the German NREN DFN is www.dfn.de.

[3]Trans European Research and Education Networking Association (www.terena.nl)

(a) NREN annual reports [rep96], [rep99a], [rep00a], [rep99b]

(b) [NRE00]

It is necessary to emphasize the role of some data sources. [Pop99] played a special role in the study and inspired the whole research project, proving that the management of RENs does indeed pose a challenge. [NRE00] was also an important source due to the wide coverage of RENs it presents.

The Internet had a crucial role in the study since the majority of mentioned data sources were discovered and accessed via the Internet. The use of the Internet has brought many benefits such as the speed at which and the ease with which necessary data can be found, and also the wide coverage of the collected data.

Besides benefits, the use of the Internet involved some difficulties, namely the linguistic diversity of some websites, and the limited amount of information they contained. The websites of some RENs were not in English and most of the vital documents were available only in national languages. This problem was partially solved by using online translators such as babelfish.altavista.com[4]. Besides the lack of an English translation, some websites of RENs contained a limited amount of information, which prevented getting a good picture of those RENs. Another problem encountered during the study was the outdated character of some REN websites; up-to-date information about the current state of the development of such RENs was not available.

2.2 User-related topics

This section presents topics related to users of RENs. The two most important topics are *the type* and *the volume* of users. The type refers to a division of users in various categories. It also refers to the eligibility of an organization to be the user of a particular REN. The volume refers to the overall number of users served by a REN and their distribution among various categories. Therefore, the volume reflects the relative volume of each category compared to those of other categories.

Note *the duality of the very term 'user'*. Because this term is used to refer both to organizations and to individuals, both meanings are considered here. A user is generally someone who consumes services. In case of RENs, such services are, for example, Internet access, email, news, directory services, and help desk[5]. Ultimate users of such services are individuals such as students, teachers and researchers, which will here be referred to as *end users*. However, the term 'user' also refers to organizations, to which end users belong (for example, students belong to a university). Various sources refer to such organizations as 'client institutions', 'institutional users', 'connected institutions', 'clients', 'customers', 'subscribers', or simply 'users'. In order to avoid multiple terminology, such organizations are hereafter referred to as *user organizations*.

[4]Usually the translation made by such an online translator enables one to understand only the basic ideas and content of the document of interest. So the quality of translations still leaves much to be desired.

[5]Detailed classification of services will be given in section 2.4.

2.2.1 User organizations

User organizations of RENs vary in nature and type. Despite the fact that the primary objective of RENs is the provision of network services to R&E institutions[6], RENs also often serve other types of organizations. Therefore, along with traditional R&E organizations such as universities, research institutes, and schools, RENs also serve libraries, museums, public authorities, hospitals, and even commercial companies.

The following list classifies user organizations into various categories and subcategories:

1. Higher education institutions (HEIs)
   (a) universities,
   (b) colleges of higher education,
2. Research institutes
   (a) governmental research institutes (academy of sciences),
   (b) industrial/private research institutes,
3. Libraries
   (a) research/university libraries,
   (b) public libraries,
4. Public/governmental authorities and administration (ministries)
5. Others
   (a) hospitals,
   (b) schools (primary and secondary),
   (c) museums,
   (d) commercial companies (industry).

The terminology used for categorizing user organizations varies from country to country. This particularly concerns HEIs, which have the largest relative volume compared to other categories of user organizations. For example, Sweden has so-called university colleges, which differ from universities in that they only offer either bachelor's or master's programmes, or a limited amount of subjects.

The presented classification lists the categories of user organizations from most to least frequent users. HEIs and research institutes are the most common users of RENs, while commercial companies and museums are the least common users.

Libraries have special importance for RENs. Due to the fact that libraries are natural information warehouses, they can provide the research and education community with the necessary information, as they potentially are the best content providers[7].

[6] See the definitions of RENs in section 1.5.
[7] See also a note on content providers in 2.4.4.

An important characteristic of every REN is the *volume of user organizations* it serves. The volumes of user organizations served by the different NRENs vary considerably from country to country (see Table 2.1); it is particularly remarkable that often these volumes are not related to the size of the corresponding countries. For instance, NRENs in Luxemburg and Spain have equal volumes of user organizations, while the population of Spain (40 million) is 1000 times higher than that of Luxemburg (0.4 million). The Latvian NREN has more than three times more user organizations than the French NREN, while Latvia is 25 times smaller than France.

The inconsistency between the volume of user organizations of a NREN and the size of a country it belongs to can be explained as follows. Some RENs serve small user organizations such as, for example, primary and secondary schools. The volume of such organizations in a country is usually much higher than the volume of other types of organizations, such as HEIs. For example, among the 4600 user organizations of a German NREN DFN there are 4000 primary schools.

Country (NREN)	Qty	Country (NREN)	Qty
Austria (ACOnet)	90	Japan (IMnet)	93
Belgium (BELnet)	130	Latvia (LATnet)	2000
Czech Rep. (CESnet)	70	Luxemburg (RESTENA)	250
Denmark (Forskningsnettet)	120	Netherlands (SURFnet)	243
Estonia (EEnet)	454	Poland (NASK)	600
Finland (FUnet)	85	Portugal (RCCN)	55
France (RENATER)	600	Russia (RELARN-IP)	93
Germany (DFN)	4600	Spain (RedIRIS)	250
Greece (GRnet)	56	Sweden (SUnet)	60
Hungary (HUNGARnet)	800	Switzerland (SWITCH)	30
Ireland (HEAnet)	37	Turkey (ULAKnet)	80
Italy (GARR)	237	UK (JAnet)	500

(Source: [NRE00], NREN websites)

Table 2.1: Volume of user organizations for some NRENs.

Types of user organizations served by a REN are often specified in a formal policy document: the so-called Acceptable Usage Policy or Connection Policy. Such documents specify among other things which organizations are eligible to be users of a REN[8].

If one looks at the history of RENs, one can see that *their target user base has been expanding*. At the time of their creation many RENs were intended to serve only a specific set of user organizations: for example, HEIs/ universities. However, over time other types of user organizations were accepted, including commercial organizations. Nowadays, it is becoming more and more common that RENs serve organizations which do not belong to the research and education community, such as public/ governmental authorities, libraries, hospitals, museums, and commercial companies. John Dyer noted in [Dye98] that many NRENs have a common theme: cross sector partnership and collaboration, which usually requires a good communication infrastructure between the collaborating sectors.

[8]Acceptable Usage Policies will be discussed in section 2.5.1.

Particularly interesting seems to be the *attitude of RENs towards servicing commercial organizations*. Various RENs approach this issue differently. Most RENs do not serve any kind of commercial organization. Some RENs serve user organizations which belong to commercial R&E such as private universities and colleges, and industrial research institutions. For example, commercial research organizations can have access to Italian NREN "GARR" in the framework of agreements or projects with research and education institutions that are regular users of GARR. Other RENs do not have specific limitations on potential user organizations, such as NRENs in the UK (JAnet), Germany (DFN), Poland (NASK) and Hungary (HUNGARnet). Therefore, virtually any commercial organization may be the user of those NRENs.

The attitude of a REN towards servicing commercial organizations strongly relates to the way it is financed: its so-called funding model[9]. Most RENs enjoy heavy state funding, which is particularly significant at the initial stage of their development. Therefore, a political issue appears as whether commercial organizations can utilize services built with the use of the state funds and primarily meant to be non-commercial.

2.2.2 End users

According to the definition given in Chapter 1, RENs interconnect R&E organizations and provide them with network services. However, because organizations consist of people, who are their most valuable assets, the ultimate user of a REN is an individual, or, in other words, an end user. The benefits that end users receive from the network services provided by the REN are crucial for the success of the organization and the success of the REN itself.

Table 2.2 gives an impression of the volumes of end users for some NRENs.

Country (NREN)	Qty	Country (NREN)	Qty
Belgium (BELnet)	125	Latvia (LATnet)	15
Czech Rep. (CESnet)	200	Lithuania (LITnet)	50
Estonia (EEnet)	101	Luxemburg (RESTENA)	10
Finland (FUnet)	300	Norway (UNINETT)	250
Germany (DFN)	1000	Portugal (RCCN)	300
Greece (GRnet)	150	Slovakia (SAnet)	100
Hungary (HUNGARnet)	300	Spain (RedIRIS)	200
Ireland (HEAnet)	120	Turkey (ULAKnet)	350
Italy (GARR)	500	UK (JANET)	1000

(Sources: [NRE00], NREN websites)

Table 2.2: Estimated quantity of end users for some NRENs (in thousands).

There are two major categories of end users, namely students (scholars) and staff members (employees). The relative volume of *students* among the end users of a REN is quite high compared to the volume of staff members. Firstly, this is due to the obvious fact that the number of students (scholars) in an educational establishment is typically higher than the number of staff members. Another reason is the growing

[9] Funding models will be considered in section 2.7.2.

popularity of computer networks and their services among young people. The survey of end users of the Dutch NREN "SURFnet" has shown a spectacular growth in the number of students using SURFnet's services (primarily email and Internet access): from 1995 till 1998 this number increased more than two times (from 32% to 74% of the total student population). At the same time, the number of staff members increased only with 11% (from 70% to 81%) [PS98].

Staff members can be classified into the following categories:

1. Teachers (academic staff)
2. Researchers
   (a) networkers
   (b) non-networkers
3. Others

Teachers (academic staff) can usually be found only in educational establishments such as HEIs. Normally, there are no teachers in organizations that do not perform educational activities such as, for example, research institutes and libraries. Employees of universities often combine teaching tasks and research activities, and hence are both teacher and researcher at the same time.

Researchers can be divided into networkers and non-networkers. *Networkers* are those researchers who study computer networks, network services, network applications, and other related network technologies. They consider networks as the subject of their studies or, in other words, the test bed[10] for their activities. *Non-networkers* are all other types of researchers. As opposed to networkers, non-networkers consider networks as a product or a tool that supports their primary research activities (for example, research in physics or chemistry).

Despite the fact that the relative volume of networkers is much smaller compared to the volume of non-networkers, the first usually have higher requirements on, for example, network capacity and performance. This often leads to a situation in which growth and development of the network is driven by the demands of a relatively small group of end users. It should be noted that such growth usually requires significant investments. Therefore, networkers are able to influence the development and growth of the RENs significantly.

The last category, *others*, includes employees that belong to financial administration, student administration, personnel administration, accountants, secretaries, managers, and technical support staff.

An alternative classification of end users can be made on the basis of their attachment to *scientific fields*. This classification is therefore only relevant for students[11], teachers, and researchers, and not for the others types of end users (category "others"). According to the UNESCO classification, the following scientific fields can be distinguished[12]:

[10] The issue of using RENs as test beds will be discussed later in section 2.5.3.

[11] For students it would be more correct to use the term "field of study".

[12] This classification of scientific fields is taken from [UNE99].

- humanities
- law & social sciences
- natural sciences
- engineering
- agriculture
- medical sciences

Traditionally, the use of computer networks started from the natural sciences and engineering ([RAR88]). However, nowadays end users that belong to other scientific fields are also intensively using services provided by RENs.

2.3 Topics related to communication links

Communication links are an essential component of any computer network. This section gives insight into some topics related to the communication links of RENs. Firstly, section 2.3.1 classifies the communication links and briefly describes each category. Secondly, the capacity (bandwidth) of communication links, one of their most essential characteristics[13], is considered in section 2.3.2. This is followed by a discussion of capacity growth. This section also gives examples of the actual capacity values for a number of European NRENs. Finally, transmission technologies are shortly discussed in section 2.3.3.

2.3.1 Classification

Technically, RENs consist of a number of communication links, where each performs a number of functions. Below we have classified the links according to the sources and the destinations of the traffic that they carry. Local links (LANs) that connect network servers within the same building, for example, were left out of consideration.

First, a distinction is made between *national* and *international* links. The first do not cross the national border and represent the domestic connectivity of a REN, while the second cross the border and therefore represent the international connectivity of a REN.

National links can be divided into the following categories:

1. Backbone links
2. User access links
3. Peering links

[13]Another vital characteristic of the communication links is the latency (delay).

Backbone links are core communication links that connect major nodes of a REN. A backbone acts as the primary path for traffic that is most often sourced from and destined for other networks: campus networks of user organizations, networks of domestic Internet service providers, other RENs, and the Internet.

User access links connect the campus network of a user organization to the backbone of a REN. The point (node) of connection is usually called the user access point or the point of presence (PoP).

Peering links connect RENs with networks of domestic Internet service providers (ISPs). This implies that a REN has a peering agreement with those ISPs. A peering agreement is the agreement by the two networks to exchange Internet traffic without payments. The vast majority of Internet peering arrangements are nowadays performed via the so-called Internet exchanges. RENs also exchange traffic with domestic ISPs via Internet exchanges.

International links can be divided into the following categories:

1. European links
2. Internet links

European links connect European NRENs to GÉANT – the pan-European Network for Research and Education (international REN). This network allows twenty-seven European NRENs to exchange traffic with each other. This category is therefore applicable only to European NRENs. Nine circuits at the core of this network operate at speeds of 10 Gbps, while eleven others run at 2.5 Gbps (May 2002).

Internet links connect RENs to the Internet. European NRENs usually utilize a transatlantic link with one of the major North American ISPs such as Teleglobe (SURFnet, NORDUnet, JAnet), or a link with a big domestic ISP such as, for example, Ebone (Austrian ACOnet), Swisscom (Swiss SWITCH), and Deutsche Telecom (German DFN).

2.3.2 Capacity

The capacity (bandwidth) of the communication link is its maximum transmission speed measured in bits per second[14]. Since RENs typically serve large volumes of users and cover wide geographical areas, they require communication links having high capacities and spanning long distances.

Table 2.3 provides an overview of the capacity of links for a number of European NRENs. The capacity of backbone links for some NRENs is given as a range, which implies that the capacity varies from link to link. User access links are not included in Table 2.3 because their capacity ranges from kilobits to megabits. Peering links are not included in this table either because their capacity usually equals that of the corresponding IX, which is typically either 100 Mbps or 1 Gbps.

Data about capacities of five Scandinavian NRENs (the Swedish SUnet, the Finnish FUnet, the Danish DAREnet, the Norwegian UNINETT and the Icelandic ISnet) is

[14]Usually thousands, millions and billions of bits per second are used to measure the capacity of a communication link, resulting in abbreviations: Kbps = 1024 bits per second (bps), Mbps = 1024 Kbps, Gbps = 1024Mbps.

not included in Table 2.3 because these NRENs have a particular way of providing international connectivity for themselves: they have set up an international network called NORDUnet. The main goal of NORDUnet is to provide external connectivity to these five NRENs. Besides to the mentioned NRENs, NORDUnet also provides international connectivity to other NRENs such as the Estonian EEnet and the Ukrainian UARnet.

Country (NREN)	Capacity of links, Mbps		
	Backbone	European	Internet
Austria (ACOnet)	4...32	45	144
Belgium (BELnet)	34...155	45	245
Czech Republic (CESnet)	34...155	21	68
Estonia (EEnet)	2...8	4	16
France (RENATER)	34...155	155	800
Germany (DFN)	155	155	622
Greece (GRnet)	2...155	155	155*
Hungary (HUNGARnet)	34...155	34	34*
Ireland (HEAnet)	34	34	43
Italy (GARR)	155	155	622
Latvia (LATnet)	100	4	6
Lithuania (LITnet)	2	no data	3
Luxemburg (RESTENA)	10	6	8
Netherlands (SURFnet)	320...622	622	622
Slovakia (SAnet)	2	12	no data
Spain (RedIRIS)	30	45	91
Switzerland (SWITCH)	155	155	300
Turkey (ULAKnet)	34	4	4
UK (JAnet)	34...155	155	620

*Use GÉANT as the provider of Internet connectivity

(Sources: [NRE00], NREN websites; December 2000)

Table 2.3: Capacity of NREN links.

RENs are constantly striving to increase the capacity of their links. However, the actual capacity of many RENs is often lower than needed. Firstly, this is due to the very high costs of the long-distance communication links on the one hand and the budget restrictions on the other. Secondly, this is due the availability of links having necessary capacities and connecting certain geographical points. This largely depends on the telecommunication infrastructure in the area where a REN operates: while North America and Europe enjoy gigabit capacities, many countries in the developing world must still rely on kilobit capacities. Links with high capacity are not available everywhere in the world, not to mention their extremely high cost. The mentioned considerations often make the capacity of communication links one of the most often discussed topic associated with RENs.

Therefore, an important topic for most RENs is *the capacity growth*, which is directly caused by the constantly increasing traffic[15]. Traffic growth in its turn is

[15]Traffic growth will be considered in section 2.5.2.

caused among other things by the introduction of new network applications and services requiring high transmission speeds. Because of the constant capacity growth, most of the numbers given in Table 2.3 are not correct by the time this dissertation will be published. Representatives of some NRENs – responders to the TERENA questionnaire [NRE00] – have estimated the growth of the capacity of backbone links in a two-years period at between 10 and 100 times compared to current capacities.

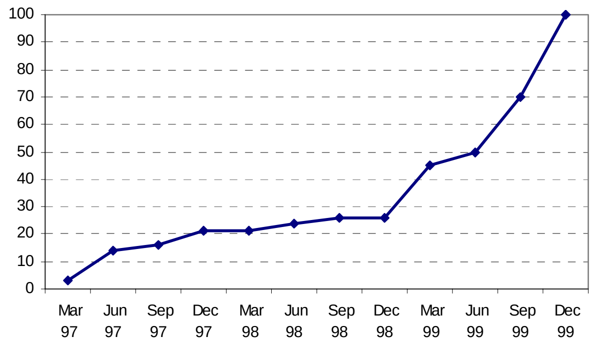

Figure 2.2: Capacity growth of international links of Austrian ACOnet, in Mbps (source: [rep99a]).

Figure 2.2 gives an example of the capacity growth of the international links for the Austrian ACOnet. As can be seen from this figure, the capacity of the international links grew from 3 Mbps in 1997 to 100 Mbps in 1999. In the beginning of 2001 international links of ACOnet had a total capacity of 190 Mbps (see Table 2.3). Similar patterns can also be observed for other RENs.

Figure 2.3 is another illustration of the capacity growth. It shows the capacity of backbone links for a number of European NRENs at the end of 2001 (in contrast with Table 2.3, whose data refer to the beginning of 2001). If the data from this figure is compared with the data from Table 2.3, it can easily be seen that the capacity of NRENs in countries such as the UK, the Netherlands, Germany, France, Belgium, and Austria has grown more than tenfold in one year.

2.3.3 Transmission technology

Another topic related to communication links is their underlying *transmission technology*, which defines among other things the medium that is used to transmit electronic signals (for example, copper, fiber, or electromagnetic waves) and the way in which the data is encoded and transmitted over the links (the transmission protocol). Nowadays the transmission technologies such as ATM, WDM, FDDI, and SDH/POS are the most popular and promising technologies.

The transmission technology is usually chosen by the telecom operator. However, it also becomes popular among telecom operators to provide so-called dark fiber communication links. In this case customers (operators of RENs) are free to use their own terminating equipment.

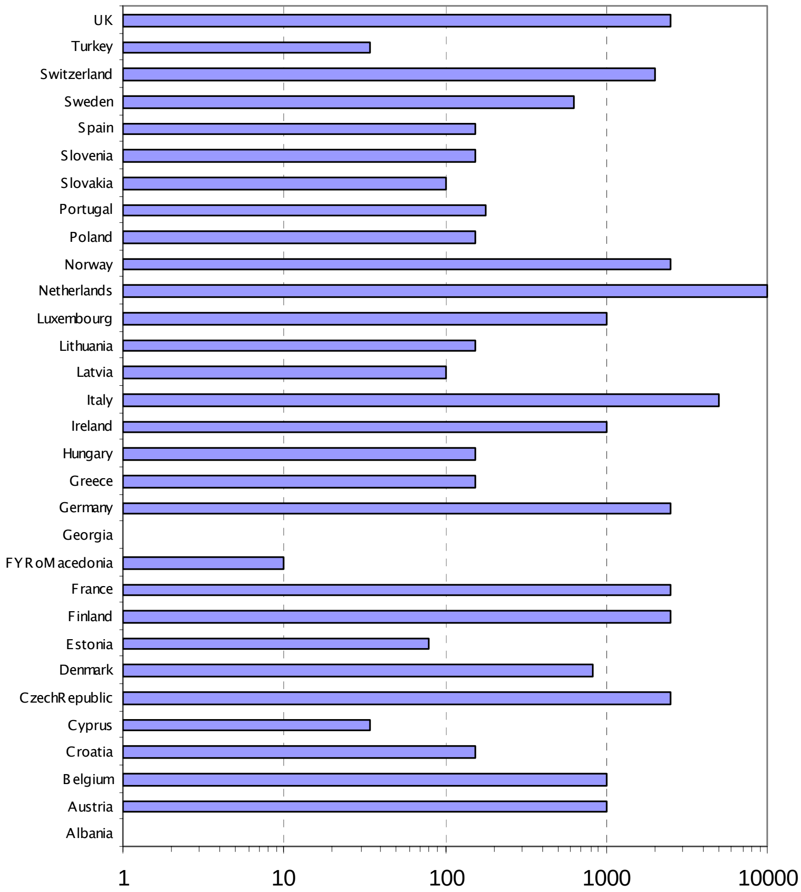

Figure 2.3: Capacities of backbone links for NRENs in European countries, in Mbps (Source [NRE00]; December 2001).

Further discussion of the transmission technologies is out of the scope of this dissertation.

2.4 Service-related topics

This section gives an overview of services that may be available to the users of RENs and classifies them. All services are divided into four categories: operational services, user support services, security services and information services. The services that belong to the categories are briefly described in the sections 2.4.1 - 2.4.4. The description of security services in section 2.4.3 ends with a note about the Computer Emergency Response Team (CERT) – the entity that provides security services.

The basis for the classification of services presented in this section was mainly [Jan00, appendix A], since this classification appeared to be the most comprehensive one among analogous classifications. Information published at the websites of RENs has also contributed to the classification. Therefore, some changes and additions have been made to make the classification of services given in [Jan00, appendix A] more universal and suitable for other RENs.

2.4.1 Operational services

Operational services support the most basic functionality of a computer network: the transmission of data. Data here implies both bits/ bytes and informational objects such as files and messages. Some of the operational services must always be in place because no network can do without them. The provision of the operational services usually implies that the specialized hardware (routers, network servers) and software must be up and running, supporting the services' functionality 24 hours a day and 7 days a week.

The following services belong to operational services:

1. Basic backbone transmission service
2. External network access provision and transmission services
3. IP multicast service
4. Naming and addressing services
5. Dial-up access service
6. Usenet News distribution service
7. Directory service
8. Web caching service
9. Messaging services
10. Network time service
11. Network monitoring and accounting services

Below, each service is briefly described.

The basic backbone transmission service offers transmission of traffic among user organizations through the backbone links[16]. This usually implies the transmission of IP (Internet protocol) traffic because it is now the standard "de facto" transmission protocol for a vast majority of computer networks, including RENs. However, some European NRENs also support the transmission of the ATM (Asynchronous Transfer Mode) traffic. The ATM services are typically used for high-speed network transmissions that require guaranteed end-to-end bandwidth between the communicating nodes. Therefore, it is often used for videoconferencing services.

The external network access provision and transmission service implies that users, besides exchange of traffic among themselves via the REN backbone, are also provided with the ability to transfer data to and from other (external) networks: other RENs, networks of domestic ISPs, and the global Internet. Access to other RENs usually implies access to the pan-European REN GÉANT. In some cases, however, RENs may have direct communication links with each other on the basis of either peering or client-provider relationships[17]. Access to networks of domestic ISPs is provided via an IX and corresponding peering links. Access to the global Internet usually implies the North American Internet – the predominant part of the Internet. The given division of external networks corresponds to the classification of communication links given in section 2.3.1.

IP multicast service allows transmission of IP traffic from a single source to multiple destinations (one-to-many). It is opposed to broadcast (one-to-all) and unicast (one-to-one) transmissions. Another term that is often used for referring to IP multicast is MBONE (Multicast Backbone), which is a virtual network layered on top of the Internet to support routing of IP Multicast packets. Provision of this service means that user organizations are able to transmit and receive IP multicast traffic.

Naming and addressing services include the domain name system (DNS) service and the domain name administration service. DNS is the system of naming of individual management domains within the Internet for the purpose of representing IP addresses in mnemonic form, and for associated purposes. Provision of the DNS service implies the existence of specialized name servers that support mentioned functionality of mapping mnemonic domain names to IP addresses. The domain name administration service coordinates and administrates domain names under a certain DNS hierarchy. Often, this is the country-code top-level domain (CCTLD). This means that all domain names having the form "name.cc", where "cc" is the two-letters ISO country code, are administered by a corresponding operator of the NREN in that country. For more information on Internet domain names and DNS see [Hus99, pp. 77- 84, 413-419] and [KK97, pp. 107-258].

Dial-up access service is the provision of intermittent network access via regular dial-up telephone lines. It is usually meant for end users rather than for user organizations because the last are typically connected to the REN via permanent communication links (leased lines). User organizations normally provide the dial-up access service for their employees and students (end users), so it rarely appears in the service profile of the REN. In Sweden, however, the dial-up access service for students

16 Recall the definition of the backbone and the backbone links in section 2.3.1.

17 See more on this in section 2.3.1.

is provided on country level due to a special arrangement between the Swedish ISP "Telenordia" and Swedish NREN SUnet. This arrangement made it possible to reduce the monthly rate for the end users (students) to 70% of the regular market rate [Pop99, p. 100-102].

Usenet news distribution service is a traditional Internet service which involves the delivery and the distribution of news articles according to the Network News Transfer Protocol (NNTP). It allows end users to read and send messages from and to various news hierarchies.

The directory service offers support of directory access protocols such as LDAP (Lightweight Directory Access Protocol) and X.500. It supports information services[18] that provide access to the white and yellow pages– structured lists of people and/or companies with various reference information such as names, addresses, telephone numbers, emails, etc. Provision of the directory service implies the existence of specialized network servers (the so-called directory servers) that support the mentioned functionality. Such servers form an integral part of the technical infrastructure of the REN which provides this service. Managing the directories' contents is not a part of this service; this is the functionality of the service "content provision", which will be discussed later on in section 2.4.4.

The web caching service offers temporary storage of web documents in a buffer for later reuse. If the end user's web browser requests a document from a website and this document is already in the cache, the document from the cache is transmitted to the browser and there is no retrieval of the document from the original website. This saves considerable transmission capacity (bandwidth) and reduces the response time. The caches of RENs are usually organized in a hierarchical way: a single (national) web cache on top of the hierarchy and the web caches of user organizations at the bottom. End users usually communicate directly with local web caches of their home organizations (user organizations). This service is also often referred to as the *web proxy service*.

Messaging services support various email transfer protocols, such as SMTP/POP (Simple Mail Transfer Protocol/ Post Office Protocol), IMAP (Internet Message Access Protocol) and X.400. Messaging services become particularly important if email messages temporarily cannot be delivered to their ultimate recipients (end users)[19]. In this situation such messages are stored on the REN server (mail relay server) for later delivery. Messaging services imply also conversion of messages between various mail systems (for example between SMTP and X.400). Such conversion systems are often called message gateways.

The network time service supports the Network Time Protocol (NTP). NTP assures accurate local time keeping with reference to the most precise radio and atomic clocks. It is capable of synchronizing distributed clocks within milliseconds over long time periods. This service is not meant to be accessed by end users but rather by user organizations and their network administrators.

Network monitoring and accounting services offer constant collection of values of various indicators such as, for example, the load status of links, the traffic volume,

[18]Information services are discussed later in section 2.4.4.

[19]For example, the link between the REN backbone and a user organization (user access link) is not working properly, or the mailserver of a user organization is malfunctioning.

the packet drop rate, the availability of services, and the latency (delay) times. This information is then continuously presented in all kinds of reports and statistics so that users – mainly the network administrators of user organizations – are able to audit Service Level Agreements (SLAs) between their user organizations and the provider of services, the REN operator. The popular indicators are the load status of links and the traffic volume. The first indicator is usually displayed as a graph presented in various time scales (daily, monthly and yearly). The second indicator shows volumes of data transferred via certain links on different time scales. It is particularly important for RENs that charge their user organizations on the basis of transmitted volumes of traffic[20]: the British JAnet, the Danish DAREnet and the German DFN. Collected data in this case also has financial implications.

2.4.2 User support services

The name of this category of services speaks for itself: user support services support both end users and user organizations in various matters that concern computer networking. In contrast to the provision of operational services, the provision of user support services usually involves human participation; operational services are usually provided in either an automated or a semi-automated way with humans playing management/ supervisory roles only.

The following services belong to user support services:

1. Customer service
2. Training
3. Technical assistance
4. Documentation provision

Customer service, commonly also referred to as *helpdesk*, is a main contact point between users and service providers for all enquiries, questions, complains, and problems that may appear. Requests can usually be made via telephone, fax, post or email. This service is not meant for end users but for user organizations: representatives of user organizations are the actual users of this service. Network administrators of the user organizations' intranets usually play the role of such representatives.

Training implies the organization of workshops and training courses. The participants of such events can be interested end users. The objectives of training are usually technical updating of the user community and the distribution of the relevant knowledge.

Technical assistance implies advising user organizations on networking matters using the expertise available within the REN community or, if necessary, making use of the expertise of external consultants. This service can be provided either as a start-up service for new user organizations or a continuous service for all user organizations. It is not meant for end users.

Documentation provision implies development of comprehensive paper and electronic documents meant for the distribution among the end users of a REN. The

[20]the so-called "usage based charging model", which will be described later in section 2.7.3.

potential readers of such documents can be either a wide end-user community or a restricted group of end users such as, for example, network administrators of user organizations' intranets. A good example of such documentation is the SURFnet's SURFkit for the network managers website (skin.surfnet.nl). This website provides knowledge, information and tools to support network and system managers with the installation, configuration and use of Internet applications. It contains software and sources, configuration options, test reports, security issues as well as links and references to relevant SURFnet web pages and other related sites. This service is closely related to the content provision service that will be discussed in section 2.4.4.

2.4.3 Security services

Computer networks are often liable to various threats, such as DoS (denial-of-service) attacks, viruses, unauthorized access to data and network resources, theft of passwords and keys, unsolicited distribution of email messages (also known as spam), spoofing[21], and other dangers. The aftermath of such threats can be disastrous if no countermeasures are taken.

Security services assure that the network is well protected against security threats. In order to protect the network against threats and to minimize their negative consequences, the service profile of each REN should include a number of security services. The following services belong to the security services:

1. The security response service
2. The security awareness service
3. The security liaison service
4. The security information service
5. The Public Key Infrastructure service

The security response service sets up procedures to monitor unauthorized use of the services provided by a REN and users' own services. There must be provided procedures for rapid assistance to users in order to help them respond to attempted unacceptable use of the network.

The security awareness service develops and provides presentations on and training in computer security in order to raise users' awareness on security issues. This service is similar to the training service from the user support services considered in a previous subsection.

The security liaison service maintains contacts with other national and international organizations working in the fields of computer security and law enforcement, to ensure that the interests of the users are presented to these organizations and that the users are informed of developments which may affect them. In particular, the promotion of the use of internationally agreed standards is an important part of this service.

The security information service involves

[21] Spoofing is when a network packet falsely claims to be from an address from which it was not actually sent. It is designed to foil network security mechanisms, such as filters and access lists.

- maintaining a list of approved contact points and service hours at user organizations;
- advising users on security mechanisms;
- providing users with regular information on general levels of threat and countermeasures available;
- maintaining publicly available information about computer security threats and countermeasures.

The Public Key Infrastructure (PKI) service is the service enabling end users to protect the security of their communication by using public key cryptography. PKI is basically a coherent structure of Certification Authorities (CAs), organizations that issue public key certificates[22] and usually also provide other cryptographic services, such as certificate distribution and revocation. Most PKIs are hierarchic, with a central root CA (or top-level CA) which certifies lower CAs, which in turn certify lower CAs or users; CAs may also occasionally cross certify. CAs are also often referred to as Trusted Third Parties. Some RENs act as root CAs, for example, the Dutch SURFnet and the German DFN.

Security services are typically provided by the *Computer Emergency Response Team (CERT)*[23]. This team handles cases of computer security incidents in which a REN user is involved, either as a victim or as a suspect.

An remarkable initiative concerning the coordination of activities among various European CERTs is TERENA's Trusted Introducer Initiative (TII). In the framework of this initiative a qualification system for CERTs is proposed. This system is based on a set of criteria such as certain attributes of security services, parameters of an information handling policy and cryptography policy, and others. Each CERT is then given a qualification level from 0 (lowest) to 2 (highest). Table 2.4 gives qualification levels for a number of CERTs of European NRENs. It is necessary to note that the TII is aimed not only at CERTs of NRENs, but also at CERTs of other (commercial) networks. For more information refer to the official website of the TII (www.ti.terena.nl).

Information given in Table 2.4 can be also used to estimate the qualification of security services provided by each CERT.

2.4.4 Information services

The provision of access to *information resources* is one of the most important functions of the RENs. Information resources – commonly also referred to as the *content* – are perhaps the primary matter which end users of RENs are interested in. The predominant part of the REN traffic is initiated by end users wishing to find and retrieve some useful information from an extremely wide choice of information resources located at billions of websites all over the Internet. Examples of information

[22] A public-key certificate certifies that the public key belongs to the holder mentioned in it. It is the way to ensure authenticity of the sender of information.

[23] This team can be also called Computer Security Incident Response Team (CSIRT).

Country (NREN)	Level	Country (NREN)	Level
Austria (ACOnet)	0	Italy (GARR)	2
Belgium (BELnet)	0	Lithuania (LITnet)	0
Croatia (CARnet)	0	Netherlands (SURFnet)	2
Denmark (Forskningsnet)	2	Norway (UNINETT)	2
Finland (FUnet)	2	Poland (NASK)	0
France (RENATER)	2	Portugal (RCCN)	0
Germany (DFN)	2	Spain (RedIRIS)	2
Greece (GRnet)	0	Sweden (SUnet)	1
Hungary (HUNGARnet)	0	Switzerland (SWITCH)	2
Iceland (ISnet)	0	UK (JAnet)	2

(Source: www.ti.terena.nl; May 2002)

Table 2.4: Qualification levels of NRENs' CERTs according to TERENA's Trusted Introducer Initiative.

resources that are of professional interest for the R&E community are library catalogs, educational materials, full-text scientific articles, abstract databases, reference databases, patent databases, vacancy databases, and other specialized information resources that are directly or indirectly related to science and education.

A number of services are required for the provision of access to information resources. These services, called information services, ensure that their users are able to find and access qualitative information resources:

1. The content provision service
2. The content mirroring service
3. The content listing service
4. The content indexing and searching service

The content provision service includes development, operation and maintenance of the very contents of information resources. It is usually provided by so-called *content providers* – organizations or individuals having some useful information to present (to sell) to certain information consumers – other organizations and/or individuals.

Various organizations can perform the content provider's role. Firstly, user organizations of RENs often perform this role: for example, a university has a website which contains general information about this university, its faculties, and its educational program; faculties and departments within this university may also have their own websites that further describe the curriculum of a particular field of study or a research field. Secondly, libraries – both university and public ones – are natural content providers due to the very nature of their business: to provide access to knowledge. Therefore, libraries often make their electronic catalogs accessible to the general public via the web. Thirdly, organizations that are not users of RENs can also act as providers of information resources which are ultimately useful for REN users: for example, famous publishing houses such as Elsevier, Springer, IEEE, Wiley, and ACM maintain huge databases of full-text scientific publications. Finally, virtually any organization having a website is a provider of the information resources which the end users of RENs may wish to access.

The content provision service can only partially be found in the service profile of most RENs. Some RENs maintain file archives that contain various software packages. Most RENs have websites full of various documents and reports about themselves, their history, and other relevant information.

The content mirroring service periodically transfers an information resource originally located at the content provider's site to the REN's site. This means that an identical copy of the information resource is created at one of the network servers comprising the infrastructure of the REN. Therefore, the mirrored content becomes physically accessible via the REN website(s). This saves capacity for international links if the mirrored content is intensively used by the users of a REN because no connection to the original source of the content is made for retrieving the information from the mirrored content. The service is somewhat similar to the web caching service, although it has a static nature, in contrast to the web caching service, which has a dynamic nature.

The content listing service maintains *web directories* – organized, categorized listings of websites put together by human reviewers. Web directories act as entry points that allow end users to locate websites on the basis of their classification. Web directories normally have a navigable tree-like structure with each branch representing certain area or subject. The most famous commercial provider of this service is Yahoo!. There are a few RENs that provide this service: for example, the Dutch SURFnet maintains the NL-menu (www.nl-menu.nl), and the Swedish SUnet maintains an Index of Swedish WWW Resources (www.sunet.se/sweden/).

The content indexing and searching service maintains *search engines* – information systems that attempt to index and locate desired information by searching for keywords which a user specifies. The method for finding information is usually maintaining indices of information resources that can be queried for the keywords entered by the user. These lists are created by the specialized programs that search the Internet, attempting to locate new, publicly accessible information resources such as web documents and files available in public file archives. Such programs are called crawlers, spiders, robots or wanderers. Search engines are somewhat similar to web directories in that they both support the function of locating information resources. However, search engines allow users to find single documents (web pages, files), while web directories only give access to whole web sites. Examples of search engines maintained by RENs are SURFnet's Search Engine (search.surfnet.nl) and BELnet's FTPSearch (ftpsearch.belnet.be).

2.5 Usage-related topics

Having discussed the users of RENs (section 2.2) and the services which are available for them (section 2.4), we can now focus on how the users use these services. Therefore, this section is devoted to topics related to the usage of RENs.

Firstly, section 2.5.1 considers what constitutes acceptable usage of RENs, e.g. which usage is allowed and which is forbidden. This section describes an important policy document which regulates various issues related to acceptable usage: the Acceptable Usage Policy (AUP). Usage analysis is the subject of section 2.5.2. Two topics are discussed here, namely the analysis of usage and the usage growth trend. Finally, in section 2.5.3 it is demonstrated that RENs are used not only as service provision platforms, but also as test beds for new technologies and applications.

2.5.1 Acceptable Usage Policy

The usage of RENs and their services is formally regulated by a document called the Acceptable Usage Policy[24] (AUP). In order to make a distinction between proper and improper usage, this document specifies a number of policy issues. Let us give a short overview of these issues.

Firstly, the AUP defines *which types of organizations are eligible users of the REN.* This includes a specification of the primary user organizations: those organizations which the REN is servicing in the first place (for example, universities from a certain geographical region), and also a specification of other types of user organizations that are allowed to connect to the REN and to utilize its services. The AUP can also include a description of the attitude of the REN towards servicing commercial organizations – whether or not commercial organizations are allowed to be the users of the REN.

Secondly, the AUP includes *a specification of activities for which the usage of the REN and its services is allowed and/or forbidden.* The following activities are typically forbidden:

- creation or transmission of any offensive, obscene or indecent data/material, and also material that infringes the copyright of other people;
- unauthorized (illegitimate) access to facilities, services, or resources;
- violation of the privacy of other users;
- corrupting or destroying other users' data;
- usage of services in a way that denies service to other users;
- introduction and distribution of computer viruses.

This part of the AUP may also include the issue of using the REN for commercial purposes or, by other words, the status of the commercial traffic on the REN. This issue differs from the aforementioned issue of the acceptance of commercial users since regular user organizations may sometimes be involved in commercial activities and therefore generate commercial traffic.

Finally, the AUP specifies the *consequences that follow and measures that are taken in case of the violation of policy rules.* Such measures are, for example, the withdrawal or interruption of services.

Jackson noted in [Jac99] that the national AUPs in various European countries are very diverse, especially concerning the aforementioned issue about the acceptance of commercial users. The AUP of the French NREN RENATER, for example, specifically emphasizes that RENATER may only be used for strictly professional purposes

[24] Sometimes it is also called the Acceptable User Policy.

– a limitation that was not found in the AUPs of other European NRENs. The AUP of some NRENs is a quite substantial document of several pages long (the French RENATER, the British JAnet), while the AUP of other NRENs consists merely of a few dozen lines of text (the Belgian BELnet, the Swedish SUnet). Some NRENs declare that they are AUP-free (for example, the Slovakian SAnet).

2.5.2 Analysis of usage

In order to get insight into how RENs are actually used, it is necessary to collect and analyze the usage statistics. The input for such statistics can be either the actual network traffic or the direct feedback from end users who use the network and therefore initiate the traffic. Let's consider both ways to collect usage statistics.

The automated collection and analysis of the actual network traffic was considered in [Liz99]. The authors of [Liz99] developed a tool called "traffic processor" which is able to perform this task. The description of the tool is accompanied by several examples of how this tool was used to analyze the usage of the Spanish NREN RedIRIS during a period of four and half months, from September 1998 till January 1999. The first example demonstrated the distribution of traffic among the three categories: academic, commercial, and leisure. The results showed that 77% of the traffic was academic, 18% – leisure, and 3% – commercial. For some links[25], however, the leisure traffic accounted for nearly 50% of the total traffic and was equal to or even more than the academic traffic. The second example demonstrated the distribution of traffic according to its origin and destination. The results showed that more than 74% of the traffic was external to RedIRIS: 12% of traffic originated from the commercial Spanish Internet, 21% from other European NRENs, and 41% from the North American Internet. Similar traffic patterns can also be seen in the usage statistics of other RENs.

The second way to collect the usage statistics is to directly ask end users about how they use the network. For example, the Joint Information Systems Committee of the British NREN JAnet commissioned a study on the reasons of network usage. The results of this study were based on interviewing students and employees of four British Universities in the cities Glasgow, Leeds, Liverpool, and Sunderland. The final report [JIS98] demonstrated the following findings. Firstly, the traffic generated by students accounted for about two thirds of the total traffic, which made students the heaviest users of JAnet. Secondly, the usage of the Web and transatlantic links was driven by services and sites which are not academic domains, in other words, much of the usage was for activities that were outside of the scope of higher education (leisure/entertainment and commercial). The same report also recommended further behavioral studies that should give more in-depth insight into the purposes and patterns of usage. Similar ideas and recommendations can also be found in other sources such as [Dye98].

The above-mentioned results of various analyses of usage raise the issue of the *purposes of usage*. Since the primary goal of RENs is supporting the professional activities of the R&E sector, the usage of RENs and their services for other activities such as leisure/ entertainment might be considered as inappropriate. This issue seems

[25]In this case a link corresponds to one of the seventeen regional networks of RedIRIS.

to be particularly important for the donor agencies that provide financial support to the RENs, which is particularly heavy at the initial phase of the REN development. If a significant part of the usage has a leisure and/ or commercial character, donor agencies may review their policy of subsidizing such RENs.

The usage statistics also shows that the usage of RENs and their services is constantly increasing. This phenomenon, referred to as *the usage growth trend*, can be quantitatively seen as the growth of volumes of data transferred through the communication links of RENs. Figure 2.4 demonstrates this trend for the Dutch SURFnet. The traffic of other RENs shows similar patterns. For example, the average monthly traffic of the German DFN grew from 2 Terabytes in 1994 to 240 Terabytes in 2000.

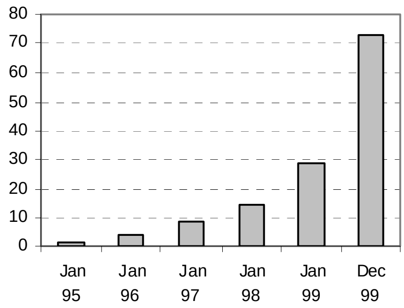

Figure 2.4: Average monthly volume of traffic on SURFnet, TBytes. Source: [rep99b].

There are two main reasons for the traffic growth. Firstly, it is due to the introduction of new networking applications having high-capacity requirements, for example, video- and audio-intense applications. Secondly, traffic growth is caused by the growth of the population of end users. This implies that more and more people at user organizations start using RENs and their services, thus becoming end users of RENs or, in other words, more and more potential end users become actual end users. Swedish NREN SUnet reported in [Pop99] that the number of its end users doubled every nine months.

As noted in section 2.3.2, the usage growth is the main driving force for the capacity growth: in order to cope with the constantly increasing traffic volumes, the network capacity has to be periodically upgraded.

2.5.3 RENs as test beds

Many RENs do not only provide services to their users, they also act as *test beds* for new networking technologies, services, and applications. Therefore, the usage of RENs also includes activities aimed at developing, testing and implementing new hardware, software, protocols, services, and applications. Usually these activities are performed in the framework of various projects, ranging from campus to national and international projects. Some examples of such projects are given below.

- Projects in the framework of the Telematics Applications Programme[26]:
  - DESIRE project (Development of a European Service for Information on Research and Education, www.desire.org);
  - SCIMITAR project (Support and Coordination for Integrated Multimedia Telematics Applications for Researchers, www.scimitar.terena.nl)
  - QUANTUM project (Quality Network Technology for User-oriented Multi-Media, www.dante.org.uk/quantum/)
  - CESAR project (Collaboration Environments and Service Architectures for Researchers, orgwis.gmd.de/projects/CESAR/)
- High (giga) speed next-generation networking projects:
  - Internet2 project in the USA (www.internet2.edu)
  - GIGAPORT project in the Netherlands (www.gigaport.nl)
  - GÉANT project in Europe (www.geant.net)

In this case, the term 'research' in the abbreviation "REN" means that RENs are also research test beds.

Tindemans pointed out in [Tin99, p.79] that "it is vital not to mix up the development, testing and introduction of new services with the provision of operational services to the users. Users are not waiting to get bogged down because of inevitable test or start-up problems associated with innovations".

2.6 Organizational topics

In the preceding sections RENs were viewed as service provision platforms utilized by users. In this section RENs are viewed from a different point of view, namely from the organizational point of view. This section deals with the organizations involved in the management of RENs, the roles of these organizations, and the relationships among them.

A number of organizations are involved in the management of RENs and the provision of services described in the section 2.4. Although organizational models of actual RENs vary and it is impossible to present a universal model, there are some common entities appearing in the organizational models of most RENs, namely the REN Operator, the Subcontractor, the Association of Users, the State Agency, the Management Board, and the Advisory Board. The first three entities are treated in the sections 2.6.1 – 2.6.3, and the last three entities in section 2.6.4. Table 2.5 gives examples of some entities for a number of European countries and their NRENs.

[26] European Commission's research programme

Country (NREN)	State Agency	Management Board	Advisory Board	REN Operator (NOC)
Austria (ACOnet)	Federal Ministry for Science and Research	Steering Committee	Technical Working Group	Vienna University
Belgium (BELnet)	Federal Office for Scientific, Technical and Cultural affairs (OSTC)		Policy Board	Service Support Team within the OSTC
Germany (DFN)	Federal Ministry for Education and Science	Administrative Board	Committees on technological and legal affairs	DFN offices in Berlin and Stuttgart
Hungary (Hungarnet)	Ministry of Culture and Education, National Committee of Technological Development	Presidential Board		No data
Ireland (HEAnet)	Higher Education Authority, Ministry of Education	Board of Directors		HEAnet ltd.
Lithuania (LITnet)	Ministry of Science and Education	LITNET Board	LITNET Technical Experts	Kaunas University of Technology
Netherlands (SURFnet)	Ministry of Education and Scientific Research	Board of Directors	Scientific Technical Council (WTR)	SURFnet ltd.
Sweden (SUnet)	National Agency for Higher Education	Board of SUnet	Technical Reference Group	Royal Institute of Technology in Stockholm
UK (JAnet)	Joint Information Systems Committee, Higher Education Funding Councils	Board of Management	Technical Advisory Unit	UKERNA ltd.

Table 2.5: Examples of entities forming the organizational structures of European NRENs.

2.6.1 REN Operator

The REN Operator is an entity responsible for the daily operation of the REN and the provision of most of the services described in section 2.4, particularly operational services. It is an important entity that can be found in the organizational model of every REN. The REN operator is also often referred to as the Network Operating Center or NOC.

Organizationally the REN Operator can be either (1) a company, (2) a subdivision of a user organization, or (3) a part of a ministry. Let us consider each form in more detail.

The REN Operator *company* is the separate legal entity owned by its stakeholders. State agencies, user organizations, and commercial companies are usually the stakeholders of such a company. Additionally, a national telecom operator can also be the stakeholder of such a company. For example, the Dutch PTT Telecom has 49% shares of the operator of the Dutch NREN SURFnet – a commercial company called SURFnet ltd. As a business, a REN Operator company is typically not for profit.

The REN Operator can also be *a subdivision of a user organization*, like the computer center of a technical university. This fact seems to be remarkable because on the one hand such a university is the user of services, and on the other it is the provider of services.

The REN Operator can be an integral *part of a government ministry*, e.g. the Ministry of Education. Such an entity does not have separate governing boards. The Executive Director reports to the Minister or to another official or body designated by the Minister. In the case of Spain, this body is itself autonomous.

2.6.2 Subcontractor

The subcontractor is an entity that together with the REN Operator performs the daily operation of the REN and provides services to the users. Subcontractors become necessary when it is inefficient or impossible for a single organization (REN Operator) to carry out all the necessary activities related to the operation of the REN. In this case some activities are outsourced to organizations who may perform them better (more efficient and effective) than the REN Operator. It is remarkable that user organizations often play the role of subcontractor. Therefore, on the one hand such organization is the user of services, and on the other hand it is the provider of services.

A good example of a REN that subcontracts various services is given by the Dutch NREN SURFnet. Until 1999 the following organizations were subcontractors of SURFnet[27]:

- the Academic Computer Center of the Utrecht University managed the SURFnet InfoService and the News service,
- the Royal Dutch Library edited information presented in SURFnet InfoService and maintained the contents of the NL-menu,
- the University of Nijmegen managed the help desk (customer service),
- the University of Amsterdam operated the SURFnet IP network,
- the Delft University of Technology managed the X.500 directory services and also the gateway between X.400 and Internet mail,
- the PTT Telecom managed the SURFnet ATM network,
- the RCC performed management of the central Directory Service.

2.6.3 Association of users

An Association of Users is a legal entity created and owned by its members. The members of such an association are typically institutional stakeholders, e.g. user organizations, and not end users[28]. Besides user organizations, various state agencies can also be members of such an association. The members form a General Assembly, which elects a Board of Directors. The Executive Director reports to the Board and/or the General Assembly.

Such associations exist in Austria, the Czech Republic, Germany, Hungary, the Netherlands, Lithuania, and Slovakia ([NRE00]). In the case of Lithuania, the members are universities and research institutions, but the structure and the regulations of the association must be approved by the Ministry of Science and Education. In

[27] In 1999 it was decided to reduce the number of subcontractors and to concentrate management of services to one partner.

[28] An exceptional case is the Hungarian NREN HUNGARNET, where individuals can also become a member of the HUNGARNET Association.

the case of the Czech Republic, only university-related bodies can join. In the cases of Germany and Slovakia, companies can become members of the association as well.

In order to explain the role of associations, let us give some examples of their goals:

- promotion of cooperation in the field of ICT and computer networking between user organizations,
- creation of conditions for the establishment and use of the computer networks by user organizations,
- research and development of advanced network technologies and applications,
- broadening the public knowledge about advanced networking topics,
- development of the RENs.

Members of associations usually meet on their meetings called *General Assemblies*. Representatives of user organizations participate in such meetings, which allow the management of the REN to get feedback from users and to discuss important issues. Meetings may take place either on a regular (several times a year) or an ad hoc basis.

2.6.4 Other entities

In addition to the REN operator, the Subcontractor, and the Association of users, there are also other three entities involved in the management of RENs, namely the State Agency, the Management Board and the Advisory Board.

The State Agency is typically a domestic ministry of research and education or similar agency. The state plays a vital role for the RENs, as it does for the research and education sector in general. It provides not only financial but also political support to RENs. According to [Tin99], a networking policy should be an integral part of the national science policy. Financial support implies that many RENs are partially or entirely funded by the state.

The Management Board is an entity responsible for the definition of the strategy and policies of a REN. Usually it comprises several representatives of the state agencies and user organizations. Typically these representatives are senior executives of user organizations and highly placed officers of the state agencies.

The Advisory Board is an entity providing advisory and consultancy services to the State Agency, the Management Board and user organizations on technical and policy matters. This entity is composed of several representatives of user organizations who are typically technical experts in various areas of computer networking.

2.7 Financial topics

Every business activity needs proper financial support. RENs are a service provision platform for research and education institutions and also require proper financial arrangements: the investments must be secured, the recurrent expenses must be covered, and the budget of the REN must be properly maintained so that the expenses do not exceed the income.

This section gives an overview of the topics with a financial and economic nature. The budget of RENs is considered and both its parts are analyzed, namely the expenditure part and the income part. The expenditure part is considered in section 2.7.1, where a number of expenditure items are described. The comparison of the relative volumes of the expenditure items shows that the connectivity costs is usually the predominant item. The income part is considered in section 2.7.2, where the REN funding models are describes: the central funding model, the user funding model, and the mixed funding model. The issue of defining a proper fee for the user funding model is considered in section 2.7.3 by describing the so-called charging models. A comparison of two basic charging models is presented, namely the flat-rate model and the usage-based model.

2.7.1 Expenditure items

Expenditure is a vital financial topic receiving a lot of attention from the management of every REN. Being an integral part of the REN budget, it should be viewed in relation to a certain legal body: often this is the REN operator.

The following expenditure items can be distinguished:

1. Connectivity costs
2. Staff costs
3. Depreciation costs
4. Network services costs
5. Development and innovation costs
6. Other costs

Connectivity costs are the costs of leasing the backbone and the international links. Therefore, connectivity costs are often divided into national connectivity costs and international connectivity costs. This expenditure item is directly connected with the tariffs of telecommunication operators and ISPs[29]. The continuous growth of the capacity of links directly affects connectivity costs and causes the continuous increase of the expenditure part of the REN budget.

Staff costs are the wages and salaries of people that manage, control, and maintain the REN. Normally, this expenditure item refers to the salaries and wages of the staff members of the REN operator.

Depreciation costs are costs incurred due to the wear and tear of assets. Assets of a REN include among other things hardware and software, for which depreciation is particularly important since hardware/ software usually has short life cycle and needs to be frequently upgraded/ updated.

Network services costs are costs of services provided by subcontractors. This expenditure item includes funds which the REN operator pays to subcontractors for the provision of certain services to user organizations.

[29]Tariffs of telecommunication operators and ISPs will be considered later in section 2.8.

Development and innovation costs include costs of upgrading the network infrastructure, the purchase of additional hardware and software, and also costs of using the REN as a test bed. Unlike other expenditure items, development and innovation costs have a non-recurrent nature. This expenditure item also includes initial investments in creating the REN and building its infrastructure.

Other costs are various costs such as the costs of training and educating personnel, administrative costs (for example, business trips), and fees for membership of international organizations such as TERENA, CEENet, and RIPE.

Expenditure item	Spain RedIRIS	Netherlands SURFnet	Sweden SUnet	UK JAnet
Connectivity	52%	34%	80%	76%
Staff	19%	22%	*	6%
Depreciation		8%	10%	
Network services	4%		10%	3%
Development & innovation		31%		2%

* SUnet does not have any permanent staff.
(Sources: [rep96], [rep99b], [rep00b], [rep00a])

Table 2.6: Relative proportions of expenditure items for some European NRENs.

The relative size of various expenditure items is dependent on the total package of services offered by a REN, which differs greatly for different countries [Vie99]. Table 2.6 illustrates this. However, connectivity costs is the predominant expenditure item in budgets of most RENs. International connectivity costs are typically several times higher than national connectivity costs.

2.7.2 Funding models

Having described the expenditure part of the REN budget, we will now consider the way in which RENs are funded; we will describe the funding sources and the way in which the funds from these sources (the income) cover the expenses for network operation and development. This is usually referred to as a funding model.

There are two types of funding sources: users and funding agencies. The first funding source is similar to a common business situation: the customers – user organizations – pay a fee for the services provided by the service providers – the REN operator and the subcontractors. The second funding source usually comprises various state agencies such as ministries of education and/or science. It also includes other domestic and foreign organizations, which are often referred to as donor organizations or simply *donors*. The following international organizations are well-known donors: Soros Foundation, NSF, NATO, UN[30], EU/EC[31]. Donors are particularly important for the financial support of RENs in developing countries. Additionally, there are also donors from the industry which often subsidize RENs in the framework

[30]Relevant is Sustainable Development Networking Programme of UN Development Programme, www.sdnp.undp.org

[31]Relevant are EU Espirit Information Technologies Programme (www.cordis.lu/esprit/) and EC Research Programmes (europa.eu.int/comm/research/)

of various collaborative research projects, for example when RENs are used as a test bed for new technologies and applications.

A funding model describes the relative share of each type of funding source in the income part of the REN budget. Usually, the three funding models are distinguished: central funding, user funding, and mixed funding. *Central funding* implies that a funding agency fully subsidizes the operation and the development of the REN. *User funding* implies that user organizations jointly fund the REN and each of them pays a certain fee. *Mixed funding* implies that both funding agencies and user organizations participate in the financial support of the REN. Therefore, it is a combination of user funding and central funding.

Table 2.7 provides an overview of the relative shares of each type of funding sources for a number of European NRENs. It can be seen that the mixed-funding model is the most common, which, nevertheless, differs from site to site in relation to the ratio between the state share and the users' share: for some RENs the state share dominates, while for other RENs it is the users' share. Correspondingly, RENs such as DFN, LATnet, and HEAnet come closer to a user-funding model, while other RENs such as ACOnet, BELnet, RENATER, and RedIRIS come closer to a central-funding model. Table 2.7 also demonstrates that funding models differ strongly from REN to REN.

Each funding model has advantages as well as disadvantages [Vie99, p. 194]. As mixed funding is a combination of central funding and user funding, it inherits advantages and disadvantages of both. Let us first outline what these consist of.

Central funding provides a good overview of the total costs and makes government (funding agencies) aware of its responsibility towards research networking. It also makes is possible to avoid complicated administration and bureaucracy. Central funding, however, cannot ensure that the services offered match the real user needs. Users can be wasteful of network services since they are not charged for them. Another disadvantage of central funding is that the continuity of network services might depend on political whims.

User funding makes users aware of the real costs of networking and provides strong feedback of their needs. User organizations can set priorities between expenditure on networking and other expenditure. However, long-term investments and innovations can hardly be funded in the framework of the user-funding model, because user charges usually cover only operational costs. It is difficult to develop and agree on a fair model for sharing the total operational costs of a REN[32]. Short-term thinking and social factors lead to the underspending of user organizations on networking [Vie99, p. 195].

The implementation of the mixed-funding model depends on several parameters, such as: (1) time, (2) expenditure item, and (3) category of user organizations [Vie99, p. 195].

Time refers to the fact that in the beginning most RENs are centrally funded and later user funding is gradually introduced. For example, the share of state funding of the Austrian NREN ACOnet decreased from 85% in 1997 to 73% in 1999 [rep99a]. The same tendency can also be seen in the financial histories of other RENs.

[32] Such a model is usually referred to as a charging model. Charging models are considered in the following section, 2.7.3.

Country (NREN)	Funding source		
	State	Users	Other (donors)
Austria (ACOnet)	73%	27%	
Belgium (BELnet)	80%	13%	7%
Czech Republic (CESnet)	72%	26%	2%
Estonia (EEnet)	97%		3%
Finland (FUnet)	55%	45%	
France (RENATER)	75%	22%	3%
Germany (DFN)	27%	72%	1%
Hungary (HUNGARnet)	90%	10%	1%
Ireland (HEAnet)	20%	80%	
Latvia (LATnet)	10%	85%	5%
Lithuania (LITnet)	93%	2%	5%
Luxemburg (RESTENA)	100%		
Norway (UNINETT)	53%	47%	
Slovakia (SAnet)	60%	10%	30%
Spain (RedIRIS)	74%	18%	8%
Sweden (SUnet)	57%	43%	
Turkey (ULAKnet)	100%		
UK (JAnet)	63%	37%	

(Sources: [NRE00], [rep00a], [rep99a]).

Table 2.7: Relative proportions of funding sources for NRENs.

Some *expenditure items* are funded centrally, while others are funded by the users. For example, in the Netherlands (SURFnet), development and innovation costs are centrally funded while other expenditure items are user funded. Similar patterns can also be also seen in other countries.

Different *categories of user organizations* can be funded in different ways. This means that some user organizations can be fully subsidized, others partially, and still others pay for everything themselves. For example, in Sweden (SUnet), universities and national museums are subsidized by the Swedish government while other organizations have to pay a fee that is proportional to the capacity of their access links [Pop99, p. 95].

2.7.3 Charging models

User funding requires a model that defines the fee which each user organization must pay – the so-called *charging model*. A charging model defines how the services are priced, or, in other words, what the *tariffs* are for the services. Charging models used by RENs are similar to those of the ISPs. There are two major charging models, namely the flat-rate and the usage-based model.

The basis for *the flat-rate charging model* is the capacity of a user access link (see the classification of communication links in section 2.3.1). Each user-access link is charged a fee, which allows unlimited usage of this link up to its transmission capacity. It is a traditional Internet charging model, and very popular among RENs.

Besides the capacity of a user-access link, the size of a user organization is an additional parameter that can be used for the definition of the flat-rate model and corresponding tariffs of the REN. The usage of this parameter implies that big user organizations pay more than small user organizations, even if their access links have equal capacities. The size of a user organization can be measured as the number of people belonging to this organization or the number of computers connected to the organization's intranet. For example, the Dutch NREN SURFnet uses the size of a user organization as an additional parameter in its flat-rate charging model.

The basis of *the usage-based charging model* is the volume of data (traffic) transmitted through either a user-access or an Internet link[33]. Correspondingly, either all traffic generated by a user organization is charged, or only that part of the traffic which originates from or is destined to the Internet. There are many variations on the usage-based model, which result from several parameters determining the nature of this charging model. These parameters are:

1. Traffic coarseness
2. Traffic direction
3. Time period

The traffic coarseness means that the traffic accounting data can be collected and processed with different levels of coarseness. The British NREN JAnet, for example, charges 2 pennies for each megabyte transmitted via its transatlantic (Internet) link. The German NREN DFN operates traffic volumes of tens of gigabytes. The JAnet charging model uses a fine traffic coarseness, while the DFN charging model uses a rough traffic coarseness.

The traffic direction can either be incoming or outgoing. Usually, only the incoming traffic is charged since it typically dominates the outgoing traffic.

Tariffs can also vary depending on *the time period*. The night-time traffic might be either free of charge or cheaper than the day-time traffic. JAnet uses this principle in its usage-based charging model. A similar pattern also applies to weekday traffic in comparison with weekend traffic.

Comparison of the flat-rate and the usage-based charging models

Let us now compare the two charging models. Each model possesses certain characteristics that can be both advantageous and disadvantageous, depending on the situation. Table 2.8 summarizes these characteristics.

The flat-rate model is easily understood by users due to its simple and clear design. The usage-based model, because of the possible variety in the design parameters (traffic coarseness, traffic direction, time period) is typically more difficult for users to understand.

The usage-based model is more difficult to implement and maintain than the flat-rate one. The development of the usage-based tariffs is more complicated than the development of the flat-rate (fixed) tariffs because of the wider choice of design

[33] No evidence has been found that charges exist that are based on the traffic through backbone, peering or European links. It is nevertheless possible to use traffic through any link as a basis for charging.

Characteristics of a charging model	Flat rate	Usage based
Easy to understand by users?	Yes	No
Simple to implement and maintain?	Yes	No
Costs	Low	High
Allows budget planning in advance?	Yes	No
Allows encouraging economical use?	No	Yes
Supports variable quality of service?	No	Yes

Table 2.8: Some characteristics of charging models.

parameters[34]. The usage-based model requires deployment and maintenance of traffic accounting and billing systems. Reliability and user confidence also play a role here.

The simplicity to implement and maintain a charging model is also reflected in its costs. The usage-based model is normally more expensive than the flat-rate one. The costs of the charging model include costs of hardware and software that needs to be deployed and/or upgraded in order to cope with the accounting and billing tasks. Such tasks usually require high-performance hardware and software, which undoubtedly increases the expenditure part of the REN budget. Personnel costs and various administrative costs are also a part of the charging model costs.

Unlike the usage-based model, the flat-rate model allows budget planning in advance. The budget here refers to the budget of user organizations. User organizations – primarily R&E institutions – are typically centrally funded by the state[35]. Expenditure on networking forms part of their budget. Because the network traffic is highly unpredictable, this form of charging removes any fear of under- or overestimation of the funds to be reserved that user organizations might have.

Unlike the flat-rate model, the usage-based model is capable of encouraging economical use of the network and its services. This seems to be important in the context of saving costly resources such as the capacity of the international links. The usage-based model can help reducing non-legitimate use of the network; it also allows auditing of the AUP and analysis of the usage of the network.

Another advantage of the usage-based model is its support of the variable quality of service (QoS). Currently most RENs mainly provide so-called "best efforts service", according to which all users are treated in an equal way. However, there is a strong trend towards variable QoS, where different categories of users receive different levels of service. The variable QoS make it possible to reserve the bandwidth and to prioritize traffic streams. The flat-rate model is not able to support variable QoS.

The usage-based model seems to be much less common than the flat-rate model. Only NRENs in the following countries were identified as RENs using the usage-based charging model: the UK, Germany, Denmark, Chile [Utr95], and New Zealand [Bro97].

[34]The tariffs of the flat-rate model have a single design parameter: the link capacity.

[35]This funding should not be mixed up with the funding considered in section 2.7.2. Here funding relates to financing of user organizations, and not of NRENs.

2.8 Environment-related topics

The topics treated in sections 2.2 – 2.7 described the internal environment of the RENs and their management. This section will discuss the topics that are associated with RENs and their management that belong to their external environment.

Section 2.8.1 considers the characteristics of telecommunication services, namely their capacity, availability, and price. It also considers the relationship between the capacity and the price. Section 2.8.2 considers the characteristics of the Internet access service. Similarly as for the telecommunication services, these are their capacity, availability, and price. However, the difference between the two is that RENs are only the customers of telecom services, while the both use and provide the Internet access service. Section 2.8.3 considers the influence of hardware and software prices on the expenditure of the RENs. The influence of technological developments is discussed in section 2.8.4. Section 2.8.5 considers the influence of the domestic Internet on the RENs. A set of indicators introduced by ITU is used to describe the Internet market in a country or region where the REN operates and the implications of these indicators on the REN. Finally, section 2.8.6 considers the importance of proper regulatory frameworks for the success of the RENs, namely the national ICT policy and the legislative basis for the telecom liberalization.

2.8.1 Characteristics of telecommunication services

The characteristics of telecommunication services refer to the condition of the cabling infrastructure owned and operated by the incumbent telecom operators and the status of the corresponding services such as basic telephony, ISDN, ADSL, leased lines, and ATM. Because such services are the basis for the RENs' transmission services[36], their characteristics are very important. Along with the technical characteristics such as the capacity, the latency, and the jitter, each telecommunication service is also characterized by its availability and price. *The capacity* is an important characteristics of a telecommunication service that refers to the maximum transmission speed with which the data can be transferred through the corresponding communication links. According to Van den Broek, the availability and the price are the two most important characteristics of a telecommunication service [Bro99, p. 77]. Let's discuss how each of these two characteristics influences RENs.

The availability of telecommunication services has direct implications on the geographical coverage of the REN and the capacity of its backbone and user-access links. If certain telecommunication services are not available in some geographical areas, they cannot be accessed by the users from that areas: for example, only users in big cities can enjoy high-speed video conferencing. Unlike the Internet access service, which can potentially be delivered from anywhere in the world using satellite communication, telecommunication services need to be available locally within the geographical area where the REN operates.

The price of telecommunication services has implications on the expenditure part of the REN budget. As mentioned in section 2.7.1, the connectivity costs is usually

[36]See the description of the basic backbone transmission service and the external networks access provision and transmission services in section 2.4.1.

the most significant expenditure item. Therefore, prices of the telecommunication services directly influence the recurrent expenditure of the REN.

Prices of telecommunication services vary strongly from country to country. Figure 2.5 demonstrates this for the Netherlands, France and the UK. As a consequence of EU telecoms liberalization, the prices of telecom services in Europe have been gradually decreased over the last several years. However, this has not happened yet in other countries, for example, in developing countries and countries of the former Soviet Union.

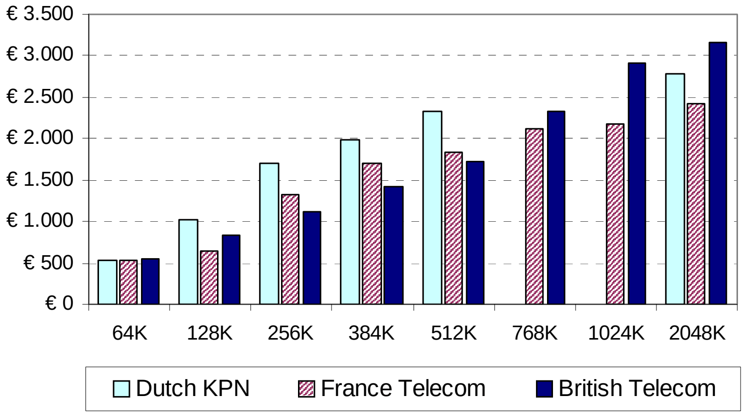

Figure 2.5: Monthly rental prices for 100km digital leased lines in the Netherlands, France and the UK, March 2001 (Sources: www.kpn.com, www.francetelecom.fr, www.bt.com)

The price of the capacity unit[37] drops as the capacity volume grows (see Figure 2.6). This means that the purchase of large volumes of capacity brings economies of scale. This is one of the reasons while it is financially beneficial for RENs to increase in size[38]. For example, the international REN NORDUnet was jointly established by several NRENs in Nordic countries with the aim to utilize a common Internet link. Due to the abovementioned relationship between the price and the capacity, it appeared to be beneficial to have a common high-capacity link instead of a separate link with lower capacity for each NREN.

Due to the liberalization of telecom markets in many countries and the further developments in the telecom sector, the prices are still dropping.

2.8.2 Characteristics of the Internet access service

Similarly to telecommunication services, the Internet access service plays an important role for the RENs. However, the difference between the two is that RENs are only the customers of telecom services, while the both use and provide the Internet

[37]The capacity unit is usually measured in Kbps or Mbps (kilo/mega bits per second).
[38]Recall also the four-stages growth model from section 1.1.1.

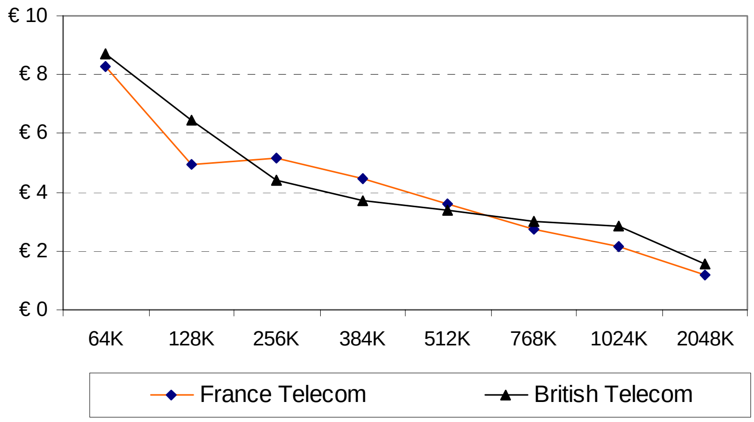

Figure 2.6: Prices of the "Kbps" capacity unit depending on the capacity volume (based on Figure 2.5).

access service. Therefore, the role of this service is twofold: on the one hand, RENs buy this service from ISPs; on the other hand, RENs provide this service to user organizations. For example, the Dutch SURFnet and the British JAnet are the customers of Teleglobe, the Austrian ACOnet is a customer of Ebone, the Swiss SWITCH is a customer of Swisscom, and the German DFN is a customer of the Deutsche Telecom.

When RENs buy the Internet access service from ISPs and, therefore, act as the customers of those ISPs, the vital characteristics of this service are similar to those of telecommunication services. Firstly, *the capacity* of the Internet access service is vital. Such a capacity corresponds to the capacity of the Internet link of the REN. Since the Internet link is usually the bottleneck for the majority of RENs, it is very important that the link's capacity matches the constantly growing demands of user organizations[39]. Secondly, *the availability* of the service is important because if the service is not available locally within the geographical area of the REN, then it should be delivered from outside of this area (for example, from abroad). This may not always be feasible due to the technical, financial and/or political constrains. Thirdly, *the price* of the service is vital because it influences the expenditure part of the REN budget. Like telecommunication services, the Internet access service also accounts for a considerable part of the expenditure.

Many of the services available to the users of RENs are not unique on the market – there are also other networks that offer similar services, for example, the Internet access service and some other services provided by RENs. Therefore, when RENs provide the Internet access service to their user organizations, they act in a competitive local or domestic Internet market. R&E institutions – potential user organizations of the REN – may wish to buy the Internet access service from commercial ISPs and not from the REN. This results in a competitive situation, which is particularly crucial at the initial phase of the REN creation, when the critical mass of users necessary for

[39] See also the discussion of the capacity growth trend in section 2.3.2.

the REN to start functioning must be obtained. Therefore, RENs must adjust their pricing policy and charging models to the market and make their tariffs attractive for user organizations. This also shows that it is important for RENs to have a proper marketing strategy.

2.8.3 Hardware and software prices

The prices for hardware and software significantly influence the expenditure of the REN. This influence is particularly strong during the initial period of the creation of the REN, when the significant investments have to be made, and it further continues during its growth and development. Often the purchase of the hardware and corresponding software is subsidize by state agencies or donors.

It is typical that the suppliers of hardware and software give special discounts to RENs, or even donate their outdated hardware to the REN. The donation of outdated hardware could be particularly useful for developing RENs, for which such hardware is far good enough and better than nothing. For example, Cisco Systems donated several dozens of routers to the Ukrainian NREN URAN. The collaboration with suppliers makes it possible to bring the discounts closer to users, so that they too can purchase hardware and software for reduced prices.

2.8.4 Technological developments

Technological developments imply developments in the whole ICT industry and the Internet. Developments such as the following play a role:

- the emergence of new services and applications such as telemedicine, telebanking, e-business;
- the developments in mobile communication (UMTS, GPRS);
- the developments in network protocols (IPv6, IPng, QoS);
- the growth of data transmission speeds – giga and tera bytes per second – and the emergence of new data transmission technologies (WDM, dark fiber, ADSL);
- the growth of the processing power (gigahertz processors) and storage capacities (gigabytes, DVDs);
- the developments in software technologies (Java, XML).

When a new technology appears, there is a strong need for a test bed. Many developed RENs act as test beds for the mentioned developments in the framework of projects in which they often collaborate with the industry. The participation of RENs in such projects is greatly appreciated by all collaborating parties as it allows them to use the state-of-the-art network infrastructure of RENs and the expertise available within the REN user community. The issue of using RENs as test beds was already discussed in section 2.5.3.

The technological developments cause big investments in the REN infrastructure – particularly hardware and communication links. This has implications on the expenditure budget of RENs.

2.8.5 Domestic Internet

RENs are an essential part of the Internet, which consists of a number of interconnected networks all over the world. Each region and country has its own sector of the Internet, represented by the networks located within that region and connected to the Internet.

Similarly to RENs, the Internet has different levels of development across regions and countries. While in Western Europe and North America a large part of the population enjoys high-speed Internet access, in many developing countries even the slow dialup access is either not available or too expensive for the majority of the population [Wan02].

The International Telecommunication Union defined a number of indicators which can be used for measuring the level of Internet development in a country or region [Min00]. These indicators are divided into three groups, namely infrastructure, access and policy. *The infrastructure indicators* are (1) the number of Internet hosts, (2) the number of telephone lines, and (3) the number of personal computers. *The access indicators* are (1) the number of Internet subscribers – individuals and organizations paying for access to the Internet, (2) the number of Internet users – individuals actually using the Internet, (3) the number of inhabitants that have access to the Internet but who may not necessarily use it, and (4) the number of inhabitants that are aware of the Internet. *The policy indicators* are (1) the number of ISPs, (2) the tariffs – the prices of the Internet access service and the telephone charges, and (3) the volume of the Internet traffic.

Most of the mentioned indicators influence RENs. Some indicators correspond to topics that were already discussed in previous sections. The infrastructure indicators and the second policy indicator (the tariffs) are similar to the characteristics of telecommunication services and the Internet access service.

The access indicators characterize the attitude of the population towards the Internet, which is often seen by many end users of RENs as the main attraction and incentive to use RENs. Most end users of RENs do not even make a distinction between the Internet and the REN through which they access the Internet, so that the REN is for them only the medium for accessing certain Internet websites, for example.

The number of ISPs in a country is often taken to be an index of market liberalization. Due to the competition between the REN and the ISPs, this indicator influences marketing strategy of the REN and its charging policy.

The volume of the Internet traffic reflects the usage of the Internet. This indicator reflects not only the volume of incoming and outgoing traffic through all the links which cross the borders of a certain country or region, but also the internal traffic among the networks that make up the domestic Internet segment. Such volumes have direct implications on the load of the REN's links and its usage patterns.

The amount of content (information resources) available within the country is an additional indicator which can be used to assess the level of the Internet development in a country or region. This indicator refers to the number of websites and their informational volume, which is typically measured in megabytes. It can be estimated by analyzing the statistics of the Internet search engines – robots which constantly browse Internet websites and index their content. This indicator has a direct influence on the capacities of communication links and therefore the expenditure of the REN. For example, peering links are usually far less expensive than international links.

2.8.6 Regulatory framework

There are two important areas within the legislative basis of a country which strongly influence RENs: the national ICT policy, and the regulatory basis for the telecom liberalization.

The national ICT policy plays a significant role for the RENs and gives the regulatory basis for their further growth and development. RENs must be given an essential place in the national ICT policy, which would ensure that the state has long-term commitment to support RENs politically and financially.

The regulatory basis for the telecom liberalization has direct implications on the capacity, the availability and the price of telecommunication services. In the liberalized markets, the competition creates a better environment for the development of the telecom infrastructure, which implies the growth of the capacity, the extension of the availability, and the lowering of prices. Therefore, RENs obviously benefit from telecom liberalization. While in most European countries the telecom market is already liberalized, in many other countries this is not yet the case.

2.9 Conclusion

This chapter gave insight into the existing knowledge about the RENs and their management. It demonstrated that the phenomenon of RENs has different sides, including technological, organizational, and financial ones. Firstly, RENs are a technological phenomenon consisting of various kinds of hardware and software, providing useful services to users. Secondly, RENs are an organizational phenomenon requiring a proper organizational structure in which the REN operator plays a particularly important role. The organizational nature of RENs is also evidenced by the fact that RENs are computer networks connecting organizations. Finally, RENs are the economical and financial phenomenon requiring proper funding and cost-recovery mechanisms.

This chapter is the answer to the first research question *"What are the relevant topics associated with RENs and their management?"*, see section 1.3. The content of this chapter was also partially presented in [Gal99].

Because this chapter was based on a purely practical approach, it cannot be claimed to be a scientific representation of existing knowledge: it is merely a collection of topics structured in a certain way to make it easier for readers to comprehend them. The knowledge about the RENs and their management is usually presented by a number of descriptions of particular experiences and existing practices. This chapter tried to summarize such descriptions and to structure the topics which they contain.

As it is based on numerous stories written by practitioners who represent the experience with particular RENs, such a practical approach has some drawbacks and limitations. Firstly, there is no guarantee that all the possible topics were analyzed and that certain topics were not left out. Among other things this is due to the limitation of the number of data sources which were studied: it was not possible to study all the available sources. Secondly, because of the variety of interpretations of certain topics in various sources, it is difficult or even impossible to demonstrate the relationships among the topics and their mutual influence. This may lead to a fragmented perception of the knowledge about RENs and their management.

This chapter demonstrated that despite the diversity in technical, financial, organizational and policy aspects across various national situations, RENs in various countries possess similar characteristics. This enables us to assume that a common theoretical model can be developed. This is the subject of the second research question and the next chapter.

The information presented in this chapter lead one to question what the differences are between RENs and their management on the one hand and other kinds of inter-organizational computer networks and their management on the another hand (for example, networks of ISPs servicing business users, or corporate networks of multi-organizational organizations such as ING or Shell). Although the investigation of this issue was outside the scope of this research, we will give an idea of such differences. Firstly, RENs are used not only for the production/ provision of services, but also as test beds for new services and applications. Therefore, they are not only a tool for conducting research, but also a subject of research: the term 'research' in the abbreviation "REN" means that RENs are also research test beds. For that reason they can get substantial financial resources from the state and the international funding agencies. Secondly, the organizational aspects and the fact the users are involved in the management make RENs rather unique compared to other kinds of computer networks. Thirdly, the Association of Users is a body that is rarely found at other networks. Finally, RENs also have a different economical/ financial situation compared to other kinds of inter-organizational computer networks. They are often heavily subsidized by the state, especially during their start-up. Unlike commercial networks, whose aim is often to bring profit to their owners (directly or indirectly), RENs are not for profit.

Chapter 3

Conceptual model

3.1 Introduction

Chapter 2 presented an extensive overview of topics associated with RENs and their management. Although these topics can be intuitively grouped in several areas, see the ovals in Figure 3.1, the nature of these topics remains diverse and the relationships among them are hard to determine. Therefore, the topics per se cannot be considered as the model: they are merely individual phenomenons which still need to be formalized and placed in a scientific framework.

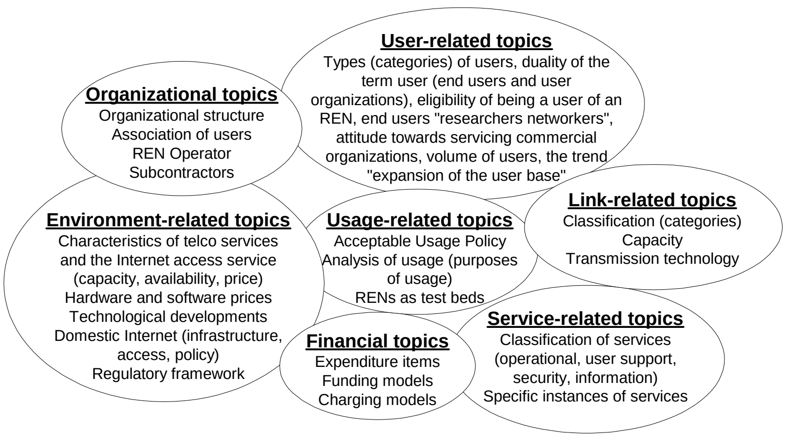

Figure 3.1: Topics associated with research and education networks (RENs) and their management.

The aim of this research is to develop a model supporting the management of RENs. The research has to produce a theoretical foundation for the management of RENs rather than a collection of facts and success stories about different RENs.

This chapter presents a model which was especially developed to fulfill this aim. This model covers the topics that were described in Chapter 2. The scientific soundness of the model is ensured by the two theoretical frameworks which it is based upon, namely the management paradigm and the entity-relationship (ER) model.

This chapter seeks an answer to the second research question *"How can we build a model that can be used to support management of both developed and developing RENs?*. It corresponds to Phase 3 of the research approach which was described in Chapter 1.

The remainder of this chapter is organized in the following way. Section 3.2 demonstrates that existing models are largely unsuitable for supporting the management of RENs. Therefore, a new model is developed in the remaining sections of this chapter. Section 3.3 presents the theoretical foundation of the conceptual model and explains an approach for its development. The remaining sections 3.4 – 3.8 describe the model itself.

3.2 Unsuitability of existing models for RENs

These days, management of computer networks (network management) is a subject receiving considerable attention in the literature and in the industry. Academic and industrial researchers have developed a number of models supporting network management. Many of these models are successfully used by various organizations worldwide.

Since RENs are essentially computer networks, some of the existing models supporting network management might also be suitable for supporting the management of RENs. In such a case, it would be unnecessary to develop a new model. Therefore, it is necessary to study the existing models before developing new ones.

Appendix A presents the results of the literature study on existing models supporting network management. It gives an overview of and compares the following models: the Looijen framework, the OSI Management framework, the Terplan framework, the TMN framework, the TMForum framework, and ITIL.

Although the Looijen framework ([Loo98], [Loo00]) was not specifically designed to support the management of computer networks, it is also included in the literature study. The Looijen framework plays a particular role in this research because it is the fundamental basis of the ongoing research programme on the management of information systems of which this research is also a part. Since computer networks may be considered as a particular kind of information systems, many parts of the Looijen framework are applicable to RENs.

The doctoral dissertation of Van Hemmen [Hem97] was an important source of information for the literature study presented in Appendix A. Van Hemmen, who was a doctorate student from the home department of this research project, compared in his dissertation several models supporting network management. The results he obtained are used in this dissertation.

Table 3.1 shows the suitability of existing models for supporting topics from Chapter 2. It demonstrates that although some models can partially reflect certain topics, no model is capable of supporting all of them. None of the existing models supports user-related, service-related, and organizational topics. Usage-related topics are partially supported by several models. Environment-related topics are supported only by the Looijen framework, and then only partly. Financial and link-related topics are supported by all models except for the OSI framework.

Topics	Looijen framework	OSI	Terplan framework	TMN	TMForum	ITIL
User-related	−	−	−	−	−	−
Link-related	±	−	±	±	±	±
Service-related	−	−	−	−	−	−
Usage-related	±	−	−	±	±	−
Organizational	−	−	−	−	−	−
Financial	±	−	±	±	±	+
Environment-related	±	−	−	−	−	−

Legend:
+ the model is suitable
± the model is partially suitable
− the model is unsuitable

Table 3.1: Suitability of existing models for supporting topics associated with RENs and their management (source: section A.4).

We used the following approach and criteria for judging the suitability of each existing model for covering the REN topics. A model is considered to be suitable if it contains references to all topics from a corresponding area (user-related, link-related, etc.). A model is considered to be partially suitable if it contains a reference to some topics from a corresponding area. A model is considered to be unsuitable if it contains no or only a few references to the topics from a corresponding area. The grade "+" (suitable), "±" (partially suitable), or "–" (unsuitable) given to each model is based on the subjective judgment of the researcher and a thorough study of each of the existing models. A detailed justification of the grades for each model is given in Appendix A, section A.4.

The results of the literature study briefly outlined in Table 3.1 and described in Appendix A allow us to conclude that the *existing models are unsuitable for supporting the management of RENs* because they cannot cover the topics associated with RENs and their management. Therefore, we developed a new model, described in the remaining sections of this chapter.

3.3 Theoretical foundation

3.3.1 The management paradigm

The management paradigm is one of the key theoretical foundations of the theory of management, control, and maintenance of information systems (MCMIS). Developed at the ICT Management department of the Delft University of Technology, the management paradigm has proven its applicability and usefulness in a number of practical situations. Due to the high level of abstraction it uses, the management paradigm is universally applicable for modelling virtually any situation involving information systems and their management. It provides a top-level view on the organization of ICT-related issues.

Because the management paradigm is based on the so-called information paradigm, let's consider the information paradigm first (see Figure 3.2). Brussaard defined the essence of the information paradigm in the following way:

> "Each set of coherent, dynamic phenomena (i.e. each dynamic system such as an organization) can be abstracted into a real system and an information system which determines the behavior of the real system" [BT80].

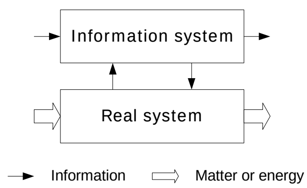

Figure 3.2: The information paradigm.

The Real System (RS) is defined as those parts or aspects of the reality that we want to investigate as a whole in order to know or eventually control them ([BT80], [Loo98]). To these ends, former, present, and also alternative future states and processes of RS have to be described. The RS can be characterized by the strategy, goals, organization structure, staff, and culture of an organization ([Hem97, p.56]).

The Information System (IS) is defined as a structured composition of hardware, associated system software, application software, data, procedures, and people for the knowledge, control, and support of a real system. As Figure 3.2 illustrates, the IS interacts with the RS and also with the outside world. It is important to understand that the behavior of the IS is determined by the RS.

Looijen introduced *the management paradigm* by adding a third system called *MCM (management, control, and maintenance)* to the information paradigm. This system was introduced by uncoupling a part of the IS that is related to the management, control, and maintenance of the IS. Figure 3.3 graphically demonstrates the management paradigm

Definition 5 ***Management of information systems*** *entails operation, control and maintenance of information systems in accordance with the requirements and preconditions imposed by the utilization, the situational factors and the characteristics of the information system's components (hardware, software, datasets, procedures, and people). Secondly, management of IS offers services in the most effective and efficient way. Finally, management of IS influences the goals of the organization in a positive way ([Loo98], [Loo00]).*

The RS, the IS, and the Management are connected by six *generic relationships*, shown as named arrows in Figure 3.3. Firstly, the RS *exploits* the IS, which means

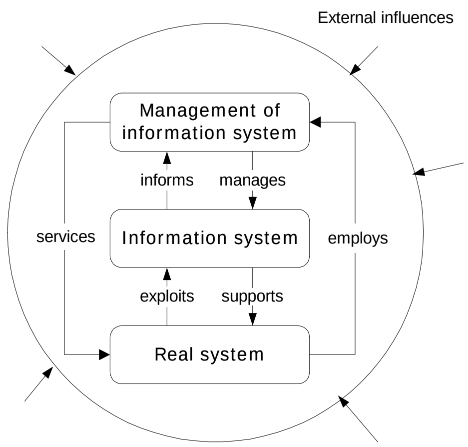

Figure 3.3: The management paradigm.

that users impose requirements on the IS and utilize its functionality. This can also be seen as an input which the RS sends to the IS expecting to get the desired output. Secondly, by responding to user requirements and processing the utilization requests from the RS , the IS *supports* the RS. This implies that the IS enhances the effectiveness and the efficiency of the activities of the RS. Thirdly, because the IS needs to be managed, controlled, and maintained, the RS *employs* the Management. For example, a company may have a separate department responsible for the ICT management. This relationship implies sending requests and incidents from the RS to the Management. Fourthly, the Management *services* the RS: it provides timely and accurate support, provides the RS with information and solutions, reacts to complaints and answers user requests. Fifthly, the Management *manages* the IS, its resources and the functionality by providing necessary operation, control, and maintenance signals to the IS. Finally, the IS gives feedback and *informs* the Management about its characteristics and the status. This implies that the IS provides the Management with the information necessary for carrying out its activities.

These six generic relationships play a significant role in the effective and efficient management of IS. Problems related to ICT in organizations can commonly be traced to breakdowns in communication between the three systems [Wan02].

The management paradigm also defines the concept of *external influences*: environmental forces affecting the RS, the IS, the Management, and the relationships between them. These forces typically have different natures such as a managerial, technical, financial, regulatory, and informational nature.

3.3.2 The Entity-Relationship (ER) model

The Entity-Relationship (ER) model is one of the most widely used methods for designing conceptual models. It is a tool for representing the reality at a high level of abstraction. Using the ER model, one can build a description of reality that is easy to understand and interpret. This section gives a brief overview of major building blocks of any conceptual model built using the ER approach.

The basic concepts provided by the ER model are entities, attributes, and relationships. *Entities* represent classes of similar real-world objects having common properties. For example, in the business of processing customer orders these objects are customers, articles, and orders. Entities normally correspond to nouns in the verbal description of a problem. They are graphically represented by means of rectangles.

Attributes represent elementary properties of entities. They carry all the extensional information. For example, a customer has a number, a name, and an address. The difference between entities and attributes depends on the purpose within a given context. For example, in a different context, addresses can be used as entities and not as an attribute of entity "customer". The association between "customer" and "address" would then be produced from a relationship. The feature that distinguishes entities from attributes feature is that entities possess attributes. Attributes, on the other hand, cannot possess entities or other attributes.

Relationships represent logical links between two or more entities. Relationships are classes of some elementary facts that relate entities. They are often expressed as verbs. Relationships are graphically represented by means of diamonds marked with the verb which connects the corresponding entities. While entities exist in isolation, relationships can only exist in combination with affected entities. Relationships are distinguished according to the number of entities linked to them, i.e., there are unary, binary and n-ary relationships.

It is not always easy to distinguish between entities and relationships, as each situation depends on the context. A guideline for distinguishing between entities and relationships is that entities, as a rule, can only be expressed by nouns; relationships, on the other hand, can only be expressed by verbs.

The decision to use entities, relationships or attributes to model some aspects of the real world is rather subtle: there are many similar schemas that model different views of the same reality. Therefore, the same reality can be described in many different ways. The same information can be represented either as an entity or as a relationship; similarly, sometimes the same information can be modelled either as an entity or as an attribute. However, similar problems arise with any data model; they are due to the difficulty of agreeing on the way how to perceive reality.

The model is meant to cover/ reflect static situations, and not dynamic transformations/ processes (see the model's objectives in Chapter 1). Therefore, only the static elements of the ER-approach were used, namely entities, attributes, and relationships. These are three basic elements of the ER-approach introduced in 1976 by Peter Chen. Although the ER-approach was later extended with procedural elements such as actions, these elements were not used in the conceptual model. This is because it appeared to be sufficient to use the aforementioned three elements for covering all the REN topics described in Chapter 2.

3.3.3 Elaborating the management paradigm using the ER model

The idea is to elaborate the management paradigm by using the ER model. This implies making a detailed description of every system of the management paradigm (the RS, the IS, and the Management of IS) and giving content to the relationships connecting these systems. A similar approach was also used by Van Hemmen in [Hem97, p.56]. The ER model is the obvious theoretical foundation for such an elaboration because it naturally suits the approach of the management paradigm. The management paradigm also uses the concept of entities and relationships, since each system of the management paradigm can be considered as an entity.

Using the approach of the management paradigm the problem area is seen as a combination of the three systems, namely the real system (RS), the network system (NS), and the management of the network system (MNS). Let us briefly describe the nature of each system.

The Real system (RS) is a composition of organizations having a need in a common network infrastructure and related services. Although the focus is placed on research and education organizations, other categories of organizations can also be part of the Real System.

The Network system (NS) is a composition of hardware, software, communication links, and network services necessary to support needs and business processes of the RS. The NS is a special kind of information system. It is important to understand that the NS does not include hardware, software, communication links and network services that are internal to user organizations. Therefore, campus networks of user organizations are not part of the NS.

The Management of the Network System (MNS) entails the operation, control and maintenance of the NS in accordance with requirements, preconditions, situational factors, and the characteristics of the NS components. Operation implies ensuring that the NS is operational, i.e. that the hardware and software resources are working properly, and the network services can be utilized. Control implies monitoring and evaluating the performance of the NS and making necessary adjustments in case the performance thresholds are exceeded. Maintenance implies making changes in the NS in response to changing requirements and preconditions. Additionally, the MNS must also offer services to the RS in the most effective and efficient way, and influence the goals of the RS in a positive way.

There are two considerations which are the basis for introducing any particular entity and relationship in the model. Firstly, every entity and its attributes should reflect topics from Chapter 2. For example, since communication links play a very significant role for RENs, they are modelled as a separate entity. Secondly, the content of an entity should correspond to the fundamental concepts of the theory of MCMIS. For example, because requirements and preconditions are vital concepts of this theory, the corresponding entities have been introduced. Similar considerations were used for choosing the relationships.

The set of attributes for each entity of the conceptual model is not fixed. This is an important feature of the conceptual model which makes it possible to adjust it to the needs of a particular situation. The attributes described in this chapter are vital for any situation, however.

3.3.4 Justification of the choice of modeling techniques

The research presented in this thesis continues the line of the doctoral projects on the management, control, and maintenance of information systems (MCMIS) that were conducted at the home department of this research. All these projects were based on the MCMIS theory – they extended and elaborated this theory, demonstrating its application in various problem areas. Because the management paradigm is a key foundation of the MCMIS theory (see [Loo98] and [Loo00]), it was also used in this research.

Besides by the mentioned relationship between this research and the MCMIS theory, the choice of the management paradigm can be justified by the fact that literature research did not yield alternative models having such a broad view on management. Due to the high level of abstraction it uses, the management paradigm is universally applicable for modelling virtually any situation involving information systems and their management.

The use of the ER-approach can be justified by the aim of this research – to formalize the knowledge about RENs and their management, and by the first objective of the model – to provide a framework for producing a description of a REN and its management (see section 1.3). The knowledge about RENs and their management was reflected in the REN topics presented in Chapter 2. All these topics are seen as certain data that needs to be modeled. Therefore, we needed a data modeling technique.

A relatively simple modeling technique such as the ER-approach had to be used to ensure that the resulting model would be understandable for people directly involved in the management of RENs, representatives of state authorities and international donor agencies, senior executives of user organizations, and other stakeholders (see the description of the stakeholders in Appendix B).

In contrast to other modeling techniques such as UML, the ER-approach is rather simple to understand and to use. The use of such complex techniques would make the model hardly usable and understandable for its intended users.

Finally, the use of other modeling techniques would not improve the conceptual model. As noted in section 3.3.2, the three elements of the ER-approach – an entity, an attribute, and a relationship – are able of capturing all the REN topics from Chapter 2. Therefore, it is not necessary to use extra elements from other modeling techniques.

3.4 Modeling the Real System (RS)

The RS is modelled by the following set of entities: User Organization, State Agency, Association of User Organizations, Business Process, End User, Need, Requirement, and Precondition. Sections 3.4.1 – 3.4.8 present these entities and their attributes. Section 3.4.9 describes the relationships among the entities.

3.4.1 User Organization

Definition 6 ***A user organization*** *is an organization that utilizes services of the NS in order to support its business processes.*

The entity User Organization covers the user-related topics presented in Chapter 2, section 2.2.1. The user is a fundamental concept of any IS including a REN, which is the instance of an IS. Typical examples of user organizations are universities, research institutes, libraries, astronomic observatories, colleges, schools, museums, public authorities, ministries, and commercial enterprises. The entity is given two attributes, namely category and size.

The category of a user organization refers to the classification of user organizations. It is usually either higher education institution, research institute, library, or public/governmental authority, or another organization. The mentioned list presents just a generalized example of possible categories: each particular REN can use a different set of categories.

The size of a user organization can be assessed by either turnover/budget, number of staff and students, number of computers in the campus network, number of departments, or the geographical dimension of the campus.

3.4.2 State Agency

Definition 7 ***A state agency*** *is a body responsible for matters concerning R&E in the geographical area where user organizations are located (country, region, or city). It is the body that provides financial and regulatory support for RENs on behalf of the state.*

The entity State Agency is introduced to emphasize the importance of the state for RENs. Chapter 2, section 2.7.2 demonstrated the significance of state support for RENs.

Financial support implies that many RENs are partially or entirely funded by the state. It is particularly important at the initial phase of the REN development, when state agencies provide significant subsidies for RENs allowing them to grow and develop. According to [Tin99], a networking policy should be an integral part of the national scientific policy.

Examples of state agencies in different countries are the Federal Ministry for Science and Research in Austria, the Federal Office for Scientific, Technical and Cultural affairs in Belgium, the Joint Information Systems Committee in UK, and the Federal Ministry for Education and Science in Germany.

3.4.3 Association of User Organizations

Definition 8 ***An association of user organizations*** *is a collection of user organizations cooperating*[1] *in the field of information and communication technologies.*

The entity Association of User Organizations was introduced for two reasons. Firstly, user organizations of RENs are typically united in such an association as shown in Chapter 2, section 2.6.3. Secondly, the attributes of this entity are meant to

[1]This definition emphasizes the fact that user organizations cooperate with each other. This fact distinguishes RENs from other kinds of computer networks such as networks of commercial service providers.

represent situational factors – an important concept of the MCMIS theory ([Loo98], [Loo00]).

This entity is given the following attributes: mission, size, organizational structure, geographical distribution, legal status, and policy.

The mission states in abstract and fairly general terms the purpose of the organization [RLW99]. For example, the SURF Foundation in the Netherlands has the following mission: "encouragement and facilitation of collaboration in the area of ICT among institutions in higher education" [SUR99]. The DFN Association in Germany has the following mission: "promotion of the creation of the scientific-technological prerequisites for the establishment, operation and use of a computer-aided information and communication system for public and non-profit research in Germany on the basis of public transmission networks considering the appropriate standards" [DFN].

The size of the association may be assessed based on the total number of member organizations, the total number of people that belong to all member organizations (the number of end users), the geographical size of the area that is covered, and the total number of computers that belong to all member organizations. This attribute allows one to compare various RENs.

The organizational structure refers to the division of tasks within the association and to the coordination among them[2]. Generic elements of the organizational structure are Management Board, Advisory Board and REN Operator.

The geographical distribution reflects the geographical scope of the REN: a city, a region, a country, or even a continent. This attribute reflects where user organizations of an REN are physically located and how the user population is distributed across the target geographical area of the REN. For example, usually the highest concentration of user organizations can be seen in cities and especially in the countries' capital.

The legal status of the association indicates whether the association is an officially registered body. For some RENs, associations are virtual bodies having no legal status. For example, user organizations of the Belgian NREN "BELNET" are not united in an association. However, because they are united under the umbrella of the Belgium Ministry of Higher Education, they can be considered as an association. Therefore, an association means here a collection of user organizations in a broad sense. Association of other RENs are officially registered bodies which sometimes even employ personnel.

The policy refers to some rules and regulations that exist within the association. For example, the statute, AUP (Acceptable Usage Policy) or the Connection Policy. The AUP or the Connection Policy regulate which organizations are eligible users. This implies that in some cases commercial companies are eligible as user organizations, while in others they are not.

Examples of associations are the SURF Foundation in the Netherlands, the DFN Association in Germany, the SAnet Association in Slovakia, the HUNGARnet Association in Hungary, and the United Kingdom Education & Research Networking Association.

This entity always has only one single instance. This is because of its very nature: to represent all user organizations.

[2] "The structure of an organization can be defined simply as the sum total of the ways in which it divides its labor into distinct tasks and then achieves coordination among them" [Min79, p. 127].

3.4.4 Business Process

Definition 9 ***A business process*** *is a set of activities (tasks) carried out in a certain order and performed to achieve a defined business outcome for a particular customer or market. It refers to the ways in which user organizations coordinate and organize their work activities, information, and knowledge to produce valuable commodities and services ([DS90], [Dav93], [LL98]).*

The entity Business Process represents the business which the RS is involved in. Business processes have received much attention in the literature, especially in the framework of business processes re-engineering (BPR) models. They are an important aspect of any organization, and provide insight into how an organization functions and its business.

Examples of business processes for target R&E organizations are research process, learning process, knowledge assessment process, admission process (enrolment of students), financial administration, and personnel administration. The instances of business processes strongly vary from organization to organization.

Various attributes can, in principle, be associated with this entity. In the literature on BPR some characteristics and properties of business processes are mentioned (see [Dav93], [DS90]) such as beginning and end points, interfaces, organization units involved (particularly customer unit), process owners. However, because the analysis and engineering of business processes are outside of the scope of this research and the presented conceptual model, no attributes are introduced for this entity. In case a more detailed description of the RS and the business processes of user organizations is necessary, such attributes can be added to the entity.

3.4.5 End User

Definition 10 ***An end user*** *is an individual that either works or studies in a user organization and utilizes services of the NS.*

The entity End User covers user-related topics from Chapter 2, section 2.2.2. The definition indicates that the number of people belonging to a user organization does not necessarily equal the number of end users within this organization. Typical instances of end users are students, teachers, researchers (scientists), technicians, clerks, and administrators. The entity is given several attributes, namely category, scientific field, and IT literacy.

The category refers to the classification of end users. Two categories of end users can be distinguished: students and staff members. Staff members can be classified into teachers (academic staff), researchers, technical support staff, and others.

The scientific field is an attribute which reflects the attachment of end users to different areas in which they receive education or conduct scientific research. Traditionally the use of computer communication facilities has been limited to the physical sciences such as high-energy physics, astrophysics, computer science, and crystallography. However, new user groups are emerging from the fields of social sciences and humanities.

IT literacy implies the extent to which an end user possesses computer literacy and experience, including networking literacy. This attribute is closely related to the awareness of the benefits that networks can bring in order to satisfy the needs of end user.

Obviously, it is hardly possible to describe each particular instance of this entity, because of the very high quantity of instances: user populations of an REN are typically measured in hundreds of thousands.

3.4.6 Need

Definition 11 ***A need*** *is a condition of the end user marked by a lack of something wanted or deemed necessary. It also refers to a necessary duty, or an obligation of the end user [Fle87].*

Where business processes give insight into the activities of user organizations, needs give insight into the activities of end users. Needs reflect the underlying reasons why end users utilize the NS. For example, end users may need to find certain information, to access/download found information, to publish papers, to disseminate research results on conferences, to communicate with colleagues, or to process data.

The entity Need covers a remarkable topic discussed in Chapter 2, section 2.5.2, namely the purposes of usage. It appears that RENs are often used for entertainment and leisure purposes. Therefore, it might be important for RENs to study activities that are undertaken by end users, and, if necessary, to prohibit the use of the network services for leisure/ entertainment purposes.

In order to reflect the purposes of usage, the entity Need is given an essential attribute – *nature*. This attribute refers to the division of needs into professional needs and private needs. Professional needs are caused by business processes; they form the essence of the professional activities of end users. Therefore, professional needs are closely related to business processes. Private needs, on the other hand, do not relate to professional activities of end users. For example, one needs to communicate with his friends/ relatives, to read latest news, to listen to the music, to do shopping, to book tickets, and to access all kinds of information. Private needs therefore often have a leisure or entertainment nature.

Professional needs of end users of RENs are influenced by many factors, highlighted in [ETA99, p.17]:

> "ICT introduce a new culture among scientists, marked by increased collaboration, increased openness and bigger exchanges with the rest of society. Digital technology allows for Science to enter the media faster and indeed in an autonomous way. Dialogue and interaction with the public are increased and under certain circumstances public involvement in large coordinated scientific efforts becomes feasible. Links with education systems are enhanced and new opportunities emerge for a better integration between research and education. Scholarly publishing, gains a new edge, as technology allows a new approach for getting across the scientific message. Peer review is enhanced and can conceivably be democratically structured. Links with industry are improved and their pace accelerated. There appear to be more opportunities for innovative and creative work than before, as people are not confound to their physical laboratories for work but can join virtual collaborates over the networks".

3.4.7 Requirement

Definition 12 ***A requirement*** *refers to the assortment and the characteristics of services*[3] *required by the users*[4]*.*

Requirements are a fundamental concept of the MCMIS theory. They are also called user requirements, and specify with which parameters information systems have to comply. Looijen gives the following examples of requirements of the information systems: availability, compatibility, security, continuity of data processing and information management, flexibility, performance, and reliability [Loo98].

As indicated by the above-given definition, two aspects of services are essential for determining requirements, namely the assortment of services and their characteristics. The assortment refers to the range and variety of the services. Some services are usually considered standard services such as the transmission/ connectivity service, the Internet access service, and the domain name service. Other services are less standard, such as videoconferencing and consultancy.

The characteristics of services refers to the properties of services. Such characteristics are, for example, the response time of a web site, the maximum allowed mean time between failures of a transmission service, the maximum allowed latency time of the Internet access service, and the minimum transmission speed of the Internet access service.

It is important for the management of a REN to know the user requirements well. According to the MCMIS theory, the management of information systems must be based on user requirements.

3.4.8 Precondition

Definition 13 ***A precondition*** *is a restrictive (limiting) condition which is laid down at the management level of the association of users, the user organizations, or the state agencies*[5]*.*

Like requirements, preconditions are a fundamental concept of the MCMIS theory. Laid down at the management level of the corresponding organization, they put certain limits on the user requirements. Looijen gives the following examples of preconditions: (de)centralization of activities, (de)concentration of hardware and software, constrains of financial resources (approved budget), hardware and software supplier-lines, personnel allocation, and standardization directives [Loo98].

It is important for the management of a REN to know and understand preconditions. According to the MCMIS theory, management of information systems must be based on preconditions.

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[3]Services imply here not only the network services described in section 3.5.1, but also the management services presented in section 3.6.3.

[4]This definition is made by applying the definition from [Loo98] within the problem area of this research.

[5]This definition is made by applying the definition from [Loo98] within the problem area of this research.

3.4.9 Relationships among entities of the RS

The entities of the RS described in the preceding sections do not exist in isolation; they are strongly related to each other by means of the relationships. Based of our exploration of the problem area in Chapter 2 and the MCMIS theory, we introduce thirteen relationships among the entities of the RS, see Table 3.2.

`r1`	Precondition limits Requirements
`r2`	User Organization defines Requirements
`r3`	End User defines Requirements
`r4`	User Organization formulates Preconditions
`r5`	End User has Needs
`r6`	End User belongs to User organization
`r7`	End User is involved in Business Processes
`r8`	Business Process causes Needs
`r9`	User Organization executes Business Processes
`r10`	User Organization is a member of Association of Users
`r11`	State Agency formulates Preconditions
`r12`	State Agency participates in or patronizes Association of Users
`r13`	Association of Users formulates Preconditions

Table 3.2: The relationships among entities of the real system.

The relationships are also shown in Figure 3.4 as diamonds containing verb phrases that represent the content of the relationships. In order to indicate referencing relationships, each of them is marked with a letter `r` and a number. Arrows connecting entities and relationships are used to indicate the direction in which each relationship should be read. Let us now describe the necessity and the content of each relationship.

Most relationships among the entities of the RS are obvious and originate from the very definition of entities and the MCMIS theory. The relationship `r1` reflects the fundamental link between requirements and preconditions, namely that preconditions put some restricting conditions on user requirements.

The relationships `r2` and `r3` reflect an evident link between requirements and users. They demonstrate there are two kinds of requirements: those formulated by end users, and those formulated by user organizations. Requirements of user organizations are typically expressed in terms of well-defined parameters. Requirements of end users are normally less professional and are usually expressed as, for example, "end user requires browsing Internet websites with a decent speed".

The relationships `r4`, `r11`, and `r13` reflect the definition of preconditions. They demonstrate that user organizations, the association of users, and state agencies each have their own preconditions.

The relationships `r5` demonstrates an evident link between end users and needs, namely that every end user has some needs. The relationship `r6` implies that an end user always belongs to a user organization. Individuals who do not belong to user organizations are not considered in the conceptual model. For various categories of end users `r6` can also be read in different ways. For example, for students this relationship would be "End User studies in User Organization", for other categories of end users it would be: "End User works in User Organization".

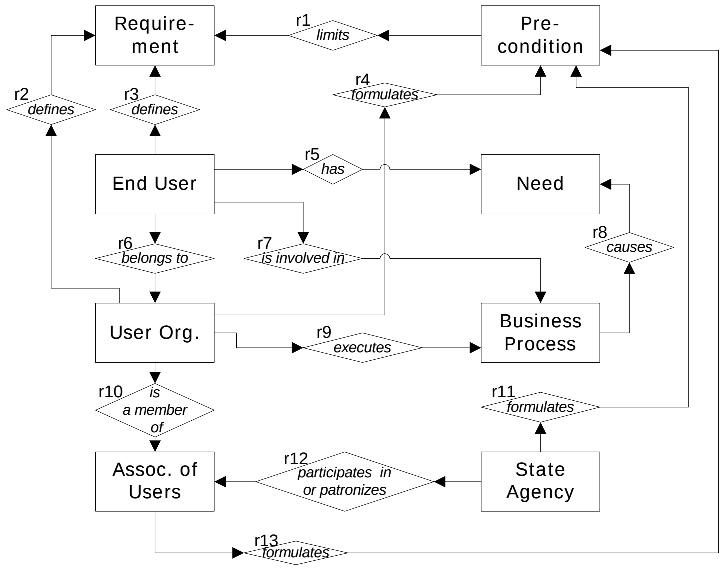

Figure 3.4: The model of the real system.

The relationship `r7` reflects the fact that end users participate in carrying out business processes. For example, teachers and students participate in educational processes, and scientists participate in research processes.

The relationship `r8` implies that some needs appear as a result of carrying out business processes: such needs were classified as professional needs. Therefore, `r8` can also be formulated as "business process causes professional needs". For example, a learning process causes students to need finding and accessing books.

The relationship `r9` reflects an evident link between user organizations and business processes, namely that the former execute the latter. Each user organization may have own peculiarities in its business processes.

The relationship `r10` basically reflect the definition of the entity Association of Users and demonstrates the obvious fact that such an association is composed out of the user organizations.

The relationship `r12` shows that state agencies are often participate in the Association or patronize their activities. This implies that the representatives of state agencies may, for example, participate in the management board of the Association.

3.5 Modeling the Network System (NS)

The NS is modelled by the following set of entities: Network Service, Communication Link, Hardware Resource, Software Resource, and Network Node. Sections 3.5.1 – 3.5.5 present these entities and their attributes. Section 3.5.6 describes the relationships among the entities.

3.5.1 Network Service

Definition 14 ***A network service*** *is a collection of capabilities that are beneficial for users, where each capability is performed by corresponding hardware and/or software resources in response to user requests*[6].

Network services reflect the users' view of a REN. They represent the functionality of the NS which users of any information systems are primarily interested in. Users are typically not interested in the remaining entities of the NS.

Network services are closely related to user requirements. While user requirements represent the demand, network services represent the supply. As in any business, the aim is to match the supply with the demand, or, in other words, to provide the required assortment of services having the required characteristics. Examples of network services are the transmission service, the messaging service, the Internet access service, the news service, the domain name service, and the IP multicast service.

The entity Network Service covers the service-related topics from Chapter 2, section 2.4. It is given the following attributes: service level and costs.

The service level is a complex attribute reflecting certain qualities of a service expected by users. It is the actual representation of user requirements. The assessment of this attribute implies measuring various indicators such as availability, mean time between failures, latency, transmission speed, and other technical parameters that are specific for network services. The availability is a particularly important indicator: it is the time that the service is available divided by the time when it is scheduled to be available.

The costs is the attribute expressing monetary expenditure paid by the MNS for the acquisition of a service from the external provider. This attribute implies that network services can in fact be divided into two kinds: services produced by the MNS, and services purchased from external providers. For example, the Internet access service is always purchased from some ISPs; transmission services such as ATM or Frame Relay are provided by telecoms.

3.5.2 Communication Link

Definition 15 ***A communication link*** *is a set of hardware that allows transmission of data. It includes physical transmission medium (copper, fiber, electromagnetic waves) and all related equipment (modems, switches, repeaters, signal amplifiers, satellite dishes, etc.) [Cis], [IBM].*

Communication links are a fundamental concept of any computer network. By transmitting the data over the network, they support an important part of the network services – the data transmission services. Examples of communication links are leased lines, digital channels, Ethernet links, Frame Relay links, ATM links, and satellite links.

The entity Communication Link covers link-related topics from Chapter 2, section 2.3. It is given the following attributes: category, capacity, transmission technology, scale, and costs.

[6] This definition is made by applying the definition from [CGH96] within the problem area of this research.

The category refers to the classification of communication links. The top level of the classification is the division of links into national and international links. Further, national links are divided into backbone, user access and peering; international links are divided into European and internet links.

The capacity is the maximum transmission speed of a link measured in bits per second (bps). It is often expressed in kilo-, mega- and gigabits per second, abbreviated to Kbps, Mbps, Gbps. The capacity of the links of most RENs increases rapidly.

The transmission technology defines among other things the medium that is used to transmit electronic signals and the way in which the data is encoded and transmitted over the links (the transmission protocol). Transmission technologies such as ATM, WDM, FDDI, and SDH/POS are the most popular and promising technologies nowadays.

The scale reflects the relative size of the geographical area covered by a communication link. The scale of point-to-point communication links reflects a distance between the links' end points. This attribute is defined as having three values, namely long-distance, city, and local. Long-distance links connect network nodes located in different cities which are many kilometers away from each other. City-wide links connect network nodes within the borders of a city and span distances of several kilometers. Local communication links connect network nodes within the building or campus and span distances of hundreds meters.

The costs of communication links are divided into procurement and recurrent costs. Procurement costs include costs of ordering communication links from telecoms, and costs of purchasing related equipment such as modems, switches, and satellite dishes. Procurement costs are typically incurred only once when a link is established. Unlike procurement costs, recurrent costs are paid on a regular basis – usually monthly. Recurrent costs of communication links – also called connectivity costs – are usually a predominant item in the budget of every REN.

3.5.3 Hardware Resource

Definition 16 ***A hardware resource*** *is a part of the machinery and equipment [Com].*

Hardware resources are an integral part of the NS; together with communication links and software resources they form the basis for network services. Two types of hardware resources are distinguished, namely communication equipment and network servers. Instances of communication equipment are routers, switches, modems, and hubs. Routers are a particularly important instance of communication equipment, designated to interconnect and to terminate communication links, and to direct the flow of data in the network. The transmission services of RENs are based upon routers.

Network servers are computers dedicated to support one or more network service(s). To serve this purpose, they always need some software resources installed. Network servers are usually named after the service which they support. Typical instances of network servers are the mail server, the DNS server, the web server, and the news server.

The entity Hardware Resource reflects financial topics from Chapter 2, section 2.7.1. It is given the following attributes: capacity and costs.

The capacity of a hardware resource has different meanings depending on the resource's type. The capacity of communication equipment implies the quantity of interfaces, the bandwidth of each interface, and the memory size. The capacity of network servers implies the storage capacity of the server disks, the memory size, the CPU clock frequency, and the number of instructions processed per second.

The costs of a hardware resource are divided into procurement and recurrent costs. Procurement costs are a vital part of the development and innovation costs. They are particularly significant at the initial phase of the REN development, but also at later phases when hardware needs to be upgraded. Unlike procurement costs, recurrent costs are paid on a regular basis, and their most significant part is the depreciation expenses. Maintenance and energy costs are other examples of recurrent costs.

3.5.4 Software Resource

Definition 17 ***A software resource*** *is a set of computer instructions (programs) for directing the operation of hardware resources and/or processing the data ([Col02], [Net]).*

Software resources are an integral part of the NS; together with communication links and hardware resources they form the basis of network services. Two types of software resources are distinguished, namely operating systems and service-support software. Usually an operating system such as BSD, Solaris, Cisco IOS, or Linux is the main control program of a network server or router which schedules tasks, manages storage, and handles communication with peripherals. It presents a software platform for other software resources, including the service-support software.

The service-support software is the application software which runs on top of the operating system and provides the functionality of network services. For example, the software resource "Squid" provides the functionality of the web caching service; the software resource "BIND" (Berkeley Internet Name Daemon) provides the functionality of the domain name service.

The entity Software Resource reflects financial topics from Chapter 2, section 2.7.1. It is given the following attributes: status and costs.

The status of software resources can be either commercial, freeware[7], or shareware[8]. This attribute has two implications. Firstly, the status of a software resource influences the way in which this resource is managed by the MNS. Unlike commercial software, which is heavily supported by its suppliers, freeware software comes with no guarantee and relies on the philanthropic efforts of the people who developed it. Nevertheless, freeware software resources are successfully used by many RENs. Secondly, the status directly relates to the costs of software resources.

The costs of software resources are divided into procurement and recurrent costs. Procurement costs are a vital part of the development and innovation costs. They are

[7]Freeware is copyrighted software given away for free by its author(s). This software usually comes as result of philantropic efforts of a group of enthusiastic people.

[8]Shareware is software delivered free of charge, but its author usually asks users to pay a small fee if they like the program and use it regularly.

particularly significant at the initial phase of the REN development, but also when the software needs to be upgraded. Unlike procurement costs, recurrent costs are paid on a regular basis in the form of licences and support costs.

3.5.5 Network Node

Definition 18 ***A network node*** *is a site where hardware resources are physically located.*

The entity Network Node is introduced with the goal to represent the topology of RENs. The topology of RENs is a topic which was discussed in Chapter 2, section 2.3. It is the physical or logical arrangement of network nodes, especially the relationships among the network nodes and communication links that connect those nodes.

Two categories of network nodes are typically distinguished, namely backbone nodes and access nodes. Backbone nodes are the termination points for backbone communication links. Backbone nodes host hardware resources which perform bulk processing of network traffic and user requests for services. High-performance routers and network servers are located at backbone nodes.

Access nodes are the termination points for user-access links. They usually host routers having many interfaces for connecting user organizations. Access nodes are connected to backbone nodes via high-capacity communication links.

3.5.6 Relationships among entities of the NS

The entities of the NS described in the preceding sections do not exist in isolation; they are strongly related to each other by means of relationships. Three relationships are introduced among the entities of the NS, see Table 3.3.

`n1`	Network Service is based on Software Resources, Hardware Resources, and Communication Links
`n2`	Hardware Resource is located in Network Node
`n3`	Network Node is connected to Network Node via Communication Link

Table 3.3: The relationships among entities of the network system.

The relationships are also shown in Figure 3.5 as diamonds containing verb phrases that represent the content of relationships. In order to indicate referencing relationships, each of them is marked with a letter `n` and a number. Arrows connecting entities and relationships indicate the direction in which each relationship should be read. Let us now describe the content of each relationship.

The relationship `n1` reflects the fundamental dependence among network services, hardware resources, communication links, and software resources. It implies that these entities cannot exist without each other. Hardware is useless without software, software always runs only on hardware, and network services are dependent on the first two by definition.

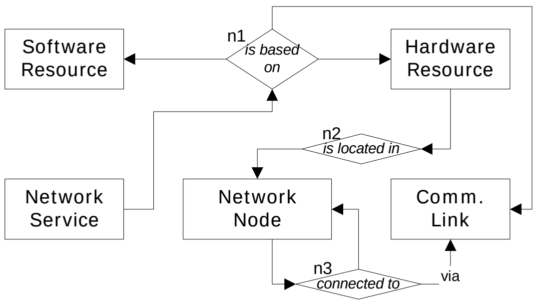

Figure 3.5: The model of the network system (NS).

The relationship `n2` reflects the definition of network nodes by showing that network nodes are sites where hardware resources are located. The relationship `n3` represents the network topology.

3.6 Modeling the Management of the NS (MNS)

According to the MCMIS theory, management of information systems can be viewed from the following four points of view, namely the systemological, infological, technological, and datalogical points of view. The systemological point of view posing the question 'why?' concentrates on the management goals; it is represented by the corresponding entity of the MNS. The infological point of view posing the question 'what?' concentrates on the contents of management and is represented by entities Management Task and Management Service. The technological point of view posing the question 'with what resources?' concentrates on the material, personnel, and financial resources; it is represented by entities Management Tool, Manager, and Financial Resource. The datalogical point of view posing the question 'how?' concentrates on the organization of management; it is represented by the entity Management Body and by various relationships among entities of the MNS.

The MNS is modelled by the following set of entities: Management Goal, Management Task, Management Service, Management Tool, Manager, Financial Resource, and Management Body. Sections 3.6.1 – 3.6.7 present these entities and their attributes. Section 3.6.8 describes the relationships among the entities.

3.6.1 Management Goal

Definition 19 ***The management goals*** *are:*
- to operate, control and maintain the NS in accordance with requirements, preconditions, attributes of the RS components, aspects of the external environment, and attributes of the NS components;
- to offer services in the most effective and efficient way;
- to influence goals of user organizations in a positive way [Loo98], [Loo00].

The first management goal reflects the very nature of management, which is operation, control, and maintenance of the NS. Operation implies ensuring that the NS is operational, i.e. that hardware and software resources are working properly, and the network services can be utilized. Control implies monitoring and evaluating the performance of the NS and making the necessary adjustments in case the performance thresholds are exceeded. Maintenance implies making changes in the NS in response to changing user requirements and management preconditions.

The second management goal implies that network services and management services must be provided efficiently and effectively. Efficiency implies the capacity to produce desired results with a minimum expenditure of material, personnel and financial resources. Effectiveness means the ability to offer services on a level which matches expectations.

The third management goal implies that management goals must be adjusted to the goals of the RS, and to goals of user organizations in particular. It demonstrates that the MNS positively influences the RS, improving certain parts of it.

The three management goals are reflected in the remaining entities of the MNS.

3.6.2 Management Task

Definition 20 ***A management task*** *is an activity or an action aimed at achieving management goals.*

Various definitions and classifications of management tasks are given in the literature such as in [dJL99], [McG84], [Ter92], [Ter95], and [Loo98].

The basic framework used in many models supporting network management is the Management Framework of the OSI Basic Reference Model [OSI89]. It defines five management functional areas, namely performance management, fault management, configuration management, accounting management, and security management. Let us briefly outline each area.

Performance management includes tasks required to continuously evaluate principal performance indicators of network operation, to verify how service levels are maintained, to identify actual and potential bottlenecks, and to establish and report on trends for management decision making and planning.

Fault management encompasses fault detection, isolation and correction of abnormal operation of the network. It includes tasks to maintain and examine the error logs, to accept and act upon error detection notifications, to trace and identify faults, to carry out sequences of diagnostic tests, and to correct faults.

Configuration management identifies, exercises control over, collects data from and provides data to the network for the purpose of preparing for, initializing, starting, providing for the continuous operation of, and terminating interconnection services. It includes tasks to set the parameters that control the routing operation of the network, to associate names with managed objects, to initialize and close down managed objects, to collect information on demand about the current condition of the network system, and to change the configuration of the network.

Accounting management includes functions to inform users of costs incurred or resources consumed, functions to set accounting limits and tariff schedules associated with the use of resources, and functions to combine costs when multiple resources are invoked to achieve a communication objective.

Security management is aimed at supporting the application of security policies by means of functions which include the creation, deletion and control of security services and mechanisms; the distribution of security-relevant information; and the reporting of security-relevant events.

The ITU-T M.3400 Recommendation "TMN management functions" [TMN00d] provides a detailed realization of the OSI Management Framework. This framework can be used for specifying management tasks in detail. The M.3400 Recommendation defines a number of management functions which can be considered as management tasks (see Appendix A, Figure A.7 and Figure A.8). For the same purpose, however, other frameworks can also be used, such as the Terplan framework, the TMForum framework, or ITIL.

3.6.3 Management Service

Definition 21 ***A management service*** *is a result of carrying out management tasks and is perceived as a service by users.*

Many management tasks are hidden from users. Users are hardly interested in which way, for example, the routing design is accomplished, or how the software resources are installed and maintained. Similarly, it is of little concern for end users how hardware resources are purchased, and in which way the budget is managed.

There are, however, a number management tasks which users often value and perceive as a service. For example, users want to know how much traffic they transmitted, or what the level of congestion of the network is. They also need help when faults or problems occur. Such issues are often handled by the help desk, whose activities also consist of a number of management tasks.

Examples of management services are the fault handling service, the network status information service, the naming domain administration service, the customer service, the provision of documentation, the training, the technical assistance, the security monitoring service, and the charging/billing service.

The introduction of the entity Management Service allows one to get a different view at the classification of services presented in Chapter 2, section 2.4. This classification divided all services provided by RENs into four categories, namely operational, user support, security, and information services. It was made intuitively on the basis of an empirical approach and the functional division of services. In contrast, the division of services into network services and management services was made on the basis of the conceptual approach suggested by the management paradigm.

Similarly to network services, management services are characterized by two attributes, namely *service level* and *costs*. The meaning and the content of these attributes are similar to corresponding attributes of network services.

3.6.4 Management Tool

Definition 22 ***A management tool*** *is a composition of hardware and software resources used to perform, support and/or automate management tasks.*

Although management tools are composed of hardware and software resources, they do not belong to the NS. The following rule can be applied to determine whether a resource is part of the NS or a management tool: if this resource supports the functionality of network services, it is a part of the NS; otherwise, it is a management tool.

Nevertheless, it is sometimes difficult to make a clear separation between management tools and hardware/ software resources of the NS. For example, a network service can be the basis of both network and management services[9]. Such resources then appear two times in the model: the first time as hardware/ software of the NS, and the second time as management tools.

Typical examples of management tools are the system monitoring tool "syslog", web server checking tools, disk space guards, uptime and CPU usage monitors, HP OpenView, and Cisco Works, and the MRTG (multi purpose traffic grapher), a specialized software package used to monitor the status of communication links. Desktop computers running Windows and Microsoft Office are also management tools. Such computers may, for example, be used by managers of a REN for accessing network servers remotely. Applications supporting accounting management and running on such computers are also examples of management tools. Regular telephones are also management tools, since they facilitate the communication among managers, and also among managers and users.

The entity Management Tool is given a single essential attribute, namely the *costs*. The meaning and the content of this attribute are similar to the corresponding attribute of the entities Hardware Resource and Software Resource.

3.6.5 Manager

Definition 23 ***A manager*** *is a person who performs carries out and/ or controls management tasks, and delivers management services to users.*

The entity Manager represents the importance of human participation in the MNS. The availability of qualified personnel is ultimately important for the efficient and effective management of RENs.

Unlike the generally accepted meaning of the word "manager" as a person who manages other people and, therefore, has subordinates, here its meaning primarily is someone who manages hardware and software resources of the NS. Therefore, typical instances of this entity are network technicians, system administrators, network engineers, network designers, and help desk employees. This entity also includes supporting personnel such as director, administrator, and bookkeeper.

This entity is given the following attributes: education, competence, and salary.

Education refers to the schooling which a manager has received, such as university or high-school education, specialized courses, and seminars. It is important for managers to receive continuous education and training in order to keep pace with rapidly

[9] Consider an example of a network server which runs under the Unix operating system. Firstly, it acts as a web caching server by running the service-supporting software resource "Squid". Therefore, this server supports the web caching service. Secondly, it is also used for monitoring the network traffic by constantly requesting the status of interfaces of backbone routers. Therefore, this server also supports the management task "usage measurement".

evolving technologies. It is important to know the value of this attribute since the execution of certain management tasks may require specific knowledge.

A competence is a set of behavioral possibilities which enables a person performing a function to act effectively [Loo00, p. 47]. Looijen mentioned the following competencies: accuracy, customer-focused, communication, cooperation, coaching, systematic work, stress-tolerance, quality-focused, responsibility, and analytical capacity [Loo00, p. 47].

Salary refers to all financial means which a manager receives for carrying out his duties. The sum of the values of this attribute for all managers refers to the total staff costs, which is an important expenditure item of the REN budget.

3.6.6 Financial Resource

Definition 24 ***A financial resource*** *is any financial means used to cover the costs of hardware resources, software resources, communication links, network services, managers, or management tools.*

The entity Financial Resource represents topics related to the income of RENs. There are two major sources of income for RENs, namely users and funding agencies. Funding agencies are further divided into state agencies and other domestic or foreign organizations which are often referred to as donor agencies. State agencies are represented by a corresponding entity of the RS. Donor agencies are represented in the conceptual model via the entity External Party.

There can be basically three instances of financial resources, namely donor grants, state subsidies, and user fees. These instances correspond to three sources of funding: donors, state, and users. The entity is given the following attributes: frequency and size.

The frequency refers to the fact that some financial means are available as a one-time subsidy or grant, others are secured on a regular basis such as user fees (for example, every month or every year).

The size refers to the monetary value of a financial resource; it is typically expressed in U.S. dollars, Euros, or another currency.

3.6.7 Management Body

Definition 25 ***A management body*** *is an organization that executes management tasks and provides network and management services.*

The entity Management Body covers an important organizational topic discussed in Chapter 2, section 2.6.1, namely the REN Operator. For many RENs this entity has a single instance, which implies that all services are provided by the REN Operator. Such a body is responsible for the daily operation of the REN and the provision of network and management services. A management body is either a subdivision of a user organization, a state agency, or a separate legal entity.

Examples of management bodies are SURFnet ltd in the Netherlands, UKERNA ltd in the UK, Vienna University in Austria, and the Service Support Team in Belgium.

Additionally to the REN Operator, there can be other organizations involved in the management of the REN. In Chapter 2, section 2.6.2 such organizations were called subcontractors. They can be considered as a management body, and, therefore, placed in the MNS. Alternatively, some subcontractors can be considered as external parties and be placed outside the MNS. The following rule should be used here: if a subcontractor is a user organization or an subdivision of a state agency, it is a management body. Otherwise, such a subcontractor is an external party, and it should be represented by the corresponding entity.

The entity is given the following attributes: size, category, and organizational structure.

The size of a management body can be assessed based on either the turnover/ budget, the number of staff members (managers), or the number of departments.

The category refers to the legal form of the management body, and is usually either a company, user organization, or a subdivision of a state agency. Situations in which the management body is a subdivision of a user organization seem to be particularly remarkable because such organizations are represented two times in the model: the first time in the RS, and the second time in the MNS.

The organizational structure is the sum total of the ways in which the management body divides its labour into distinct tasks (management tasks) and then achieves coordination among them [Min79]. This attribute demonstrates that the way in which the management body organizes its activities influences the MNS to a large extent. It also shows that business activities of management bodies are directly related to management tasks.

3.6.8 Relationships among entities of the MNS

The entities of the MNS described in the preceding sections do not exist in isolation; they are strongly related to each other by means of relationships. A number of relationships are introduced among the entities of the MNS, see Table 3.4.

`m1`	Manager is responsible for Management Tasks
`m2`	Manager uses Management Tools
`m3`	Manager belongs to Management Bodies
`m4`	Financial Resource covers the costs of Managers and Management Tools
`m5`	Management Body executes Management Tasks
`m6`	Management Body provides Management Services
`m7`	Management Tool supports or automates Management Tasks
`m8`	Management Service is based on Management Tools
`m9`	Management Service is derived from Management Goals
`m10`	Management Service is a result of carrying out a sequence of Management Tasks
`m11`	Management Task is derived from Management Goals

Table 3.4: The relationships among entities of the management of the network system.

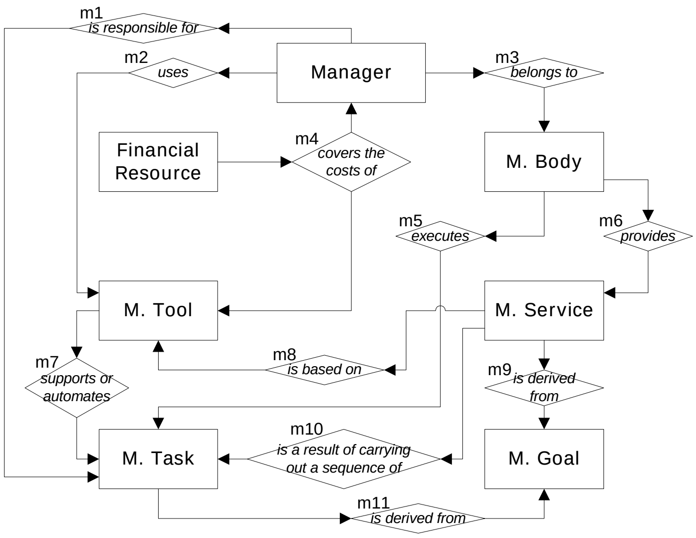

Figure 3.6: The model of the management of the network system (MNS).

The relationships are also shown in Figure 3.6 as diamonds containing verb phrases that represent the content of relationships. In order to indicate referencing relationships, each of them is marked with a letter `m` and a number. Arrows connecting entities and relationships are used to indicate the direction in which each relationship should be read. Let us now describe the content of each relationship.

The relationship `m1` demonstrates that management tasks are controlled or performed by people. Each manager usually has a list of tasks and responsibilities comprising his work profile. It is important to demonstrate the content of this relationship in order to get insight into how management tasks are attached to managers, and what the position of each manager is.

The relationship `m2` points out that management tools do not operate by themselves, but are utilized by managers. Only their utilization by people makes them useful. This relationship reflects the auxiliary nature of management tools. The relationship `m3` indicates that managers do not work in isolation from the organizations they belong to – management bodies. The relationship `m4` is an obvious relationship reflecting the definition of the entity Financial Resource.

The relationship `m5` shows the division of management tasks among management bodies. For example, many security management tasks are often performed by a special team, called the Computer Emergency Response Team (CERT).

The relationship `m6` is an obvious relationship which reflects the definition of the entity Management Body. Its content reflects the division of management services among management bodies: what management bodies provide which services. The relationship `m7` is an obvious relationship which reflects the definition of the entity Management Tool. It shows which management tasks are supported by management tools. Tasks which are not supported by tools can be considered as candidates for support or automation. The relationship m8 indicates that management tools are also related to management services. Because services are based on tasks which in their turn are supported by tools, services can also be considered as being supported by tools.

The relationships m9 and m11 indicate that management goals are the fundamental starting point for management tasks and management services. Originating from the MCMIS theory, this relationship plays an important role for the conceptual understanding of the MNS. The relationship m10 reflects the definition of the entity Management Service. Its content indicates how management services are dependent on the management tasks.

3.7 Modelling generic relationships

According to the management paradigm, the real system, the information system, and the management of the information system are interconnected by six generic relationships. Arrows connecting these systems in Figure 3.3 graphically represent these relationships. This section divides these generic relationships into a number of relationships connecting the entities described in sections 3.4 – 3.6. Because these relationships cross the borders of the systems (RS, NS, MNS), they are referred to as *intersystem relationships*.

Intersystem relationships are divided into fourteen relationships, see Table 3.5. These relationships are also graphically presented in Figure 3.7 as diamonds containing verb phrases representing the content of relationships[10].

3.7.1 RS exploits NS

There are three relationships representing the generic relationship of the management paradigm "RS exploits NS", namely e10, e11, and e12. Below we describe the content of these relationships.

The relationship e10 represents the definition of the entity Requirement. It reflects the importance of user requirements for the exploitation of the NS by the users. It shows that users are primarily interested in network services, and not in hardware resources, software resources, or communication links. It also emphasizes the importance of two aspects of network services, namely their characteristics and the assortment.

The relationship e11 reflects the utilization of network services by end users. For example, end users browse the Internet, send and receive E-mail messages, read the latest network news, download files from file archives, and participate in videoconferences. This relationship can be practically expressed using different utilization indicators. Such indicators are the number of visited web sites, the volume of downloaded web pages, the number and the size of E-mail or news messages, the number

[10] Relationships e3, e5, e6, and e7 are illustrated on Figure 3.7 in a simplified way. Arrows originating at the relationships' diamonds go only until the border of the NS and not until the entities' reactangles. This is done to save space and the simplify the reading of the figure. In fact, the diamonds of these relationships must be connected to all depicted entities of the NS, except for the entity "network node".

	Relationship among entities of RS, NS, and MNS	Generic relationship
e1	Management Body is a subdivision of State Agency or User Organization	MNS services RS
e2	User Organization or State Agency provides Financial Resources	RS employs MNS
e3	Financial Resource covers the costs of the Network System (Hardware Resources, Software Resources, and Communication Links)	MNS manages NS
e4	Management Body provides Network Services to User Organizations	MNS services RS
e5	Management Goal is based on the characteristics of the Network System, Requirements, Preconditions, and the attributes of the Association of Users	NS informs MNS, RS employs MNS
e6	Management Task is related to Hardware Resources, Software Resources, and/or Communication Links	MNS manages NS
e7	Network System reports to Management Tasks	NS informs MNS
e8	Management Body provides Management Services to User Organizations	MNS services RS
e9	Network Service supports Needs and Business Processes	NS supports RS
e10	Requirement specifies the assortiment and the characteristics of Network Services and Management Services	RS exploits NS
e11	End User utilizes Network Services	RS exploits NS
e12	User Organization utilizes Network Services	RS exploits NS
e13	User Organization utilizes Management Services	RS employs MNS

Table 3.5: The relationships among RS, NS, and MNS.

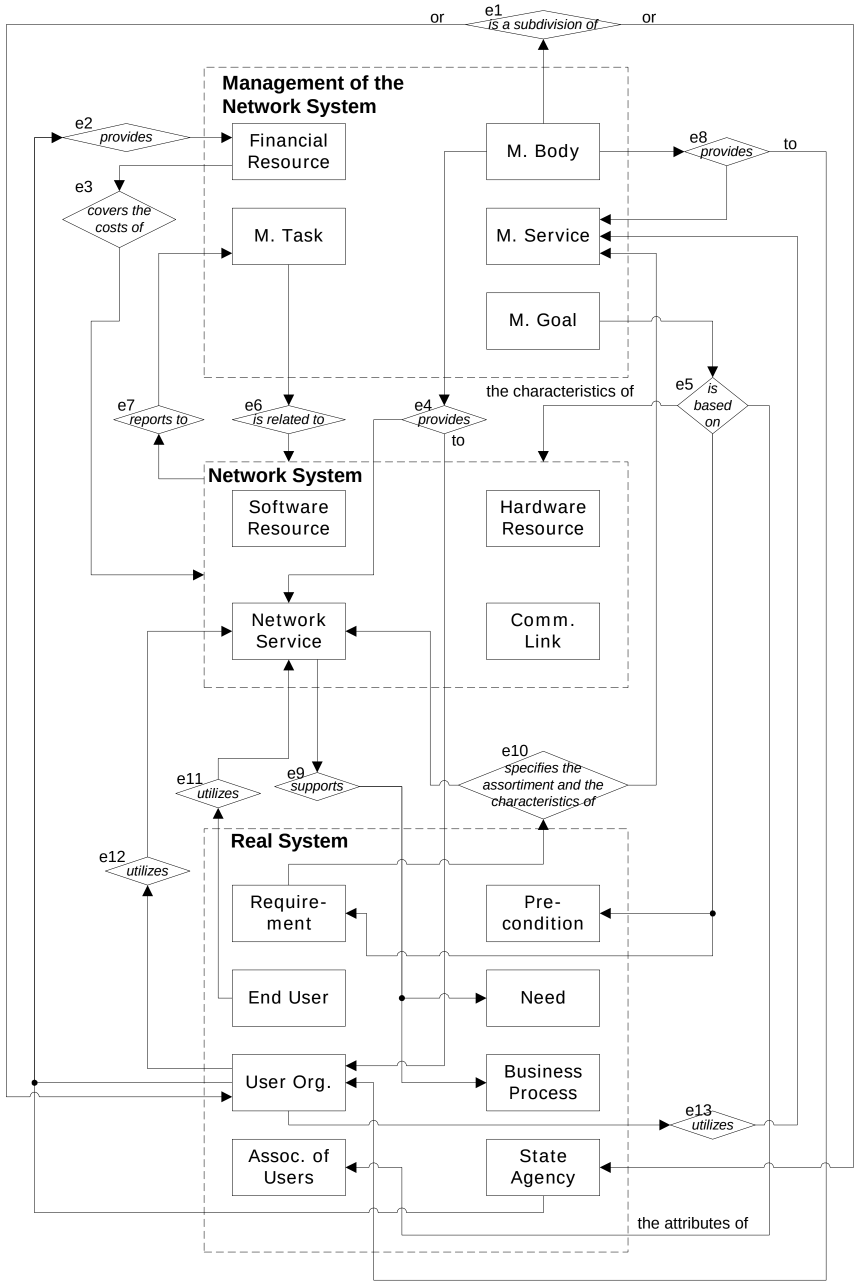

Figure 3.7: The relationships among entities of the RS, the NS, and the MNS.

and the volume of downloaded files, and the duration of videoconferencing sessions. The mentioned indicators always have to be used in the context of a certain time period, such as minute, hour, day, month, or year.

The relationship `e12` reflects the utilization of network services by user organizations. Each instance of this relationship represents the aggregate utilization of a network service by the end users which belong to a particular user organization. This relationship has financial implications if the usage-based charging model is used: recurrent fees paid by a user organization are calculated on the basis of the volume of traffic transmitted by all end users within this organization. Therefore, it reflects topics related to charging models.

3.7.2 NS supports RS

The generic relationship of the management paradigm "NS supports RS" is represented in the conceptual model by the relationship `e9`. Similarly to the relationship `e11`, the relationship `e9` emphasizes that users are primarily interested in network services which support their activities.

Let us illustrate this relationship by several examples of how network services can support needs and business processes. For example, the network service "Internet access" supports the needs related to searching and accessing information. Additionally, it supports educational, financial, health, and juridical needs. Due to the huge variety of services offered via the Internet, we can even speak about the emergence of a need called "need to access the Internet". Internet access is becoming a utility service similar to gas, electricity, or telephone.

Other network services also support needs. For example, the domain name service supports the need of referring to network resources via their mnemonic names instead of numerical network addresses. The messaging services support the need to communicate with other people. The directory services support the need to find information about people or organizations.

Network services also support business processes. For example, messaging and news services support the research process because they enhance an exchange of scientific information and facilitate the communication among researchers. The network service "Internet access" supports the learning process since it provides students with the ability to learn new facts and information accessible via Internet web sites.

3.7.3 MNS manages NS

The generic relationship of the management paradigm "MNS manages NS" is represented in the conceptual model by the relationships `e3` and `e6`. Below we describe the content of these relationships.

The relationship `e3` demonstrates that financial resources are used not only to cover the costs of managers and management tools, but also to cover the costs of the NS. The last implies the costs of hardware resources, software resources, communication links, and network services. Each entity of the NS has an attribute reflecting its costs. This relationship emphasizes the importance of financial aspects in the management.

The relationship `e6` demonstrates that the link between the MNS and the NS goes via management tasks. It implies that each management task is related to a number of hardware resources, software resources, communication links, or network services. For example, the task "loading software into hardware" prescribes which software resources should be loaded in each hardware resource, and in which way this has to be accomplished. A detailed description of each instance of this relationship goes beyond the scope of the conceptual model. Due to the huge variety and complexity of management tasks, no this relationship is not specified here further. Such a specification is the subject of the existing models supporting network management, such as the TMN Functional model or other models discussed Appendix A.

3.7.4 NS informs MNS

The generic relationship of the management paradigm "NS informs MNS" is represented in the conceptual model by the relationships `e5` and `e7`. Below we describe the content of these relationships.

The relationship `e5` links management goals with entities of the NS and the RS. Only a part of this relationship is related to the generic relationship "NS informs MNS", namely the part stating that management goals are based on the attributes of the NS (the left arrow coming out of the diamond representing `e5` in Figure 3.7). This part of `e5` implies that the attributes of hardware resources, software resources, communication links, and network services are reported to the MNS. By means of management goals, other entities become aware about the characteristics of the NS.

The relationship `e7` implies that hardware resources, software resources, and communication links report status information. Such information is then used by the MNS for managing, controlling, and maintaining the NS. For example, routers report information about the level of congestion of their interfaces to the management task "traffic control". Network servers and routers report information about unauthorized intrusion attempts to the management task "network security alarm".

Both relationships provide some information about the NS to the MNS. The relationship `e5` provides static information about the NS. For example, a communication link reports its bandwidth to the management goal. Unlike `e5`, the relationship `e7` provides the real-time or dynamic information. In our example the communication link reports its current load to the management task "traffic control".

3.7.5 MNS services RS

The generic relationship of the management paradigm "MNS services RS" is represented in the conceptual model by the relationships `e1`, `e4`, and `e8`. Below we describe the content of these relationships.

The relationship `e1` implies that management bodies are often subdivisions of either user organizations or state agencies. This remarkable topic was already mentioned in Chapter 2, section 2.6.1, and `e1` is introduced to cover this topic in the conceptual model.

The relationship `e4` means that management bodies provide network services to user organizations. It reflects the service-oriented view on management and corresponds to the third fundamental management goal. This relationship covers various aspects related to legal arrangements of service provision such as contracts and SLAs (Service Level Agreements).

The relationship `e8` implies that management bodies provide management services to user organizations. Like the relationship `e4`, it corresponds to the third fundamental management goal. Management bodies provide various reports and other kinds of information which could be interesting for the real system such as annual reports, financial statements, news, technical updates, and announcements (for example, announcements of planned maintenance activities, which may cause interruptions in the provision of services). This relationship also reflects in which way the management reacts to inquiries and requests coming from user organizations.

3.7.6 RS employs MNS

The generic relationship of the management paradigm "RS employs MNS" is represented in the conceptual model by the relationships `e2`, `e5`, and `e10`. Let us present the content of these relationships.

The relationship `e2` represents the way in which user organizations and state agencies provide financial resources. It covers topics related to the funding models of RENs: the proportion between the financial resources provided by the state on the one hand, and user organizations on the other hand, see Chapter A, see section 2.7.2. This relationship implies that the RS provides the MNS with financial means for compensating the costs of the NS, management tools, and managers.

The relationship `e5` implies that the RS communicates its requirements, preconditions, and situational factors to the MNS. This communication goes via the management goals, where requirements, preconditions, and situational factors are evaluated and analyzed. The situational factors are represented in the conceptual model by the attributes of the association of users. The content of `e5` originates from the MCMIS theory and it also reflects the definition of management goals.

The relationship `e10` indicates that user requirements concern not only network services but also management services. This relationship reflects the definition of the entity Requirement.

3.8 Modelling the External Environment (EE)

The External Environment (EE) is modelled as a number entities representing topics discussed in Chapter 2, section 2.8. These entities are External Party, Telecommunication Service, Internet Access Service, Domestic Internet, and Legislation. Sections 3.8.1 – 3.8.5 describe these entities in detail. They also demonstrate their influence on other parts of the model, namely entities and relationships of the NS, the RS, and the MNS.

It is necessary to note that definitions of entities of the EE contain the reference to the target geographical area of the REN. This imposes geographical constraints on the external environment and implies that local external environment, such as country or region has the most impact.

3.8.1 External Party

Definition 26 ***An external party*** *is an organization related to the REN, but is neither a user organization, nor a state agency, nor a management body.*

The entity External Party typically has the following instances: suppliers of hardware or software resources, Internet service providers, telecommunication operators, and donor agencies.

This entity affects several entities of the NS, and the MNS. Firstly, The entities Hardware Resource and Software Resource are affected: the assortment, the technical characteristics, and the price of these resources strongly depend on their suppliers. Similarly, the entities Network Service and Communication Link are affected. Secondly, donor agencies may provide significant financial support, and, therefore, the entity Financial Resource is affected. Such support is crucial for new RENs in developing countries which do not have enough internal financial resources to support their RENs.

3.8.2 Telecommunication Service

Definition 27 ***A telecommunication service*** *is a data-transmission service available in the target geographical area of the REN.*

The entity Telecommunication Service represents an alternative view on communication links which are not owned by the management bodies but rented or leased from telecoms. It is a service-oriented, view which is opposed to a technology-oriented view on communication links. In such a service-oriented view management bodies are service customers, and telecoms are service providers. Therefore, this entity and its attribute influence the communication links of the NS significantly. This entity covers topics discussed in Chapter 2, section 2.8.1.

Instances of telecommunication services are ISDN, xDSL, PDH/SDH, ATM, X.25, Frame Relay, and FDDI. A discussion on these instances lays beyond the scope of this thesis. For more information refer to [Hus99, p.158-191].

The entity is given several attributes that are similar to the attributes of the entity Communication Link, namely the capacity, the availability, and the price. According to Van den Broek, the availability and the price are the two most important characteristics of telecommunication services [Bro99, p. 77].

Telecommunication services are relevant for communication links which are not directly owned and operated by the management bodies of a REN. For example, management bodies rent long-distance communication links owned and operated by telecoms. In the service-oriented view this implies that telecoms provide telecommunication services to management bodies. In contrast, local communication links such as LANs are normally built and operated by management bodies themselves.

3.8.3 Internet Access Service

Definition 28 ***An Internet access service*** *is a capability of transmitting and receiving the traffic to and from the Internet.*

The Internet access service is an important topic described in Chapter 2, section 2.8.2. There are two reasons why this topic is important. Firstly, RENs provide this service to user organizations, and, therefore, they are players on the competitive market of the Internet service provision. Secondly, RENs buy this service from ISPs, and, therefore, they act as customers looking for the best deal. The service quality and the price are important factors.

The entity Internet Access Service is given the following attributes, namely capacity, availability, and price.

This entity usually has many instances since it implies various methods of connection and different charging schemes. Firstly, a distinction is made between dialup and dedicated Internet access. Dedicated access implies that the service is accessible 24 hours a day, 7 days a week, which is opposed to dialup access, requiring a telephone call to be made. Secondly, asymmetric connections are often used, which implies that the incoming bandwidth differs from the outgoing bandwidth. Finally, flat-rate tariffs differ considerably from usage-based tariffs.

3.8.4 Domestic Internet

Definition 29 ***A domestic Internet*** *is a part of the global Internet which includes a number of computer networks located within the target geographical area of the REN.*

RENs are an essential part of the Internet. Therefore, they are significantly influenced by the Internet. Because of the geographical, economical, and political proximity, the domestic Internet influences RENs most.

The entity Domestic Internet has a strong influence on several entities and relationships of the RS, the NS, and the MNS. Firstly, it affects the entities End User, Need, and Requirement. This is because it reflects the awareness of the population of the Internet: new end users emerge, their needs and requirements evolve as they become more and more aware about the possibilities which the Internet offers. Secondly, it affects the entities Management Body and Management Task. This is because it shows the extent to which the domestic Internet market is liberalized: management bodies may face strong competition from ISPs, and their management tasks have to include certain activities aimed at securing their position on the market. Finally, it affects the relationship `e11` and `e12`.

This entity is given the following attributes: the number of Internet hosts, the number of personal computers, the number of Internet users, the number of Internet service providers, the volume of the network traffic, and the amount of information resources available within the domestic Internet. The last attribute can be evaluated as the number of websites available in the target geographical area of the REN.

3.8.5 Legislation

Definition 30 ***The legislation*** *is a series of laws regulating ICT-related issues in the target geographical area of the REN.*

The entity Legislation has two vital instances, namely the national ICT policy and the regulatory basis for telecom liberalization. The national ICT policy provides the legislative basis for the growth and development of RENs, and ensures the long-term commitment of the state to support RENs politically and financially. Therefore, the national ICT policy influences the relationship `e2`. It also influences the formulation of preconditions by user organizations and by the association of user organizations: relationships `r4` and `r13` in Figure 3.4.

The regulatory basis for the telecom liberalization has direct implications for all attributes of telecommunication services (capacity, availability, and price). This is because in the liberalized markets, competition creates a better environment for the development of the telecom infrastructure which implies the growth of capacity, the extension of availability, and the decrease of prices. Therefore, the entity Legislation affects the entity Communication Links and its attributes.

According to Van den Broek, "laws may be enacted at the country level (e.g. by the country government), at a higher level, the so-called supranational level, or lower level, e.g. the state level. Important instances of supranational laws are regulations of the European Union. For example, in 1990 the EU's Open Network Provision directive mandated the opening of infrastructures that were controlled by a dominant or monopoly operator to other operators. Laws from the supranational level may or may not have direct effect on the REN" [Bro99].

3.9 Conclusion

This chapter answered the second research question *"How can we build a model that can be used to support management of both developed and developing RENs?.* It demonstrated that existing models are largely unsuitable for supporting the management of RENs. Therefore, a new model was presented in this chapter. This model was developed by using the management paradigm and the entity-relationship model.

The model's entities have two origins: REN topics from Chapter 2, and some fundamental concepts of the MCMIS theory. Table 3.6 demonstrates this for each entity. In the description of every element of the model (entity, attribute, or relationship), there are more detailed references to corresponding REN topics (corresponding sections of Chapter 2). Table 3.7 shows in which way the REN topics are reflected by the model's elements. The model's relationships originate from the decomposition of the six generic relationships of the management paradigm. The decomposition was accomplished by using the MCMIS theory and trying to find associations among the entities.

System	Entities of the conceptual model	Origin
Real System	User Organization	REN topics
	State Agency	REN topics
	Association of User Organization	REN topics
	Business Process	MCMIS theory
	End User	REN topics
	Need	MCMIS theory
	Requirement	MCMIS theory
	Precondition	MCMIS theory
Network System	Network Service	REN topics
	Communication Link	REN topics
	Hardware Resource	MCMIS theory & REN topics
	Software Resource	MCMIS theory
	Network Node	REN topics
Management of Network System	Management Goal	MCMIS theory
	Management Task	MCMIS theory
	Management Service	MCMIS theory & REN topics
	Management Tool	MCMIS theory
	Manager	MCMIS theory
	Financial Resource	REN topics
	Management Body	REN topics

Table 3.6: Origins of the entities of the conceptual model.

Area of REN topics	Sub-area of REN topics	Corresponding model's element(s)
User-related topics	User organizations	Entity User Organization
	End users	Entity End User
Topics related to communication links	Classification	Entities Communication Link, Network Node
	Capacity	
	Transmission technology	
Service-related topics	Operational services	Entities Network Service, Management Service, Hardware Resource and Software Resource
	User support services	
	Security services	
	Information services	
Usage-related topics	Acceptable Usage Policy	Attribute "policy" of the entity Association of User organizations
	Analysis of usage	Relationships e11, e12, and e13 (RS exploits NS)
	RENs as test beds	
Organizational topics	REN Operator	Entity Management Body
	Subcontractor	Entity Management Body
	Association of users	Entity Association of Users
	Other entities	Entities State Agency, Management Body, and External Party
Financial topics	Expenditure items	Attribute "costs" of various entities
	Funding models	Entity Financial Resource, relationships e2 and e3
	Charging models	Relationship e2
Environment-related topics	Characteristics of telecommunication services	Entity Telecommunication Service
	Characteristics of the Internet access service	Entity Internet Access Service
	Hardware and software prices	Attribute "costs" of the entities Hardware Resource, Software Resource, and Communication Link
	Technological developments	Entities Telecommunication Service and Internet Access Service
	Domestic Internet	Entity Domestic Internet
	Regulatory framework	Entity Legislation

Table 3.7: Demonstration in which way the REN topics are covered by the model's elements.

Chapter 4

Case study "URAN"

4.1 Introduction

This chapter begins the validation of the conceptual model in the case of URAN. It starts answering the third research question *"How can the developed model be validated in practical situations?"* and corresponds to Phase 4 of the research approach defined in Chapter 1. This phase consists from three steps, namely (1) bidirectional confrontation between the model and the real situation, (2) adjustment of the model and development of recommendations, (3) evaluation of the model by the sites. This chapter covers the first two steps; the third step is covered in Chapter 6.

This case study is necessary not only for validating the model, but also for bringing it to a higher level. This is achieved via the adjustment of the model after its confrontation with the real situation as explained below.

The first step implies using the model to produce a description of URAN. In this step the model's elements (entities, relationships, and attributes) formally defined in Chapter 3 are filled with the actual data of URAN, or, in other words, the real situation of URAN is confronted with the model. During this confrontation it might turn out that the real situation of URAN does not have certain elements of the model, or that these elements have been developed improperly. Such missing elements are referred to as *gaps in the real situation*, see Figure 4.1.

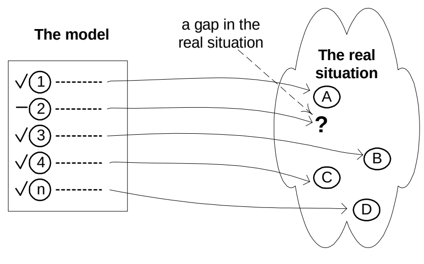

Figure 4.1: Visual interpretation of gaps in the real situation.

The first step also includes the confrontation of the model with the real situation.

This means that we analyze whether the model reflects all the important aspects of the real situation. The model might prove unable to reflect certain aspects of the real situation, or, in other words, these aspects may not match any of the model's elements, see Figure 4.2. Such aspects, called *gaps in the model*, are registered and analyzed. The first step is covered in sections 4.2 – 4.7.

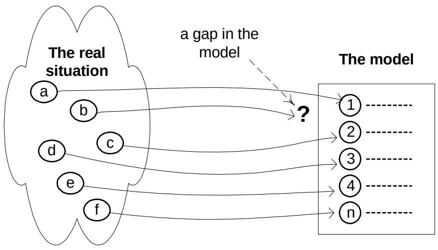

Figure 4.2: Visual interpretation of gaps in the conceptual model.

The second step demonstrates in which way the model and the real situation can mutually benefit from each other. On the one hand, the real situation gives indications on how to adjust the model in order to fill gaps in it. On the other hand, the model provides the real situation with recommendations on how to fill gaps in the real situation. The recommendations result from the use of the model, and are based solely on own judgments of the researcher: no other people are involved. The second step is covered in sections 4.8 and 4.9.

The information presented in this chapter is valid for August 2002. It is vital to give this date because new instances of entities emerge, and the values of attributes change over time. For example, new user organizations are connected to the network every day, and the capacity of communication links is constantly increasing.

The information presented in this chapter was collected from two sources. Firstly, the representatives of the site were consulted. During personal, telephone, and email interviews the representatives were asked a number of questions; each question was related to a certain element of the model (entity, attribute, or relationship). Tables B.1 – B.8 in Appendix B present the list of questions. Secondly, the documentation was studied. This were electronic and paper documents which were available at the site, such as reports, work documents, web pages, regulatory documents, etc.

4.2 Real System

4.2.1 User organizations

According to the conceptual model, the entity User Organization has two attributes, namely the category and the size. The user organizations of URAN can be classified into the following categories: universities, research institutes, academies, and others. The majority (more than 60%) of the user organizations of URAN are universities. Table 4.1 demonstrates the distribution of the user organizations among these categories, and also presents the size of the user organizations. It is remarkable that the ratio between the number of computers and the number of students/ staff varies significantly across user organizations.

N	Full name of the user organization	Category	Size		
			Students	Staff	Computers
1	Computing center of the Ministry of Education and Science	Others	-	50	no data
2	Donetsk State Technical University	University	6331	800	500
3	Institute of Mathematical Machines and Systems	Research institute	-	900	no data
4	Institute of Space Research	Research institute	-	no data	no data
5	International Research and Training Center	Research institute	-	no data	no data
6	International Science and Technology University	University	1238	150	32
7	International University of Finance	University	130	65	no data
8	Kharkiv Institute of Humanities "People's Ukrainian Academy"	Academy	887	120	40
9	Kharkiv State Academy of Culture	Academy	855	179	no data
10	Kharkiv State Grygory Skovoroda Pedagogical University	University	12405	603	74
11	Kiev National University of Construction and Architecture	University	5100	450	60
12	Main Astronomical Observatory	Research institute	-	120	65
13	National Mining University of Ukraine	University	5515	450	no data
14	National Technical University of Ukraine "Kiev Polytechnical Institute"	University	26000	1805	1000
15	National University "Lvivska Politekhnika"	University	13645	1300	460
16	Odessa State Polytechnic University	University	6578	789	550
17	Tavrical National University	University	10000	600	no data
18	Ukrainian National Academy of Pharmacy	Academy	2149	360	100
19	Ukrainian State University of Food	University	5220	570	700
20	Zaporizhzhya State Technical University	University	9000	670	no data
21	Chernihiv State Technological University	University	3600	200	300
22	East-Ukrainian National University	University	15000	1000	no data

Table 4.1: User organizations of URAN.

The model was found to be unable of supporting the following issue related to the user organizations of URAN. Some user organizations of URAN, such as commercial universities, are in a better financial situation than others, such as state-funded research institutions. Since URAN strongly depends on user payments, it is important for the management of URAN to be aware of the financial condition of every particular user organization[1]. This allows it to make prognoses regarding the financial sustainability of URAN.

[1] In order to understand the financial condition of Ukrainian universities – the predominant category of user organizations of URAN – it is necessary to analyze their income sources. There are basically two income sources, namely the state budget and the commercial activities. The state

Conclusion There were found no gaps related to the user organizations of URAN: the entity User Organization has a number of instances in case of URAN, and the attributes introduced by the model are applicable for those instances.

A gap in the model was found: the model is unable to reflect the financial condition of the user organizations of URAN.

4.2.2 State agency

According to the conceptual model, instances of this entity provide regulatory and financial support for the REN on behalf of the state. The single instance of this entity for URAN is the Ministry of Education and Science of Ukraine. This ministry is the central body of the government executive power performing the management in the area of education and science.

State agencies play a crucial role in the financial sustainability of most RENs. In most countries they usually provide significant subsidies for RENs, allowing those RENs to grow and develop. At the initial phase of the REN's creation, such subsidies normally cover recurrent and development expenses entirely, whereas at later phases they may cover those expenses only partially. Consequently, state agencies are usually major investors of RENs.

Unlike similar agencies in other countries, the Ministry of Education and Science of Ukraine provides only limited financial support to URAN. So far, the total amount of state subsidies was only 150.000 Euro which is definitely too little for a country such as Ukraine, which has hundreds of potential user organizations spread across an area of many thousands of square kilometers. URAN has received only two state subsidies. One of the explanations for such a weak financial support is the poor economic condition of the whole R&E sector in Ukraine in general.

Conclusion There were found no gaps related to the state agencies of URAN: the entity State Agency has a single instance in case of URAN, namely the Ministry of Education and Science of Ukraine. Although this ministry provides only limited financial support to URAN, this does not indicate a gap in the real situation. This is because the conceptual model does not specify a minimum level of financial support that a state agency should provide.

4.2.3 Association of user organizations

According to the model, this entity has always one instance. In case of URAN, this instance is the officially registered body called the Association of Users of Ukrainian Research and Academic Network (shortly the URAN Association). It has a mission defined in its statute. It is a public organization having no legal status. The geographical distribution of the association's members resembles the geographical distribution

budget for research and education is allocated annually by the Ukrainian government. For example, in 2000 the state budget for R&E was 5.1 billion UAH (~1 billion Euro), which is 15.4% of the national budget. Each R&E institution receives a certain amount of funds from this budget. Commercial activities include enrolling commercial students and performing R&D projects for the industry. For example, the budget of the National Technical University of Ukraine in 1998 was 60 million UAH; 60% of this budget was received as the state subsidies, and 40% was the result of commercial activities.

of all Ukrainian HEIs: the majority of the user organizations is located in Kiev (11), and Kharkiv (4); in each other city depicted in Figure 4.3 there is only one user organization so far (August 2002) .

Figure 4.3: The map of Ukraine indicating cities where user organizations of URAN are located.

The organizational structure of the URAN Association consists of three administrative bodies, namely the General Assembly, the General Council, and the Technical Committee. The decisions made by these bodies are binding for all members of the Association.

There are no policy documents at URAN: the Acceptable Usage Policy and the Connection Policy are lacking. Therefore, it is not clear what kinds of organizations are eligible users of URAN, what kinds uses of URAN are not allowed, and what measures can be taken in case the policy rules are violated.

Conclusion The entity Association of User Organizations has a single instance in case of URAN, and five out of six attributes introduced by the model are applicable to this instance. The attribute ”policy” is missing (there are no policy documents at URAN), which points to a gap in the real situation.

4.2.4 Business processes

According to the model, the entity Business Process reflects core activities of user organizations. The user organizations of URAN execute a number of business processes that can generically be grouped in educational, research, and administration processes. Among the user organizations of URAN only universities execute educational processes. Unlike educational processes, research and administration processes are carried out by all user organizations of URAN.

Conclusion There were found no gaps related to the business processes of the user organizations of URAN. The entity Business Process has a number of instances in case of URAN, and these instances fall into the classification suggested by the model: educational, research and administration processes.

4.2.5 End users

According to the model, not every person that works or studies at a user organization is an end users of a REN. This is also true for end users of URAN: only those individuals who actually use the services provided by URAN are its end users. That is why the number of end users per organizations is significantly lower than the quantity of students and staff members at this organization, see Table 4.1.

Abbreviated name	Qty	Abbreviated name	Qty
IRTC	80	OSPU	3500
KIHPUA	350	UNAP	150
MAO	120	KSGSPU	50
ISTU	150	KSAC	57
DSTU	500	KNUCA	38
USUFT	300	NULP	1200

Table 4.2: Number of end users per user organization

The model divides the end users into two major categories: students and staff members. The percentage of students (73%) among the end users of URAN is significantly higher than the percentage of staff members (23%). Subcategories defined by the conceptual model are also relevant for the case of URAN: teachers, researchers, technical support staff, and others.

Scientific field of end users can be assessed by looking at the statistics on the admission of students of Ukrainian HEIs by the areas of training. Figure 4.4 demonstrates the distribution of students among a number of areas of training.

Conclusion There were found no gaps related to the end users of URAN: the entity End User has a number of instances in case of URAN, and the attributes introduced by the model are applicable for those instances.

4.2.6 Needs

The vast majority of the end users of URAN primarily need to access the Internet and its resources and services. For example, an end user of URAN needs to search for information, to download information from a web site, to publish information on a web site, or to exchange data with other end users; the exchange of audio files in

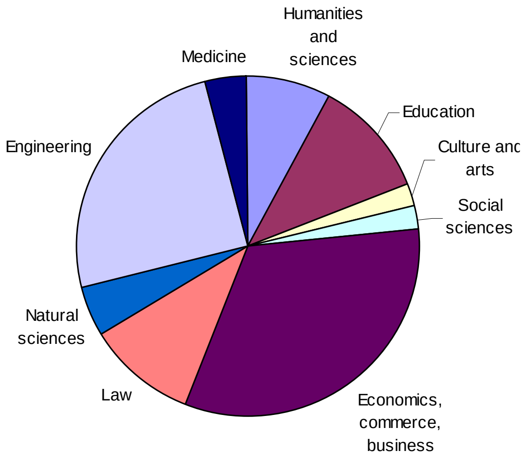

Figure 4.4: Distribution of students of Ukrainian HEIs among the areas of training.

the MP3 format has become very popular among the Internet end users, including those of URAN.

The model suggests that the identification of the ratio between private and professional needs requires separate studies. No studies investigating this matter were conducted in case of URAN.

Conclusion There were found no gaps related to the needs of the end users of URAN: the entity Need has a number of instances in case of URAN, and the division of needs into private and professional needs is relevant for URAN. However, it was impossible to identify a ratio between the private and the professional needs.

4.2.7 Requirements

There is no objective nor credible information concerning the requirements. No studies investigating this matter were found.

The user organizations of URAN might need some extra services that are currently provided neither by URAN nor by Ukrainian ISPs. For example, URAN users might require a good connectivity with other RENs in Europe and the US. The provision of such a service would require establishing communication links between URAN and the Trans-European REN "GEANT", and between URAN and the North-American REN "Abilene". Furthermore, it is expected that some user organizations might require the guaranteed capacity and the possibility of routing multicast traffic in order to run distance education courses.

The characteristics of services required by user organizations are not clearly defined. Although there are a few characteristics which seem to be important for user organizations, the acceptable values of these characteristics are not properly defined.

These characteristics are the average maximal throughput[2] and the transmission delay of a user access link. Consecutively, there are no SLAs (Service Level Agreements) between the URAN operator "CEI" and the user organizations: all services are provided in a so-called "best-effort" manner without quality guarantees. This implies that it is up to every particular user organization to decide whether the services' characteristics match the desired level.

Conclusion The entity Requirement does not have clearly specified instances in case of URAN, which points out to a gap in the real situation.

4.2.8 Preconditions

The conceptual model defines a precondition as a restrictive condition which is laid down at the management level of the Association of Users, the State Agency, or individual user organizations. This implies that the URAN Association, the Ministry of Education and Science, and every user organization has its own preconditions.

The preconditions of the URAN Association are laid down in its Statute. Firstly, the organizational structure of the network is defined as a three-level hierarchical structure of telecommunication centers consisting of a main center, regional centers, and district centers. Secondly, the membership to the Association is restricted to Ukrainian educational and scientific establishments and their branches which are financed, as a rule, from the state budget. Finally, all executive functions and financial operations of the Association are carried out by central, regional, and district telecommunication centres according to their rights and responsibilities.

There is no objective nor credible information concerning the preconditions of user organizations. No studies investigating this matter were found. Even though financial preconditions are recognized, they are not clearly specified in terms of financial budgets. For example, it is unclear how much money each particular user organization can spend on computer networking, including network services of URAN.

Conclusion The entity Precondition does not have clearly specified instances in case of URAN, which points out to a gap in the real situation.

4.2.9 Relationships among entities of the RS

Most of the relationships among the entities of the RS (see Table 4.3) cannot be given an actual content. On the one hand this is due to the very high or even unknown number of instances of some entities. For example, because there are around eight thousand end users, there must be thousands of instances of relationships in which the entity End User participates (relationships `r2`, `r5`, `r6`, and `r7`). Similarly, because the entities Business Process and Need have an unidentified number of instances, it is also impossible to present instances of the relationships in which these entities participate (relationships `r5`, `r7`, `r8`, and `r9`).

[2] The average maximal throughput is calculated by averaging the instant throughput of a link during the period of time in which the link is usually heavily used (for example, on weekdays from 8:00 till 18:00)

`r1`	Precondition limits Requirements
`r2`	User Organization defines Requirements
`r3`	End User defines Requirements
`r4`	User Organization formulates Preconditions
`r5`	End User has Needs
`r6`	End User belongs to User organization
`r7`	End User is involved in Business Processes
`r8`	Business Process causes Needs
`r9`	User Organization executes Business Processes
`r10`	User Organization is a member of Association of Users
`r11`	State Agency formulates Preconditions
`r12`	State Agency participates in or patronages Association of Users
`r13`	Association of Users formulates Preconditions

Table 4.3: The relationships among entities of the real system.

On the other hand, some relationships have been introduced with the aim of representing logical associations between entities, and not for giving them an actual content. Such relationships have an abstract nature; they are merely illustrations of dependencies among certain concepts of reality. For example, it is obvious that every end user belongs to a certain user organization, which makes it pointless to validate the relationship `r6`. Similarly, there are no doubts that each user organization executes some business processes (relationship `r9`). However, it is hardly possible to describe every business process of every organization, since producing such a description would require conducting a study on a very large scale, which is beyond the scope of this research project.

Some relationships cannot be described separately from the entities that they connect. The relationships `r1`, `r2`, `r4`, and `r13` have already been described earlier in this section, when describing entities connecting these relationships: Requirement, Precondition, User organization, and Association of User Organizations.

Conclusion There were found no gaps in the relationships among the entities of the RS of URAN: the relationships `r1`– `r13` introduced by the model all exist in the real situation of URAN. However, most of these relationships cannot be given an actual content because of their abstract nature.

4.3 Network System

4.3.1 Network services

The following network services are available to the users of URAN:

1. the IP connectivity services
   (a) the backbone connectivity service
   (b) the external connectivity service

2. the domain name service
3. the web caching service
4. the mail relaying service
5. the network news distribution service
6. the file archive service

The service level of the network services of URAN cannot be estimated because there are no corresponding indicators which are defined and measured on a periodical basis. According to the conceptual model, the service level reflects the actual quality of a network service and its adequacy with the requirements. The model also states that the determination of this attribute requires defining a set of indicators whose values must be periodically measured. For example, the period of time during which the external link was operational can be used to assess the availability of the external connectivity service. Similarly, the duration of failures of the web proxy server can be used to assess the mean time between failures of the web caching service. In case of URAN, no indicators of this kind were defined and measured.

Conclusion The service levels of the network services of URAN are not recognized, which indicates a gap in the real situation.

4.3.2 Communication links

According to the conceptual model, communication links are divided into several categories, namely backbone, user-access, peering, European, and Internet links. The last three categories of links are also called external links. There are instances of links which belong to all categories except for European links, since URAN is not connected to the Trans-European REN "GÉANT" yet (August 2002).

Tables 4.4, 4.5, and 4.6 present instances of backbone, user-access, and external links correspondingly. They also present the attributes of each instance. Let us present several remarkable observations related to communication links of URAN.

The capacity of most backbone links (64 or 128 Kbps) seems to be very low taking into account that RENs in other countries nowadays operate links with megabit and even gigabit capacities.

The capacity of external links significantly exceeds the capacity of backbone and user-access links. This is because user organizations mostly transfer data from the Internet and not to exchange data with each other. As a consequence, backbone and user-access links are merely used to distribute the Internet traffic coming from the external links to the user organizations; little communication among user organizations takes place.

The recurrent costs of communication links account for more than 80% of the expenditure budget of URAN. This particularly concerns external communication links, whose recurrent costs are most significant.

Regional node	Scale	Capacity, Kbps	Technology*	Recurrent costs, Euro
Kiev (NTUU)	city	1500	HDSL	5
Kiev (IRTC)	city	128	DRC	35
Kiev (CCMES)	city	128	HDSL	5
Lviv	long-dist.	64	DRC	245
Dnepropetrovsk	long-dist.	256	DRC	286
Kharkiv	long-dist.	128	DRC	278
Odessa	long-dist.	64	DRC	242
Zaporizhya	long-dist.	128	DRC	84
Chernihiv	long-dist.	128	DRC	139
Simferopol	long-dist.	128	FR	290
Lugansk	long-dist.	128	FR	290

* DRC - digital rendered channel; FR - frame relay;
HDSL - high-speed digital subscriber line

Table 4.4: Backbone communication links of URAN.

Node	User org.*	Scale	Capacity, Kbps	Technology **
Central node	MAO	city	64	HDSL
Central node	KNUCA	city	128	HDSL
Central node	USUFT	city	128	HDSL
Central node	ISTU	city	64	DRC
Central node	TEU	city	64	DRC
Kiev (IRTC)	IRTC	local	10000	Ethernet
Kiev (CCMES)	CCMES	local	10000	Ethernet
Kiev (NTUU)	NTUU	local	512	Ethernet
Lviv	NULP	local	10000	Ethernet
Dnepropetrovsk	NMUU	local	10000	Ethernet
Odessa	OSPU	local	10000	Ethernet
Simferopol	TNU	local	10000	Ethernet
Kharkiv	KSAC	city	128	HDSL
Kharkiv	KSGSPU	city	64	HDSL
Kharkiv	UNAP	city	64	HDSL
Kharkiv	KIHPUA	city	64	HDSL

*Full names of user organizations see in Table 4.1
** DRC - digital rendered channel; HDSL - high-speed digital subscriber line

Table 4.5: User-access communication links of URAN.

ISP	Scale	Capacity, Kbps	Recurrent costs, Euro	Comments
Ukrsat	city	1200	1200	Internet link
SkyVision	city	1200	800	Internet link
Ukrtelecom	local	10000	100	Peering link

Table 4.6: External communication links of URAN.

Conclusion There were found no gaps related to the communication links of URAN: the entity Communication Link has a number of instances in case of URAN, and the attributes introduced by the model are applicable for those instances.

4.3.3 Hardware resources

The hardware resources of URAN consist of eight network servers and twelve routers, whose characteristics are presented in tables 4.7 and 4.8.

Server's mnemonic name	umbra	swami	rn_server
Number of instances	1	1	5
RAM size, MBytes	256	256	128
HDD size, GBytes	13	22	12
Processing speed, MHz	333	333	333
Procurement costs, Euro	2200	2200	2500

Table 4.7: URAN network servers.

Type (model) of the router	2522	2611	2620	3640	7200
Number of instances	1	6	1	3	1
Quantity of interfaces	2	2...3	3	5...10	5
Total bandw. of interfaces, Kbps	256	256...2240	640	1024...6144	12816
RAM size, MBytes	8	16...32	64	64...96	128
Flash memory size, MBytes	4	8...16	16	16	16
Processing speed, MHz	20	40	40	80	80
Procurement costs, Euro	4200	7850	8500	14060	15000

Table 4.8: URAN routers.

Conclusion There were found no gaps related to the hardware resources of URAN: the entity Hardware Resource has a number of instances in case of URAN, and the attributes introduced by the model are applicable for those instances.

4.3.4 Software resources

The following software resources are used to provide the network services described in section 4.3.1:

- Cisco IOS (internetwork operating system)
- FreeBSD (the operating system from the Unix family)
- Squid (proxy caching server)
- BIND (domain name server)

The status of all software resources except Cisco IOS is freeware. Cisco IOS is a commercial software resource.

The procurement and recurrent costs of software resources of URAN are basically zero. This is because all software resources except Cisco IOS belong to the public domain and can be used freely by every interested party without any restrictions. This fact lowers the expenditure part of the URAN budget and, therefore, positively influences the financial sustainability. Costs of Cisco IOS are included in the costs of routers and, therefore, they can be neglected.

Conclusion There were found no gaps related to the software resources of URAN: the entity Software Resource has a number of instances in case of URAN, and the attributes introduced by the model are applicable for those instances.

4.3.5 Network nodes

Although the conceptual model classifies network nodes into backbone and access nodes, traditionally in the URAN community another classification of network nodes is used. Network nodes of URAN are classified into the central node and the regional nodes.

If the model's classification is applied to the situation of URAN, the central node and the regional nodes perform the functions of both backbone and access nodes at the same time. Firstly, this is because communication links connecting regional nodes with the central node are also backbone links since they carry the bulk of the network traffic, and secondly, because user organizations are connected both to the central node and to the regional nodes.

The network nodes of URAN are mostly located at the sites of user organizations. Table 4.9 presents the list of the regional nodes and the corresponding organizations hosting them.

City	User organization – host of the network node
Kiev	National Technical University of Ukraine “Kiev Polytech. Inst.“
Kiev	International Research and Training Center
Kiev	Computer Center of the Ministry of Education and Science
Lviv	National University “Lvivska Politekhnika“
Odessa	Odessa State Polytechnic University
Dnepropetrovsk	National Mining University of Ukraine
Donetsk	Donetsk State Technical University
Kharkiv	National Technical University ”Kharkiv Politechnical Institute”
Simferopol	Tavrical National University
Lugansk	East-Ukrainian National University
Zaporizhya	Zaporizhya National Technical University
Chernihiv	Chernihiv State Technological University

Table 4.9: The regional network nodes of URAN.

Conclusion There were found no gaps related to the network nodes of URAN: the entity Network Node has a number of instances in case of URAN, and the classification of network nodes suggested by the model is applicable for URAN.

4.3.6 Relationships among entities of the NS

`n1`	Network Service is based on Software Resources, Hardware Resources, and Communication Links
`n2`	Hardware Resource is located in Network Node
`n3`	Network Node is connected to Network Node via Communication Link

Table 4.10: The relationships among entities of the network system.

The relationship `n1` represents hardware resources, software resources, and communication links which every network service is based upon. Table 4.11 demonstrates the content of this relationship in case of URAN.

Network service	Hardware resources	Software resources	Comm. links
Backbone connectivity	Routers	CiscoIOS	backbone links
External connectivity	Cisco 7200 router	CiscoIOS	external links
Mail relaying service	Servers "umbra" and "swami"	FreeBSD	-
Web caching service	Network server "swami"	FreeBSD, Squid	-
Domain name service	Network server "umbra"	FreeBSD, BIND	-

Table 4.11: The relationship n1 "Network Service is based on Hardware Resources and Software Resources" in case of URAN.

Relationship `n2` has the following content. Network servers "umbra" and "swami", and the Cisco 7200 router are located in the central node. Other routers and network servers "rn_server" are located in regional nodes. Figure 4.5 graphically represents this relationship.

The relationship `n3` represents the network topology. Figure 4.6 graphically presents this relationships showing the connectivity among the network nodes of URAN. As seen from this figure, URAN has a star-like topology with the central node in Kiev and regional nodes radially connected to the central node. The only regional node that is not connected to the central node but to another regional node is the Donetsk regional node.

Conclusion There were found no gaps in the relationships among the entities of the NS of URAN: the relationships `n1`– `n3` introduced by the model all exist in the real situation of URAN.

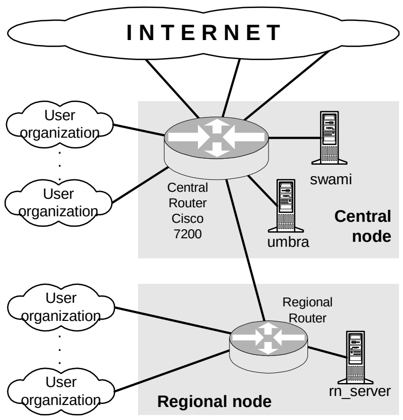

Figure 4.5: Graphical representation of the relationship `n2` "Hardware Resource is located in Network Node" in case of URAN.

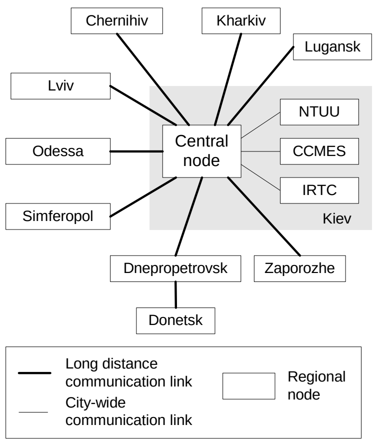

Figure 4.6: Graphical representation of the relationship `n3` "Network Node is connected to Network Node via Communication Link" in case of URAN.

4.4 Management of the Network System

4.4.1 Management goals

The conceptual model defines three management goals. Below we assess to which extent each theoretical goal is actually fulfilled in case of URAN.

The first goal implies that the management of the NS has good knowledge of requirements, preconditions, aspects of the external environment, and of attributes of the NS components. Although the management of URAN has good knowledge about the NS, it lacks knowledge about requirements and preconditions (see sections 4.2.7 and 4.2.8). Therefore, it is unlikely that the NS is managed in accordance with requirements and preconditions.

The second goal implies that the goals of user organizations are influenced in a positive way. It is hard to establish whether the URAN management realizes this goal: influencing the goals of its user organizations positively. This is because there is a lack of information about the actual goals of the URAN user organizations, and because the impact of the management of URAN on these goals has not been studied. It is a common phenomenon in Ukraine that the goals of institutes of higher education are either not properly formulated or not communicated to a wide audience.

The third goal implies that the services are offered in the most effective and efficient way. It is impossible to assess the fulfillment of this goal, because the knowledge about the effectiveness and the efficiency of the service provision is unavailable. This is also related to a gap in the network services of URAN, namely the lack of service levels (see section 4.3.1).

Conclusion The entity Management Goal does not have clearly specified instances in case of URAN. The first management goal defined by the conceptual model is not fulfilled because the management of URAN lacks knowledge about requirements and preconditions. The fulfillment of the second and the third management goals is impossible to estimate because of the lack of relevant information.

4.4.2 Management tasks

Table 4.12 presents a list of management tasks of URAN. The tasks are divided into five management areas according to the OSI Management Framework's classification: performance management, fault management, configuration management, security management, and accounting management [OSI89].

Performance management tasks of URAN are aimed at avoiding congestion of communication links. To fulfill this goal, several indicators are defined: the ratio of dropped packets, the availability, and the utilization of a communication link. The values of these indicators are constantly monitored and analyzed. While the collection of data is performed automatically, the analysis of collected data is done manually. The task "creating and modifying routing patterns" aims as relieving the congestion of communication links. It includes balancing the load of links and changing the rules for forwarding the network traffic between adjacent routers. The task "traffic forecasting" enables the management to make prognoses about the capacity of communication links, and the necessary upgrades of corresponding hardware and software resources.

Management area	Management task
Performance management	P1. Setting up performance goals
	P2. Definition of performance indicators
	P3. Collecting performance data
	P4.Providing current traffic status information
	P5. Setting up network traffic management policy
	P6. Creating and modifying routing patterns
	P7. Traffic forecasting
Fault management	F1. Network fault event analysis
	F2. Verification of parameters and connectivity
	F3. Network fault localization
	F4. Management of repair process
Configuration management	C1. Supplier and technology policy
	C2. Infrastructure planning
	C3. Network infrastructure design
	C4. Routing design
	C5. Procurement
	C6. Management of installation
	C7. Contracting
	C8. Network installation administration
	C9. Software administration
	C10. Marketing
	C11. Management of sales process
	C12. External relations
	C13. Solution proposal

Management area	Management task
Security management	S1. Provision of necessary environmental conditions
	S2. Provision of power supply
	S3. Severing connections
	S4. Administration of access control
Accounting management	A1. Usage measurement, storage and accumulation
	A2. Managing pricing strategy
	A3. Tariff and price administration
	A5. Costing
	A6. Providing access to tariff information
	A7. Rating usage
	A8. Totaling usage charges
	A9. General accounting operations
	A10. Accounts receivable
	A11. Accounts payable
	A12. Taxation
	A13. Assembling and sending invoices
	A14. User account administration
	A15. Budgeting
	A16. Profitability analysis
	A17. Managing subsidies

Table 4.12: URAN management tasks.

Fault management tasks of URAN are aimed at detecting, isolating, and correcting abnormal operations of hardware/ software resources. The detection of faults implies the ability to receive and recognize fault notifications. Such notifications can be sent either by user organizations, or by hardware/ software resources. Faults having the largest impact on the service provision are breakdowns of communication links, particularly external communication links. Other faults are dumps of the electric power and hang-ups of software resources. Because most faults are of a nature which is already familiar to the URAN managers, their isolation implies following some known patterns which include analyzing certain parameters, or performing diagnostic tests. The correction of faults implies that the operation of malfunctioning resources must be recovered. The correction and the isolation of faults often requires the participation of external parties such as Ukrtelecom or ISPs.

The number of the fault management tasks (four) is considerably lower than the number of management tasks from other management areas. The model defined management tasks directed at tracing faults and at reporting their status to the users. These tasks were missing in case of URAN. The management of URAN was not familiar with the concept of a trouble ticket, which is often used to accomplish these tasks.

Configuration management tasks of URAN are aimed at identifying, exercising control over, collecting data from, and providing data to hardware/ software resources. The first four configuration management tasks from Table 4.12 relate to determining of he growth needs, and the introduction of new technologies. These tasks support the evaluation of alternative plans which are further fulfilled by other management tasks. The following four tasks support the installation of new resources as well as the removal of outdated resources. They include initial selection, further control, and coordination of subcontractors, vendors, and suppliers of resources. The task "software administration" deals with controlling the operation of software resources. The remaining four tasks support the communication between the management of URAN and prospective user organizations. An important outcome of these tasks is the attraction of new user organizations.

Security management tasks of URAN are aimed at preventing security threats, and responding to intrusions and thefts of service. Security threats are prevented by administering access to hardware/ software resources. Remote access to network servers and routers is permitted only via secured network protocol. Additionally, remote access can be initiated only from network hosts having certain IP addresses, and it also requires a valid combination of a username and a password. Security threats are also prevented by installing various security patches and updates of software resources released by the suppliers of these resources. Since this task is an integrated part of the software administration task of the configuration management, it is not included in security management tasks.

The number of the security management tasks (four) is considerably lower than the number of management tasks from other management areas. The following tasks defined by the model were missing: the creation, deletion and control of security services and mechanisms, the distribution of security-relevant information, and the reporting of security-relevant events.

Accounting management tasks of URAN are aimed at ensuring financial sustainability of URAN. The task "usage measurement, storage and accumulation" is concerned with collecting data on the volumes of traffic transmitted by user organizations. User charges are calculated on the basis of prices that are set by the tasks "managing pricing strategy" and "price administration". The pricing strategy of URAN is aimed at establishing prices that 1) sufficiently cover the operational expenses and bring no losses (zero profit), 2) are based on actual use of the services, 3) are lower than the competitors' prices. The task "costing" supports determination and analysis of both recurrent and non-recurrent costs of the NS, management tools, and managers. A number of tasks support the administration of financial data of URAN and various financial transactions: "general accounting operations", "accounts receivable", "accounts payable", "taxation", "assembling and sending invoices", and "user account administration". Unlike the accounting management tasks that are performed on a daily basis and have an operational nature, the tasks "budgeting", "profitability analysis", and "managing subsidies" have a strategic nature.

Conclusion The number of the fault and security management tasks is quite low, and several significant tasks are missing.

4.4.3 Management services

The following management services are provided to the users of URAN: (1) access to current traffic status information, (2) access to usage information, (3) access to tariff information. Each management service and the information it provides brings some benefits to users.

The first service implies that user organizations are able to see the current and accumulated historical loads of their access links. User organizations can use this information for deciding whether and when to upgrade the capacity of their access links.

The second service implies that user organizations are able to analyze the volumes of traffic which they transmitted and received. Since tariffs are usage sensitive, usage information allows user organizations to control the fees which they pay each month. The correct and stable operation of this service is important for financial sustainability of URAN, because usage information forms the basis for the fees paid by user organizations.

The third service implies that user organizations are informed about current tariffs and about any changes in the tariff structure.

Several management services introduced by the model are missing, namely the customer service (helpdesk), the fault handling service, and the security monitoring service. The lack of these services implies that in case of questions and problems it is difficult for user organizations to reach the network engineers of URAN. User organizations are not systematically notified about planned outages of the network, nor about the fault resolution status. The reporting of security-relevant events is missing so that user organizations are not warned early of security threats.

Conclusion There are only three management services available to the users of URAN, and a number of the management services introduced by the model are missing in the real situation of URAN.

4.4.4 Management tools

Most software resources of URAN are supplied with some tools which allow one to manage, control, and maintain them. However, it is difficult to divide a software resource into one part supporting the service provision, and another part facilitating the management of the first part. For example, the operating system FreeBSD has numerous tools facilitating the management of this software resource, such as the system monitoring tool syslog, disk space guards, and CPU usage monitor. These tools are always supplied with the operating system.

The most common management tool of URAN is a regular PC which runs under Microsoft Windows NT/2000 supplied with the bundled software, such as Microsoft Word, Excel, and Outlook. Such a PC facilitates the execution of many management tasks, since it is often used as an entry point for remote terminal sessions through which the hardware and software resources of the NS are actually managed.

Besides management tools which are integrated with the NS and the regular PCs, three specialized management tools are used, namely MRTG, the traffic accounting tool, and the Apache HTTP server. MRTG is a tool for monitoring the utilization of communication links. The traffic accounting tool supports measurement, storage, accumulation, and presentation of information on traffic volumes transmitted via communication links of URAN. It makes it possible to calculate the volumes of traffic transmitted by each user organization during certain periods of time. The Apache HTTP server is the most popular web server on the Internet.

The attribute "costs" is also applicable for the management tools of URAN. Because regular PCs are owned by other organizations than the Center of European Integration (CEI), their costs are included in the budget of URAN. The tools MRTG and the Apache HTTP server are freeware software resources which can be freely downloaded from the Internet and used without limitations. Because the traffic accounting tool was developed by an employee of the CEI, its costs were accounted for in the salary of this employee.

Conclusion There were found no gaps related to the management tools of URAN: the entity Management Tool has a number of instances in case of URAN, and the attributes introduced by the model are applicable for those instances.

4.4.5 Managers

A number of people perform and control the management tasks described in section 4.4.2. They are attached to a certain network node, so that they perform management tasks pertaining to hardware and software resources located at this node.

Since the central node has the highest concentration of resources, it is crucial that management tasks pertaining to the central node are performed by qualified people. The central node is managed by five managers: Vladimir Galagan, Yaroslav Halchinsky, Yaroslav Kiselev, Mikhail Dombrougov, and Victoriya Beshlega. These managers are also responsible for the Kiev regional node located in NTUU "KPI".

Managers of the central node have diplomas in engineering and informatics. Most managers are graduates from the National Technical University of Ukraine "Kiev Polytechnic Institute", a university which initiated the URAN. Vladimir Galagan and Mikhail Dombrougov also have a doctoral degree.

The competence of these managers well corresponds to their duties and responsibilities. Vladimir Galagan, Yaroslav Kiselev, and Yaroslav Halchinsky are managers which are highly competent in the technical aspects of network management. Vladimir Galagan is a senior networking professional having more than twenty years of experience in computer networks and information technologies. Apart from using his competencies in practice, he also gives lectures and teaches students. Additionally, he is one most active members of the team which established URAN.

Yaroslav Kiselev and Yaroslav Halchinsky are young but competent network engineers possessing excellent knowledge of various networking technologies. They have several years of experience in the administration of operating systems FreeBSD and Cisco IOS, which are core software resources of URAN. These managers know how to use numerous tools and applications supporting the provision of services to URAN users, such as squid, MRTG, gated, sarg, ipa, postfix, cucipop, and ipfw.

Mikhail Dombrougov and Victoriya Beshlega are senior managers competent in the financial aspects of network management. Mikhail Dombrougov has experience with tariffs, charging models, and financial planning for computer networks. Victoriya Beshlega is a financial administrator having many years of experience in bookkeeping and financial administration. She has gained this experience from working as a chief financial officer of the International University of Finance.

The salaries of managers of the central node lay in the wide range between 50 and 500 Euro per month. The exact salary amounts are, however, confidential information. The salaries are often lower than the salaries received by the employees of most commercial network operators in Ukraine. Most managers have another full-time job.

Conclusion There were found no gaps related to the managers of URAN: the entity Manager has a number of instances in case of URAN, and the attributes introduced by the model are applicable for those instances.

4.4.6 Financial resources

External grants are a very significant income source for URAN. The first external grant of 150000 Euro was given by the NATO Scientific Affairs Division in 1998. Since no state subsidies were available at that time, this grant played a crucial role in the creation of URAN. This and also the following two NATO grants (see Table 4.13) were given in the framework of a special NATO program[3]. Awarded funds can be used to cover the purchase of computer networking equipment only, as well as some of the costs for services such as leased lines but no longer than one year. No salaries or stipends for any of the collaborators, students, or technical assistants can be funded under these grants. NATO grants are usually paid in two installments, the

[3] This NATO program is called "Research Infrastructure Support on Computer Networking" and its objective is "to advance electronic communication within the scientific community in NATO partner countries in order to bring scientists into contact with the international scientific community" [www.nato.int]. The main financial mechanisms are the Networking Infrastructure Grants (NIGs) "whose aim is to augment the computer networking infrastructure of the academic community in partner countries. A NIG provides assistance to partner country institutions primarily for purchasing equipment that will improve the level and the quality of the connectivity of a whole community in a specific geographic region" [www.nato.int]

second installment being released after receipt of a satisfactory interim report on the progress achieved.

Cisco Systems donated a number of hardware resources – primarily routers and LAN switches – to URAN in August 1999. Although donated equipment was second-hand, it was very useful for establishing several regional nodes of URAN and providing them with the necessary equipment. The donated equipment is still used, proving its usefulness for URAN, and showing the importance of non-monetary donations.

The Ukrainian state contributed three subsidies to URAN: in 2000, 2001, and 2002 (see Table 4.13). Although state subsidies had a monetary value which was considerably lower than the value of the NATO grants, they demonstrated that the state recognized URAN as the Ukrainian NREN and was willing to support it. The creation of URAN was initiated in 1998 by a group of enthusiastic managers from several leading technical universities of Ukraine. At that time it was not clear whether the state would support this initiative; it was initially supported only by NATO. Therefore, by subsidizing URAN the state not only provided a significant income for URAN, but it also demonstrated its commitment to supporting URAN in the future, both financially and politically.

Income source	Monetary value, Euro's	Year received
NATO Scientific Affairs Division	150,000	1998
Cisco Systems, Inc.	200,000	1999
NATO Scientific Affairs Division	100,000	2000
Ukrainian State	60,000	2000
Ukrainian State	40,000	2001
NATO Scientific Affairs Division	150,000	2002
Ukrainian State	50,000	2002
Total	750,000	

Table 4.13: State subsidies and external grants received by URAN.

User fees are a considerable part of the income of URAN. Figure 4.7 demonstrates the total funds paid by user organizations monthly during the period from November 2001 to August 2002. As can be seen, the amount fluctuates considerably from month to month because it depends on the amount of traffic that user organizations transmit via the network. The average amount of total user fees is 6000 Euro per month, which is 72000 Euro annually. User fees depend on the capacity of user-access links and the volume of traffic transmitted via this link over a certain period of time – usually a month.

The proportion of funds supplied by the three funding sources (external parties, state, and user organizations) is the following (see Figure 4.8). The external parties contributed most: 600.000 Euro. The user organizations contributed slightly less, with 250.000 Euro over the four years 1998 – 2002. The Ukrainian state contributed 150.000 Euro. Unfortunately the state grants are currently extremely limited, and hardly enough for a network that has to cover a country as large as Ukraine, which has hundreds of potential user organizations spread across an area of many thousands of square kilometers.

Conclusion There were found no gaps related to the financial resources of URAN:

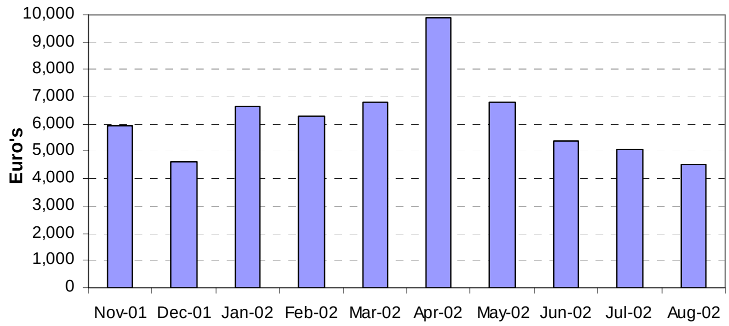

Figure 4.7: Total user fees paid monthly by user organizations of URAN.

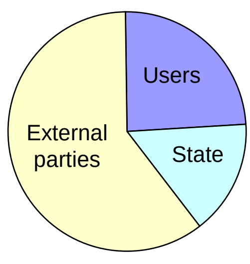

Figure 4.8: The relative proportion of the three sources of funding of URAN.

the entity Financial Resource has a number of instances in case of URAN, and the attributes introduced by the model are applicable for those instances.

4.4.7 Management bodies

The NS of URAN described in section 4.3 is managed by thirteen management bodies; each body is responsible for a part of the NS. The responsibility is divided in such a way that hardware and software resources located at each network node is managed by same management body. Backbone and external communication links are managed by a body which is responsible for the central node. Each user-access link is managed by a body which manages the corresponding node which this link is connected to.

The Center of European Integration (CEI) manages the central node. This management body was especially established in 1998 as a dedicated operator of the central node of URAN, and all backbone and external communication links. It is rather a virtual organization, because it does not have any full-time staff: all personnel is employed on a part-time basis.

The remaining twelve bodies manage regional nodes; these are user organizations – hosts of the nodes (see Table 4.9). Each organization is responsible for the management of hardware and software resources located at its site. It also manages user-access links connected to a corresponding regional node. Since currently there is only one user-access link connected to most regional nodes (see Table 4.5), their management bodies actually only provide services to their own organization. The only management body providing services to other user organizations is the National Technical University "Kharkiv Polytechnic Institute". This management body is responsible for the Kharkiv regional node, serving four user organizations.

According to the conceptual model, a management body can be characterized by the three attributes, namely the category, the size, and the organizational structure. Let us describe values of these attributes in case of the Center of European Integration. This management body belongs to the category of commercial companies. Its size equals six part-time employees. Because of its small size, the organizational structure is also very simple and consists of a few positions such as director, bookkeeper, and network engineer.

Conclusion There were found no gaps related to the management bodies of URAN: the entity Management Body has a number of instances in case of URAN, and the attributes introduced by the model are applicable for those instances.

4.4.8 Relationships among entities of the MNS

The conceptual model has defines eleven relationships among entities of the MNS presented below in Table 4.14. Below we describe the content of these relationships for URAN.

The relationship `m1` represents the distribution of management tasks among managers. The content of this relationship is demonstrated in Table 4.15. The set of tasks performed by the managers corresponds to their competence profiles described in section 4.4.5. Vladimir Galagan is responsible for many policy and planning tasks which have strategic importance, such as setting up performance goals, supplier and

m1	Manager is responsible for Management Tasks
m2	Manager uses Management Tools
m3	Manager belongs to Management Bodies
m4	Financial Resource covers the costs of Managers and Management Tools
m5	Management Body executes Management Tasks
m6	Management Body provides Management Services
m7	Management Tool supports or automates Management Tasks
m8	Management Service is based on Management Tools
m9	Management Service is derived from Management Goals
m10	Management Service is a result of carrying out a sequence of Management Tasks
m11	Management Task is derived from Management Goals

Table 4.14: The relationships among entities of the management of the network system.

technology policies, and external relations. Some management tasks he performs together with Mikhail Dombrougov, such as contracting, managing pricing strategy, and managing subsidies. Mikhail Dombrougov is responsible for most of the accounting tasks together with Victoria Beshlega. Yaroslav Halchinsky and Yaroslav Kiselev are responsible for management tasks having a technical nature.

The relationship m2 implies that Vladimir Galagan, Yaroslav Kiselev, and Yaroslav Halchinsky periodically use the MRTG tool for controlling the current state of communication links. They open web pages which contain graphs showing the daily load of communication links, and visually analyze the content of these graphs. Besides MRTG, these managers also use numerous other tools embedded in the operating systems FreeBSD and CiscoIOS. Mikhail Dombrougov frequently uses the traffic accounting tool, which provides input information for the compilation of bills to user organizations.

The relationship m3 implies that the managers described in section 4.4.5 belong to the management body responsible for the central node – the Center of European Integration. It is remarkable that Vladimir Galagan, Yaroslav Halchinsky, and Yaroslav Kiselev also belong to another management body responsible for the Kiev regional node in NTUU "KPI".

The relationship m4 for URAN can be reformulated as "financial resource covers the costs of managers" because the costs of management tools are basically zero. For the three kinds of financial resources, namely user fees, state subsidies, and external grants, the content of the relationship is basically "the user fees cover the costs of managers" (the salaries of managers). This implies that external grants and state subsidies are used for covering the costs of the NS.

The relationships m5 and m6 have the following content. Since there is only one management body – the Center of European Integration, it executes the management tasks and provides the management services described in the preceding sections.

The relationship m7 has the following content. Regular PCs support nearly all management tasks since they are the usually the main entry point for managers to

Manage ment area	Management task	Managers *)				
		VG	MD	YK	VB	YH
Performance management	P1. Setting up performance goals	+				
	P2. Definition of performance indicators	+				
	P3. Collecting performance data			+		+
	P4.Providing current traffic status information					+
	P5. Setting up network traffic management policy	+				
	P6. Creating and modifying routing patterns	+				+
	P7. Traffic forecasting	+				
Fault management	F1. Network fault event analysis	+				
	F2. Verification of parameters and connectivity			+		+
	F3. Network fault localization	+		+		+
	F4. Management of repair process	+				
Configuration management	C1. Supplier and technology policy	+	+			
	C2. Infrastructure planning	+				
	C3. Network infrastructure design	+		+		+
	C4. Routing design			+		+
	C5. Procurement	+				
	C6. Management of installation	+				
	C7. Contracting	+	+			
	C8. Network installation administration	+				
	C9. Software administration			+		+
	C10. Marketing	+	+			
	C11. Management of sales process	+				
	C12. External relations	+				
	C13. Solution proposal	+	+			
Security management	S1. Provision of necessary environmental conditions	+				
	S2. Provision of power supply	+				
	S3. Severing connections			+		+
	S4. Administration of access control			+		+
Accounting management	A1. Usage measurement, storage and accumulation	+				
	A2. Managing pricing strategy	+	+			
	A3. Tariff and price administration	+	+			
	A5. Costing		+			
	A6. Providing access to tariff information		+			
	A7. Rating usage		+			
	A8. Totaling usage charges		+			
	A9. General accounting operations				+	
	A10. Accounts receivable				+	
	A11. Accounts payable				+	
	A12. Taxation				+	
	A13. Assembling and sending invoices				+	
	A14. User account administration		+		+	
	A15. Budgeting		+			
	A16. Profitability analysis		+			
	A17. Managing subsidies	+	+			

*) VG - Vladimir Galagan, MD - Mikhail Dombrougov,
YH - Yaroslav Halchinsky, VB - Victoriya Beshlega, YK - Yaroslav Kiselev,

Table 4.15: Management tasks of URAN and their attachment to managers.

get access to hardware and software resources of the NS. The Apache HTTP server supports management tasks P4, A1, and A5 (see Table 4.15). MRTG supports the management task P4. The traffic accounting tool supports management task A1. Other management tasks are often supported and/or automated by the tools which are integrated into the software resources of the NS, particularly in the operating systems FreeBSD and CiscoIOS.

The relationship `m8` has the following content. Since all management services are delivered via the web browser, they are all partially based on the Apache HTTP server. Additionally, the first two management services are based on other management tools: the service "access to current traffic status information" is based on MRTG, while the service "access to the usage information" is based on the traffic accounting tool.

The relationships `m9` and `m11` refer to the fact that all management tasks and management services must be derived from management goals. However, it was not possible to verify these relationships for URAN because the management goals of URAN were insufficiently clear.

The content of the relationship `m10` becomes obvious if we consider the names of the management services which correspond to the names of these management tasks. The three management services are the result of carrying out the management tasks P4, A1, and A5, respectively.

During the application of the model in case of URAN the following *two gaps in the model were detected*. The model is unable to reflect (1) relationships between different management tasks, (2) contractual relationships among multiple management bodies.

Certain management tasks are strongly dependent on other tasks. For example, the task "traffic forecasting" from the performance management area depends on the task "routing design" from the configuration management area: this is because the changes in the routing design influence traffic flows, which, in their turn, affect the forecasting of traffic volumes of such flows. Similarly the tasks "procurement" and "contracting" are also related to each other. The model does not reflect such dependencies among management tasks.

The network system of URAN is managed by as many as thirteen management bodies listed in Table 4.9, with each management body being responsible for a single network node. Center of European Integration – the management body responsible for the central node – has contracts with other management bodies. These contracts specify among other things the services which the CEI provides to regional networks, and the responsibilities of contracting parties. An important responsibility is, for example, a timely payment of user fees. The practice shows that sometimes payments can be significantly delayed. The model is currently unable to cover mentioned aspects which are ultimately important for URAN.

Conclusion A gap in the management goals of URAN affects the relationships `m9` and `m11`. The remaining relationships among the entities of the MNS all present in the real situation of URAN.

Two gaps in the conceptual model were identified: the model is unable to reflect (1) relationships between different management tasks, (2) contractual relationships among multiple management bodies.

4.5 Relationships among NS, RS, and MNS

	Relationship among entities of RS, NS, and MNS	Generic relationship
e1	Management Body is a subdivision of State Agency or User Organization	MNS services RS
e2	User Organization or State Agency provides Financial Resources	RS employs MNS
e3	Financial Resource covers the costs of the Network System (Hardware Resources, Software Resources, and Communication Links)	MNS manages NS
e4	Management Body provides Network Services to User Organizations	MNS services RS
e5	Management Goal is based on the characteristics of the Network System, Requirements, Preconditions, and the attributes of the Association of Users	NS informs MNS, RS employs MNS
e6	Management Task is related to Hardware Resources, Software Resources, and/or Communication Links	MNS manages NS
e7	Network System reports to Management Tasks	NS informs MNS
e8	Management Body provides Management Services to User Organizations	MNS services RS
e9	Network Service supports Needs and Business Processes	NS supports RS
e10	Requirement specifies the assortment and the characteristics of Network Services and Management Services	RS exploits NS
e11	End User utilizes Network Services	RS exploits NS
e12	User Organization utilizes Network Services	RS exploits NS
e13	User Organization utilizes Management Services	RS employs MNS

Table 4.16: The relationships among RS, NS, and MNS.

The conceptual model grouped such relationships in six generic relationships "RS exploits NS", "NS supports RS", "MNS manages NS", "NS informs MNS", "MNS services RS", "RS employs MNS". Coming sections 4.5.1 – 4.5.6 present the content of these relationships in case of URAN.

4.5.1 RS exploits NS

There are three relationships representing the generic relationship of the management paradigm "RS exploits NS", namely `e10`, `e11`, and `e12`, see Table 4.16.

The relationship `e10` represents the definition of the entity Requirement. A gap in this entity affects also the relationship `e10` and makes it is rather weak: because of the lack of clearly specified requirements, it is questionable whether the assortment and the characteristics of network services match the demands of users.

The relationship `e11` is applicable for URAN. However, it is difficult to present its description because this would require detailed statistics about traffic transferred from each PC within the campus networks of the user organizations – such statistics are lacking.

The relationship `e12` reflects a fundamental link between the RS and the NS, namely that the former utilizes the latter. The content of this relationship is demonstrated for the National Technical University of Ukraine "Kiev Polytechnic Institute" – the biggest and heaviest user of URAN, and the IP connectivity service – the most heavily utilized network service of URAN. Figure 4.9 demonstrates traffic volumes transmitted via the user-access link of this organization. Similar graphs can also be drawn for other user organizations. The relationship `e12` strongly influences `e2`, since the fees paid by a user organization depend on the traffic volumes sent.

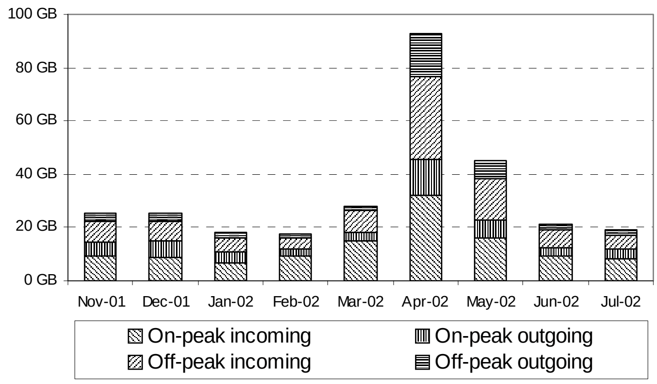

Figure 4.9: The demonstration of the relationship `e12` "User Organization utilizes Network Services" for the user NTUU "KPI" and the IP connectivity service (traffic volumes transmitted via the user-access link of NTUU "KPI").

Conclusion There were found no gaps in the generic relationship "RS exploits NS" for URAN: the relationships `e10`, `e11` and `e12` exist in the real situation of URAN. However, a gap in the entity Requirement affects the relationship `e10` and makes it is rather weak.

4.5.2 NS supports RS

The generic relationship of the management paradigm "NS supports RS" is represented in the conceptual model by the relationship `e9` "Network Service supports Needs and Business Process". Like the relationship `e11`, the relationship `e9` emphasizes that users are primarily interested in network services which support their activities. It reflects the primary aim of the NS which is to support the RS.

Network services support research processes by providing the basis for searching for literature, and also for communication among scientists at different R&E institutes, both within Ukraine and abroad. Some user organizations start to make use of distance learning courses which rely on the network services of URAN.

Conclusion There were found no gaps in the generic relationship "NS supports RS" for URAN: the relationship `e9` exists in the real situation of URAN.

4.5.3 MNS manages NS

The generic relationship of the management paradigm "MNS manages NS" is represented in the conceptual model by the relationships `e3` and `e6`.

The relationship `e3` reflects the way in which financial resources are used for covering costs of the entities which comprise the NS. It has the following content in case of URAN. External grants and state subsidies cover procurement costs of hardware resources such as network servers, routers, and modems. External grants provided by NATO also partially cover recurrent costs of communication links, namely those of the external communication links. The last NATO grant was planned to cover the costs of a communication link to the Trans-European REN "GÉANT". User fees cover the costs of communication links.

The relationship `e6` implies that management tasks are related to entities comprising the NS. The names of the management tasks clearly indicate that these tasks are related to some hardware resources, software resources, or communication links.

Conclusion There were found no gaps in the generic relationship "MNS manages NS" for URAN: the relationships `e3` and `e6` exist in the real situation of URAN.

4.5.4 NS informs MNS

The generic relationship of the management paradigm "NS informs MNS" is represented in the conceptual model by the relationships `e5` and `e7`.

The relationship `e5` reflects the fundamental basis of the management goal: the characteristics of the NS, the requirements, the preconditions, and the attributes of the association of users. A gap in the entities Requirement and Precondition affects this relationship and makes it is rather weak.

The relationship `e7` implies that the status of the hardware resources, software resources, and communication links is reported to the management of URAN. The collected information is then used for managing, controlling, and maintaining the NS. For example, the management tool MRTG collects the status of the interfaces of the central router. In case if an interface is down, appropriate actions are necessary for its recovery.

Conclusion There were found no gaps in the generic relationship "NS informs MNS" for URAN: the relationships `e5` and `e7` exist in the real situation of URAN. However, gaps in the entities Requirement and Precondition affect the relationship `e5` and make it weak.

4.5.5 MNS services RS

The generic relationship of the management paradigm "MNS services RS" is represented in the conceptual model by the relationships `e1`, `e4`, and `e8`.

The relationship `e1` implies that management bodies are subdivisions of user organizations or state agencies. Table 4.9 demonstrated which user organizations host regional nodes of URAN. The subdivisions of these user organizations are management bodies. For example, a Kiev regional node located at the site of the NTUU

"KPI" is managed by the Center of Computer Communication, which is a subdivision of NTUU "KPI". Another Kiev regional node is managed by the Computer Center of the Ministry of Education and Science, which is a subdivision of the state agency.

The relationships `e4` and `e8` imply that management bodies provide the network services and the management services to the user organizations. The CEI provides the network services to user organizations connected to the central node. The operators of the regional nodes provide the network services to user organizations connected to those nodes. The CEI also provides all management services; this is accomplished by making the management services accessible via the web site. The services "access to current traffic status information" and "access to usage information" are available to authorized representatives of user organizations via secured login accounts.

The relationship `e4` is affected by a gap in the entity Network Service. This is because this relationship reflects the contractual agreements between the management bodies and the user organizations. In case of URAN, such agreements do not specify agreed service levels as the conceptual model prescribes.

Conclusion There were found no gaps in the generic relationship "MNS services RS" for URAN: the relationships `e1`, `e4`, and `e8` exist in the real situation of URAN. However, the relationship `e4` is affected by a gap in the entity Network Service.

4.5.6 RS employs MNS

The generic relationship of the management paradigm "RS employs MNS" is represented in the conceptual model by the relationships `e2` and `e10`.

The relationship `e2` is meant to represent the way in which financial resources are obtained. According to the conceptual model, it represents the logical association between financial resources and their providers: external parties, user organizations, and state agencies. Table 4.13 already demonstrated which financial resources were provided by the external parties NATO and Cisco, and by the Ministry of Education and Science of Ukraine. This relationship also represents a charging model forming the basis for the determination of user fees. Since URAN uses the usage-based charging model, the user fees depend on the traffic volumes received by these organizations.

The relationship `e10` is abstract in nature. It reflects the very definition of the entity Requirement by showing an obvious dependency between this entity and the entities Network Service and Management Service.

Conclusion There were found no gaps in the generic relationship "RS employs MNS" for URAN: the relationships `e2` and `e10` exist in the real situation of URAN.

4.6 External Environment

4.6.1 External parties

The following organizations are external parties of URAN: Cisco Systems, Folgat, Ukrtelecom, SkyVision, Ukrsat, and the NATO Scientific Affairs Division. Cisco

Systems is the main supplier of the networking equipment for URAN. This company is the worldwide leader in networking for the Internet. In 1999 it donated a number of primarily routers and LAN switches to URAN. Folgat is the supplier of the network servers for URAN. It is a domestic Ukrainian company whose core business is sale of Intel-compatible computers and their components. Ukrtelecom is the supplier of the data transmission services for URAN. It the national telecommunication operator in Ukraine – a leader in the field of national telecommunications by the scope and range of telecommunication services. SkyVision and Ukrsat are the suppliers of the Internet access service for URAN. SkyVision is a company which specializes in the provision of the Internet access over satellite. Its geographical reach covers well over sixty countries, including Ukraine. Ukrsat (full name "Ukrainian Satellite Systems") is a multi-profile Ukrainian enterprise providing various telecommunication services including Internet access over satellite. The NATO Scientific Affairs Division is the provider of financial grants for URAN.

The model was found to be *unable to reflect contractual relationships between the management bodies and the external parties.* The Center of European Integration has a number of contracts with the external parties. The conclusion of such contracts involves many management activities and is a special point of interest for the management of URAN. For example, the management constantly tries to find a better provider of the Internet access service, attempting to purchase the service at a good quality at a low price. Over the period from 1999 to 2002, URAN changed the Internet providers several times. The conceptual model cannot reflect this matter.

Conclusion There were found no gaps related to the external parties of URAN: the entity External Party has a number of instances in case of URAN.
A gap in the model was found: the model was unable to reflect contractual relationships between the management body "CEI" and the external parties.

4.6.2 Telecommunication services

The NS of URAN is strongly dependent on the telecommunication infrastructure and services provided by the national telecom operator Ukrtelecom. This is because many of the communication links connecting network nodes of URAN are based on this infrastructure and on the corresponding data transmission services. Although local links can be established simply by putting wires and cables, long-distance links are always dependent on the existing telecommunication infrastructure and services.

The Ukrtelecom's network is the only telecommunication infrastructure in Ukraine which can be used as a basis for URAN communication links. Although in Kiev and some other big cities there are alternative telecommunication networks run by other telecoms, only a few organizations can afford paying connection fees. Additionally, the geographical coverage of such networks is too small compared with the national coverage of the Ukrtelecom's network.

Ukrtelecom offers a number of telecommunication services which can be used for the transmission of data. The DRC (digital rendered channels), the FR (frame relay), and the HDSL (high-speed digital subscriber line) services form the basis for the communication links of URAN.

The capacity of the Ukrtelecom's telecommunication services is in the range between 64 Kbps and 2 Mbps. Until recently, the capacity of the DRC service was either 64 K, 128 K, or 2048 K. This fact significantly limited the choice of the capacity for long-distance communication links of URAN: it was possible to use either cheap but slow 64K/128K-links, or expensive but fast 2048K-links. Both alternatives were not always efficient. This limitation hindered the gradual growth of the links' capacity. In 2002, however, it became possible to order communication links with arbitrary capacity.

The price of each service is formed in a different way and depends on a different set of parameters. It consists of two parts, namely the installation fee, and the recurrent fee. The installation fee is paid initially, once the service is ordered, and it is usually between 100 and 300 Euro. The recurrent fee of the DRC service depends on the capacity and the length of a corresponding link, which is measured in units of 100 km. URAN and other state-funded customers of Ukrtelecom enjoy discount prices. Figure 4.10 gives the regular prices of the DRC service compared with discount prices.

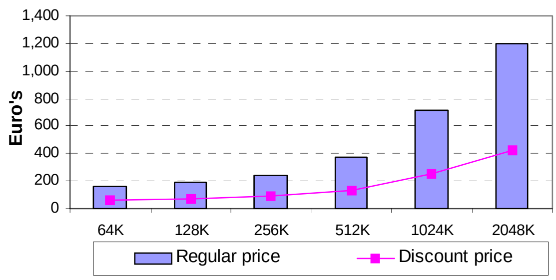

Figure 4.10: Monthly price of 100 km digital rendered channel depending on the bandwidth (source: www.ukrtelecom.ua)

The area of availability of telecommunication services is limited to big cities of Ukraine – capitals of regions. It also covers most cities hosting the regional nodes of URAN. Since the DRC service is not yet available in Lugansk and Simferopol, the FR service is the only alternative to connect these regional nodes to the central node of URAN. Since data-transmission services are currently unavailable in small cities and rural areas, it is difficult for URAN to serve users located in those areas.

The so-called "last mile problem" often severely constrains the availability of the DRC service. Ukrtelecom is sometimes unable to deliver this service to the sites where regional nodes are physically located. In some cities, only a single telephone exchange is connected to the long-distance digital channels. Therefore, connecting the sites of the regional nodes to such an exchange poses a problem.

Conclusion There were found no gaps related to the telecommunication services of Ukrtelecom: the entity Telecommunication Service has a number of instances in case of URAN, and the attributes introduced by the model are applicable for those instances.

4.6.3 Internet access service

The Internet access service is probably the most important service of URAN. URAN is both a provider and a customer of this service. One the one hand, URAN provides this service to its user organizations. On the other hand, URAN purchases this service from two Internet Service Providers Ukrsat and SkyVision.

The conceptual model defines several attributes of the entity Internet Access Service: the capacity, the price, and the area of availability. It also pointed out that the dedicated Internet access is more relevant for the analysis than the dialup access.

The capacity of the Internet access service shows significant variations. Organizations located in big industrial centers such as Kiev, Donetsk, Dnepropetrovsk, Kharkiv, and Odessa have relatively fast Internet access via links having capacities up to 1024 Kbps. Organizations located in small provincial cities often have only slow connections via leased analog telephone lines; the maximum capacity of such lines is 56 Kbps. In total, only 10% of corporate Internet users in Ukraine use dedicated links, the rest use dialup. Broadband connections are only starting to be developed.

The price of the Internet access service varies depending on the charging model. The model recognizes two kinds of charging models, namely flat rate and usage-based charging models. The usage-based model has two implementations in Ukraine, namely the volume-based model and the average-load model. Table 4.17 demonstrates the popularity of these charging models among ISPs in different regions of Ukraine.

Region	Flat rate	Volume based	Average load
Kiev	93%	30%	43%
Dnepropetrovsk	100%	10%	10%
Donetsk	100%	44%	44%
Kharkiv	36%	91%	36%
Lviv	88%	38%	63%
Odessa	40%	60%	30%
Other regions	50%	20%	30%
Whole Ukraine	76%	40%	37%

Table 4.17: Percentage of Internet service providers in different regions of Ukraine using each charging model.

The area of availability of the Internet access service generally covers all regional and provincial centers of Ukraine. Kiev, Donetsk, Dnepropetrovsk, Kharkiv, and Odessa are the best served areas for Internet access, while the Khmelnitskiy and Volynsk are the worst served areas. Many users in rural areas have no telephone, and therefore not even dialup Internet access. In total, only 4% of the Ukrainian population has access to the Internet, while in Western Europe this number is 30–40%.

Conclusion There were found no gaps related to the Internet access service in Ukraine: the entity Internet Access Service has a number of instances in case of URAN, and the attributes introduced by the model are applicable for those instances.

4.6.4 Domestic Internet

The conceptual model defines several attributes of the entity Domestic Internet. These attributes and also their values in case of URAN are presented Table 4.18.

Attribute	1998	2002	Annual growth rate
Number of Internet hosts, '000	10	62	155%
Number of personal computers, '000	710	1200	42%
Number of Internet users, '000	120	900	187%
Number of Internet service providers	150	280	46%

Table 4.18: Values of attributes reflecting the growth of the Ukrainian Internet.

According to [RIP], the number of Internet hosts in Ukraine is significantly lower than that in other European countries, including former socialistic countries of Eastern Europe. For example, in July 2002, Hungary had 228.000 Internet hosts, Poland 731.000, and the Czech Republic 230.000. Nevertheless, the Ukrainian annual growth rate of the number of Internet hosts is higher than that in some Western European countries. For example, in Germany the number of Internet hosts grows annually by 73%, and in the UK by 63%, while in Ukraine there is a 155% growth.

Although the number of Internet users in Ukraine is considerably lower than in most developed countries, it grows rapidly. From 1998 to 2002, the number of Internet users in Ukraine grew from 120 to 900 thousand, which is an annual growth of 187%. More than half of the Ukrainian Internet users are located in Kiev. Other large regional centers are Odessa, Dnipropetrovsk, Donetsk, Kharkiv, Lviv, and Zaporizhya, which account for about one third of the Ukrainian Internet audience. Other regions account for the remaining 20–25%.

The growth of the population of Internet users in Ukraine is limited by the number of PCs. Only 2,6% of the Ukrainian population has access to PCs, while in developed countries this number reaches 70–80%. By the end of 2002, there were only 1,2 million computers in Ukraine, while the population of Ukraine is nearly 50 million people.

The trend of rapidly growing population of Internet users has an impact on the RS of URAN. It indicates that the number of end users of URAN will also grow, and, therefore, this aspect of external environment influences the number of instances of the entity End User.

By the end of 2002 the number of Internet service providers in Ukraine exceeded 280. This fact indicates that the market for Internet service provision in Ukraine is highly competitive. The pattern of geographical distribution of ISPs follows the distribution of Internet users: Kiev has the largest amount (80) of ISPs, followed by large regional centers.

Commercial ISPs are often competitors of URAN, many user organizations buy network services from them rather than from URAN. Such a situation creates certain challenges for the management of URAN, and requires it to undertake some business activities aimed at promotion of its services. This makes the management tasks "marketing", "external relations", and "management of sales process" very important.

Conclusion There were found no gaps related to the Ukrainian Internet: the attributes of the entity Domestic Internet are applicable for the Ukrainian Internet.

4.6.5 Legislation

According to the conceptual model, the entity Legislation has two vital instances, namely the national ICT policy, and the regulatory basis for telecom liberalization.

The national ICT policy of Ukraine is represented by several legislative acts. Firstly, it is the law "On the National Programme of Informatization" accepted by the parliament in 1998. This law has undergone several minor changes in the next several years. Secondly, it is the decree "On the Approval of the Tasks of the National Programme of Informatization for 2000 – 2002". This decree was approved by the Ukrainian Parliament in 2000. One of the tasks stated in this decree was the creation of the national computer network for education, research, and culture. Several state subsidies were given to URAN in the framework of this decree. Thirdly, it is the decree of the President of Ukraine "Measures for Developing the National Component of the Global Information Net Internet and Securing Public Access to it in Ukraine". This decree states that the State Committee on Communication and Informatization is in charge of the realization of prioritized goals aimed at further Internet development in Ukraine.

The regulatory basis for the telecom liberalization in Ukraine is not yet fully crystallized. The law "On Telecommunications" initially accepted in 1995 received much criticism in Ukraine over the last years. Policy-makers realized the high priority and necessity of the telecommunication sector for the country's economy and, therefore, have been thoroughly discussing various new versions of this law. Regrettably though, so far all versions were turned down by the Parliament of Ukraine (August 2002).

Conclusion The regulatory basis for telecom liberalization is missing in Ukraine. The incumbent telecom operator, Ukrtelecom, has a monopoly on the provision of terrestrial telecommunication services. This keeps the price of telecommunication services high and the transmission capacity low.

4.7 Summary of gaps

This section summarizes the gaps in the model and in the real situation which were identified in the preceding sections of this chapter. Section 4.7.1 summarizes gaps in the conceptual model – aspects of the real situation which are not properly covered by the model. Section 4.7.2 summarizes gaps in the real situation – entities and relationships which are either missing in the real situation, or have been developed improperly.

The information presented in this section is based solely on the opinion of the researcher – the author of this dissertation; no other people have been involved. The representatives of the sites will be involved in the evaluation of the model later on, as shown in Chapter 6.

4.7.1 Gaps in the conceptual model

During the application of the conceptual model in case of URAN, it was found that some vital aspects of the real situation were not properly covered by the conceptual model. The model was found to be unable to reflect the following issues of the real situation:

1. financial conditions of user organizations, see section 4.2.1,
2. relationships between different management tasks, see section 4.4.8,
3. contractual relationships among multiple management bodies, see section 4.4.8,
4. contractual relationships between the management bodies and the external parties, see section 4.6.1.

4.7.2 Gaps in the real situation of URAN

Before giving an overview of gaps in the real situation of URAN, let us make the following remark. We did not attempt to cover all possible missing points of the real situation – that would be an enormous task which is hardly possible to accomplish within the scope of a doctorate research. Moreover, this research is positioned not on an operational level, but rather on a strategic level. The gaps in the real situation of URAN relate to the existence of the model's elements (entities, attributes, and relationships) in case of URAN.

During the application of the conceptual model in case of URAN, it was found that some entities, attributes, and relationships were either missing in the real situation, or had been hardly developed. The following gaps in the real situation of URAN were identified:

1. Lack of the Acceptable Usage Policy (AUP)
2. The management of URAN does not know requirements and preconditions of user organizations
3. Lack of service levels of the network services
4. Lack of management goals
5. Limited number of fault and security management tasks
6. Limited number of management services
7. Lack of regulatory basis for telecom liberalization and the monopoly of Ukrtelecom on the provision of terrestrial telecommunication services

These gaps affect a number of entities and relationships highlighted in Figure 4.11. Let us briefly describe each gap together with entities and relationships it affects.

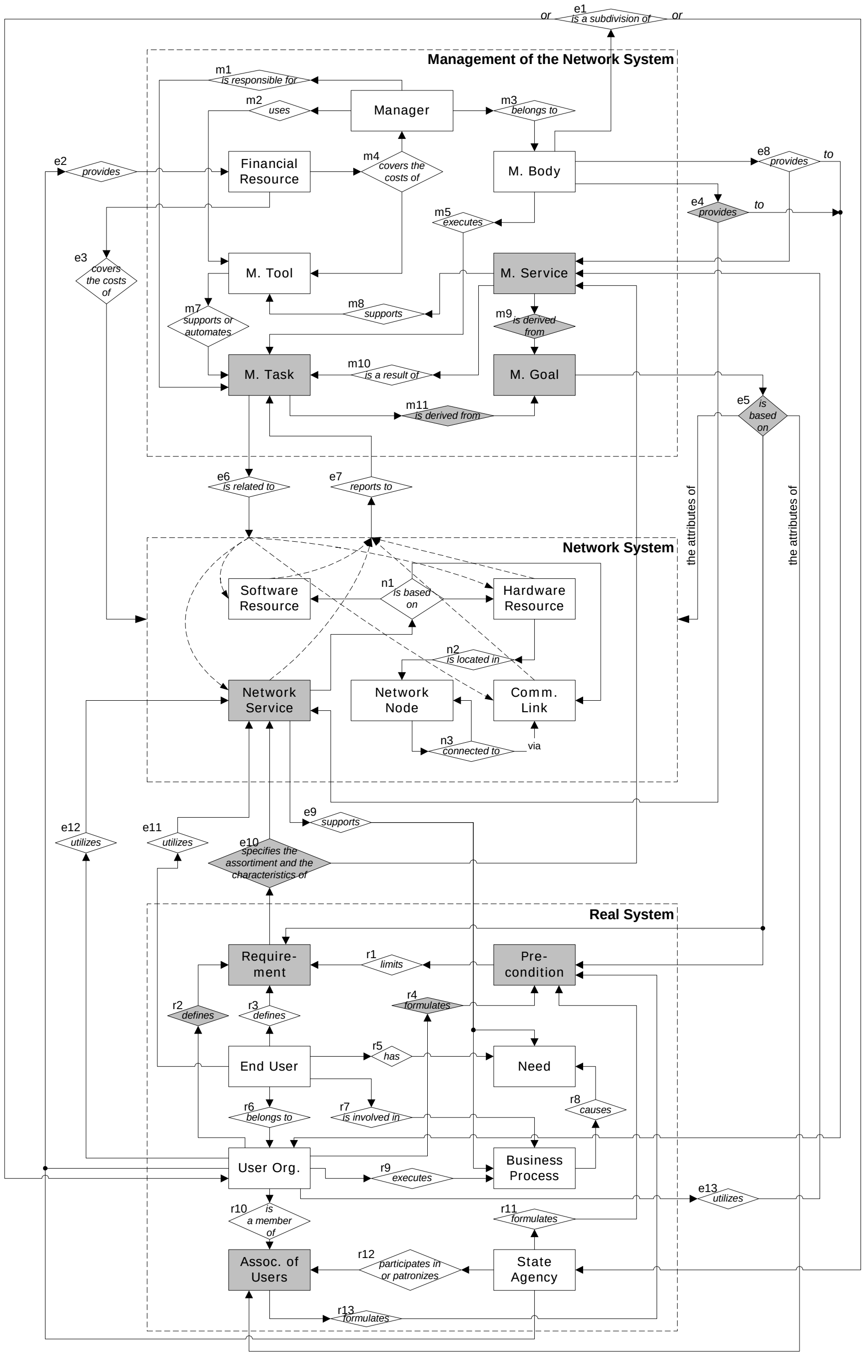

Figure 4.11: Gaps in the real situation of URAN seen from a perspective of the conceptual model (affected entities and relationships are highlighted by the gray color).

1. Lack of the Acceptable Usage Policy (AUP)

Because of the lack of the AUP, it is unclear what kinds of organizations are eligible users of URAN, what kinds of activities related to the usage of URAN are not allowed, and what the measures can be taken in case the policy rules are violated. In the model this gap relates to lack of the attribute "policy" within the entity Association of Users, see section 4.2.3.

2. The management of URAN does not know requirements and preconditions of user organizations

The management of URAN does not know what services user organizations need, and what conditions restrain the needs. Services here mean both network services and management services. Even though financial preconditions are recognized, they are not clearly specified in terms of financial budgets. For example, it is unclear how much money each particular user organization can spend on computer networking, including on the services of URAN.

In the model this gap mainly relates to the entities Requirement and Precondition. In case of URAN these entities do not have clearly specified instances, see sections 4.2.7 and 4.2.8. Besides these two entities, this gap also relates to the relationships `r2`, `r4`, and `e10`. The relationship `r2` "User Organization defines Requirements" is weak, which means that it is unclear whether user organizations define their requirements, and whether they are able to do this at all. Similarly, the relationship `r4` "User Organization formulates Preconditions" is also weak, since the preconditions are unknown. Finally, the relationship `e10`[4] is weak: because of the lack of clearly specified requirements, it is doubtful whether the current assortment and the characteristics of services match the users' needs.

3. Lack of service levels of the network services

This gap means that the service levels of the network services of URAN are not recognized. Although the management of URAN is aware of service levels and does recognize their importance, no efforts aimed at defining and measuring the service levels of network services were undertaken to date. According to the model, the service level reflects a certain quality of a service expected by users. In case of URAN it is, for example, unclear what the actual availability of the transmission services is, and what the effective transmission speed is with which every user organization can transmit data.

In the model this gap relates to the attribute "service level" of the entity Network Service, see section 4.3.1. In case of URAN this attribute is missing so that it cannot be filled with the actual data. Indirectly, this gap is also linked to the relationship `e4` "Management Body provides Network Services to User Organizations". This is because the contractual agreements between the management bodies and the user organizations of URAN do not specify any agreed service levels as the conceptual model prescribes.

[4] Requirement specifies the assortiment and the characteristics of Network Services and Management Services

4. Lack of management goals

This gap means that the management of URAN is not directed by clearly specified goals. It unclear why the network system of URAN should be managed, and what kind of matters should be taken into account when managing it. The theoretical management goals suggested by the conceptual model are not fulfilled because of lack of knowledge on preconditions and requirements.

In the model this gap mainly relates to the entity Management Goal. In case of URAN this entity does not have clearly specified instances, see section 4.4.1. Additionally, this gap affects the relationships `e5`, `m9`, and `m11`. The relationship `e5`[5], which plays a fundamental role in linking the management with the NS and with the RS, is rather weak in case of URAN: it is questionable whether the management of URAN is based on the attributes of the NS, the requirements, the preconditions, and the attributes of the URAN Association. The relationships `m9` "Management Service is derived from Management Goals" and `m11` "Management Task is derived from Management Goals" are affected, because management services and management tasks cannot be derived from management goals if the latter are not available.

5. Limited number of fault and security management tasks

The number of fault and security management tasks in Table 4.12 is considerably lower than the number of management tasks from other management areas, and a number of tasks defined by the model is missing. The tasks directed at tracing faults and reporting the status of faults to the users are not performed. The management of URAN is not familiar with the concept of a trouble ticket, which is often used for such purposes. A number of security management tasks defined by the model is also missing. This relates to the tasks of the creation, deletion and control of security services and mechanisms; the distribution of security-relevant information, and the reporting of security-relevant events.

In the model this gap relates to the number of instances of the entity Management Task, see section 4.4.2. This entity has a limited number of instances, so in URAN many fault and security management tasks described by the model are missing.

6. Limited number of management services

This gap means that there are only three management services available to the users of URAN: a number of the management services introduced in the model are missing, namely the customer service (helpdesk), the fault handling service, and the security monitoring service.

In the model this gap relates to the entity Management Service, see section 4.4.3. This entity has a limited number of instances, so that many management services described by the model are missing in case of URAN.

[5]Management Goal is based on the characteristics of the Network System, Requirements, Preconditions, and the attributes of the Association of Users

7. Lack of a regulatory basis for telecom liberalization and the monopoly of Ukrtelecom on the provision of terrestrial telecommunication services

The regulatory basis for telecom liberalization is missing in Ukraine. This particularly relates to the liberalization of the market for terrestrial telecommunication services. There is no legislative basis which would stimulate the appearance of new players on this market. The incumbent telecom operator, Ukrtelecom, has a monopoly on the provision of such services.

This gap relates to the entity Legislation, see section 4.6.2. This entity has only one instance in case of URAN, namely "national ICT policy". The second instance, "regulatory basis for telecom liberalization", is missing. This gap also affects the attributes of the entity Telecommunication Service: because of Ukrtelecom's monopoly, the price of telecommunication services is high, the transmission capacity is low, and the availability of the services is low, so that many services are only available in big cities of Ukraine.

4.8 Adjustment of the conceptual model

Before proceeding to Step 2 of the validation methodology "adjustment of the model and development of recommendations", let us recall the visual interpretation of this step from Chapter 1, see Figure 4.12. One goal of the model is to help bringing the management of a REN to a higher level. Therefore, the model has been designed in such a way that it produces a number of recommendations for improving the site. Another goal however, is to improve the model by confronting it with the validation site, and by analyzing the feedback coming from this site. It is important to understand that the recommendations are not developed at the same time as the model is modified: these are two independent events that occur in sequence.

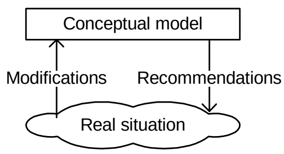

Figure 4.12: Visual interpretation of Phase 4, Step 2 "Adjustment of the model and development of recommendations".

The previous section demonstrated four gaps in the conceptual model – vital aspects of the real situation which are not reflected in the model. Therefore, the model has to be modified so that it will include those aspects as well. In this way the conceptual model benefits from the real situation. This section explains in which way the model has to be adjusted in order to remove these gaps. Figure 4.13 graphically demonstrates[6] the relationships which are added to the model in order to remove the gaps.

[6]In order to simplify reading the model, only new relationships are shown in Figure 4.13. Similarly, only entities related to these relationships are shown.

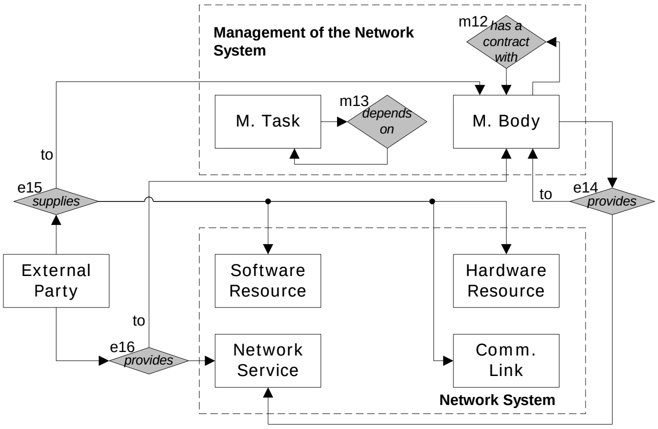

Figure 4.13: The new relationships introduced to the conceptual model after the confrontation of the model with the real situation of URAN (the adjusted conceptual model).

The gap *"inability to reflect financial conditions of user organizations"* can be corrected by simply adding an extra an attribute "financial condition" to the entity User Organization. This attribute would reflect the fact that some user organizations are richer than others. The addition of this attribute is in line with the strategy of the conceptual model, since the model defines only the attributes which are relevant for every RENs. Therefore, the introduction of an extra attribute is merely an adaptation of the model to a particular situation. The proposed attribute reflects the availability of funds within a user organization. It influences the volume of funds which an organization can spend on computer networking, including the subscription to network services of URAN.

The gap *"lack of relationships between different management tasks"* can be corrected by introducing the new relationship `m13`, "Management Task depends on Management Task". This relationship will ensure that the dependency of management tasks on each other are represented by the conceptual model.

The gap *"inability to reflect the relationships among multiple management bodies"* can be corrected by introducing two new relationships: `m12` "Management Body has a contract with Management Body", and `e14` "Management Body provides Network Service to Management Body". These relationships will ensure that the contractual relationships between the CEI and the operators of regional nodes are represented by the model.

The gap *"inability to reflect contractual relationships between management bodies and external parties"* can be corrected by introducing two new relationships between entities Management Body and External Party: the relationship `e15` "External Party provides Network Services to Management Body" and `e16` "External Party supplies Hardware Resources, Software Resource, or Communication Links to Management Body" (see Figure 4.13). These relationships will ensure that contracts between the CEI and Ukrtelecom, and between the CEI and Internet providers such as Ukrsat, can be represented in the model.

4.9 Development of recommendations

The application of the model to the case of URAN revealed a number of gaps in the real situation, which were summarized in section 4.7.2. These gaps have allowed producing a number of recommendations which are expected to be beneficial for the real situation:

1. Draw up an Acceptable Usage Policy
2. Investigate requirements and preconditions of user organizations
3. Introduce service levels for network services
4. Define management goals and control their fulfillment
5. Introduce new fault and security management tasks
6. Introduce new management services

These recommendations are related to the first six gaps in the real situation. The seventh gap, "lack of a regulatory basis for telecom liberalization and the monopoly of Ukrtelecom on the provision of terrestrial telecommunication services", belongs to the external environment, on which the management of URAN has little influence. Although the management of URAN is well aware of this gap and its negative consequences, there is little it can do improve the situation. In this research we do not attempt to give recommendations for removing gaps related to the external environment. However, we do inform the management of the REN of such gaps and their consequences.

It is important to emphasize two peculiarities of the recommendations presented in this section. Firstly, the recommendations result from the use of the model, and not from a practice-based approach. This distinguishes them from recommendations generated by practitioners. Secondly, the recommendations are based solely on own judgments of the author of this dissertation: no other people were involved in the development of these recommendations.

1. Draw up an Acceptable Usage Policy

This recommendation implies answering three questions and putting the answers in a document which should be accepted by the administrative bodies of the URAN Association, namely the General Assembly, the General Council, and the Technical Committee. These questions are: 1) which organizations are eligible users of URAN, 2) what are activities for which the usage of URAN and its services is not allowed, 3) what measures are taken in case the policy rules are violated. Examples of AUPs of other NRENs can be used as a starting point.

2. Investigate requirements and preconditions of user organizations

This recommendation implies getting specifications of services needed by user organizations, and also conditions restraining the need for these services. Such specifications would benefit both users and management bodies of URAN. Users would get services that fill their needs, and management bodies would be able to provide services at a more professional level . Additionally, users would become more aware of possible services that might be provided to them in the near future.

The input should be provided by both existing and potential users. The involvement of potential users would facilitate promotion of URAN and attraction of new users. Each user organization should be represented by people having certain positions. Firstly, a technical manager of the campus network and a director of the computing centre should be interviewed. Secondly, because preconditions by definition are formulated by the management of user organizations, it is important to interview people having decision-making power such as rectors, deans, and heads of departments

Besides surveying R&E institutions, we also recommend using the results of similar investigations conducted by other NRENs. For example, the British NREN JANET conducted a requirements analysis in 1999. The result of this study[7] can be used as a good example.

3. Introduce service levels for network services

This recommendations implies defining and measuring indicators which will reflect actual quality characteristics of the network services of URAN. We recommend to introduce the following two indicators for all network services, namely the availability of services and the mean time between failures. Additionally, we recommend to introduce the following three indicators for the IP connectivity services: the latency (response time), the average maximal throughput[8], and the packet loss rate. The values of these indicators should be monitored 24 hours a day, 7 days a week. The results of monitoring should be reported to user organizations via the web site of URAN.

The introduction of service levels will make it possible to estimate objectively the relationship `e4` "Management Body provides Network Services to User Organizations". Reporting on these service levels could also be the basis for the Service Level Agreements (SLAs) between the management bodies of URAN such as the CEI, and user organizations. Although there are legal agreements between management bodies and user organizations, these agreements cannot be called SLAs because they do not include the concept of agreed service levels.

[7] The results of this study are available at www.superjanet4.net/requirements/ra_initial_report.html

[8] The average maximal throughput is calculated by averaging the instant throughput of a link during the period of time in which the link is usually heavily used (for example, on weekdays from 8:00 till 18:00)

4. Define management goals and control their fulfillment

We recommend to take the theoretical management goals defined by the model as a basis, and then to adjust them to the actual situation of URAN. The suggested formulation of management goals of URAN is the following:

> The management goals of URAN are to operate, control and maintain the existing and future network infrastructure of URAN (communication links, hardware resources, software resources, and network services). This must be accomplished in accordance with (1) the requirements specified in <reference1>, (2) the preconditions specified in <reference2>, (3) the mission, legal status, and geographical distribution of the URAN Association, (4) the categories, sizes, and financial conditions of user organizations, (5) the capacities, prices, and areas of availability of telecommunication services and the Internet access service in Ukraine, (6) the characteristics of the URAN network infrastructure.

The two above-mentioned references should refer to documents describing the user organizations' requirements and preconditions. Therefore, this recommendation depends upon the fulfillment of the second recommendations.

We also recommend that the management goals of URAN are agreed with the administrative bodies of the URAN Association, namely the General Assembly, the General Council, and the Technical Committee, and also with the Ministry of Science and Education of Ukraine. These bodies should also control the actual fulfilment of the management goals.

5. Introduce new fault and security management tasks

Firstly, we recommend to introduce management tasks directed at tracing faults and reporting their status to the users. Every fault that is detected should be recorded and forwarded to the party that investigates and resolves it (for example, to a network engineer of the central node, Ukrtelecom, or the ISP). Between the moment that a fault is reported and the moment that it is resolved users should be able to see its actual status. The users should be timely informed upon the resolution of the fault. There are many tools that support the execution of these tasks; such tools are usually called defect tracking tools.

Secondly, we recommend to introduce a number of security management tasks: the tasks of the creation, deletion and control of security services and mechanisms, the distribution of security-relevant information, and the reporting of security-relevant events.

For more information about the content of the mentioned fault and security management tasks, refer to the existing models supporting the network management, see Appendix A. The Terplan framework, the TMN framework, and the IT Infrastructure Library provide good descriptions of these tasks.

6. Introduce new management services

This recommendation implies introducing the customer service, the fault handling service, and the security monitoring service. The security services were extensively described in Chapter 2, see section 2.4.3. Let us briefly describe the first two services.

The customer service implies opening a new organizational unit within the URAN operator "CEI" – the so-called helpdesk – which should perform a number of activities. Firstly, it should "act as the primary point of contact for all reports, enquiries and requests for action and information from the user community". Secondly, it should "deal with reports and enquiries made by telephone, fax, post or electronic mail". Finally, it should "operate procedures to route complex queries to the appropriate service provider for resolution" [Jan00].

The fault handling service implies that the URAN operator "CEI" should perform a number of activities. Firstly, it should "provide a means by which client institutions may report faults". Secondly, it should "publish procedures for fault reporting". Finally, it should "organize a sufficient set of mechanisms for call out in response to faults and for escalation in response to continuing problems" [Jan00].

We have quoted the JANET's description of these services [Jan00], since it appeared to be the most comprehensive one among analogous descriptions, see section 2.4. All mentioned services should not be meant for end users but for user organizations; representatives of these user organizations are the actual users of this service. Network administrators of the user organizations' intranets usually play the role of such representatives.

4.10 Summary

This chapter started the validation of the conceptual model in the case of URAN. It corresponds to Phase 4 of the research approach defined in Chapter 1, and covers the first two steps of this phase: (1) bidirectional confrontation between the model and the real situation, (2) adjustment of the model and development of recommendations. This chapter started answering the third research question *"How can the developed model be validated in practical situations?"*.

The first step implied using the model to produce a description of URAN. At this step the model's elements (entities, relationships, and attributes) were filled in with the actual data of URAN, or, in other words, the real situation of URAN was confronted with the model. Sections 4.2 – 4.6 presented the results of this confrontation for each part of the model (RS, NS, MNS, Relationships, and External Environment). During this confrontation it appeared that the real situation of URAN did not have certain model's elements, or these elements were improperly developed. Such missing elements – gaps in the real situation – were summarized in section 4.7.2. The first step also included the confrontation of the model with the real situation: parallel to making a description of the real situation of URAN we analyzed whether the model reflects all the important aspects of the real situation. The model was unable to reflect several aspects of the real situation. Such aspects – gaps in the model – were summarized in section 4.7.1.

The second step demonstrated that the model and the real situation mutually benefit from each other. On one hand, the real situation gave indications on how to adjust the model in order to remove gaps in it, see section 4.8. On the other hand, the model provided the real situation with recommendations on how to remove gaps in the real situation, see section 4.9.

Chapter 5

Case study "SUNET"

5.1 Introduction

This chapter begins the validation of the conceptual model in the case of SUNET. It starts answering the third research question *"How can the developed model be validated in practical situations?"* and corresponds to Phase 4 of the research approach defined in Chapter 1. This phase consists from three steps, namely (1) bidirectional confrontation between the model and the real situation, (2) adjustment of the model and development of recommendations, (3) evaluation of the model by the sites. This chapter covers the first two steps, the third step is covered in Chapter 6.

This case study is necessary not only for validating the model, but also for bringing it to a higher level. This is achieved via the adjustment of the model after its confrontation with the real situation as explained below.

The first step implies using the model to produce a description of SUNET. In this step the model's elements (entities, relationships, and attributes) formally defined in Chapter 3 are filled with the actual data of SUNET, or, in other words, the real situation of SUNET is confronted with the model. During this confrontation it might turn out that the real situation of SUNET does not have certain elements of the model, or that these elements have been developed improperly. Such missing elements are referred to as *gaps in the real situation*, see Figure 5.1.

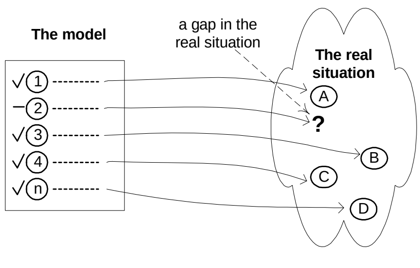

Figure 5.1: Visual interpretation of gaps in the real situation.

The first step also includes the confrontation of the model with the real situation.

This means that we analyze whether the model reflects all the important aspects of the real situation. The model might prove unable to reflect certain aspects of the real situation, or, in other words, these aspects may not match any of the model's elements, see Figure 5.2. Such aspects, called *gaps in the model*, are registered and analyzed. The first step is covered in sections 5.2 – 5.7.

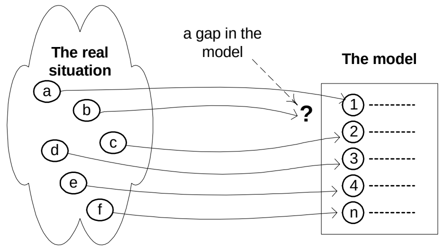

Figure 5.2: Visual interpretation of gaps in the conceptual model.

The second step demonstrates in which way the model and the real situation can mutually benefit from each other. On the one hand, the real situation gives indications on how to adjust the model in order to fill gaps in it. On the other hand, the model provides the real situation with recommendations on how to fill gaps in the real situation. The recommendations result from the use of the model, and are based solely on own judgments of the researcher: no other people are involved. The second step is covered in sections 5.8 and 5.9.

The information presented in this chapter is valid for December 2001. It is vital to give this date because new instances of entities emerge, and the values of attributes change over time. For example, the capacity of communication links is constantly increasing.

The information presented in this chapter was collected from two sources. Firstly, the representatives of the site were consulted. During personal, telephone, and email interviews the representatives were asked a number of questions; each question was related to a certain element of the model (entity, attribute, or relationship). Tables B.1 – B.8 in Appendix B present the list of questions. Secondly, the documentation was studied. This were electronic and paper documents which were available at the site, such as reports, work documents, web pages, regulatory documents, etc.

5.2 Real System

5.2.1 User organizations

According to the conceptual model, the entity User Organization has two attributes, namely the category and the size. The user organizations of SUNET can be classified into the following categories:

1. Higher education institutions

    (a) Universities

   (b) University colleges
   (c) University colleges of arts

2. Museums
3. State agencies
4. Research establishments
5. External organizations

Instances of higher education institutions (HEIs) are listed in Table 5.1. The table demonstrates an important division of HEIs into state-run and private institutions.

Table 5.2 presents the size of several biggest user organizations of SUNET. The size of a user organization can have different relative values across the indicators used. For example, Göteborg University and Chalmers University of Technology are of equal size in terms of the number of computers, but they have a different size in terms of the number of students or staff. Similarly, Uppsala University is nearly the same size as Lund University in terms of the number of students or staff, but it is nearly three times smaller in terms of the number of computers.

Conclusion There were found no gaps related to the user organizations of SUNET: the entity User Organization has a number of instances in case of SUNET, and the attributes introduced by the model are applicable for those instances.

5.2.2 State agencies

According to the conceptual model, instances of this entity provide regulatory and financial support for the REN on behalf of the state. User organizations of SUNET are formally under the patronage of the Swedish Ministry of Education and Science. Sweden has a tradition of rather independent agencies doing the bulk of the work, while the ministries are rather small.

There are two agencies under the Ministry's jurisdiction: the National Agency for Higher Education and the Swedish Research Council. The National Agency for Higher education (Högskoleverket) is a central authority for matters concerning institutions of higher education. The Swedish Research Council (Vetenskapsrådet) is a state agency whose main objective is to support basic research in all scientific fields. It is an important decision-making body concerning grants because it decides on grants for research. This agency is responsible for funding of SUNET.

Conclusion There were found no gaps related to the state agencies of SUNET: the entity State Agency has two instances in case of SUNET, namely the National Agency for Higher Education and the Swedish Research Council.

5.2.3 Association of user organizations

According to the model, this entity has always one instance. In case of SUNET, such instance is the Association of Swedish Higher Education, which unites all 39 universities and university colleges. The mission of the Association is "to safeguard the

Universities	run by
Chalmers University of Technology (Göteborg)	private
Göteborg University	state
Karlstad University	state
Karolinska Institute (Stockholm)	state
Linköping University	state
Luleå University of Technology	state
Lund University	state
Örebro University	state
Royal Institute of Technology (Stockholm)	state
Stockholm School of Economics	private
Stockholm University	state
The Swedish University of Agricultural Sciences (Uppsala)	state
Umeå University	state
Uppsala University	state
Växjö University	state
University colleges	
Blekinge Institute of Technology (Karlskrona)	state
Borås University College	state
Dalarna University College (Borlänge)	state
Gävle University College	state
Gotland University College (Visby)	state
Halmstad University College	state
Jönköping University College	private
Kalmar University College	state
Kristianstad University College	state
Mälardalen University College (Västerås)	state
Malmö University College	state
Mid-Sweden University College (Sundsvall)	state
Skövde University College	state
Södertörn University College (Stockholm)	state
Stockholm Institute of Education	state
Stockholm University College of Physical Education and Sports	state
Trollhättan/Uddevalla University College	state
University Colleges of Arts	
University College of Dance	state
University College of Film, Radio, Television and Theatre	state
University College of Arts, Craft and Design	state
Royal University College of Fine Arts	state
Royal University College of Music (Stockholm)	state
Stockholm University College of Opera	state
Stockholm University College of Acting	state
University College of Music Education (Stockholm)	private

Table 5.1: User organizations of SUNET: higher education instititions.

Name of a user organization	Students	Staff	Turnover (MSEK)	Computers
Royal Institute of Technology	11000	3200	2232	17600
Lund university	34000	6000	4081	34500
Uppsala university	37000	5500	3300	10100
Luleå University of Technology	11700	1400	850	12700
Göteborg University	36000	4700	3039	21600
Linköping University	21000	3200	2068	24300
Chalmers University of Technology	6800	2500	1904	20500

(December 2001, Sources: web sites of universities, www.sunet.se)

Table 5.2: Size of some user organizations of SUnet.

external interests of the member institutions and to strengthen their internal cooperation" [www.suhf.se]. The size of the Association can be assessed by several indicators suggested by the conceptual model: 73 user organizations, 400000 people that belong to user organizations[1], and more than 200.000 computers installed at the campuses of user organizations[2]. The geographical distribution of the Association is demonstrated in Figure 5.3; the majority of the user organizations (65%) are located in Stockholm. The Association does not have legal status: it is the result of a bottom-up initiative having no support from the state. The organizational structure of the Association consists from the Assembly and the Board. The Assembly is the highest decision-making body of the Association. It comprises all members and usually meets three times a year. It takes decisions in the form of recommendations for its members. The Board is appointed by the Assembly and consists of seven vice-chancellors (Rectors) and one Director.

The Association of Swedish Higher Education has an important role for the SUNET: it nominates eight members of the SUNET Board. Other members of the SUNET Board represent libraries and museums.

Conclusion There were found no gaps related to the Association of Swedish Higher Education: the entity Association of User Organizations a single instance in case of SUNET, and the attributes introduced by the model are applicable for this instance.

5.2.4 Business processes

According to the model, the entity Business Process reflects core activities of user organizations. The user organizations of SUNET execute a number of business pro-

[1] The total number of people that belong to the user organizationsvalue was estimated by using the official statistics of the National Agency of Higher Education. According to the statistics there were 320,000 students in basic higher education in the academic year 1999/2000. The number of staff employed by the Swedish higher education institutions was 48,900 FTEs (full-time equivalents) in the same academic year. Therefore, the number of people that belong to user organizations can be roughly estimated at 400,000 (taking into account that in addition to HEIs there are also other user organizations).

[2] The total number of computers installed at the campuses of user organizations was estimated using the statistics of registered computers per domain of the user organizations (source: www.sunet.se). The given value is dated 30/11/2001.

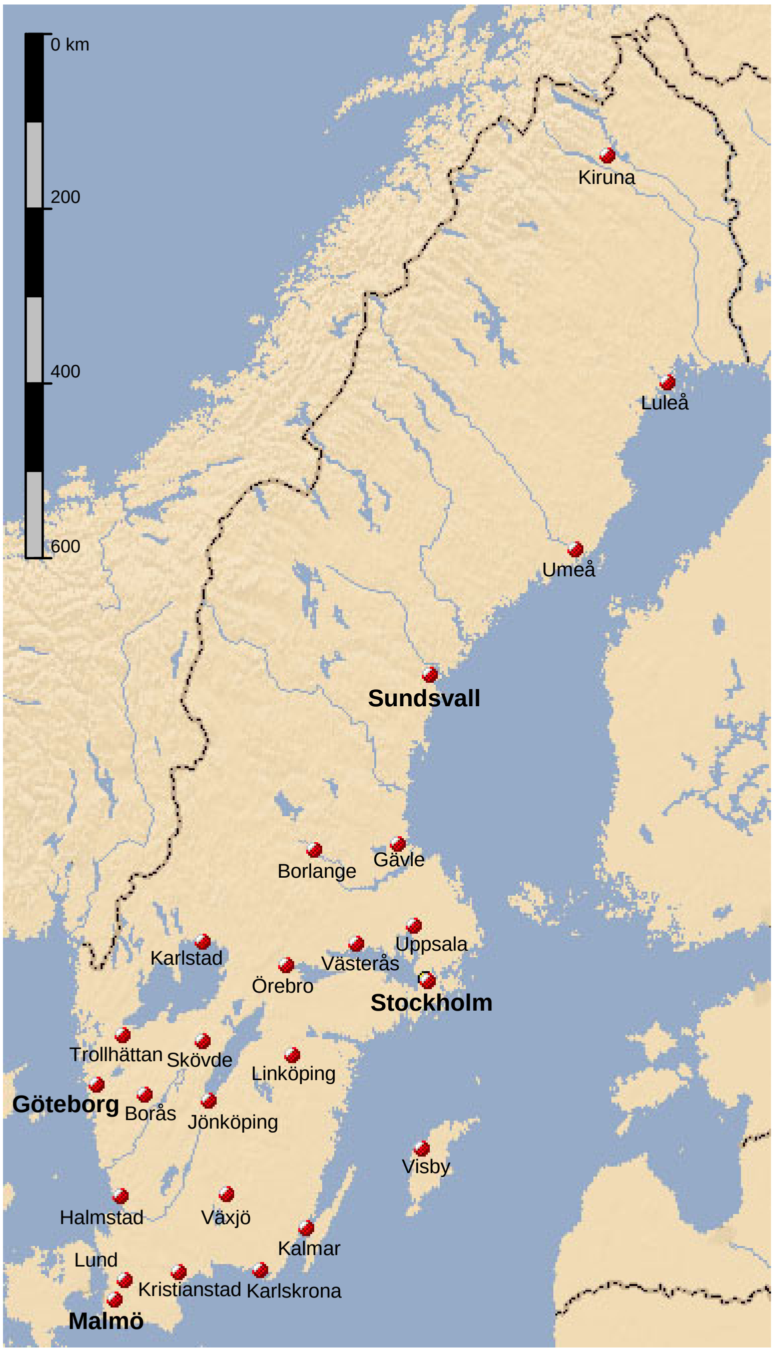

Figure 5.3: The map of Sweden: the cities where user organizations of SUNET are located.

cesses that can generically be grouped in educational, research and administration processes.

The user organizations of SUNET execute educational processes, which usually include numerous activities aimed at transferring knowledge from the teacher to the students. The knowledge of students is periodically checked through various tests and examinations. The development of curricula and the admission of new students are other important educational processes executed by the Swedish universities. Distance learning education is quite popular in Sweden: many universities and institutions of higher education offer hundreds of distance learning courses in different subjects.

The user organizations of SUNET carry out various kinds of research. Multidisciplinary and interdisciplinary researches are stimulated. Swedish universities participate in joint research projects with other universities worldwide. The provision of information about the research and the communication among researchers are important examples of research processes.

Conclusion There were found no gaps related to the business processes of the user organizations of SUNET. The entity Business Process has a number of instances in case of SUNET, and these instances fall into the classification suggested by the model: educational, research and administration processes.

5.2.5 End users

As already mentioned in section 3.4.5, it is hardly possible to describe every instance of the entity End User. This is because it is estimated that more than 400000 people are the end users of SUNET.

Below we describe the attributes of the entity End User in case of SUNET. The model divides end users into two major categories: students and staff members. This classification is also valid for SUNET. The subcategories defined by the model are also applicable for the end users of SUNET: teachers, researchers, technical support staff, and others. More than 70% of staff members are teachers. Table 5.3) demonstrates the distribution of scientific fields within the Swedish universities The predominant scientific fields are medicine (22%) and technology (20%).

The model was found to be *unable to reflect the division of end users between heavy and light users.* Heavy users intensively utilize the network services of SUNET, transfer large volumes of data, and, therefore, use a considerable part of the transmission capacity. Light users utilize network services occasionally: they do not generate considerable traffic on the network. The representatives of SUNET proposed to make a classification of end users which has to be based on the intensity with which they use the network services – primarily transmission services. Therefore, end users of SUNET can be also divided into intensive (heavy) and non-intensive (light) end users. Because intensive end users are an important driving force for the growth of bandwidth, they can also be called "bandwidth promoters". The model does not consider this issue.

Conclusion There were found no gaps related to the end users of SUNET: the entity End User has a number of instances in case of SUNET, and the attributes

Research area	Percentage
Medicine	22.60%
Technology	20.00%
Social sciences	16.00%
Natural sciences	13.20%
Humanities/Theology	13.10%
Agriculture	5.50%
Mathematics	2.70%
Law	2.30%
Odontology	1.90%
Other	1.50%
Veterinary medicine	0.90%
Pharmacy/pharmacology	0.40%

Source: [NAH99]

Table 5.3: Distribution of scientific fields within the Swedish universities.

introduced by the model are applicable for those instances.
A gap in the model was found: the model was unable to reflect the division of end users between heavy and light users.

5.2.6 Needs

The vast majority of the end users of SUNET primarily need to access the Internet and its resources and services. For example, an end user of SUNET needs to search for information, to download information from a web site, to publish information on a web site, or to exchange data with other end users; the exchange of audio files in the MP3 format has become very popular among the Internet end users, including those of SUNET.

The model suggests that the identification of the ratio between private and professional needs requires separate studies. No studies investigating this matter were conducted in case of SUNET.

The representatives of SUNET indicated that it seems to be very difficult to conduct studies among end users. On the one hand, this is because many people at Swedish universities use SUNET without knowing that they use it. On the other hand, people often think that they are connected to SUNET just because they use some of the SUNET services, such as the LISTSERV service, or the file archive service (ftp.sunet.se). However, because these services are also accessible to virtually any Internet user, usage of these services does not make one a SUNET user.

Conclusion There were found no gaps related to the needs of the end users of SUNET: the entity Need has a number of instances in case of SUNET, and the division of needs into private needs and professional needs is relevant for SUNET. However, it was impossible to identify a ratio between the private and the professional needs.

5.2.7 Requirements

There is no objective nor credible information concerning the requirements of the user organizations of SUNET. The SUNET management shares the opinion that often universities cannot define the requirements. Therefore, instead of inquiring requirements from user organizations, the SUNET management tries to predict requirements by analyzing technological trends and developments in the IT and networking fields. Some requirements are also obtained via informal communication with representatives of user organizations.

The characteristics of services required by user organizations are not clearly defined. Although there are two characteristics which seem to be important for user organizations (the bandwidth and the availability), the acceptable values of these characteristics are not defined. Consecutively, there are no Service Level Agreements between the SUNET and the user organizations: all services are provided in a so-called "best-effort" manner without quality guarantees. This implies that it is up to every particular user organization to decide whether the services' characteristics match the desired level.

Conclusion The entity Requirement does not have clearly specified instances in case of SUNET, which points out to a gap in the real situation.

5.2.8 Preconditions

The conceptual model defines a precondition as a restrictive condition which is laid down at the management level of the Association of Users, the State Agency, or individual user organizations. This implies that the Swedish Research Council, the National Agency for Higher Education, and every user organization has its own preconditions.

The preconditions of the state agencies are mostly of a financial nature. The SUNET budget is defined at the beginning of each year and it has to be approved by the SUNET Board. The part of the SUNET budget which is provided by the state (roughly 30% of the total budget) is based on the national budget for R&E.

There is no objective nor credible information concerning the preconditions of user organizations. No studies investigating this matter were found. Even though financial preconditions are recognized, they are not clearly specified in terms of financial budgets. For example, it is unclear how much money each particular user organization can spend on computer networking, including network services of SUNET.

Conclusion The entity Precondition does not have clearly specified instances in case of SUNET, which points out to a gap in the real situation.

5.2.9 Relationships among entities of the RS

Most of the relationships among the entities of the RS (see Table 5.4) cannot be given actual content. On the one hand this is due to the very high or even unknown number of instances of some entities. For example, because there are around 400.000 instances of end users, there must be thousand instances of relationships in which the entity End User participates (relationships `r2`, `r5`, `r6`, and `r7`). Similarly, because the

`r1`	Precondition limits Requirements
`r2`	User Organization defines Requirements
`r3`	End User defines Requirements
`r4`	User Organization formulates Preconditions
`r5`	End User has Needs
`r6`	End User belongs to User organization
`r7`	End User is involved in Business Processes
`r8`	Business Process causes Needs
`r9`	User Organization executes Business Processes
`r10`	User Organization is a member of Association of Users
`r11`	State Agency formulates Preconditions
`r12`	State Agency participates in or patronages Association of Users
`r13`	Association of Users formulates Preconditions

Table 5.4: The relationships among entities of the real system.

entities Business Process and Need have an unidentified number of instances, it is also impossible to present instances of the relationships in which these entities participate (relationships `r5`, `r7`, `r8`, and `r9`).

On the other hand, some relationships have been introduced with the aim of representing logical associations between entities, and not for giving them actual content. Such relationships have an abstract nature; they are merely illustrations of dependencies among certain concepts of the reality. For example, it is obvious that every end user belongs to a certain user organization, which makes it pointless to validate the relationship `r6`. Similarly, there are no doubts that each user organization executes some business processes (relationship `r9`). However, it is hardly possible to describe every business process of every organization, since producing such a description would require conducting a study on a very big scale, which is beyond the scope of this research project.

Some relationships cannot be described separately from the entities that they connect. The relationships `r1`, `r2`, `r4`, and `r13` have already been described earlier in this section when describing entities connecting these relationships: Requirement, Precondition, User Organization, and Association of User Organizations.

Conclusion There were found no gaps in the relationships among the entities of the RS of SUNET: the relationships `r1`– `r13` introduced by the model all exist in the real situation of SUNET. However, most of these relationships cannot be given an actual content because of their abstract nature.

5.3 Network System

5.3.1 The model and the switch-over from SUNET to Giga-SUNET

We have come across the following issue during the confrontation of the model with the real situation: most of the NS of SUNET had to be replaced as a result of the upgrade of the network to gigabit speeds (GigaSUNET). In the first place, this concerned communication links and routers. However, network servers also had to be changed in order to support new network services to be introduced by GigaSUNET. High transmission capacities of GigaSUNET would allow to introduce services such as grid computing, large-scale multi-site computation and data mining, high-quality videoconferencing, shared virtual reality, and telemedicine. The process of switch-over from SUNET to GigaSUNET was a long and a complicated one; it had a number of phases and involved the participation of many parties. The challenge was to build the new network along the existing one, and to gradually switch from this existing network to the new network. This process should have had a minimum impact on the operation of the existing network.

The model cannot cover this issue because it is meant to support static situations and not dynamic processes. The model was primarily developed for supporting the management of a REN at a given moment in time. The building of new RENs is outside the scope of this research. Therefore, the inapplicability of the model to support this issue cannot be called a gap in the model: this issue simply lies outside the model's scope.

Using the model for approaching this issue

Let us describe how the conceptual model can be used to approach the mentioned issue of switching from SUNET to GigaSUNET. Figure 5.4 presents this idea graphically.

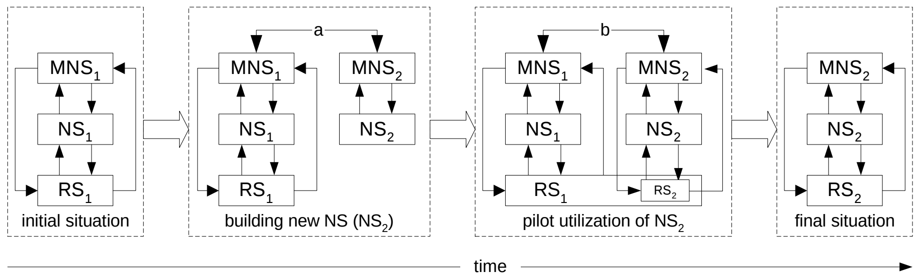

Figure 5.4: Modelling the switch-over from SUNET (NS_1) to GigaSUNET (NS_2).

Initially, there are MNS_1, NS_1, and RS_1, which represent the situation when SUNET (NS_1) is utilized by the Swedish universities (RS_1), and is managed as described in section 5.4 (MNS_1). NS_1 was described in section 5.3, and RS_1 in section 5.2.

In the next phase, a new network NS_2 (GigaSUNET) is built; a corresponding management MNS_2 is necessary to accomplish this. It is important that the management responsible for the building of the new network (MNS_2) communicates with the management responsible for the existing network (MNS_1). The relationship, marked as "a" in Figure 5.4, ensures that the management of the NS_2 (GigaSUNET) is aware of the possible requirements, preconditions, and situational factors of the RS. It also implies the transfer of knowledge and the synchronization of activities between the two managements which coexist during the time of transition from the existing network NS_1 to the new network NS_2.

The following phase, depicted as ”pilot utilization of NS_2” in Figure 5.4, implies that some user organizations of SUNET start utilizing the new network NS_2: they comprise the new real system RS_2. Besides the set of organizations that belong to each real system RS_1 and RS_2, these real systems also differ in the set of requirements and preconditions: this is because user organizations will most probably have different requirements for NS_2.

Finally, all user organizations become connected to the new network NS_2 so that the old network NS_1 becomes obsolete, and so does its management, MNS_1. At this point, the switch is completed.

The given approach implies that each block depicted in Figure 5.4 has to be described in terms of the entities, attributes, and relationships of which it consists. Additionally, each entity and relationship can be placed on a time axis; this would allow one to analyze cross dependencies among the state of various entities and relationships. This approach would make it possible to give a dynamic picture of the switch-over process. However, the compilation of such a picture seems to be a difficult task requiring significant efforts from all parties participating in the switch-over process.

5.3.2 Network services

The following network services are available to the users of SUNET:

1. the backbone IP connectivity
2. the external IP connectivity and access to
   (a) the global Internet, NRENs in Western Europe (GÉANT), Scandinavian countries (Denmark, Finland, Iceland, Norway), Estonia, Russia, Poland and Ukraine (via NORDUNET)
   (b) the Swedish part of the Internet (via national Internet exchanges)
3. the IP Multicast service[3]
4. the domain name service
5. the newsfeed delivery service
6. the white-pages service
7. the fax service
8. the LISTSERV service
9. the provision of information about SUNET (www.sunet.se)
10. the file archive service (ftp.sunet.se)

[3]IP Multicase service in its native mode is supported. MBONE is forbidden.

11. the content listing service "Swedish websites" (katalogen.sunet.se)

The service level of most network services of SUNET cannot be estimated because there are no corresponding indicators which are defined and measured on a periodical basis. According to the conceptual model, the service level reflects the actual quality of a network service and its adequacy with user requirements. The model also states that the determination of this attribute requires defining a set of indicators whose values must be periodically measured. For example, the period of time during which a network service is operational can be used to assess its availability. In case of SUNET, no indicators of this kind are defined.

Only the connectivity services are monitored and various types of reports concerning service levels of the IP connectivity service are available via the web site stats.sunet.se. The following indicators are monitored: the availability, the load, and the error rate (packet loss).

Conclusion Only the levels of the connectivity services are recognized and monitored. For the rest, the levels of the services are neither defined nor monitored, which indicates a gap in the real situation.

5.3.3 Communication links

According to the conceptual model, communication links are divided into several categories, namely backbone, user-access, peering, European, and Internet links. The last three categories of links are also called external links. This classification is also applicable for SUNET: there are instances of links for all mentioned categories.

Figure 5.5 presents instances of communication links. It demonstrates that all backbone and access communication links are redundant: if a link goes down, the connection is immediately switched over to an alternative link.

Table 5.5 described the attributes of the communication links. It demonstrates that backbone links have a long-distance scale, and that user-access links have either a long-distance or a city scale. The capacity of the communication links varies from 100 to 2488 Mbps.

The recurrent costs of backbone and access grew from 36.6 million SEK in 1999 to 61.4 million SEK in 2001. The recurrent costs of the NORDUNET link decreased from 47.8 million SEK in 1999 to 37.8 million SEK in 2001.

Conclusion There were found no gaps related to the communication links of SUNET: the entity Communication Link has a number of instances in case of SUNET, and the attributes introduced by the model are applicable for those instances.

5.3.4 Hardware resources

The hardware resources of SUNET consist of a number of network servers and routers. The routers of SUNET are shown in Figure 5.5. Every box in the figure represents two physical routers, except for boxes having a number in their titles, such as GBG-PR-1, STK-PR-1, or KTHNOC-1. The following boxes represent routers of external parties: NORDUNET, Tele2, Telia, and Netnodtest. The mnemonic name of a router can be

Links		Category	Scale	Capacity,
Router 1	Router 2			Mbps
stk-bb	mlm-bb, svl-bb and gbg-bb	backbone	long distance	622
stk-bb	slu (Uppsala), gavle, orebro, uu (Uppsala), vasteras, du (Borlange), linkoping, visby	user access	long distance	155
stk-bb	Nordunet	Internet *)	local	2488
stockholm	su, ki, lhs, sh and handels	user access	city	155
stk-pr-1	D-GIX (Internet Exchange in Stockholm)	peering	city	100
stk-pr-2	DPT-GIX (Internet Exchange in Stockholm)	peering	city	155
mlm-bb	kalmar, ronnedy, kristianstad, lund, vaxjo, halmstad	user access	long distance	155
svl-bb	kiruna, umea, lulea	user access	long distance	155
gbg-bb	karlstad, trollhattan, jonkoping, boras, skovde	user access	long distance	155
gbg-pr-1	GBG-GIX (IX in Goteborg)	peering	city	155

*) The link to NORDUNET is also a link to GEANT

Table 5.5: Communication links of SUNET.

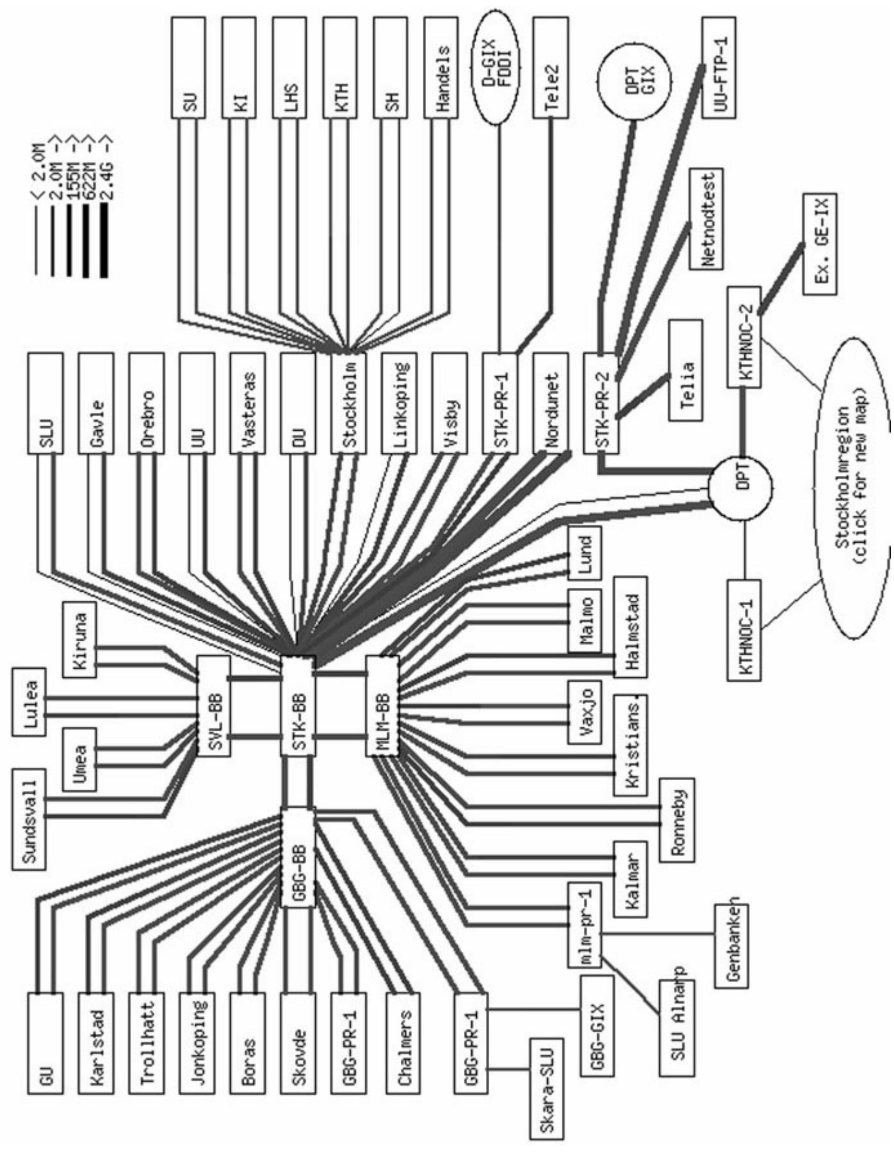

Figure 5.5: Routers and communication links of SUNET: boxes represent routers, lines represent communication links [www.sunet.se].

used to determine its location: the name either contains the whole or the abbreviated name of the network node where corresponding router is located (for instance, STK – Stockholm, SVL – Sundsvall, and MLM – Malmö). The letters "BB" indicate backbone routers, and the letters "PR" indicate external connectivity routers. The capacity of the backbone routers is presented in Table 5.6.

Mnemonic name	Qty of 155M interfaces	Qty of 622M interfaces	Qty of 2488M interfaces	Total capacity of interfaces, Mbps
STK-BB	11	4	2	9169
GBG-BB	8	2	-	2484
MLM-BB	8	2	-	2484
SVL-BB	4	2	-	1864

Table 5.6: Capacity of the backbone routers of SUNET.

The instances of the network servers are the name servers (ns*.sunet.se), the web server (www.sunet.se), the file archive servers (ftp*.sunet.se), the LISTSERV server (segate.sunet.se), the LDAP directory server (ldap.sunet.se), the WIXI server (wixi.umu.se), the newsfeed servers (news*.sunet.se), the fax server (fax.umu.se), and the web catalog server (katalogen.sunet.se). Table 5.7 illustrates the capacity of the file archive servers.

Server model	RAM, MB	Qty of processors	Processor clock rate, MHz	Disk drive, GB
Sun Enterprise 450	4096	4	400	no info
Sun Enterprise 4500	1024	4	336	1332
Sun Ultra 2100	128	1	no info	no info

Table 5.7: Capacity of network servers supporting the operation of the file archive ftp.sunet.se.

Conclusion There were found no gaps related to the hardware resources of SUNET: the entity Hardware Resource has a number of instances in case of SUNET, and the attributes introduced by the model are applicable for those instances.

5.3.5 Software resources

The following software resources are used to provide the network services described in section 5.3.2:

1. Operating systems
2. Apache HTTP server (web server)
3. BIND (an implementation of the Domain Name System)
4. LDAP server (directory services)
5. WIXI (web access to the white pages service)

6. Diablo (Usenet news transit and reader package)
7. LISTSERV server (E-mail list management software)
8. mnoGoSearch (web search engine)

The following instances of operating systems are used: CiscoIOS, Linux, Dell Unix, DEC VMS, BSD Unix, Sun Solaris, and Compaq Unix. CiscoIOS (Internetwork Operating System) is the industry's leading network system software, which is run on the SUNET routers. The remaining operating systems are designed to support the operation of network servers manufactured by the hardware vendors Dell, DEC, Sun, and Compaq.

The software resources have different status. Cisco IOS is the commercial software that is delivered together with the hardware (routers). The same can be stated about other operating systems, except for the Linux, which is a freeware resource. The Apache HTTP server, BIND, Diablo, and mnoGoSearch are also freeware resources. The LISTSERV server is a commercial product.

Conclusion There were found no gaps related to the software resources of SUNET: the entity Software Resource has a number of instances in case of SUNET, and the attributes introduced by the model are applicable for those instances.

5.3.6 Network nodes

According to the conceptual model, the network nodes can be divided into backbone and access nodes. The network nodes of SUNET can also be placed in this classification. The backbone nodes of SUNET are located in the cities Göteborg, Sundsvall, Malmö, and Stockholm. The access nodes are located at other 21 cities of Sweden depicted in Figure 5.3.

Physically the network nodes of SUNET are usually located at the premises of user organizations. For example, the Stockholm node is located at the premises of the Royal Institute of Technology (KTH). Figure 5.6 also shows the connectivity between the backbone and the access nodes. Each line in this figure actually represents two physical communication links, which means that there are redundant communication links connecting SUNET nodes: if a link goes down, the connection is immediately switched over to the alternative (parallel) link.

Conclusion There were found no gaps related to the network nodes of SUNET: the entity Network Node has a number of instances in case of SUNET, and the classification of network nodes suggested by the model is applicable for SUNET.

5.3.7 Relationships among entities of the NS

The relationship `n1` represents the hardware resources, software resources, and communication links which every network service is based upon. Table 5.9 demonstrates the content of this relationship in case of SUNET.

The relationship `n2` has the following content. The location of routers was already shown in section 5.3.4. Network servers are located at network nodes in cities

n1	Network Service is based on Software Resources, Hardware Resources, and Communication Links
n2	Hardware Resource is located in Network Node
n3	Network Node is connected to Network Node via Communication Link

Table 5.8: The relationships among entities of the network system.

Network Service	Hardware Resources	Software Resources
Backbone IP connectivity	backbone links, backbone routers stk-bb, mlm-bb, gbg-bb, svl-bb and other routers	Cisco IOS
Access to global Internet and GEANT	Nordunet link, backbone routers stk-bb-[1,2]	Cisco IOS
Access to the Swedish internet	links to IXs in Stockholm and Goteborg, routers stk-pr-[1,2], gbg-pr-1	Cisco IOS
IP Multicast	backbone and user-access links, routers	Cisco IOS
Domain name service	network servers ns*.sunet.se, sunic.sunet.se	Unix, BIND
Usenet newsfeed	several newsfeed network servers news*.sunet.se	Unix, Diablo
White pages	network servers wixi.umu.se, ldap.sunet.se	Unix, Apache, WIXI, LDAP server
Fax service	network server fax.umu.se	Unix
LISTSERV service	network server segate.sunet.se	Unix, Apache, LISTSERV server
www.sunet.se	network server basun.umdc.umu.se	Unix, Apache
File archive ftp.sunet.se	several network servers ftp*.sunet.se	Unix, Apache, mnoGoSearch
Swedish Internet Index	network server katalogen.sunet.se	Unix, Apache

Table 5.9: Relationship "Service is based on Hardware and Software Resources".

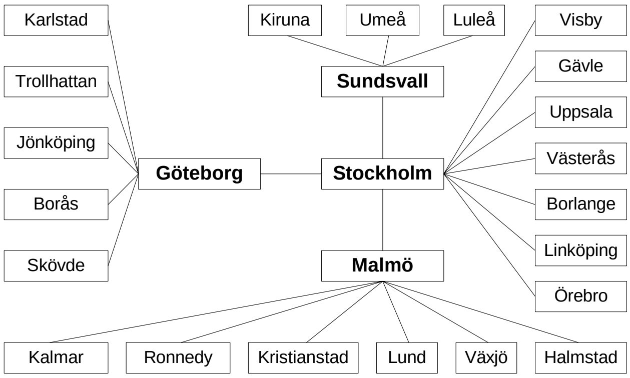

Figure 5.6: Backbone and access nodes of SUNET and connectivity among them.

Stockholm and Umeå, more specifically – at the sites of KTHNOC and the Umeå university.

The relationship `n3` represents the network topology; it was already shown in Figure 5.6. The backbone of SUNET has the star topology: the nodes in Göteborg, Sundsvall and Malmö are radially connected to the Stockholm node. Other nodes are radially connected to one of the four backbone nodes. Therefore, the topology of SUNET can be characterized as a tree with the root in Stockholm and leaves in other cities.

Conclusion There were found no gaps in the relationships among the entities of the NS of SUNET: the relationships `n1`– `n3` introduced by the model all exist in the real situation of SUNET.

5.4 Management of the Network System

5.4.1 Management goals

The conceptual model defines three management goals. Let us assess to which extent each theoretical goal is actually fulfilled in case of SUNET.

The first goal implies that the management of the NS has good knowledge of requirements, preconditions, aspects of the external environment, and of attributes of the NS components. Although the management of SUNET has good knowledge about the NS, it lacks knowledge about requirements and preconditions (see sections 5.2.7 and 5.2.8). Therefore, it is unlikely that the NS is managed in accordance with requirements and preconditions.

The second goal implies that the goals of user organizations are influenced in a positive way. It is hard to establish whether the SUNET management realizes this goal: influencing the goals of its user organizations positively. This is because there is a lack of information about the actual goals of the SUNET user organizations, and because the impact of the management of SUNET on these goals has not been studied.

The third goal implies that the services are offered in the most effective and efficient way. It is impossible to assess the fulfillment of this goal, because the knowledge about the effectiveness and the efficiency of the service provision is unavailable. This is also related to a gap in the network services of SUNET, namely the lack of service levels (see section 5.3.2).

Conclusion The entity Management Goal does not have clearly specified instances in case of SUNET. The first management goal defined by the conceptual model is not fulfilled because the management of SUNET lacks knowledge about requirements and preconditions. The fulfillment of the second and the third management goals is impossible to estimate because of the lack of relevant information.

5.4.2 Management tasks

Supervision of communication links	Mail management
Facility management	LISTSERV management
Incident handling	News management
Security response	Unix administration
Router configuration	System development
Multicast management	Web server management
Regional coordination with user organizations	Web catalog management
IP addresses management	Fault monitoring
DNS management	Administration

Table 5.10: Management tasks at KTHNOC.

Table 5.10 lists the management tasks which are performed by the staff members of KTHNOC – the management body responsible for the SUNET backbone. Below we briefly describe the content of some of these tasks. Supervision of communication links implies ensuring that scripts which monitor the state of communication links work well and reflect the state of the link properly. Security response implies setting up procedures for monitoring unauthorized use of the services provided via SUNET, including users' own services. Router configuration implies maintaining the configuration of SUNET routers and changing it if necessary. Multicast management implies ensuring that the IP multicast service is operational. The web catalog management implies the management of the content of this service: registration of new resources, editing the classification of resources, and removal of outdated resources. Administration implies performing various management responsibilities and supervising the staff.

The following management tasks are performed by the SUNET Chief Executive Officers Olle Thylander and Hans Wallberg: (1) coming up with suggestions for the yearly budget and presenting them to the SUNET Board, (2) planning activities for the coming year, (3) contracting and negotiating with suppliers/ providers, (4) procurement of new services, links, and equipment, (5) signing bills for the procurement of new services, links, and equipment, (6) external relations, and (7) presenting SUNET on various conferences and workshops.

Conclusion We found no gaps related to the management tasks of SUNET: the entity Management Task has a number of instances in case of SUNET.

5.4.3 Management services

The following management services are provided to the users of SUNET:

1. The network monitoring service
2. The training service
3. The technical assistance service
4. Security services
   (a) The security response service
   (b) The security liaison service
   (c) The security information service

The network monitoring service covers connectivity services, the Usenet newsfeed delivery service, and the LISTSERV service. The statistics about the utilization of these services is publicly accessible to any Internet end user via the SUNET web site.

The training service implies organizing seminars and educational courses on technical matters. This management service is aimed at updating the technical knowledge of the user community. Additionally, this service includes the organization of scheduled technical meetings of the SUNET user community – the so-called TREFPUNKT meetings. Networking experts from user organizations and from the industry meet to give presentations and to exchange ideas, knowledge, and experience.

The technical assistance service implies advising user organizations on networking matters using the expertise available within the SUNET community or, if necessary, making use of the expertise of external consultants.

Three kinds of security services are available to SUNET users. The security response service implies monitoring unauthorized use of SUNET services and rapidly responding to security threats. The security liaison service implies maintaining contacts with national and international organizations that work in the field of computer security. The security information service implies maintaining a list of approved contact points and service hours at user organizations, advising users on security mechanisms, providing users with regular information on general levels of threat and countermeasure available, and maintaining publicly available information about security threats and countermeasures.

Conclusion There were found no gaps related to the management services of SUNET: the entity Management Service has a number of instances in case of SUNET.

5.4.4 Management tools

Most software resources of SUNET are supplied with some tools which allow one to manage, control, and maintain them. However, it is difficult to separate a software resource into one part supporting the service provision, and another part facilitating the management of the first part. For example, every operating system belonging to the Unix family has numerous tools facilitating its management, such as the system monitoring tool syslog, disk space guards, and CPU usage monitors. These tools are always supplied with the operating system.

A common management tool is a regular PC which runs under Microsoft Windows NT/2000 supplied with the bundled software, such as Microsoft Word, Excel, Outlook, and Internet Explorer. Such a PC facilitates the execution of many management tasks, since it is often used as an entry point for remote terminal sessions through which hardware and software resources of the NS are actually managed.

Besides management tools which are integrated with the NS and regular PCs, a number of specialized management tools are used, namely NORDstat, TTAS, Sysmon, and Multicast Beacon. NORDstat is router traffic statistics package; it is a freeware tool developed by a staff member of NORDUNET. TTAS (Trouble Ticket Administration System) is the information system used for registering and tracing the progress of trouble tickets – records of problems that occur. Sysmon is a freeware network monitoring tool designed to provide high performance and accurate network monitoring; it is used for monitoring most of the SUNET communication links and corresponding interfaces of routers. Multicast Beacon is a freeware measurement tool used for monitoring the performance of multicast sessions.

Conclusion There were found no gaps related to the management tools of SUNET: the entity Management Tool has a number of instances in case of SUNET, and the attributes introduced by the model are applicable for those instances.

5.4.5 Managers

A number of people perform and control management tasks described in section 5.4.2. Since these management tasks relates to KTHNOC, let's shortly describe managers working at this management body.

About 20 staff members are working at KTHNOC. The staff members of KTHNOC are highly competent networking professionals, possessing many years of experience in computer networks and related technologies. The staff members are deeply devoted to their job, which includes not only the effective and efficient management of SUNET, but also the management of the campus network of the Royal Institute of Technology, and also involvement in the management of NORDUNET.

Unfortunately, there are not enough people at KTHNOC to perform all desired management tasks. The director of KTHNOC, Mr. Peter Graham, estimated that as much as twice more people is required. Because of the lack of personnel, certain tasks are regrettably not executed, such as the compilation of reports and the provision of documentation. In the beginning of 2002 considerable time of the KTHNOC staff were also required for upgrading SUNET to its gigabit version – GigaSUNET. This fact also negatively influenced the availability of KTHNOC staff members for performing operational tasks for SUNET.

Conclusion There were found no gaps related to the managers of SUNET: the entity Manager has a number of instances in case of SUNET, and the attributes introduced by the model are applicable for those instances.

5.4.6 Financial resources

The financial resources of SUNET come from two sources, namely the Swedish government and the user organizations. The Swedish government annually allocates the national budget for research and education. A part of this budget is allocated to SUNET. The Swedish Research Council administers the national budget for R&E including the part which is allocated to SUNET.

User organizations pay fees which depend on their size and the capacity of their access links. Because most universities and university colleges are connected to SUNET via access links having a uniform capacity of 155Mbps, the fee they pay basically depends only on their size. The SUNET Board determines the fee to be paid for every user organization. For example, the Royal Institute of Technology, having a size of about 15000 students, pays annually around 5 million SEK. The Lund University, having a size of 35000 students, pays annually around 20 millions SEK. The SUNET Board intended to double the fees in 2002 for covering expected expenses of upgrading SUNET to gigabit capacities.

The relative proportion between the state subsidies and the user fees is roughly 1 to 3. Therefore, state subsidies cover approximately 30% of the SUNET expenses, and user fees cover the remaining 70%. The amount of financial resources necessary for the operation of SUNET in 1999, 2000, and 2001 was 117.7, 163.7, and 133.1 million SEK, respectively.

Conclusion There were found no gaps related to the financial resources of SUNET: the entity Financial Resource has a number of instances in case of SUNET, and the attributes introduced by the model are applicable for those instances.

5.4.7 Management bodies

The management of the NS of SUNET and the provision of network and management services is carried out by several management bodies, namely KTHNOC, TREF, the UU-ITS, and UMDAC.

KTHNOC is a Network Operating Center of SUNET – the main body responsible for the operation of the hardware/ software resources. It also provides most network services of SUNET. Organizationally, KTHNOC is a subdivision of the Royal Institute of Technology, the department of Numerical Analysis and Computing Science. Because the Royal Institute of Technology is a user organizations of SUNET, the management body "KTHNOC" belongs to a category of user organizations. About 20 people are working at KTHNOC. Some staff members of KTHNOC are also involved in the management of NORDUNET.

TREF (the Technical Reference Group) is a team of several networking professionals from leading Swedish universities and university colleges. This team acts as a clearing house for various technical issues concerning the development of SUNET.

It provides assistance to user organizations and the SUNET Board regarding technical matters. The team is responsible for the organization of various events aimed at distributing the technical knowledge and expertise among the SUNET user community. An important event taking place twice a year is TREFPUNKT. Networking experts from user organizations and from the industry meet to give presentations and to exchange ideas. TREF also organizes various seminars, workshops, and technical courses on a number of technical subjects.

UU-ITS is the IT Support Department of the Uppsala University. This management body has several important roles in the management of SUNET. Firstly, it is the provider of the file archive service. Secondly, UU-ITS is the provider of the security liaison service, and the security information service. These services are provided by a team of three people; it is formally called the SUNET CERT (Computer Emergency Response Team). This team acts as a clearing house for various security-related issues. About 80 people are working at UU-ITS, although only a few of them are involved in the management of SUNET. Organizationally, UU-ITS consists from five units: (1) the network and servers management unit, (2) the institution support unit, (3) the administrative system support unit, (4) the administration and internal services unit, and (5) the unit IT support for students.

UMDAC is the Computer center of the Umeå University. Its primary mission is to provide hardware and software support to researchers, students and staff at the University of Umeå. This management body is also responsible for development of SUNET, and also for the SUNET's information activities; it maintains the web site of SUNET. Additionally, UMDAC is involved in the provision of the fax service. Finally, UMDAC performs certain bookkeeping tasks for SUNET. More than 70 people are working at UU-ITS, although only a few of them are involved in the management of SUNET. Organizationally, UMDAC consists of four units: the consulting unit, the production unit, the purchasing unit, and the accounting unit.

Conclusion There were found no gaps related to the management bodies of SUNET: the entity Management Body has a number of instances in case of SUNET, and the attributes introduced by the model are applicable for those instances.

5.4.8 Relationships among entities of the MNS

The conceptual model defines eleven relationships among entities of the MNS presented below in Table 5.11. Below we describe the content of these relationships for SUNET.

The relationship `m1` represents the distribution of management tasks among managers. The content of this relationship is demonstrated in Table 5.12. Typically, two people are responsible for each management task. Some management tasks, such as Unix administration and fault monitoring, are allocated to three or more managers. The task "fault monitoring" requires a manager to be available 24 hours a day. This is to ensure the high availability of the network and the quick response in case faults disrupt its operation. Therefore, several network engineers are allocated to perform this task in turns. Every manager has a set of tasks he or she is responsible for. Table 5.12 demonstrates that some managers have more tasks than others.

`m1`	Manager is responsible for Management Tasks
`m2`	Manager uses Management Tools
`m3`	Manager belongs to Management Bodies
`m4`	Financial Resource covers the costs of Managers and Management Tools
`m5`	Management Body executes Management Tasks
`m6`	Management Body provides Management Services
`m7`	Management Tool supports or automates Management Tasks
`m8`	Management Service is based on Management Tools
`m9`	Management Service is derived from Management Goals
`m10`	Management Service is a result of carrying out a sequence of Management Tasks
`m11`	Management Task is derived from Management Goals

Table 5.11: The relationships among entities of the management of the network system.

	Supervision of comm. links	Facility management	Incident handling	Security response	Router management	Multicast management	Regional coord. with user org.	IP addresses management	DNS management	Mail management	LISTSERV management	News management	Unix administration	System development	Web server management	Web catalog management	Fault monitoring	Administration
Peter Graham																		+
Bengt Gördén					+	+	+											
Björn Danielsson												+	+	+			+	
Björn Eriksen			+					+	+	+		+						
Björn Rhoads						+							+				+	
Daniel Stolpe																+		
Elisabeth Hegrad																		+
Fredrik Widell	+		+		+			+	+								+	
Hans Fischer	+						+						+		+		+	
Joachim Malmquist				+														
Magnus Hoem															+	+		
Magnus Tigerschiöld		+																
Måns Nilsson										+	+			+				
Martin Rydström											+							
Per Olovson		+																

Table 5.12: Distribution of management tasks among the staff members of KTHNOC.

The relationship `m2` implies that managers use the management tools. For example, Peter Graham frequently uses his PC and the TTAS (Trouble Ticket Administration System) for collecting and checking trouble tickets, and for creating new trouble tickets. Every manager uses his or her PC for performing various management tasks and for accessing information collected by management tools.

The relationship `m3` implies that the managers described in section 5.4.5 belong to KTHNOC. Bengt Gördén also belongs to TREF. In addition to being a CEO of SUNET, Hans Wallberg is also the director of UMDAC.

The relationship `m4` implies that the subsidies of the Swedish government and the user fees are partially used to cover the costs of management tools and the salaries of managers. Because most management tools are basically freeware software tools, their costs are in fact zero. Therefore, this relationship reflects the fact that financial resources are used to pay the salaries of staff members of KTHNOC, UMDAC, UU-ITS, and the salaries of SUNET CEOs Olle Thylander and Hans Wallberg.

The relationships `m5` implies that each management body executes certain management tasks. KTHNOC executes the management tasks described in section 5.4.2. Other management bodies also execute some management tasks.

The relationship `m7` implies that the management tools support or automate certain management tasks. The regular PCs support nearly all management tasks since they are the usually the main entry point for managers to get access to hardware and software resources of the NS. NORDstat and Sysmon support the task "supervision of communication links". TTAS and Sysmon support the tasks "incident handling" and "fault monitoring".

The relationship `m8` implies that some management services are based on management tools. The network monitoring service is based on NORDstat, since this tool produces various graphs which are accessible via the web interface. The remaining management services are based on regular PCs. Such PCs are used for various purposes, such as the preparation and the distribution of documents containing information which is vital for a management service.

The relationships `m9` and `m11` refer to the fact that all management tasks and management services must be derived from management goals. However, in case of SUNET these relationships could not be validated because the management goals of SUNET were not clear enough.

The relationship `m10` implies that each management service is the result of some management tasks. This relationship reflects the definition of the management service. Its content was already described in section 5.4.3.

Conclusion A gap in the management goals of SUNET affects the relationships `m9` and `m11`. The remaining relationships among the entities of the MNS all present in the real situation of SUNET.

5.5 Relationships between NS, RS, and MNS

The conceptual model grouped such relationships in six generic relationships "RS exploits NS", "NS supports RS", "MNS manages NS", "NS informs MNS", "MNS

	Relationship among entities of RS, NS, and MNS	Generic relationship
e1	Management Body is a subdivision of State Agency or User Organization	MNS services RS
e2	User Organization or State Agency provides Financial Resources	RS employs MNS
e3	Financial Resource covers the costs of the Network System (Hardware Resources, Software Resources, and Communication Links)	MNS manages NS
e4	Management Body provides Network Services to User Organizations	MNS services RS
e5	Management Goal is based on the characteristics of the Network System, Requirements, Preconditions, and the attributes of the Association of Users	NS informs MNS, RS employs MNS
e6	Management Task is related to Hardware Resources, Software Resources, and/or Communication Links	MNS manages NS
e7	Network System reports to Management Tasks	NS informs MNS
e8	Management Body provides Management Services to User Organizations	MNS services RS
e9	Network Service supports Needs and Business Processes	NS supports RS
e10	Requirement specifies the assortiment and the characteristics of Network Services and Management Services	RS exploits NS
e11	End User utilizes Network Services	RS exploits NS
e12	User Organization utilizes Network Services	RS exploits NS
e13	User Organization utilizes Management Services	RS employs MNS

Table 5.13: The relationships among RS, NS, and MNS.

services RS”, ”RS employs MNS”. Coming sections 5.5.1 – 5.5.6 present the content of these relationships in case of SUNET.

5.5.1 RS exploits NS

There are three relationships representing the generic relationship of the management paradigm ”RS exploits NS”, namely `e10`, `e11`, and `e12`, see Table 5.13.

The relationship `e10` represents the definition of the entity Requirement. A gap in this entity affects also the relationship `e10` and makes it is rather weak: because of the lack of clearly specified requirements, it is questionable whether the assortment and the characteristics of network services match the demands of users.

The relationship `e11` is fully applicable for SUNET. However, it is difficult to present its description because this would require detailed statistics about traffic transferred from each PC within the campus networks of the user organizations – such statistics are lacking. The utilization of SUNET services by end users is formally regulated by the SUNET Ethical Rules. These rules define a number of actions which are considered to be unethical, such as ”gaining access to network resources without having the right to do so” and ”disturbing or interrupting the legitimate use of the network” [www.sunet.se].

The relationship `e12` reflects the utilization of network services by user organizations. Since the utilization of many network services is monitored, there is statistical information reflecting this relationship. Such information is available for the following network services: backbone IP connectivity, external IP connectivity, the file archive service ftp.sunet.se, the newsfeed delivery service, and the LISTSERV service. The utilization of network services by user organizations is formally regulated by the SUNET Acceptable Use Policy. According to this policy, ”SUNET may be used for business activity, but not in a manner which is intrusive or undesirable for other organizations” [www.sunet.se].

Conclusion There were found no gaps in the generic relationship ”RS exploits NS” for SUNET: the relationships `e10`, `e11` and `e12` exist in the real situation of SUNET. However, a gap in the entity Requirement affects the relationship `e10` and makes it is rather weak.

5.5.2 NS supports RS

The generic relationship of the management paradigm ”NS supports RS” is represented in the conceptual model by the relationship `e9`. Like the relationship `e11`, the relationship `e9` emphasizes that users are primarily interested in network services which support their activities. It reflects the primary aim of the NS which is to support the RS. The conceptual model defines more specifically that the network services support business processes of user organizations, and also needs of end users. The following examples illustrate this relationship in case of SUNET.

The student administration information systems and personnel administration information systems of some universities are placed outside their campuses, at the sites of other universities. For example, the student administration information system of the Royal Institute of Technology runs on servers that are physically located at the campus of the University of Umeå. Therefore, the users of this system are strongly dependent on good connectivity between the campus networks of these two universities. Such connectivity is provided by SUNET, which offers the IP connectivity service to its user organizations. Therefore, the IP connectivity service supports the business process "student administration" of the Royal Institute of Technology.

An important task of Swedish universities is to provide information to society. This informational role is particularly important for new universities. Therefore, the web sites of the universities play an important role. By providing the external IP connectivity service, SUNET makes the information published at the universities' web sites available for the outside world – both within Sweden and internationally. Therefore, this service supports an important business process of universities which can be called "provision of the information to society".

Distance education courses have become very popular in Sweden in the recent years. Most of the Swedish HEIs offer a range of such courses. The SUNET network infrastructure is the main transmission medium for this courses. Therefore, the services of SUNET support this type of educational processes.

Conclusion There were found no gaps in the generic relationship "NS supports RS" for SUNET: the relationship `e9` exists in the real situation of SUNET.

5.5.3 MNS manages NS

The generic relationship of the management paradigm "MNS manages NS" is represented in the conceptual model by the relationships `e3` and `e6`.

The relationship `e3` reflects the way in which financial resources are used for covering costs of the entities which comprise the NS. It basically represents the budget of SUNET. Table 5.14 gives an overview of the expenditure items of the SUNET budget, and their absolute and relative values in the years 1999, 2000, and 2001.

Expenditure item	1999		2000		2001	
	MSEK	%	MSEK	%	MSEK	%
National connectivity	36.6	31.1	60.2	36.8	61.4	46.1
International connectivity	47.8	40.6	53.4	32.6	37.8	28.4
Services	9.8	8.3	11.2	6.8	11.8	8.9
Depreciation	17	14.4	17.9	10.9	20.6	15.5
Service to libraries	6.5	5.5	21	12.8	1.5	1.1
TOTAL	12.8		17.8		14.5	

1 SEK (Swedish Kronor) is ˜0.11 Euro

Table 5.14: The annual budget of SUNET.

The relationship `e6` implies that management tasks are related to entities comprising the NS. The names of management tasks described in section 5.4.2 clearly indicate that these tasks are related to some hardware resources, software resources, or communication links. For example, the task "supervision of communication links" clearly relates to communication links. Similarly, the task "LISTSERV management" relates to a LISTSERV server segate.sunet.se and the corresponding software resources. The task "Unix management" relates to software resources "operating systems from the Unix-family".

Conclusion There were found no gaps in the generic relationship "MNS manages NS" for SUNET: the relationships `e3` and `e6` exist in the real situation of SUNET.

5.5.4 NS informs MNS

The generic relationship of the management paradigm "NS informs MNS" is represented in the conceptual model by the relationships `e5` and `e7`.

The relationship `e5` reflects the fundamental basis for the management goal: the characteristics of the NS, the requirements, the preconditions, and the attributes of the association of users. A gap in the entities Requirement and Precondition affects this relationship and makes it is rather weak.

The relationship `e7` implies that the status of the hardware resources, software resources, and communication links is reported to the management of SUNET. The collected information is then used for managing, controlling, and maintaining the NS. For example, the status of communication links is reported to the management task "supervising of communication links". If a link goes down, the management tool "Sysmon" receives a signal from the terminating equipment of this link (a router).

Conclusion There were found no gaps in the generic relationship "NS informs MNS" for SUNET: the relationships `e5` and `e7` exist in the real situation of SUNET. However, gaps in the entities Requirement and Precondition affect the relationship `e5` and make it weak.

5.5.5 MNS services RS

The generic relationship of the management paradigm "MNS services RS" is represented in the conceptual model by the relationships `e1`, `e4`, and `e8`.

The relationship `e1` implies that management bodies are subdivisions of user organizations or state agencies. KTHNOC is a subdivision of the Royal Institute of Technology; the Department of Numerical Analysis and Computing Science. UMDAC is a subdivision of the Umeå university – it is a computer centre within this user organization. UU-ITS is an IT Support department within the Uppsala University.

The relationship `e4` and `e8` imply that each management body provides some network and/or management services to user organizations. Nearly all network services are provided by KTHNOC, except for the file archive service (ftp.sunet.se), which is provided by the UU-ITS. UMDAC provides the white-pages service, the fax service, and the LISTSERV service. Table 5.15 illustrates the relationship `e4`. The distribution of management services among management bodies is shown in Table 5.16. This table illustrates the relationship `e8`.

The relationship `e4` is affected by a gap in the entity Network Service. This is because this relationship reflects the Service Level Agreements between the management bodies and the user organizations. In case of SUNET, such agreements do not exist. The SUNET services are offered on the basis of verbal agreements. Expectations of user organizations are fulfilled in a so-called best-effort way.

Network service	Management body
The backbone IP connectivity	KTHNOC
The external IP connectivity	KTHNOC
The IP Multicast service	KTHNOC
The domain name service	KTHNOC
The newsfeed delivery service	KTHNOC
The white pages service	UMDAC
The fax service	UMDAC
The LISTSERV service (segate.sunet.se)	KTHNOC
The provision of information about SUNET (www.sunet.se)	UMDAC
The file archive service (ftp.sunet.se)	UU-ITS
The content listing service (katalogen.sunet.se)	KTHNOC

Table 5.15: The distribution of network services among management bodies (the relationship e4 ”management body provides network services”)

Management service	Management body
The network monitoring service	KTHNOC
The training service	TREF
The technical assistance service	TREF
The security response service	KTHNOC
The security liaison service	UU-ITS
The security information service	UU-ITS

Table 5.16: The distribution of management services among management bodies (the relationship e8 ”management body provides management services”).

Conclusion There were found no gaps in the generic relationship "MNS services RS" for SUNET: the relationships `e1`, `e4`, and `e8` exist in the real situation of SUNET. However, the relationship `e4` is affected by a gap in the entity Network Service.

5.5.6 RS employs MNS

The generic relationship of the management paradigm "RS employs MNS" is represented in the conceptual model by the relationships `e2` and `e10`.

The relationship `e2` is meant to represent the way in which financial resources are obtained. According to the conceptual model, it represents the logical association between financial resources and their providers: external parties, user organizations, and state agencies. As already mentioned in section 5.4.6, SUNET has mixed funding: it is financed partly by state grants and partly by contributions from user organizations. User contributions account for about 70% of the total financial resources.

The relationship `e2` also reflects the charging model, which is used for calculating the fees paid by user organizations. SUNET uses a flat-rate charging model: the user fees depend on the size of the user organization in terms of the number of people that belong to this organization. A remarkable fact is that charges for regular users of SUNET (universities and university colleges) are not based on the capacity of user-access links because all these links have a uniform capacity of 155 Mbps.

The relationship `e10` is abstract in nature. It reflects the very definition of the entity Requirement by showing an obvious dependency between this entity and the entities Network Service and Management Service.

Conclusion There were found no gaps in the generic relationship "RS employs MNS" for SUNET: the relationships `e2` and `e10` exist in the real situation of SUNET.

5.6 External Environment

5.6.1 External parties

The following organizations are external parties of SUNET: NORDUNET, Cisco Systems, Banverket Telecom, and Stokab. NORDUNET is the provider of the external connectivity for SUNET. It is the common international IP service provider for the five Nordic NRENs in Sweden, Denmark, Finland, Norway, and Iceland. Cisco Systems supplies SUNET with networking equipment such as routers and switches. SUNET has long-term agreements with Cisco Systems which allows it to get significant discounts on the networking equipment. Banverket Telecom provides the underlying communication infrastructure for SUNET: long-distance communication links are provided by Banverket Telecom. Stokab operates a data transmission network which is used by SUNET for connecting user organizations located in the Stockholm region.

Conclusion There were found no gaps related to the external parties of SUNET: the entity External Party has a number of instances in case of SUNET.

5.6.2 Telecommunication services

The NS of SUNET is strongly dependent on the telecommunication services provided by telecom operators. This is because many communication links connecting the network nodes of SUNET are based on this infrastructure and the corresponding data transmission services.

Sweden is considered to be one of the most "wired" countries in the world. As much as 7,72% of Sweden's GDP is invested in telecommunications and in information technology. The existing telecommunication infrastructure in Sweden is based on copper, coaxial, and optical fiber cable, and also on various radio-based solutions. CATV companies also offer telecommunication services via their TV cable networks.

Unlike RENs in other countries, which have no alternatives for their network infrastructure, SUNET can choose between several physical telecommunication networks operating on a national scale. Until several years ago, SUNET was based on the infrastructure of Telia – the incumbent telecom operator in Sweden. But some years ago SUNET switched to Banverket – the operator of the Swedish railway network, which also owns a fibre optic network and provides data transmission services to corporate clients. In addition to Telia and Banverket, there is also a third telecom operator offering long-distance data transmission services via its own terrestrial telecommunication network: the national electricity infrastructure provider Svenska

The capacity of data transmission services offered in Sweden ranges from kilobits to gigabits. The services having virtually any capacity are provided. The area of availability of the services covers nearly the whole country including the cities where user organizations of SUNET are located.

According to [Tel01], Sweden has the lowest price for data transmission services in Europe. Figure 5.7 illustrates this for circuits having a capacity of 34 Mbps and 155 Mbps, and spanning a distance of 200 km (prices of incumbent telecom operators are shown).

Conclusion There were found no gaps related to the telecommunication services available in Sweden. The telecommunication environment in Sweden is favorable for the development and further growth of SUNET. The competitive telecommunication environment enables it to lease high-capacity communication links for rather low prices compared to those in other countries.

5.6.3 Internet access service

Internet access service is one of the most important services of SUNET. SUNET is both a provider and a customer of this service. One the one hand, SUNET provides this service to its user organizations. On the other hand, SUNET purchases this service from NORDUNET.

In case of SUNET, the characteristics of the Internet access service are not very relevant, since NORDUNET does not have competitors in providing this service to SUNET. This is because NORDUNET was jointly established by SUNET and the other four Nordic NRENs whose interests it represents. Therefore, NORDUNET is basically an extension of SUNET. The same people who manage SUNET are also involved in the management of NORDUNET, so that these two RENs form an insep-

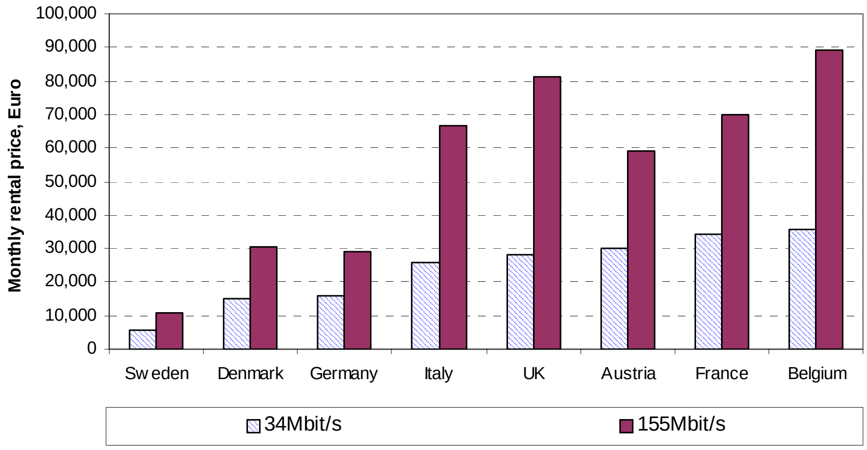

Figure 5.7: Comparison of tariffs for renting digital leased lines in some European countries (Source: [Tel01]. VAT is not included)

arable conglomerate. Consecutively, it is unlikely that SUNET will buy the Internet access service from another provider.

Similarly, SUNET has little competition with commercial Internet Service Providers (ISPs) in Sweden. It is unlikely that user organizations would prefer buying the Internet access service from a commercial ISP rather than from SUNET. Historically, all Swedish HEIs have a close collaboration with SUNET. This collaboration keeps them from switching to other network providers. The heavy funding which SUNET receives from the Swedish government enables it to keep the prices lower than those the rest of commercial ISPs are able to offer.

Conclusion The entity Internet Access Service and its attributes are not very relevant in case of SUNET. Firstly, because NORDUNET does not have competitors in providing this service to SUNET. Secondly, because SUNET hardly has competition with commercial ISPs in Sweden.

5.6.4 Domestic Internet

The conceptual model defines several attributes of the entity Domestic Internet. These attributes and also their values in case of SUNET are presented Table 5.17.

Indicator	1999	2001	Annual growth rate
Number of Internet hosts, '000	430	1141	88%
Number of PCs per 100 inhabitants	45	56	41%
Number of Internet users, '000	2900	4800	55%
Number of Internet service providers	80	120	50%

Table 5.17: Values of indicators reflecting the growth of the Swedish Internet.

According to [ITi03] Sweden has the highest percentage of the population with access to a computer and the Internet among the EU countries. The EcaTT survey (Electronic Commerce and Telework Trends, [ECA99]) which compared the development in ten EU nations concluded that "Sweden is one of the frontrunners when it comes to PC penetration, Internet access and E-mail use in households". More than 70% of Swedes have access to computers either at home or at work.

The growth of the Swedish Internet market influences SUNET. The growth of the Internet population and the increase of awareness of Swedes about the Internet influences the SUNET end users community, which is a subset of the whole Swedish population. Because there must be an increase in the number of potential end users – people at user organizations who so far have not used the Internet or used it very little, an upgrade of the network capacity can be necessary.

Conclusion There were found no gaps related to the Swedish Internet: the attributes of the entity Domestic Internet are applicable for the Swedish Internet.

5.6.5 Legislation

According to the conceptual model, the entity Legislation has two vital instances, namely the national ICT policy, and the regulatory basis for telecom liberalization.

The national ICT policy of Sweden is formulated in the bill "An Information Society for All", which was accepted by the Swedish Parliament in March 2000. This bill set a challenging goal for Sweden: to become the world-leading information society by 2005. The bill includes an action plan in which SUNET is given an important role. The bill provides, therefore, an important legislative basis for the growth and development of SUNET, and ensures the long-term commitment of the state to support SUNET politically and financially.

The regulatory basis for telecom liberalization is favorable for the development of SUNET. The Swedish telecommunication market was liberalized in 1993, well ahead of that of most other EU countries. Many aspects of regulation in the Swedish market have progressed quickly, and the number of operators offering fixed telephony has doubled in the last several years.

Conclusion There were found no gaps related to the Swedish legislation relevant for RENs. Both the national ICT policy and the regulatory basis for telecom liberalization is favorable for the development of SUNET.

5.7 Summary of gaps

This section summarizes the gaps in the model and in the real situation which were identified in the preceding sections of this chapter. Section 5.7.1 summarizes gaps in the conceptual model – aspects of the real situation which are not properly covered by the model. Section 5.7.2 summarizes gaps in the real situation – entities and relationships which are either missing in the real situation, or have been developed improperly.

The information presented in this section is based solely on the opinion of the researcher – the author of this dissertation; no other people have been involved. The representatives of the sites will be involved in the evaluation of the model later on, as shown in Chapter 6.

5.7.1 Gaps in the conceptual model

During the application of the conceptual model in case of SUNET, it was found that one aspect of the real situation is not properly covered by the conceptual model. The model was found to be unable to reflect the *division of end users into "heavy" and "light" users*, see section 5.2.5.

5.7.2 Gaps in the real situation of SUNET

Before giving an overview of gaps in the real situation of SUNET let us make the following remark. We did not attempt to cover all possible missing points of the real situation – that would be an enormous task which is hardly possible to accomplish inside of the scope of a doctorate research. Moreover, this research is positioned not on an operational level, but rather on a strategic level. The gaps in the real situation of SUNET relate to the existence of the model's elements (entities, attributes, and relationships) in case of SUNET.

During the application of the conceptual model in case of SUNET, it was found that some entities, attributes, and relationships were either missing in the real situation, or had been hardly developed. The following gaps in the real situation of SUNET were identified:

1. The management of SUNET does not know requirements and preconditions of user organizations
2. Lack of service levels for services other than the connectivity services
3. Lack of service level agreements (SLAs)
4. Lack of management goals

These gaps affect a number of entities and relationships highlighted in Figure 5.8. Let us briefly describe each gap together with entities and relationships it affects.

1. The management of SUNET does not know requirements and preconditions of user organizations

The characteristics of services required by the user organizations of SUNET are not defined, and the conditions that restrain these characteristics are unclear. Instead of inquiring about requirements with user organizations as the model prescribes, the SUNET management tries to predict requirements by analyzing technological trends and developments in the IT and networking fields. Even though financial preconditions are recognized, they are not clearly specified in terms of financial budgets.

In the model this gap relates to the lack of instances of the entities Requirement and Precondition, see sections 5.2.7 and 5.2.8. Additionally, it affects the relationships `r2`, `r4` and `e10`. Its impact is similar to that of the second gap from the case study of URAN, see section 4.7.2.

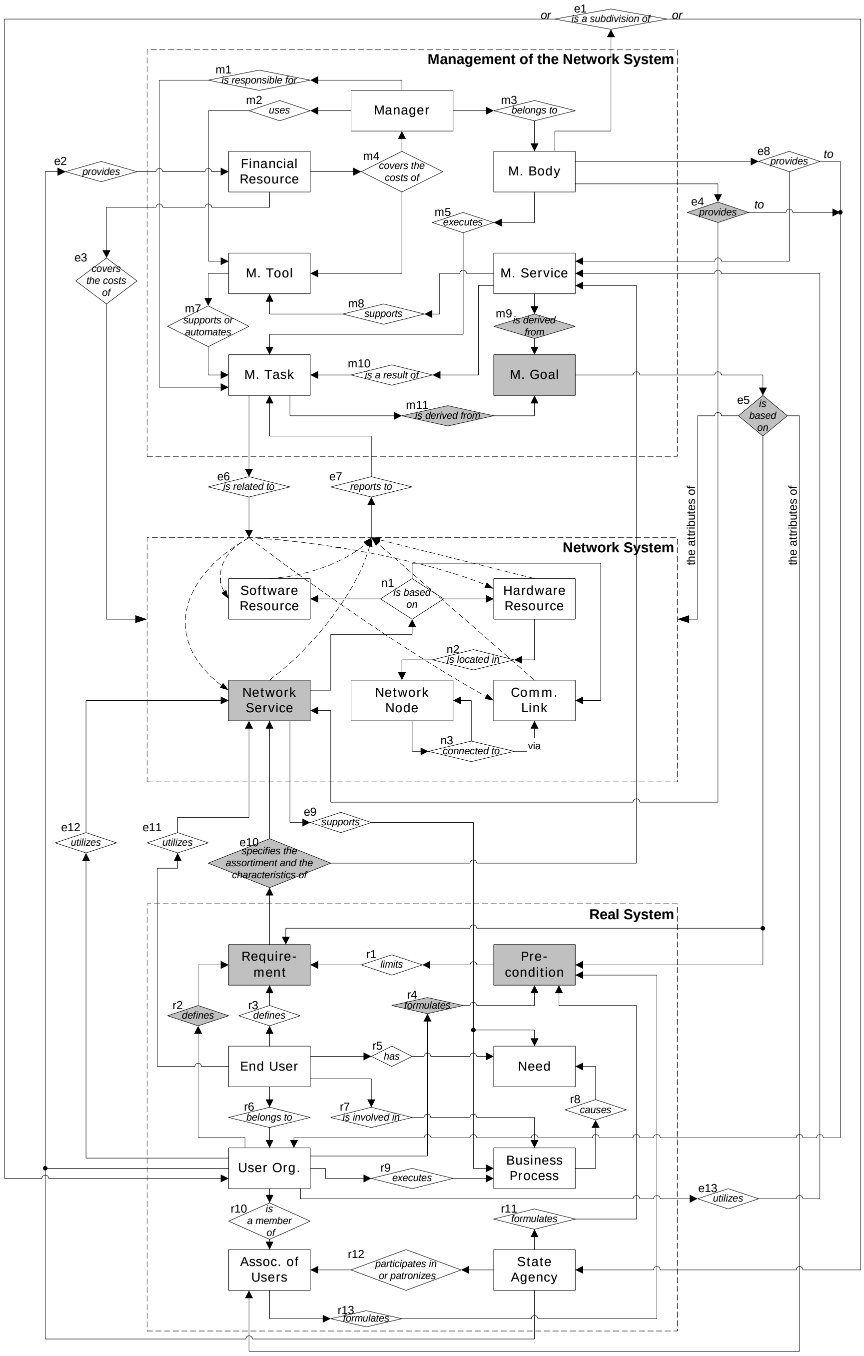

Figure 5.8: Gaps in the real situation of SUNET seen from a perspective of the conceptual model (affected entities and relationships are highlighted by the gray color).

2. Lack of service levels for network services other than the connectivity services

This gap means that indicators reflecting the service levels of the following services are neither defined nor monitored: the IP Multicast service, the domain name service, the newsfeed delivery service, the white-pages service, the fax service, the LISTSERV service, the provision of information about SUNET (www.sunet.se), the file archive service, and the content listing service.

In the model this gap relates to the attribute ”service level” of the entity Network Service, see section 5.3.2. In case of SUNET, most instances of this entity are missing the mentioned attribute.

3. Lack of service level agreements (SLAs)

This gap means that all SUNET services are provided in a so-called ”best-effort” manner without quality guarantees. Instead of providing services on the basis of written documents (SLAs) as the model prescribes, the services are offered on the basis of verbal agreements. It is up to every particular user organization to decide whether the services' characteristics match the desired (verbally agreed) level.

In the model this gap relates to the relationship `e4` ”Management Body provides Network Services”, see section 5.5.5. This is because this relationship reflects the contractual agreements between management bodies and user organizations. In case of SUNET, there are no SLAs between SUNET and user organizations, while the conceptual model prescribes the need of such agreements.

4. Lack of management goals

This gap means that the management of SUNET is not directed by clearly specified goals. The theoretical management goals defined by the conceptual model are not fulfilled, see section 5.4.1. In the model this gap affects the entity Management Goal and the relationships `e5`, `m9`, and `m11`. The gap's impact is similar to that of the fourth gap from the case study of URAN, see section 4.7.2.

5.8 Adjustment of the conceptual model

Before proceeding to Step 2 of the validation methodology “adjustment of the model and development of recommendations”, let us recall the visual interpretation of this step from Chapter 1, see Figure 5.9. One goal of the model is to help bringing the management of a REN to a higher level. Therefore, the model has been designed in such a way that it produces a number of recommendations for improving the site. Another goal however, is to improve the model by confronting it with the validation site, and by analyzing the feedback coming from this site. It is important to understand that the recommendations are not developed at the same time as the model is modified: these are two independent events that occur in sequence.

The previous section demonstrated one gap in the conceptual model – the vital aspect of the real situation which is not reflected in the model. Therefore, the model

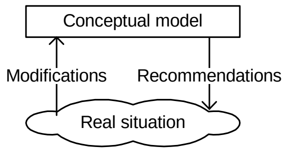

Figure 5.9: Visual interpretation of Phase 4, Step 2 "Adjustment of the model and development of recommendations".

has to be modified so that it will include this aspect as well. In this way the conceptual model benefits from the real situation.

The gap *"inability to reflect the division of end users into heavy and light users"* can be corrected by simply adding an extra attribute "expected intensiveness of utilizing network services" to the entity End User. This attribute would reflect the fact that some end users require more network resources than others. The addition of this attribute is in-line with the strategy of the conceptual model, since the model defines only the attributes which are relevant in case of all RENs. Therefore, the introduction of an extra attribute is merely an adaptation of the model to a particular situation.

5.9 Development of recommendations

The application of the model to the case of SUNET revealed a number of gaps in the real situation, which were summarized in section 5.7.2. These gaps have allowed producing a number of recommendations which are expected to be beneficial for the real situation:

1. Investigate requirements and preconditions of user organizations
2. Introduce service levels for network services other than the connectivity services
3. Conclude service level agreements
4. Define management goals and control their fulfillment

It is important to emphasize two peculiarities of the recommendations presented in this section. Firstly, the recommendations result from the use of the model, and not from a practice-based approach. This distinguishes them from recommendations generated by practitioners. Secondly, the recommendations are based solely on own judgments of the author of this dissertation: no other people were involved in the development of these recommendations.

1. Investigate requirements and preconditions of user organizations

As shown in section 5.2.7 and 5.2.8, the management of SUNET has little knowledge about the requirements and the preconditions of user organizations. Instead of asking user organizations what requirements they have, the management of SUNET tries to envisage them by analyzing technological trends and developments in the fields of

IT and networking. Although such an approach seems to work in practice, it is not according to the conceptual model: technological trends are indeed important, but because they are external influences, they should not be the direct basis for requirements. According to the model, user organizations and end users are the parties that must formulate requirements. Technological trends influence requirements by being first assessed by users.

The investigation of requirements and preconditions of user organizations implies conducting a survey among them. Representatives of user organizations can be vital input for such a survey, namely directors of IT departments and managers of campus networks. Additionally, it is important to interview those people who have decision-making power, such as rectors, deans, and heads of departments. Identified requirements and preconditions should be properly documented and communicated to the user community.

A concise specification of requirements and preconditions would benefit both user organizations and management bodies of SUNET. User organizations would be able to get qualitative services, and management bodies – KTHNOC in the first place – would be able to take their service provision to a more professional level. Such a specification would also raise the awareness of user organizations and end users about possible services to be provided to them in the near future.

2. Introduce service levels for network services other than the connectivity services

We recommend to introduce service level indicators for the following network services: the domain name service, the newsfeed delivery service, the white-pages service, the fax service, the LISTSERV service, the service "provision of information about SUNET (www.sunet.se)", the file archive service (ftp.sunet.se), and the content listing service (katalogen.sunet.se). Suggested indicators are the response time, the availability, and the mean time between failures. The values of these indicators should be monitored 24 hours a day, 7 days a week. Furthermore, it is important that the monitoring results are reported to user organizations, just as the results of monitoring the connectivity services.

3. Conclude SLAs with user organizations

Currently, there are no legal agreements between user organizations and SUNET. The provision of services is carried out in a best-effort manner. The introduction of service levels and SLAs will make it possible to estimate and to control objectively the qualitative characteristics of the service provision.

This recommendation implies that the management bodies of SUNET – KTHNOC in the first place – should conclude Service Level Agreements (SLAs) with each user organization. Such agreements should stipulate agreed service levels and commit the management bodies to these. "An SLA should contain a specified level of service, support options, enforcement or penalty provisions for services not provided, a guaranteed level of system performance as relates to downtime or uptime, and a specified level of customer support" [www.webopedia.com]. Besides mentioned matters, an SLA also typically contains a short description of each service provided. A good example to be followed is the SLA of JANET [Jan00].

This recommendation depends on the realization of the second recommendation. The indicators of service levels should be used as the basis for the SLAs that describe the agreed values of these indicators. The results of monitoring these indicators can be used to control the actual compliance with an SLA.

4. Define management goals and control their fulfillment

We recommend that more attention should be given to management goals. It implies that management goals must be properly defined, and their fulfilment must be controlled by the management of SUNET. The definition of management goals can be accomplished by taking the theoretical management goals as a basis, and then adjusting them to the actual situation of SUNET. For example, management goals of SUNET could be formulated as follows:

> The management goals of SUNET are to operate, control and maintain the existing and future network infrastructure of SUNET (communication links, hardware resources, software resources, and network services). This must be accomplished in accordance with (1) the requirements specified in <reference1>, (2) the preconditions specified in <reference2>, (3) the mission, legal status, and geographical distribution of the Association of Swedish Universities, (4) the categories, size, and financial conditions of user organizations, (5) the capacities, prices, and areas of availability of the telecommunication services and the Internet access service in Sweden, (6) the characteristics of the SUNET network infrastructure.

Two of the above-mentioned references should refer to documents describing requirements and preconditions. Therefore, this recommendation is dependent on the fulfillment of the first recommendation. The management goals must be agreed with the SUNET Board, and also with the Swedish Research Council and the National Agency for Higher Education.

5.10 Conclusion

This chapter started the validation of the conceptual model in the case of SUNET. It corresponds to Phase 4 of the research approach defined in Chapter 1, and covers the first two steps of this phase: (1) bidirectional confrontation between the model and the real situation, (2) adjustment of the model and development of recommendations. This chapter started answering the third research question *"How can the developed model be validated in practical situations?"*.

The first step implied using the model to produce a description of SUNET. At this step the model's elements (entities, relationships, and attributes) were filled in with the actual data of SUNET, or, in other words, the real situation of SUNET was confronted with the model. Sections 5.2 – 5.6 presented the results of this confrontation for each part of the model (RS, NS, MNS, Relationships, and External Environment). During this confrontation it appeared that the real situation of SUNET did not have certain model's elements, or these elements were improperly developed. Such missing elements – gaps in the real situation – were summarized in section 5.7.2. The first step also included the confrontation of the model with the real situation: parallel to making a description of the real situation of SUNET we analyzed whether the model reflects all the important aspects of the real situation. The model was unable to reflect several aspects of the real situation. Such aspects – gaps in the model – were summarized in section 5.7.1.

The second step demonstrated that the model and the real situation mutually benefit from each other. On one hand, the real situation gave indications on how to adjust the model in order to remove gaps in it, see section 5.8. On the other hand, the model provided the real situation with recommendations on how to remove gaps in the real situation, see section 5.9.

Chapter 6

Evaluation by the sites

6.1 Introduction

The two preceding chapters, 4 and 5, describe the first part of the validation of the conceptual model using two RENs: URAN and SUNET. They covered the first two steps of the validation approach (1) bidirectional confrontation between the model and the real situation, (2) adjustment of the model and development of recommendations (this was Phase 4 of the research approach; see section 1.4.4). Although these chapters demonstrated that the model is capable of meeting its main objectives, they did not show *how well* the model is capable of doing this: no claims about the quality of the model have been made so far.

This chapter presents Step 3 of the validation process. In this step, the quality of the model is evaluated by the people that are involved in the management of URAN and SUNET. Since these people represent the intended users of the model, they can provide the best input for assessing the model's quality. The model is considered here as a product which is meant to be used by these people.

6.2 Approach

6.2.1 Steps

The approach used for the evaluation of the model consists of five steps, described below:

1. Defining evaluation criteria
2. Designing questionnaire
3. Developing manual for the model
4. Selecting respondents
5. Distributing questionnaire and collecting responses

Step 1: Defining evaluation criteria

The criteria to be used for the evaluation of the model were defined on the basis of the ISO/IEC 9126 standard ([ISO01], [Bev99]). This standard provides a framework for the evaluation of software quality. It defines a quality model which is applicable for any kind of software. Six characteristics, and a number of sub-characteristics are defined in this standard. The six characteristics are functionality, reliability, usability, efficiency, maintainability, and portability. Figure 6.1 illustrates these characteristics and their sub-characteristics.

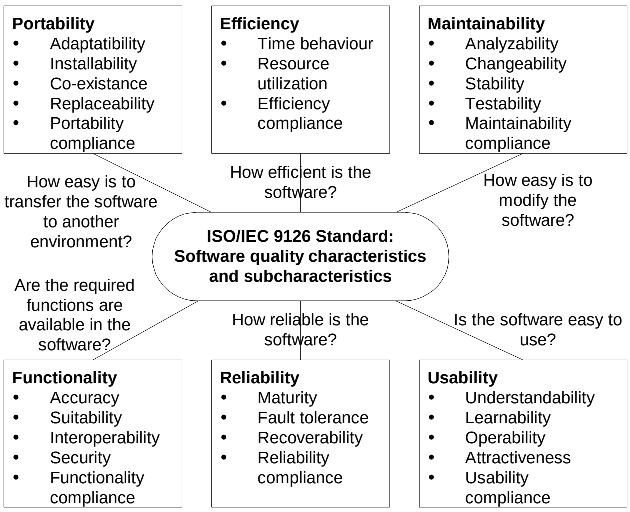

Figure 6.1: ISO/IEC 9126 Software quality characteristics and subcharacteristics ([ISO01]).

The framework of the ISO/IEC 9126 standard was used for defining the evaluation criteria for the model developed in Chapter 3. This model is seen as a product whose quality needs to be evaluated by its intended users.

Since the model is not a software product but rather a set of procedures, prescriptions, and rules, not all of the quality characteristics defined in this standard are applicable. Two quality characteristics were chosen, namely the functionality and usability. Based on the definition of the quality characteristics from the ISO/IEC 9126 standard, these two criteria were defined in the following way. *Functionality* is the capability of the model to provide functions that meet stated and implied objectives. *Usability* is the capability of the model to be understood, learned, used, and attractive to the user.

Both evaluation criteria, functionality and usability, are broken down into several sub-criteria. The definitions of these sub-criteria are based on the ISO/IEC 9126 standard.

Functionality is divided into suitability and accuracy. *Suitability* is the capability of the model to provide an appropriate set of functions for specified (formulated) objectives. *Accuracy* is the capability of the model to provide the right or agreed results, or effects with the needed degree of precision.

Usability is divided into understandability, learnability, operability, and attractiveness. *Understandability* is the capability of the model to enable the user to understand whether the model is suitable, and how it can be used for reaching its objectives. *Learnability* is the capability of the model to enable the user to learn its application. *Operability* is the capability of the model to enable the user to use (apply) it in a given situation (to a given REN). *Attractiveness* is the capability of the model to be attractive to the user.

Step 2: Designing questionnaire

Based on the evaluation criteria identified in Step 1, we designed the questionnaire shown in figures 6.2 and 6.3. This questionnaire consists of sixteen questions divided into two parts according to two main evaluation criteria: functionality and usability. The first part of the questionnaire (questions 1 – 12) is devoted to the evaluation of the model's functionality. The second part of the questionnaire (questions 13 – 16) is devoted to the evaluation of the model's usability. According to the definition of functionality, questions evaluating the model's functionality were coupled to the model's objectives, see section 1.3.

Every question was a closed question having three alternative answers. The first answer represents a positive reaction/ attitude of the respondent towards the question. The second answer represents a rather neutral reaction/ attitude. The third answer represents a negative reaction/ attitude. Additionally, each question was supplied with the place for writing comments. The second and the third answer asked the respondent to explain why he had chosen this answer.

Step 3: Developing manual to the model

The next step of the evaluation methodology involved developing a manual for the model. Such a manual had to be a document which (1) could be understood well by the intended users of the model, and (2) could provide clear directions on how to apply (use) the model in practice.

The manual for the model was meant to reflect not only the content of Chapter 3, but also the experience gained by the researcher during the model's application in two case studies URAN and SUNET. The manual can be found in Appendix B of this dissertation.

Step 4: Selecting respondents

Seven people were selected as respondents to the evaluation questionnaire that was developed in Step 2. Figure 6.4 presents their names, roles, and also the site to which they belong (SUNET/ URAN). Six respondents were directly involved in the management of URAN/ SUNET – either on a strategic, or on a tactical level. Mr. Gert Schellbach-Mattay represented NATO – the international agency providing financial support to URAN.

Questionnaire for the evaluation of the Model
supporting the management of Research and Education Networks

Before completing this questionnaire please study the following two sources (integrate parts of the dissertation "Modeling Management of Research and Education Networks (RENs)"):
1st source: Appendix B "Manual to the model"
2nd source: Chapter 4/5 "Case study URAN/SUNET"
Optionally, Chapter 3 "Conceptual model" can also be consulted in case more information about the model is needed. Certain questions are linked to the model's main and additional objectives formulated in the 1st source.

Part 1. Evaluation of the model's functionality
(the capability of the model to provide functions that meet its objectives; see the model's objectives in the 1st source, section A.2)

1. How well is the model capable of providing an appropriate set of functions for producing **a description of the REN and its management**? /main objective №1/	❑ The model is a very good tool, capable of showing a clear picture of all vital aspects related to the REN and its management ❑ The model is a rather good tool, capable of covering many vital aspects related to the REN and its management. However, certain aspects are not reflected in the developed description (please explain) ❑ The model is not a good tool; it is incapable of producing a realistic picture of the REN and its management. The developed description does not cover sufficiently a number of vital issues (please explain)
Comments:	

2. How accurate/ correct is the description of the REN and its management?	❑ Very accurate/ correct ❑ Rather accurate, although a few aspects are not reflected/ interpreted accurately(please explain) ❑ Inaccurate/ incorrect (please explain)
Comments:	

3. How well is the model capable of providing an appropriate set of functions for identifying **gaps in the real situation of the REN and its management**? /main objective №2/	❑ Very capable ❑ Rather capable (please explain) ❑ Incapable (please explain)
Comments:	

4. How accurate is the model in its reflection of gaps in the real situation of the REN (2nd source, section 4.7.2/ 5.7.2)?	❑ I fully agree that the topics depicted in section 4.7.2/ 5.7.2 are indeed gaps which would should be filled (either very soon or in the future) ❑ I agree that certain topics depicted in section 4.7.2/ 5.7.2 are gaps which should probably better be eliminated (please explain) ❑ I disagree that topics depicted in section 4.7.2/ 5.7.2 are gaps in the real situation of the REN (please explain)
Comments:	

5. How well is the model capable of providing an appropriate set of functions for developing **useful recommendations** that could enable filling of the gaps and improving the management of the REN (2nd source, section 4.9/ 5.9)? /main objective №3/	❑ Very good ❑ Rather good (please explain) ❑ Not good (please explain)

Figure 6.2: The evaluation questionnaire (first page).

Please indicate to which extent the model is capable of:	Very well capable	Rather capable	Incapable
6. Raising the awareness of the stakeholders of the REN (see the description of stakeholders in section A.3 of the 1st source) /additional objective №1/	☐	☐	☐
7. Facilitating communication among the stakeholders (the model is a common communication language) /additional objective №2/	☐	☐	☐
8. Improving the effectiveness and the efficiency of management /additional objective №3/	☐	☐	☐
9. Providing guidelines for building new RENs (the model is a blueprint of a desirable situation the REN is aiming to achieve- a sort of "cookbook") /additional objective №4/	☐	☐	☐
10. Assisting in compiling project proposals for further development of the REN, including applications for grants -- state subsidies and/or donor grants /additional objective №5/	☐	☐	☐
11. Facilitating the transfer of knowledge between developing RENs and developed RENs /additional objective №6/	☐	☐	☐
12. Promoting the use of scientific approaches in the management of RENs as opposed to practice-based approaches (avoiding the use of trial-and-error approaches) /additional objective №7/	☐	☐	☐
Please elaborate on your answers (particularly if you have answered “rather capable” or “incapable”):			

Part 2. Evaluation of the model’s usability
(the capability of the model to be understood, learned, used and attractive to the user)

13. How well do you **understand** the model and the way in which it is applied? Comments:	❑ Yes, I understand the model and the way in which it is applied very well ❑ Well, I understand the model rather well. However, there are a few things which I don’t fully understand (please explain) ❑ No, I don’t understand the model (please explain)
14. Do you think that you can **learn** the way in which the model is applied (used)? Comments:	❑ Yes, I think I can learn the way in which the model is applied ❑ Maybe; I think that I can learn the way in which the model is applied, but this will take too long and it will take much effort to do this (please explain) ❑ No, I don’t think that I can learn the way in which the model should be applied. It is too complex for me to learn, or there are other reasons (please explain)
15. Do you think that you can **apply** the model in the real situation (for example, for making an updated description of the REN in a few years)? Comments:	❑ Yes, I can apply the model in the real situation ❑ Probably; I’m not sure whether I can apply the model in the real situation (please explain) ❑ No, I don’t think I can apply the model in the real situation (please explain)
16. Do you find the model (and its presentation) **attractive**? Comments:	❑ Yes, I find the model attractive ❑ Well, the model is quite attractive, but it could be better (please explain) ❑ No, I find the model unattractive (please explain)

Thank you very much for your contribution.

Figure 6.3: The evaluation questionnaire (second page).

Name	Role	Site
Mikhail Dombrugov	Scientific Secretary of the URAN Technical Committee, Director of the the Center for European Integration (URAN Operator)	URAN
Vladimir Galagan	Acting Head of the URAN Technical Committee, Technical Director of the CEI	URAN
Vladimir Timofeev	Senior executive of the Coordinative Council of the URAN Association, Deputy of First vice-rector of NTUU "KPI"	URAN
Gert Schellbach-Mattay	NATO Networking Expert, Head of the Communication networks division of the Computing centre of RWTH Aachen (technical university)	URAN
Peter Graham	Director of KTHNOC (SUNET Network Operations Center)	SUNET
Olle Thylander	SUNET Chief Executive Officer (CEO)	SUNET
Hans Wallberg	SUNET CEO, Head of the Computing Centre of the Umeå University.	SUNET

Figure 6.4: The respondents to the questionnaire.

Step 5: Distributing questionnaire and collecting responses

The questionnaire and the accompanying documents were sent to the respondents. The accompanying documents included the manual to the model (Appendix B) and the results of the model's application (chapters 4 and 5). Chapter 4 was sent to the URAN respondents, and Chapter 5 was sent to the SUNET respondents. It took about two months to collect all responses to the questionnaire.

6.2.2 Advantages and disadvantages

The positive side of the evaluation approach was the relative ease for the respondents to evaluate the model. The respondents were asked to review the documents given to them by the researcher, and answer a relatively short questionnaire. This requires minimum time input from the respondents compared to a situation where they are asked to apply the model. Another positive side of this approach is that people involved in the management of URAN and SUNET are confronted with a state-of-the-art scientific view of their familiar working environment. This might result in the improvements of the sites if, for example, the recommendations described in chapters 4 and 5 are implemented in practice.

The evaluation approach also has some limitations. The respondents do not apply the model themselves but fill in a questionnaire which contains closed questions. The responses given by respondents are rather subjective, and the amount of people that was interviewed was rather limited – there were only seven respondents. Therefore, it might be arguable whether the results of the evaluation objectively reflect the model's quality.

Besides the approach that was used in this research, there are also alternative approaches. For instance, the description of the model (Chapter 3) and its manual (Appendix B) could be sent to each site, to URAN and SUNET, without sending the results of applying the model obtained by the researcher (chapter 4 or 5). The representatives of both sites could then be asked to apply the model themselves.

The results of the model's application by the sites could be compared to those of the researcher, and the feedback of both sites would be collected and analyzed. A possible modification to this approach would sending the model to respondents representing a site which was not involved in the research project (other REN), and to ask them to apply the model.

Despite the above-mentioned limitations, the approach used here is the most realistic and feasible one. This is because other approaches require a lot of time of the site's representatives. It would have been unrealistic to expect the managers of URAN or SUNET to apply the model.

6.3 Results URAN

This section presents the results of the evaluation in the case of URAN. Table 6.1 presents an overview of the answers of the URAN respondents. The first column presents the evaluation criteria functionality and usability, and their underlying sub-criteria: suitability, accuracy, understandability, learnability, operability, and attractiveness. The second column presents the specification of suitability and accuracy into a number of detailed characteristics. The first ten characteristics show that suitability is composed of ten capabilities related to the model's main and additional objectives. The last two characteristics show that accuracy is composed of the accuracy of the formal description and the accuracy of the reflection of gaps. The third column gives the number of the question in the questionnaire which corresponds to each evaluation criterion or detailed characteristic.

The last three columns of Table 6.1 show the distribution of reactions per question for three alternative answers, and the generalized reaction for all URAN respondents. The numbers show how many respondents answered each question positively (very good/ very well capable), neutrally (rather good/ rather capable), or negatively (not good/ incapable). Each marked cell shows the generalized response to a question for all respondents. The response which received most votes is considered to be the generalized response, unless a negative response was given: a negative response lowers the positiveness of the generalized response.

6.3.1 Functionality

The answers of the URAN respondents show that they consider the functionality of the model to be of good quality: the model can provide functions that meet the objectives formulated for the model. Since the functionality is composed of suitability and accuracy, each of these criteria is evaluated separately in a subsection below.

Suitability

Three respondents considered *the model to be a very good tool, capable of producing a formal description of URAN and its management* – the first model's objective. According to received answers, the model is capable of showing a clear picture of all vital aspects related to URAN and its management. One respondent noted, however, the weakness of the model in covering all the variety of political aspects.

Evaluation criterion		Detailed characteristic	Question number	Number of reactions		
				Positive ("very good/ very well capable")	Neutral ("rather good/ rather capable")	Negative ("not good/ incapable ")
Functionality	Suitability	Capability of providing an appropriate set of functions for producing a description of the REN and its management (main objective #1)	1	3	1	0
		Capability of providing an appropriate set of functions for identifying gaps in the real situation of the REN (main objective #2)	3	2	2	0
		Capability of providing an appropriate set of functions for developing useful recommendations (main objective #3)	5	3	1	0
		Capability of raising the awareness of the stakeholders (additional objective #1)	6	2	1	1
		Capability of facilitating communication among the stakeholders (additional objective #2)	7	1	2	1
		Capability of improving the effectiveness and the efficiency of management (additional objective #3)	8	3	1	0
		Capability of providing guidelines for building new RENs (additional objective #4)	9	2	1	1
		Capability in assisting in compiling project proposals for further development of the REN (additional objective #5)	10	3	1	0
		Capability of facilitating the transfer of knowledge between developing RENs and developed RENs (additional objective #6)	11	3	0	1
		Capability of promoting the use of scientific approaches in the management of RENs (additional objective #7)	12	1	3	0
	Accuracy	Accuracy of the description of the REN and its management	2	4	0	0
		Accuracy of the reflection of gaps in the real situation	4	3	1	0
Usability	Understandability		13	3	0	1
	Learnability		14	2	2	0
	Operability		15	3	1	0
	Attractiveness		16	2	2	0

Table 6.1: An overview of the answers of the respondents to the questionnaire (URAN).

The respondents considered *the model to be a rather good tool, capable of identifying gaps in the real situation of URAN* – the second model's objective. Two respondents gave a positive answer and two respondents gave a neutral one. One respondent noted important two gaps, namely the lack of management goals, and the weak link between network services of URAN and business processes of user organizations.

The respondents considered *the model to be a very good tool, capable of developing useful recommendations* – the third model's objective. Three respondents considered the model as a very good tool for such an objective, and one respondent gave a neutral reaction. One respondent noted that the recommendation "investigate how network services support business processes" was important. Another respondent noted that the model could not provide recommendations in the field of politics.

The respondents considered the model to comply with its additional objectives either very well or rather well. *The model was found to be very suitable* for improving the effectiveness and the efficiency of management, and for assisting in compiling project proposals. Three out of four respondents gave a positive answer.

The model was found to be rather suitable for

- raising the awareness of the stakeholders,
- facilitating communication among the stakeholders,
- providing guidelines for building new RENs,
- facilitating the transfer of knowledge between developing RENs and developed RENs,
- promoting the use of scientific approaches.

The URAN respondents gave valuable comments supporting their reactions. It was noted that due to the model's complexity, it can be used as a common language only when its intended users have studied it, and this requires considerable time and effort. One respondent also commented that practice-based approaches are sometimes preferable to scientific approaches. Another respondent noted that the managers of RENs are hardly ready to use scientific approaches. Regarding the model's capability of providing guidelines for building new RENs: one respondent gave an interesting comment: in his opinion, new RENs will not be built, but are developing continuously.

Accuracy

Three URAN respondents considered *the accuracy of the model to be very good.* All respondents found the formal description of URAN to be very accurate. Similarly, all respondents found the formal description of gaps in the real situation to be very accurate. Three respondents fully agreed that all topics depicted in section 4.7.2 were indeed gaps which should be filled either very soon or in the coming future.

One respondent agreed that not all, but only certain topics described in section 4.7.2 are gaps. He commented that if the designers of the model want to stipulate that URAN's management goals and preconditions must be formulated in the documents, they must first prove that other RENs also have such documents. He also noted that every regional user organization has its own requirements, which are registered in the contracts between that user organization and CEI. However, the sets of these requirements are very diverse across regions due to various technical and financial constraints. He commented that the main imperfection of URAN is its inability to guarantee the same levels of service for every part of Ukraine.

6.3.2 Usability

The respondents considered *the usability of the model to be rather good*. Three out of four respondents understood the model and the way in which it is applied very well. They indicated that they can learn the way in which the model is applied and can eventually apply it in a real situation, for example, for making an updated description of URAN.

One respondent did not understand the model. He commented that in his view, a model should be an algorithm operating in the way "if you do A and B, the result will be C". He missed equations and flowcharts in the presentation of the model.

The model's attractiveness was described in the following way: two respondents considered the model to be very attractive, and two respondents as rather attractive.

6.4 Results SUNET

This section presents the results of the evaluation in the case of SUNET. Table 6.2 presents an overview of the answers received from the SUNET respondents. This table has a similar set of columns as Table 6.1 presented in section 6.3. The last three columns of this table show the distribution of reactions per question for three alternative answers, and the highlighted cells show generalized responses for all SUNET respondents.

6.4.1 Functionality

The SUNET respondents considered the functionality of the model to be of good quality – the model is rather capable of providing functions that meet the objectives formulated for the model. Since the functionality is composed of suitability and accuracy, each of these criteria is evaluated separately in a subsection below.

Suitability

The respondents considered *the model to be a rather good tool, capable of producing a formal description of SUNET and its management* – the first objective for the model. Although the formal description covers many vital aspects related to SUNET and its management, certain aspects were not reflected. The respondents commented that certain relationships are missing. One respondent commented that in his opinion, models can never reflect real situations. Additionally, the respondents noted that the model is more suitable for relatively stable business environments rather than for dynamic research environments. According to one of the responses the model seems to be business oriented regarding the management goals, which does not necessarily fully map goals of a REN like SUNET.

Evaluation criterion		Detailed characteristic	Question number	Number of reactions		
				Positive ("very good/ very well capable")	Neutral ("rather good/ rather capable")	Negative ("not good/ incapable")
Functionality	Suitability	Capability of providing an appropriate set of functions for producing a description of the REN and its management (main objective #1)	1	0	3	0
		Capability of providing an appropriate set of functions for identifying gaps in the real situation of the REN (main objective #2)	3	0	3	0
		Capability of providing an appropriate set of functions for developing useful recommendations (main objective #3)	5	0	3	0
		Capability of raising the awareness of the stakeholders (additional objective #1)	6	2	1	0
		Capability of facilitating communication among the stakeholders (additional objective #2)	7	2	1	0
		Capability of improving the effectiveness and the efficiency of management (additional objective #3)	8	0	3	0
		Capability of providing guidelines for building new RENs (additional objective #4)	9	1	1	1
		Capability in assisting in compiling project proposals for further development of the REN (additional objective #5)	10	0	3	0
		Capability of facilitating the transfer of knowledge between developing RENs and developed RENs (additional objective #6)	11	1	2	0
		Capability of promoting the use of scientific approaches in the management of RENs (additional objective #7)	12	0	3	0
	Accuracy	Accuracy of the description of the REN and its management	2	0	3	0
		Accuracy of the reflection of gaps in the real situation	4	0	3	0
Usability	Understandability		13	3	0	0
	Learnability		14	3	0	0
	Operability		15	3	0	0
	Attractiveness		16	0	3	0

Table 6.2: An overview of the reactions of the respondents to the questionnaire (SUNET)

The respondents considered *the model to be a rather good tool, capable of identifying gaps in the real situation of SUNET* – the second objective. One respondent noted that although the model is capable of identifying gaps, it cannot identify all existing gaps. Another respondent commented that the identification of gaps strongly depends on the availability of data about the site. Therefore, certain gaps might be caused by the insufficient input of data about the site.

The respondents considered *the model to be a rather good tool, capable of developing useful recommendations* – the third objective. They noted that the model could give useful recommendations provided that the identified gaps were important and well understood. The respondents noted that the recommendations "introduce service levels" and "conclude service level agreements" are particularly important and useful: they agreed that SLAs could be useful in the dialogue with user organizations. One respondent noted that the model did not take into account informal discussions between the management of SUNET and user organizations about service levels.

One respondent reported two interesting facts which prove the usefulness of the recommendation "investigate requirements", and show its realization in practice. Firstly, some 3000 end users of SUNET were being interviewed with the purpose to investigate their network habits and to study their needs in relation to network services. Such interviews were carried out in the framework of an ongoing project. Secondly, the requirements were also investigated by collecting and analyzing samples of network traffic in order to establish usage patterns of the network. The data is still being analyzed (September 2003).

The respondents considered the model to comply with its additional objectives either very well or rather well. *The model was found to be very suitable* for raising the awareness of the stakeholders, and facilitating communication between them. It was commented that it is good to have a common reference model for discussions. One respondent noted that few of the stakeholders of SUNET would be willing to study the model. Another respondent noted that the model is a good start, but that one must bear in mind that goals and local situations may vary.

The model was found to be rather suitable for

- improving the effectiveness and the efficiency of management,
- facilitating the transfer of knowledge between developing RENs and developed RENs,
- providing guidelines for building new RENs,
- assisting in compiling project proposals,
- promoting the use of scientific approaches.

The respondents gave a number of interesting comments explaining their answers. It was noted that although the model could be very useful for providing guidelines for building new RENs, one should not forget that "a new REN has to be working in a different environment with other important dependencies and relations that may not be covered by the model. The model now handles static situations and for a developing REN things are very dynamic". Commenting on his answer about the model's ability to promote the use of scientific approaches, one respondent wrote that there will always be an element of trial and error, even in a scientific approach. Another respondent noted that the model opens new ways of thinking, which is always useful. It was also commented that by raising the awareness and stimulating new ways of thinking, the model should contribute to improving the REN's management.

Accuracy

The respondents considered *the accuracy of the model to be rather good.* All respondents characterized the formal description of SUNET as being rather accurate, although a few aspects were not wholly reflected or interpreted. They noted that the model relates only to existing formal documents; it cannot handle information that is informal or unavailable in the formal documents.

The respondents agreed that certain topics depicted in section 5.7.2 are gaps which should probably be filled. They noted that SLAs between the SUNET Board and KTHNOC already exist. However, the respondents agreed that SLAs between KTHNOC and user organizations should also be introduced.

6.4.2 Usability

The respondents considered *the usability of the model to be very good.* All respondents *understood* the model and the way in which it is applied very well. Additionally, they indicated that they can *learn* the way in which the model is applied and eventually *apply* it in a real situation, for example, for making an updated description of SUNET in a few years.

The respondents considered the model to *quite attractive.* It was noted that although the model is a good start, probably further research and development will be needed to make it more suitable for a typical university or R&D environment. One respondent noted that although it is possible to learn a lot from the model, it not the ultimate answer to identifying problems and developing recommendations for a REN.

6.5 Conclusions

This chapter presented the evaluation of the model's quality by the people that are involved in the management of URAN and SUNET. Six criteria reflecting the quality of the model were introduced, namely the suitability, accuracy, understandability, learnability, operability, and attractiveness. The representatives of the sites were asked to chose one of the three quality levels to describe these criteria: 'very good', 'rather good', and 'bad'.

Figure 6.5 presents consolidated results of the answers given by the representatives of both sites, SUNET and URAN. It shows the distribution of reactions per evaluation criterion. The vast majority of reactions belongs to the quality levels 'very good' and 'rather good'. The evaluation of the criterion 'suitability' was particularly important, since this criterion reflects the extent to which the model's objectives are met, which is the major purpose of validating the model. Figure 6.6 presents the consolidated results of the answers for this criterion.

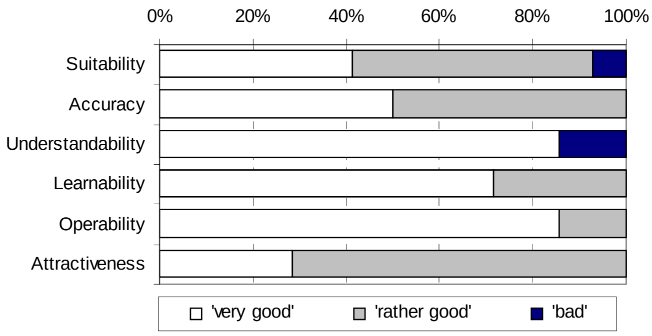

Figure 6.5: The quality of the model: the distribution of reactions per evaluation criterion.

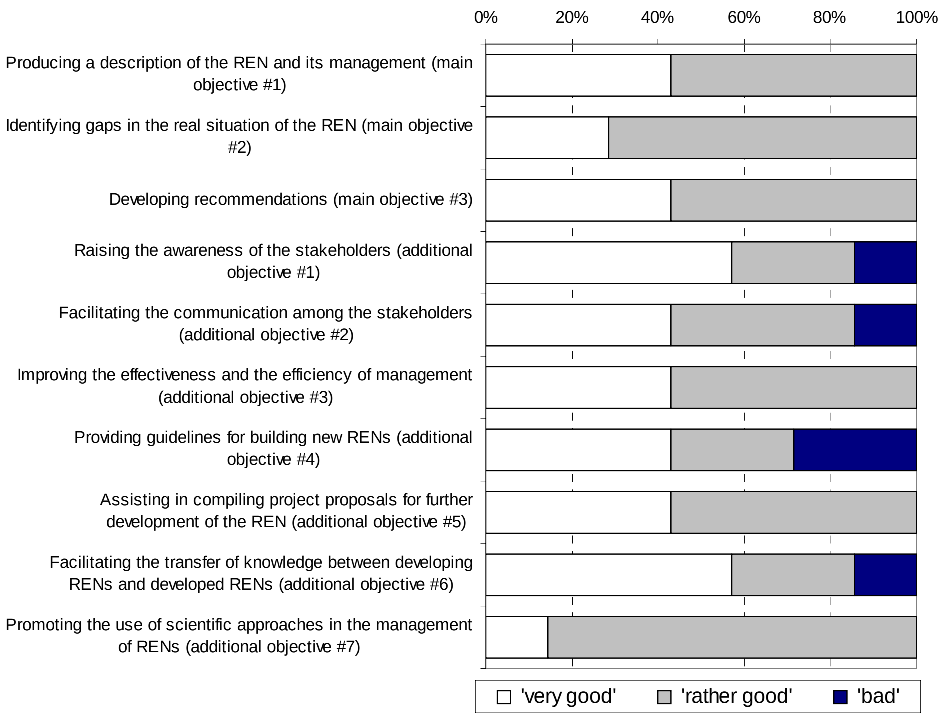

Figure 6.6: The suitability of the model (capability of the model to meet its objectives): the distribution of the answers per objective.

The responses concerning the suitability and understandability contain a few answers representing the quality level 'bad'. These responses refer to the capability of the model to meet its additional objectives #1, 2, 4, and 6 (see Figure 6.6). There was also one reaction representing the quality level 'bad' referring to the understandability: one URAN respondent did not understand the model.

Although the small number of respondents (seven) does not allow making a statistical analysis of the results, we can draw some qualitative conclusions when we compare the responses of the URAN respondents with those of the SUNET respondents. The SUNET respondents were less positive in their evaluation compared to the URAN respondents. The majority of responses from the SUNET respondents were neutral, while those from the URAN respondents were very positive. We explain this by the fact that the SUNET respondents had more experience with the management of RENs compared with the URAN respondents. SUNET was the developed REN having a long history, and URAN was a developing REN having a short history. This fact enabled the SUNET respondents to be more critical on certain matters compared to the URAN respondents.

Chapter 7

Epilogue

7.1 Summary of the research

7.1.1 Background to the research

Computer networks have become an indispensable tool for research and education. Internal computer networks of R&E organizations – also called intranets or campus networks – are an important platform for the automation of the business processes of organizations. In addition to networks *within* R&E organizations, there are networks *among* R&E organizations: networks that connect R&E organizations with each other and with other networks, including the Internet. Such networks, called *Research and Education Networks (RENs)*, provide services to R&E organizations within geographical areas of different sizes: a city, a region, a country, or a continent. RENs exist in many countries all over the world. Europe, North America and Eastern Asia are the main parts of the world where the most developed RENs can be found.

Research and education networks, like any other computer network, must be properly managed if they are to be a successful platform for the services they provide. They need continuous support during their entire lifetime: faults and failures appear, performance degrades, and hardware and software needs to be installed and maintained.

Management of RENs includes a broad range of activities such as monitoring performance, resolving faults and failures, billing and charging of users, maintaining hardware and software, recruiting staff, securing funds, developing prices, marketing and promoting services, negotiating with suppliers, and developing policy documents. Therefore, it requires various types of knowledge such as technical, administrative, organizational, financial/ economical, and legal knowledge. Although usually most attention is paid to technical knowledge, other types of knowledge are also vital.

A number of issues has to be taken into account in order to ensure the effectiveness and efficiency of the management, like the networks' governing structures, funding models, charging schemes, usage policies, capacities and technologies of communication links, network traffic, characteristics of hardware and software, range and quality of the services, staff, and help desk. The volume and complexity of these and other matters make management of RENs a big challenge, which is complicated even further by the fact that there are many parties involved, such as government authorities, donors, user organizations, network operators, software and hardware vendors, and Internet service providers.

Knowledge about RENs and their management is usually presented in the form of descriptions of particular experiences and existing practices. There are no effective ways in which such knowledge can be exchanged or transferred, for example, from developed RENs to developing RENs. As a result, knowledge about RENs and their management is typically concentrated at the places (RENs) from which it originates.

The management of RENs has previously been neglected by researchers. There are only a few studies which focus partially on the management of RENs, concentrating on a broad range of issues related to RENs. Literature study did not yield examples of scientific research having the aim to study knowledge about the management of RENs.

Conclusion There is a need for a model that formalizes the knowledge about management of RENs. We discovered this need not only in the literature, but also in practice, in a project aimed at the creation of an NREN in Ukraine, namely the Ukrainian Research and Academic Network (URAN). The research described in this thesis initially started as an attempt to help building this NREN in a systematic way, rather than in a trial-and-error manner.

7.1.2 Research problem and questions

The previous section presented the background of the need to learn more about the management of RENs. To address this need we formulated the following research problem:

Research problem *How can the knowledge about RENs and their management be formalized in a model that is able to support such management?*

The research problem was approached by first studying the knowledge about the management of RENs, then developing a model, and then validating this model in practical situations. For this purpose, three research questions were posed:

Research question 1 *What are the relevant topics associated with RENs and their management?*

Research question 2 *How can we build a model that can be used to support management of both developed and developing RENs?*

Research question 3 *How can the developed model be validated in practical situations?*

Because the nature of the term "knowledge" is very broad and ambiguous, it would be too ambitious to declare that we try to study all the existing knowledge related to the management of RENs. Therefore, in the formulation of the first research question, this term was replaced by a more concrete term, namely "topics associated with management of RENs". These topics are meant to represent the most significant parts of the whole body of knowledge.

The sections 7.1.3 – 7.1.5 describe findings of the research, and outline answers to the research questions. Each of the sections answers one of the research questions and presents related findings.

7.1.3 Studying topics associated with RENs and their management

The first research question: *"What are the relevant topics associated with RENs and their management?"* is answered in Chapter 2.

Research answer 1 Topics associated with RENs and their management can be grouped into organizational, user-related, environment-related, usage-related, link-related, financial, and service-related topics. Chapter 2 describes these topics in detail.

Findings related to this research answer are described below.

1. RENs are often not only used to produce services, but also to research the possibilities of new networking technologies, services, and applications. Therefore, they are often used as test beds for innovative technologies. This makes them the pioneers in networking technologies, and this is why they can be used to develop state-of-the-art networking services and applications. Such innovative projects usually require growth of the transmission capacity, and, therefore, require significant investments.

2. Many RENs are struggling to get more transmission capacity. The difference in transmission capacities between RENs in developing countries and RENs in developed ones is enormous: it is the difference between transmitting kilobits (2^{10}) and gigabits (2^{30}) per second. Financial, technological, and political aspects play a role here.

3. Services provided by RENs are similar to those provided by various commercial service providers, such as the Internet Service Providers. Most RENs concentrate on the provision of operational services such as data transmission services.

4. Although the organizational structures of RENs are very diverse, a number of generic elements can be identified. These are the REN Operator, the Subcontractor, the Association of Users, the Management Board, the Advisory Board, and the State Agency.

5. The operator of a REN is usually an entity which has been specifically designed to fulfill this task. RENs are unlikely to be managed by commercial organizations aiming to get a profit out of the provision of services to R&E organizations. Subdivisions of state agencies or the user organizations themselves are often the operators of RENs.

6. RENs are often heavily dependent on state or donor subsidies, especially in the initial stage of their development. However, as a REN develops, more user funding is gradually introduced.

7. It is arguable in which way the recurrent expenses for the REN's operation should be covered. Both the usage-based and the flat-rate charging models have their advantages and disadvantages. However, the usage-based charging model is preferable if the resources are scarce and expensive.

7.1.4 Developing conceptual model

The second research question: *"How can we build a model that can be used to support management of both developed and developing RENs?"* was answered in Chapter 3.

Research answer 2 The conceptual model supporting the management of RENs was developed using the management paradigm and the entity-relationship approach. Chapter 3 presented an extensive description of this model.

Studying the existing models

The second research question was first approached via the literature study on existing models supporting network management. Since RENs are essentially computer networks, some of these models might also be suitable for supporting the management of RENs. In such a case, it would be unnecessary to develop a new model.

Existing models supporting the management of computer networks (OSI, Terplan framework, Looijen framework, TMN, TM Forum, and ITIL) appeared to be unable to support the management of RENs. This is demonstrated in Appendix A. The management of RENs involves a number of topics that are very specific for RENs. Because existing models are generic models, they do not cover most of the specific topics identified in Chapter 2. This conclusion justifies the need for developing a new model.

Developing a new model

A model supporting the management of RENs was developed on the basis of two fundamental theoretical frameworks, namely the management paradigm and the entity-relationship (ER) approach. In accordance with the management paradigm, four systems were considered, namely the real system (RS), the network system (NS), the management of the network system (MNS), and the external environment (EE). Using the ER approach, each system was modelled as a collection of entities connected by a number of relationships. Additionally, six generic relationships among the systems (RS exploits NS, NS supports RS, MNS manages NS, NS informs MNS, MNS services RS, and RS employs MNS) were modelled as a number of relationships among the entities of corresponding systems. Figure 7.1 presents a simplified view of the conceptual model.

7.1.5 Validating the conceptual model

The third research question: *"How can the developed model be validated in practical situations?"* is answered in chapters 4, 5, and 6.

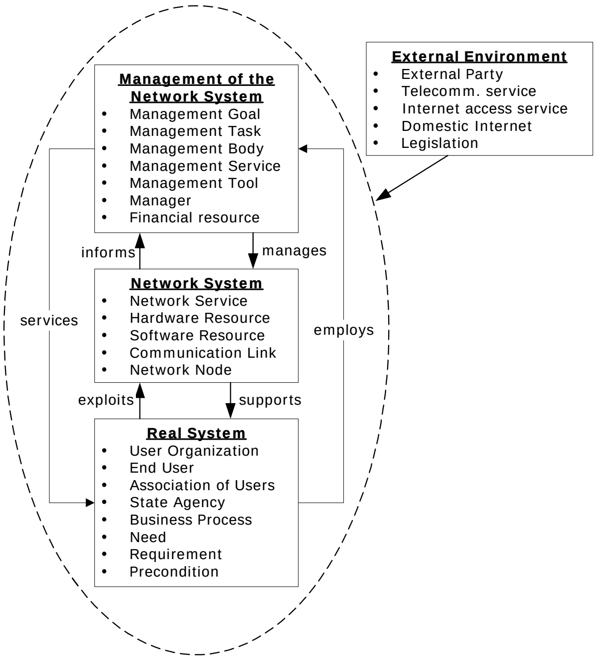

Figure 7.1: Simplified view of the conceptual model.

Research answer 3 The conceptual model has been validated based on the practical situations of two sites (RENs), namely the Ukrainian Research and Academic Network (URAN) and the Swedish University Network (SUNET). An approach consisting of three steps was used: 1) bidirectional confrontation between the model and the real situation, 2) adjustment of the model and development of recommendations, 3) evaluation of the model by representatives of the sites. Chapters 4 and 5 present the results of the first two steps for each site. Chapter 6 presents the results of the third step for both sites.

Below, each step is briefly described together with related research findings.

Step 1. Bidirectional confrontation between the model and the real situation

In Step 1 the model was applied to compile the descriptions of the sites. The entities and relationships of which the model consists were filled in with the actual data from the sites.

The experience of applying the model to real situations showed us that several prerequisites should be met before the model can be applied. Firstly, the senior management of the site should be committed to supporting and facilitating the application of the model. Secondly, those who apply the model should be familiar with the real situation and have access to various kinds of information, including financial and technical information. Thirdly, the stakeholders should be willing to cooperate and share information. Finally, considerable time input is required. This includes not only the time of those who apply the model, but also that of the personnel of the site. It is estimated that depending on the complexity of the real situation, the time necessary for drawing up the description of this situation can range from several weeks up to several months.

During the compilation of the descriptions, it was found that the real situations lacked certain elements of the model (entities, relationships, or attributes), or that elements had been developed improperly. Such missing elements are referred to as *gaps in the real situations*. The sites showed the following gaps:

- The management does not know requirements and preconditions of user organizations (URAN, SUNET)
- Lack of service levels of the network services (URAN, SUNET)
- Lack of management goals (URAN, SUNET)
- Lack of the Acceptable Usage Policy (URAN)
- Limited number of fault and security management tasks (URAN)
- Limited number of management services (URAN)
- Lack of service level agreements (SUNET)
- Lack of a regulatory basis for telecom liberalization and the monopoly of Ukrtelecom on the provision of terrestrial telecommunication services (URAN)

Based on our findings that both validation sites possess several similar gaps we could conclude that these gaps are quite common among RENs. Based on our exploration in Chapter 2, we expect that other RENs also possess similar gaps, so that they, for example, do not know the requirements of their users, and do not have management goals. Additionally, the meaning of the term "a gap in the real situation" in this research should be explained. The fact of the existence of such a gap means that an appropriate element of the model (entity, attribute, or relationship) is not present in the real situation. The model basically originated from two sources, namely the REN topics and the MCMIS theory. Of these two, the MCMIS theory is more likely to expose a gap in the real situation in the confrontation. In other words, it is more likely that the MCMIS theory suggests something that is not present in the real situation.

During the compilation of the descriptions, it was also found that the model could not reflect certain aspects of the real situations, or, in other words, that these aspects did not match any of the model's entities, attributes, or relationships. Such aspects were referred to as *gaps in the model*. The model appeared to be unable of reflecting: 1) contractual relationships among multiple management bodies, and between management bodies and external parties (URAN), 2) financial conditions of user organizations (URAN), 3) relationships between different management tasks (URAN), 4) a division of end users into heavy and light users (SUNET).

Step 2. Adjustment of the model and development of recommendations

The gaps discovered in the real situations led us to make the following recommendations to fill them:

- Investigate requirements and preconditions of user organizations (URAN, SUNET)
- Introduce service levels for network services (URAN, SUNET)
- Define management goals and control their fulfillment (URAN, SUNET)
- Draw up an Acceptable Usage Policy (URAN)
- Introduce new fault and security management tasks (URAN)
- Introduce new management services (URAN)
- Conclude service level agreements (SUNET)

Sections 4.9 and 5.9 provided detailed descriptions of these recommendations. The gaps in the model were filled by adjusting the model itself.

Step 3. Evaluation of the model by the sites

The purpose of Step 3 was evaluating the quality of the model according to the people involved in the management of the sites. Chapter 6 presented the results of this step. Six criteria reflecting the quality of the model were introduced, namely its suitability, accuracy, understandability, learnability, operability, and attractiveness. The representatives of the sites were asked to describe these criteria choosing one of three quality levels: 'very good', 'rather good', and 'bad'. The results of the evaluations show that the vast majority of the responses belong to the quality levels 'very good' and 'rather good'.

An important result of this step was the development of a manual of the model, see Appendix B. The manual provides directions on how to use the model in practice. It enables the intended users of the model to understand it better than based on the model's academic description given in Chapter 3.

7.2 Recommendations for further research

This section suggests directions for future research in the field of modelling of management of research and education networks.

A promising direction for future research seems to be to investigate how to extend the model developed in this research with measurable variables or parameters. Input, control, and output variables can be defined, which would make the model more quantitative, and also more programmable, so that it can be computerized, for example, with the use of the artificial intelligence and/or simulation techniques. The possibility of using simulation techniques would make it possible to forecast the behavior of a modelled situation, and to get a visual impression of real situations and ongoing processes.

The possibility of using simulation techniques also makes it possible to add the time dimension to the model. This implies modelling the behavior of entities, attributes, and relationships over time. Such an improvement would make the model dynamic; the model developed in this research supports only static situations. The addition of the time dimension would solve the problem of how to switch over from the current situation to a future situation, which problem was indicated in Chapter 5, section 5.3.1. The switch from one network infrastructure to another (in case of Chapter 5: the switch from SUNET to GigaSUNET) was outside of the scope of the model developed in this research: the model was not meant to support dynamic processes. The model was primarily developed for supporting the management of a REN at any given moment in time, including in future situations. The building of new RENs was out of the scope of this research.

It is recommended to study the applicability and behavior of the model outside the environment considered in this research. The suggested environments include computer networks of Internet Service Providers serving corporate clients, and computer networks of big multi-organizational conglomerates.

Appendix A

Existing models

A.1 Introduction

Management of computer networks (network management) is a subject receiving much of attention in the literature and in the industry. Academic and industrial researchers have developed a number of models supporting network management. Many of these models are successfully used by various organizations worldwide.

This appendix gives an overview of and compares existing models supporting network management. Additionally, it also analyzes the suitability of existing models for supporting the management of RENs.

The remaining sections of this appendix are organized as follows. Section A.2 gives an overview of the six existing models: the Looijen framework, the OSI Management framework, the Terplan framework, the TMN framework, the TeleManagement Forum models, and IT Infrastructure Library. Section A.3 compares these models on the basis of two approaches. The first approach implies the use of five key success factors: each model is analyzed to which extent it suffices these success factors. The second approach uses a set of comparison criteria, for each existing model values of these criteria are estimated. Section A.4 presents an analysis of the suitability of existing models for supporting the topics associated with RENs and their management. Each model is analyzed to which extent it is suitable for reflecting these topics.

A.2 Overview

This section presents an overview of several existing models supporting the management of computer networks. Computer networks are here not only seen as a technical phenomenon, but also as organizational and financial entities that should be managed, controlled, and maintained. Organizations executing such management activities are the focus of the analysis. Therefore, models reviewed in this section are primarily designed for supporting activities of such organizations. Some models present a blueprint of the business activities which must be performed within such organizations.

A.2.1 Looijen framework (the management paradigm and related models)

The Looijen framework is a collection of several models which were developed as part of the research and educational programme on the management of information systems at Delft University of Technology. Originally written in Dutch, the book describing it [Loo98] was translated in English and published in 1998. During the next two years this framework underwent several extensions and corrections, which were published in [Loo00]. Besides English, this framework has also been recently translated in Chinese.

Although the Looijen framework is not specifically designed for supporting the management of computer networks, it is also considered here due to the following considerations. Firstly, since computer networks are a particular kind of information systems, many parts of this framework are also valid and applicable for computer networks. Secondly, this research is also a part of the research programme on the management of information systems at the Delft University of Technology. Therefore, it is worthwhile to describe this framework here. Finally, the conceptual model described in Chapter 3 is based on one of the models out of this framework, namely the management paradigm.

The Looijen framework consists of the management model, the frame of reference for MCM tasks, the state model, and the triple management model. Let's briefly describe these models and their relevance for supporting the management of computer networks.

Management paradigm

The management paradigm – often also called the MCM (management, control, and maintenance) paradigm – is a foundation of the research and educational programs on the management of information systems at the Delft University of Technology. It basically consists of the three systems interconnected with each other, namely the real system (RS), the information system (IS), and the management of information system. The three systems are interconnected with each other as shown on Figure A.1. Additionally, some external influences affect the three systems and the relationships among them.

The power of the management paradigm lays in its abstractness and universal validity: the paradigm is applicable in virtually any situation involving information systems. Since computer networks are a particular case of information systems, the paradigm is also suitable for supporting the management of computer networks. The paradigm is described in more detail in Chapter 3, section 3.3.1.

Frame of reference for MCM tasks

The frame of reference for MCM tasks divides all tasks related to the management of information systems in a number of clusters called "task areas". Ten task areas are distinguished – these are shown as named rectangles on Figure A.2. Task areas are further divided into task fields, which are also shown on Figure A.2 as the elements of the bullet lists. Every task field consists out of several tasks (not shown on the

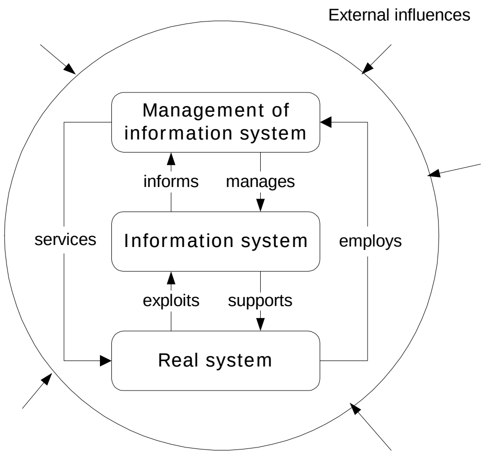

Figure A.1: The management paradigm (source: [Loo98]).

figure). Such tasks represents activities of a certain nature. For example, the task field Strategic Management from the task area Management consists of the following tasks: (1) formulating strategic goals, preconditions, and starting points, (2) drawing up policy plans, (3) finding ways to obtain material, human, and financial resources.

Most tasks from the Looijen's frame of reference are also relevant for the network management. However, because these tasks are rather generic in their nature, their content has to be adjusted to the needs of network management. Certain tasks would have a different content which would be more specific for computer networks.

State model

The state model reflects the life cycle of an IS. It distinguishes a number of states which an IS passes through during its life cycle. Figure A.3a graphically represents these states and the relationships among them.

The contents of these basis six states is the following. During the state IPP information policy and information planning are determined. This leads to the IS being developed on the following state D. Then, the IS is either accepted or not at the next state AI. If not accepted, it goes back to the previous state. Otherwise, the IS is utilized, exploited, and maintained at the following three states U, E, and M which run parallel to each other. The state U implies that the functionality of the IS are being used. The state E implies that the IS is kept operational or exploited for utilization. The state M implies that the IS or its part is being changed/ modified as a result of maintenance, initiated from the states U and E. For each state there are task areas and task fields which are relevant for this state. [Loo98, p. 87 - 90] gives a detailed overview of the relationships between the states and task areas/ fields.

The extended state model (see Figure A.3b) is meant to illustrate the advancing character of information systems together with the consequences connected with it. Being based on the state model, it shows that the modifications of the IS will also

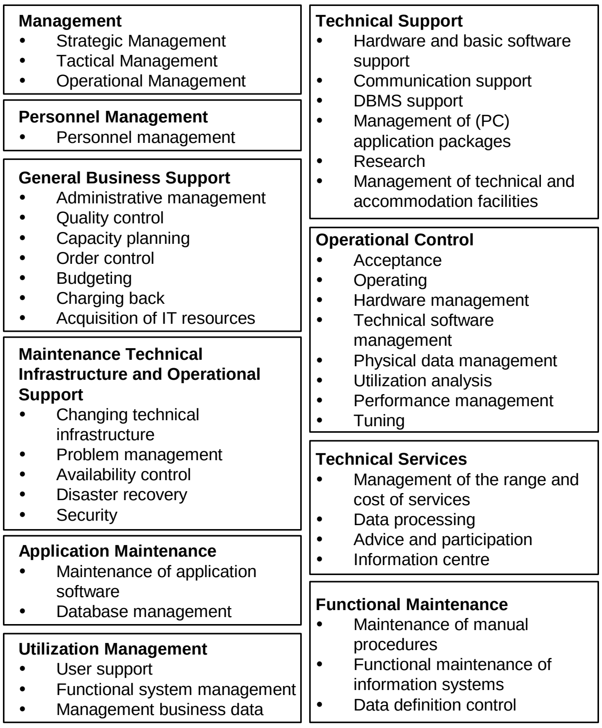

Figure A.2: The frame of reference for MCM tasks: task areas and task fields ([Loo98]).

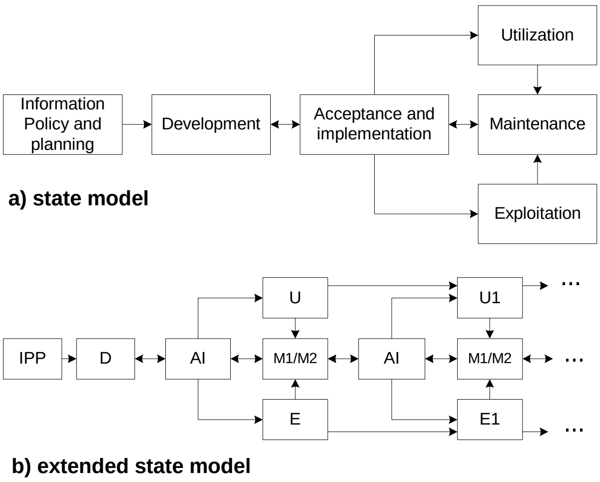

Figure A.3: The state model, and the extended state model (source: [Loo98]).

result in the changes of its management. Therefore, after the modifications take place, the state U is followed by a new instance of this state U1; this implies that the utilization of the modified IS differs from the utilization of the original IS. Correspondingly, the state E is followed by a new instance of this state E1.

Triple management model

The triple management model makes a distinction among three forms of management: functional management, application management, and technical management. Each form of management has different responsibilities. The functional management is responsible for the maintenance and control of the functionality of the IS. The application management is responsible for the maintenance and control of the application software and the databases. The technical management is responsible for the maintenance and control of the operalization of the IS consisting of hardware, software, and datasets which, in relation to practical applications, have to be continuously available for use.

The model positions the task fields illustrated on Figure A.2 within the three forms of management and the three organizational levels according to the Mintzberg's organizational logo ([Min79]). The three organizational levels are the strategic level, the tactical level, and the operational level. The Mintzberg's logo divides an arbitrary organization into five generic management units: strategic apex, middle line, operating core, technostructure, and support staff. Figure A.4 illustrates the triple management model and the above-mentioned principles.

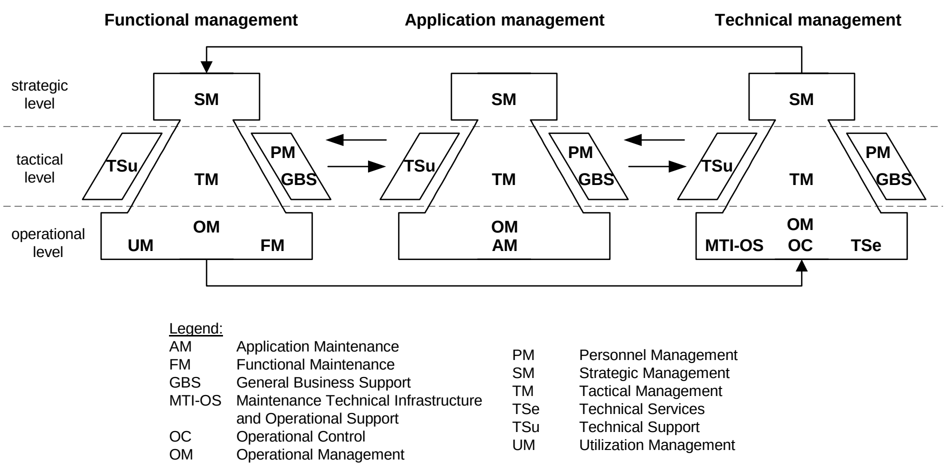

Figure A.4: The triple management model (source: [Loo98]).

A.2.2 OSI Management Framework

The International Organization for Standardization (ISO) developed the so-called Basic Reference Model of Open Systems Interconnection (OSI). The model provides the description of the activities necessary for open systems to interwork using communication media. Open systems are systems whose characteristics comply with specified, publicly maintained, readily available standards, and which, therefore, can be connected to other systems that comply with these same standards ([OSI89]). A system implies a collection of personnel, equipment, and methods organized to accomplish a set of specific functions. Therefore, computer networks are seen as collections of open systems with each connected device being an open system.

A part of the OSI Basic Reference Model is *the OSI Management Framework*. Its aim is to establish a framework for coordinating the development of existing and future standards for OSI Management. This framework is generally applicable for both OSI and non-OSI networks: it supports the management of not only computer networks built according to the OSI standards, but also all other kinds of networks, including IP-networks, for example.

The OSI Management Framework has several objectives. Firstly, it is to define common terminology and describe the concepts of network management. Secondly, it is to provide a structure for network management together with an overview of the objectives and facilities. Finally, it is to describe the activities of the network management.

OSI Management Functional Areas

An important part of the OSI Management Framework are *OSI Management Functional Areas*. Five areas are defined, namely fault management, accounting management, configuration management, performance management, and security management. These functional areas are briefly described below.

Fault management encompasses fault detection, isolation and correction of abnormal operation of the network. It includes tasks to maintain and examine the error logs, accept and act upon error detection notifications, trace and identify faults, carry out sequences of diagnostic tests, and correct faults.

Accounting management enables charges to be established for the use of the network resources, and for costs to be identified for the use of those resources. It includes functions to inform users of costs incurred or resources consumed; to enable accounting limits to be set and tariff schedules to be associated with the use of resources; and to enable costs to be combined where multiple resources are invoked to achieve a given communication objective.

Configuration management identifies, exercises control over, collects data from and provides data to the network for the purpose of preparing for, initializing, starting, providing for the continuous operation of, and terminating interconnection services. It includes tasks to set the parameters that control the routing operation of the network, to associate names with managed objects, to initialize and close down managed objects, to collect information on demand about the current condition of the network system, and to change the configuration of the network.

Performance management includes tasks required to continuously evaluate principal performance indicators of network operation, to verify how service levels are maintained, to identify actual and potential bottlenecks, and to establish and report on trends for management decision making and planning.

Security management is aimed at supporting the application of security policies by means of functions which include the creation, deletion and control of security services and mechanisms; the distribution of security-relevant information; and the reporting of security-relevant events.

A.2.3 Terplan framework (communication networks management)

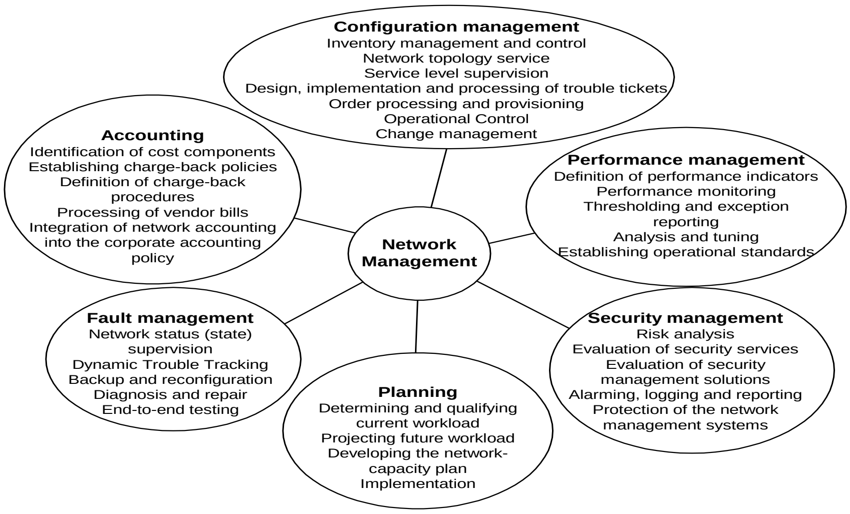

Figure A.5: The contents of network management according to Terplan [Ter92].

A framework supporting management of communication networks is described in [Ter92]. This framework approaches the management of communication networks from three perspectives, namely technological, procedural, and organizational. The technological perspective was oriented towards technical network components to be managed, and instruments/ tools to be used for supporting the network management. The procedural perspective was oriented towards management processes necessary to use the instruments. The organizational perspective was oriented towards functions and tasks which have be carried out. The technological perspective was in the focus of the framework. Since this framework had no specific title, we call it after the name of its author "Terplan framework".

According to the Terplan framework, the network management can be divided into six *management areas*: performance management, fault management, security management, planning, accounting, and configuration management. As seen, the names of these areas are basically equal to the names of the OSI Management Functional Areas, except for the area "planning" which is not defined in the OSI Management Framework (see section A.2.2).

The Terplan framework also contains an extensive description of the management areas. A number of *functions* are defined within each management area. Figure A.5

demonstrates an overview of these functions. Each function consists from a number of activities or responsibilities. For example, the function "order processing and provisioning" out of Configuration Management consists from the following activities: (1) the installation of new equipment and facilities, (2) preparation and tracking of service orders, (3) providing access to vendor ordering system, (4) update inventory and configuration database when installation are completed, (5) initiating billing process. Similarly, [Ter92] presents activities composing other management functions.

In addition to giving a division of management areas into a number of functions and describing activities comprising these functions, the Terplan framework also describes *workflow processes*. These processes demonstrate the flow of activities and their mutual dependency within each management function. However, such processes are given not for all functions.

Additionally to describing a functional/ procedural side of the network management, the Terplan framework also gives a significant attention to *the instruments and tools supporting the network management*. Firstly, this framework presents several generic architectures of a network-management products. Both ISO-based and proprietary architectures are reviewed and analyzed. Secondly, this framework presents instruments for collecting and extracting information related to the network management; various network monitoring tools are analyzed here. Thirdly, the framework presents an overview of systems for compressing, processing, and storing network management-related information; several database architectures are reviewed. Fourthly, the framework describes tools for performance prediction; various techniques are considered here such as statistical analysis, operational analysis, and simulation. Finally, the framework presents instrumentation supporting each of the six management areas depicted on Figure A.5.

A.2.4 TMN framework

Just as its name suggests, the Telecommunication Management Network (TMN) framework was developed within the telecommunication industry. The International Telecommunication Union, section Telecommunication Standardization Sector (ITU-T[1]) carries out the development of this framework since 1985. Although the framework is continuously updated, its architecture is rather stable. Various parts of the TMN framework are defined in documents that are called "ITU-T Recommendations". The ITU-T recommendations is given a number; the most important recommendations are M.3010[TMN00a], M.3013[TMN00b], M.3200[TMN00c], and M.3400[TMN00d].

The main idea behind the TMN approach is to provide a framework for achieving interconnectivity and communication across heterogeneous operating systems and telecommunications networks. This is accomplished using standardized interfaces

[1] The International Telecommunication Union is the United Nations Specialized Agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the ITU. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

which imply the use of agreed protocols, and the exchange of messages having standardized formats.

TMN principles are incorporated into a telecommunications network to send and receive information and to manage its resources. A telecommunications network is comprised of switching systems, circuits, terminals, etc. In TMN terminology, these resources are referred to as network elements (NEs). TMN enables communication between operations support systems (OSS) and NEs. Additionally, it defines standard ways of doing network-management tasks.

The TMN framework is largely based on the OSI Management Framework (see section A.2.2). It uses an object-oriented approach, with managed information in network resources modeled as attributes in managed objects.

TMN describes telecom network management from two viewpoints: a logical or business model, and a functional model. Each of these is critically important and interdependent.

TMN Logical model

To deal with the complexity of telecommunications management, management functionality may be considered to be partitioned into *logical layers*. The TMN model distinguishes four layers that are usually arranged in a triangle or a pyramid as shown in Figure A.6. *The business management layer* has responsibility for the total enterprise; its main functions concern optimal investment and use of new resources. *The service management layer* is concerned with, and responsible for, the contractual aspects of services that are being provided to customers or available to potential new customers. Some of the main functions of this layer are service order handling, complaint handling, and invoicing. *The network management layer* provides the functionality to manage a network by coordinating activity across the network and supports the demands made by the service management layer. It knows what resources are available in the network, how these are interrelated and geographically allocated and how the resources can be controlled. *The element management layer* manages each network element on an individual or group basis and supports an abstraction of the functions provided by the network element layer. This layer screens the upper layers from vendor-specific details of network elements.

Although management decisions at each layer are different, they are interrelated. For example, detailed information is needed to keep a switch operating (at the element management layer), but only a subset of that information is needed to keep the network operating (e.g. is the switch operating at full capacity). Working from the top down, each layer imposes requirements on the layer below. Working from the bottom up, each layer provides a capability to the layer above.

TMN Functional model

The TMN functional model is a structural and generic framework of management functionality ([TMN00a]). It provides means for transporting and processing management information. It is based on the following fundamental elements, namely function blocks, reference points, and management functions. TMN management

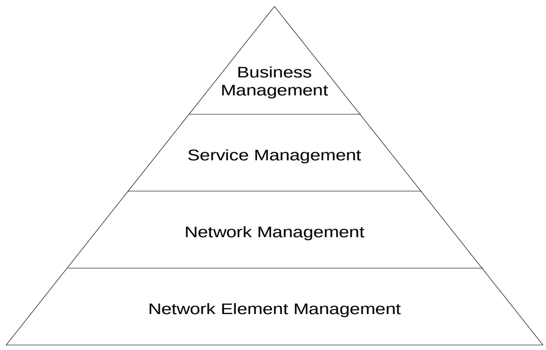

Figure A.6: The TMN Logical model.

functionality to be implemented can then be described in terms of these fundamental elements. Let's briefly describe each element.

Function block is the smallest deployable unit of the TMN management functionality. It is basically a cluster of functions having common characteristics. For example, the functions used to measure network traffic. Four types of function blocks are defined, namely operations system, network element, workstation, and transformation.

Function blocks exchange information at *reference points*. The name of each reference point is determined by the types of function blocks exchanging information at this point. Therefore, function blocks and reference points are used to model the standardized exchange of management information.

To perform TMN management services, interactions take place between different function blocks. These interactions are referred to as *management functions*. Management functions which cover the interactions from a single function block are grouped together in management function sets. An extensive description of the TMN management functions is given in [TMN00d]. Figures A.7 and A.8 present a list of management function sets. As seen from these figures, management functions are grouped according to the OSI Management Functional Areas (see section A.2.2).

A.2.5 TeleManagement Forum models

The TeleManagement Forum (TMForum) is a non-profit global consortium of over 340 companies working in the area of network and telecommunication services. Its members are service providers, network operators, vendors of computing and networking equipment, software suppliers, and customers of communications services. Established in 1988, the TMForum has provided successful solutions to many business and technology challenges born from the global telecom deregulation and the growth of IP-related services. The TMForum's mission is to help service providers and network operators automate their business processes.

The TMForum approaches its mission from two contexts, namely a systems context and a business context. The systems context implies the development of a technology-independent software facilitating the management of communication networks – the so-called New Generation of Operations Systems and Software (NGOSS).

Accounting Management

Usage Measurement
Planning of the usage measurement process
Management of the usage measurement process
Usage aggregation
Service usage correlation
Service usage validation
Usage distribution
Usage surveillance
Usage error correction
Usage testing
Measurement rules identification
Network usage correlation
Usage short-term storage
Usage long-term storage
Usage accumulation
Usage validation
Administration of usage data collection
Usage generation

Tariffing/pricing
Pricing strategy
Tariff and price administration
Costing
Settlements policy
Feature pricing
Provision of access to tariff/price information
Rating usage
Totalling usage charges

Collections and Finance
Planning of the billing process
Management of the billing process
General accounting operations
General ledger
Accounts receivable
Accounts payable
Payroll
Benefits administration
Pension administration
Taxation
Human resources
Invoice assembly
Sending invoice
Customer tax administration
In-call service request
Storage of invoice
Receipt of payment
Inquiry response
Collections
Customer account administration
Customer profile administration

Enterprise Control
Budgeting
Auditing
Cash management
Raising equity
Cost reduction
Profitability analysis
Financial reporting
Insurance analysis
Investments
Assets management
Tracking of liabilities

Security Management

Prevention
Legal review
Physical access security
Guarding
Personnel risk analysis
Security screening

Detection
Investigation of changes in revenue patterns
Support element protection
Customer security alarm
Customer (external user) profiling
Customer usage pattern analysis
Investigation of theft of service
Internal traffic and activity pattern analysis
Network security alarm
Software intrusion audit
Support element security alarm reporting

Containment and Recovery
Protected storage of business data
Exception report action
Theft of service action
Legal action
Apprehending
Service intrusion recovery
Administration of customer revocation list
Protected storage of customer data
Severing external connections
Network intrusion recovery
Administration of network revocation list
Protected storage of network configuration data
Severing internal connections
NE(s) intrusion recovery
Administration of NE(s) revocation list
Protected storage of NE(s) configuration data

Security Administration
Security policy
Disaster recovery planning
Manage guards
Audit trail analysis
Security alarm analysis
Assessment of corporate data integrity
Administration of external authentication
Administration of external access control
Administration of external certification
Administration of external encryption and keys
Administration of external security protocols
Customer audit trail
Customer security alarm management
Testing of audit trail mechanism
Administration of internal authentication
Administration of internal access control
Administration of internal certification
Administration of internal encryption and keys
Network audit trail management
Network security alarm management
NE(s) audit trail management
NE(s) security alarm management
Administration of keys for NEs
Administration of keys by an NE

Fault Management

RAS Quality Assurance
Network RAS goal setting
Service availability goal setting
RAS assessment
Service outage reporting
Network outage reporting
NE(s) outage reporting

Alarm surveillance
Alarm policy
Network fault event analysis, including correlation and filtering
Alarm status modification
Alarm reporting
Alarm summary
Alarm event criteria
Alarm indication management
Log control
Alarm correlation and filtering
Failure event detection and reporting

Fault localization
Fault localization policy
Verification of parameters and connectivity
Network fault localization
NE(s) fault localization
Running of diagnostic

Fault Correction
Management of repair process
Arrangement of repair with customer
forces
NE(s) fault correction
Automatic restoration

Testing
Test point policy
Service test
Circuit selection, test correlation and fault location
Selection of test suite
Test access network control and recovery
Test access configuration
Test circuit configuration
NE(s) test control
Results and status reporting
Test access path management
Test access

Trouble administration
Trouble report policy
Trouble reporting
Trouble report status change notification
Trouble information query
Trouble ticket creation notification
Trouble ticket administration
Management of trouble by service customer

Figure A.7: TMN management functions (source: [TMN00d]).

Performance Management

Performance Quality Assurance
QOS performance goal setting
Network performance goal setting
Subscriber service quality criteria
QOS performance assessment
Network performance assessment
NE(s) performance assessment
Data integrity check

Performance Monitoring
Performance monitoring policy
Network performance monitoring event correlation and filtering
Data aggregation and trending
Circuit-specific data collection
Traffic status
Traffic performance monitoring
NE(s) threshold crossing alert processing
NE(s) trend analysis
Performance monitoring data accumulation
Detection, counting, storage and reporting

Performance Management Control
Network traffic management policy
Traffic control
Traffic administration
Performance administration
Execution of traffic control
Audit report

Performance Analysis
Recommendations for performance improvement
Exception threshold policy
Traffic forecasting
Customer service performance summary (excludes traffic)
Customer traffic performance summary
Traffic exception analysis
Traffic capacity analysis
Network performance characterization
NE(s) performance characterization
NE(s) traffic exception analysis
NE(s) traffic capacity analysis

Configuration Management

Network Planning and Engineering
Product line budget
Supplier and technology policy
Area boundary definition
Infrastructure planning
Management of planning and engineering process
Demand forecasting
Network infrastructure design
Access infrastructure design
Facility infrastructure design
Routing design
NE(s) design

Installation
Procurement
Management of installation
Contracting
Real estate management
Arrangement of installation with customer
Network installation administration
Material management
Scheduling and dispatch administration of installation force
Installation completion reporting
Software administration
NE installation administration
Loading software into NEs

Service Planning and Negotiation
Service planning
Service feature definition
Marketing
Management of sales process
External relations (legal, stockholders, regulators, public relations)
Customer identification
Customer need identification
Customer service planning
Customer service feature definition
Solution proposal

Configuration Management (cont-d)

Provisioning
Provisioning policy
Material management policy
Access route determination
Directory address determination
Leased circuit route determination
Request for service
Service status administration
Network resource selection and assignment
Interexchange circuit design
Access circuit design
Leased circuit design
Facility design
Manage pending network changes
Network connection management
Circuit inventory notification
Circuit inventory query
NE(s) configuration
NE(s) administration
NE(s) database management
Assignable inventory management
NE(s) resource selection and assignment
NE(s) path design
Loading program for service feature(s)
NE(s) inventory notification
NE(s) inventory query
Manage pending changes in NE(s)
Access to parameters and cross-connects in NEs
Access to service features in NEs
Self-inventory

Status and control
Priority service policy
Priority service restoration
Message handling systems network status
Leased circuit network status
Transport network status
NE(s) status and control
Access to state information in NEs
Notification of state changes by NEs

Figure A.8: TMN management functions continued (source: [TMN00d]).

The business context implies the development of various models supporting the management of communication networks. Two TMForum's models are relevant for this research, namely the *Telecom Operations Map (TOM)* and the *Network Management Detailed Operations Map (NMDOM)*. Let's briefly describe each of these models.

Telecom Operations Map (TOM)

The Telecom Operations Map (TOM) is focused on the business processes used by service providers and the linkages between these processes. It serves as the blueprint for process direction and the starting point for development and integration of Business and Operations Support Systems (OSS). It is the 'de facto' standard for operations management processes within the communication industry.

The objectives of the TOM are to continue the progress made in establishing [TMF00]:

- an "industry owned" common business process model,
- a common terminology regarding business processes of a service provider,
- an agreement on the basic information required to perform each process, sub-process, and process activities,
- a process framework for identifying which processes and interfaces are in most need of integration and automation, and most dependent on industry agreement.

The TOM is not intended to be prescriptive about how the tasks are carried out, how a provider or operator is organized, or how the tasks are identified in any one organization. It is not a specification, but rather a snapshot of industry views expected to continue to evolve based on changes in the industry. It is not intended to be too detailed and, therefore, it provides a directional statement for the industry.

The most important part of the TOM is the Business Process Framework shown in Figure A.9. This framework divides all business processes into several *layers* similar to the layers of the TMN model (see section A.2.4 and Figure A.6): Customer Interface Management Processes, Customer Case Processes, Service Development and Operations Processes, Network and Systems Management Processes, Network Element Management Processes. Comparing these layers with the TMN logical layers there can be seen that the TOM divides the Service Management layer of the TMN into two parts: Customer Care and Service Development and Operations Processes. This division reflects differences between processes triggered by individual customer needs from those applied to a group of customers to a single service or service family. The Business Management layer of the TMN model corresponds to Customer Interface Management Processes.

The TOM [TMF00] describes each business process in terms of inputs, outputs, and activities. For example, inputs to the Customer Interface Management Process are sales inquiries, customer needs, orders, payments, and trouble reports. Activities performed within this process include receiving and recording contact, directing inquiries to appropriate processes, monitoring and controlling status of inquiries and escalation, ensuring a consistent image and securing use of systems. Activities result

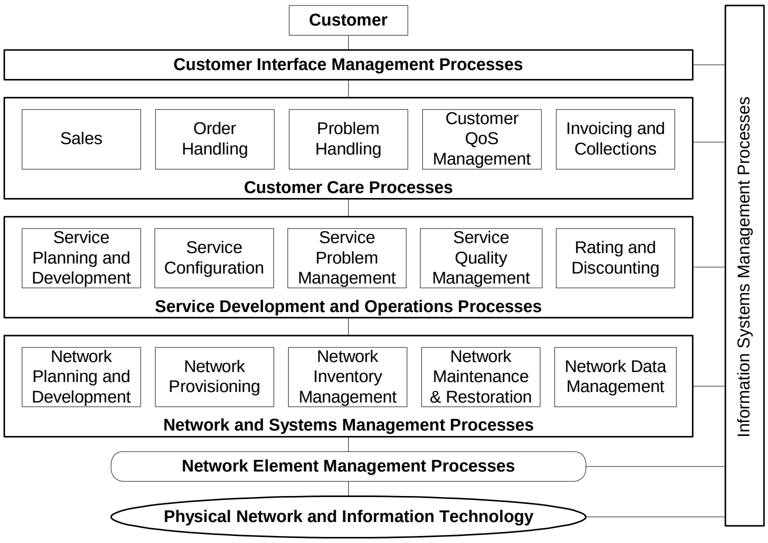

Figure A.9: Telecom Operations Map: Business Process Framework (source: [TMF00])

in the outputs being produced: reports, requests, orders and inquiries are sent to other processes such as Order Handling, Problem Handling, and Service Configuration. Figure A.10 presents a more detailed overview of activities performed within various Network and Systems Management Processes.

Network Management Detailed Operations Map (NMDOM)

The Network Management Detailed Operations Map (NMDOM) [TMF99] is basically the elaboration of the Network and Systems Management Processes of the TOM (see Figure A.10). Processes describe the flow of activities to solve a particular business problem or part of it. The NMDOM describes the content of these processes, and identifies information flows among them. This is done by using the concepts of triggers, functions, and data as shown in Figure A.11.

Triggers represent information flows among processes; they contain data which set processes in action. Each process has a number of input and output triggers. For example, the Network Provisioning process has input triggers such as network capacity available, configuration requirements, network provisioning requests, and configuration requests. Output triggers generated by this process are network capacity requests, "network configuration ready" message, work orders to Network Inventory Management, "start monitoring" requests, and network configuration requests.

Functions are units of processing – either initiated by humans or through an automated action – with specific, well-defined inputs and outputs. Unlike processes, it is important to identify data processed by a function; each function has input data and output data as shown in Figure A.11. Functions are dedicated to a single purpose and highly granular. Processes typically make use of activities in a number of

Network Planning & Development
- Developing and implementing procedures
- Negotiating and implementing (setting-up) agreements with suppliers
- Developing new networks and architectures, determine network capabilities
- Planning required network capacity
- Planning the mutation of network capacity (including destruction of obsolete networks)
- Optimizing network
- Issuing orders to suppliers and other providers (network operators)
- Planning the logical network configuration (including routing design)
- Planning the required physical site facilities

Network Provisioning
- Configuring the network
- Administering the logical network to prepare for service provisioning
- Managing connection (assigning identifiers)
- Testing the network

Network Inventory Management
- Installing and accepting equipment
- Physical configuration of the network
- Managing numbers
- Align inventory information with actual network
- Managing spare and faulty parts
- Upgrading software and hardware

Network Maintenance & Restoration
- Analyzing problem (including testing)
- Network quality maintenance and restoration
- Maintaining historic data of network problems and performance

Network Data Management
- Collecting, correlating and formatting of usage data and events
- Determining performance in terms of capacity, utilization and traffic
- Providing notification of performance degradation
- Implementing traffic control functions

Figure A.10: Telecom Operations Map: Activities within the Network and Systems Management Processes.

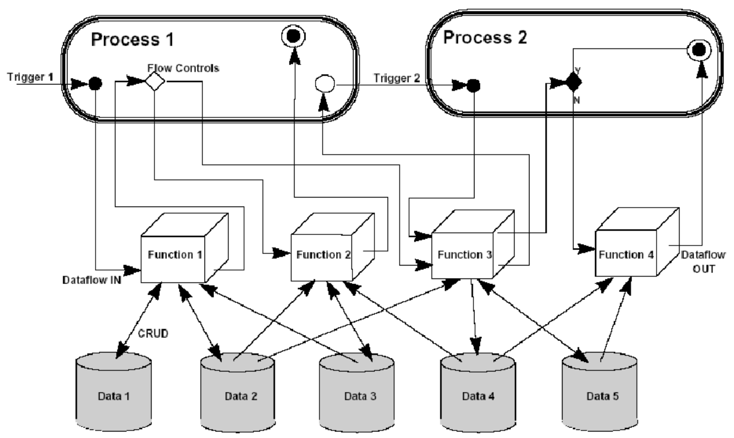

Figure A.11: Network Management Detailed Operations Map: relationships between processes, functions, and data (source: [TMF99]).

functions. Therefore, there is in principle many-to-many mapping between processes and functions. The NMDOM model relies on the TMN Functional model for the specification of functions. Based on the TMN standards described in section A.2.4, functions with relates or complementary capabilities are grouped into *Function Set Groups*, which then provide support to individual processes (see Figure A.12). The NMDOM model specifies which function set groups are relevant for each particular process.

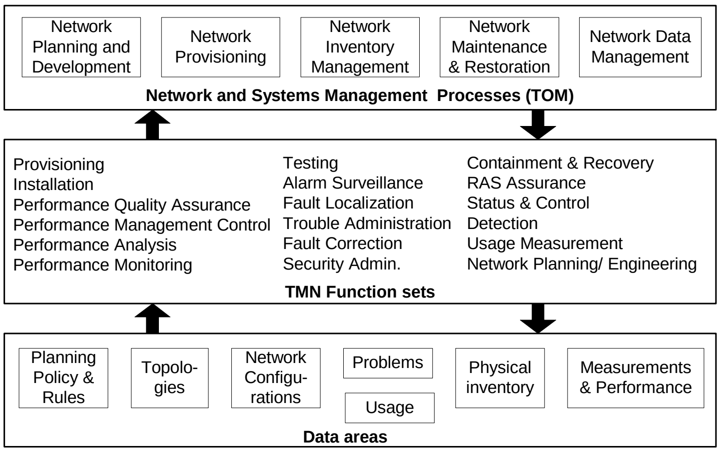

Figure A.12: Network Management Detailed Operations Map: processes, functions, and data areas (source: [TMF99]).

Data processed by functions is divided into a number of areas as shown in Figure A.12: (1) policy planning and rules, (2) topologies, (3) network configuration, (4) problems, (5) usage, (6) physical inventory, and (7) measurements & performance. The NMDOM specifies which data areas are relevant for each particular process. Each function may perform four types of operations on data, namely "create", "read", "update", and "delete".

A.2.6 IT Infrastructure Library

The office of Government Commerce (OGC) formally known as the Central Computing and Telecommunications Agency (CCTA) is a UK government agency that provides services and advice to the government regarding the use and management of IT. Their goal is to improve business effectiveness and efficiency in the government through the use of IT. The OGC was aware that making the government effective and efficient through IT was going to take more than good software and hardware. There had to be good management to ensure that it was being used to the best advantage. With the assistance of recognized experts in IT management fields the OGC began to document what experience had taught were the best practices in the management of an IT Infrastructure. These documents were completed, and the result is a library of books called *the IT Infrastructure Library (ITIL).*

ITIL is a widely accepted approach to IT Service Management. It provides a cohesive set of best practice, drawn from the public and private sectors internationally. It is supported by a comprehensive qualification scheme, accredited training organizations, and implementation and assessment tools. The best-practice processes promoted in ITIL both support and are supported by the British Standards Institution's Standard for IT Service Management.

The main purpose of ITIL is to "facilitate improvements in efficiency and effectiveness in the provision of quality IT services, and the management of the IT infrastructure within any organization" [ITI94]. This objective is realized by defining a set of subjects that attempt covering the whole field of the IT management. The subjects are combined in several sets, with each set being described in a separate book. The diagram on Figure A.13 illustrates that ITIL is comprised out of five principal sets, each of which have interfaces and overlaps with each of the other four. These sets are:

- the business perspective
- managing applications
- delivery of IT services (Service Delivery)
- support of IT services (Service Support)
- manage the infrastructure.

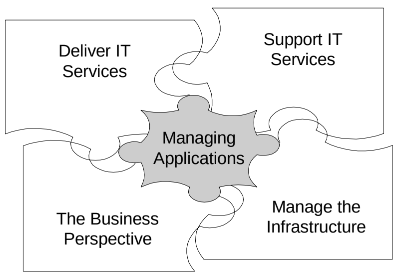

Figure A.13: The ITIL jigsaw diagram: five vital ITIL elements and the relationships among them (source: [ITI01]).

Let's briefly describe major subjects that are discussed within these sets and corresponding books. *The Business Perspective* book[2] will cover a range of issues concerned with understanding and improving IT service provision, as an integral part of an overall business requirement for high quality IS management. These issues include: Business Continuity Management, partnerships and outsourcing, surviving

[2] The Business Perspective book was not published yet at the time this dissertation was prepared. It was due to be published in Autumn 2003.

change, and transformation of business practice through radical change. *The Application Management* book embraces the software development lifecycle expanding the issues touched upon in Software Lifecycle Support and Testing of IT Services. Applications Management will expand on the issues of business change with emphasis on clear requirement definition and implementation of the solution to meet business needs. *The Service Delivery* book ([ITI01]) looks at what service the business requires of the provider in order to provide adequate support to the business customers. To provide the necessary support the book covers the following topics: Capacity Management, Financial Management for IT Services, Availability Management, Service Level Management, and IT Service Continuity Management. *The Service Support* book ([ITI00]) is concerned with ensuring that the User has access to the appropriate services to support the business functions. Issues discussed in this book are Service Desk, Incident Management, Problem Management, Configuration Management, Change Management, and Release Management. *The ICT Infrastructure Management* book includes the following subjects: Network Services Management ([RS94]), Operations Management, Management of Local Processors, Computer Installation and Acceptance, and Systems Management.

It is important to emphasize a dynamic character of ITIL. After its first appearance in late eighties, ITIL has been revised several times. The latest revision of this framework is dated 2001.

Network management in ITIL

ITIL was designed as a framework supporting the complete infrastructure for information systems and communications. Therefore, network management is only one of the many subjects covered by this framework. The subject "Network Services Management" (NSM) is the major subject of ITIL related to the network management. Additionally, many other subjects are also partially related to the network management. These subjects include nearly all subjects from the Service Delivery and the Service Support sets. Especially the following subjects are important: capacity management, availability management, service level management, help desk, problem management, configuration management, and change management. Each of these subjects has an important meaning for organizations providing network services. Figure A.14 illustrates the interdependency among NSM and other subjects within ITIL.

The subject "Network Services Management" (NSM) defines the management procedures necessary to provide a quality network service, either direct to end users or as a component part of a larger system. It also examines the planning and design issues necessary to allow coherent network growth.

Major phases of NSM are "planning", "implementation", and "post implementation and audit". Each phase is described from four different perspectives: procedures, dependencies, people, and timing. The first perspective "procedures" describes the flow of activities within a phase. The second perspective "dependencies" describe the relationships of this phase and its activities with other ITIL subjects. The third perspective "people" lists requirements to duties, qualifications, and training of the network management staff. The last perspective "timing" describes the time planning of various milestones and deliverables within a phase.

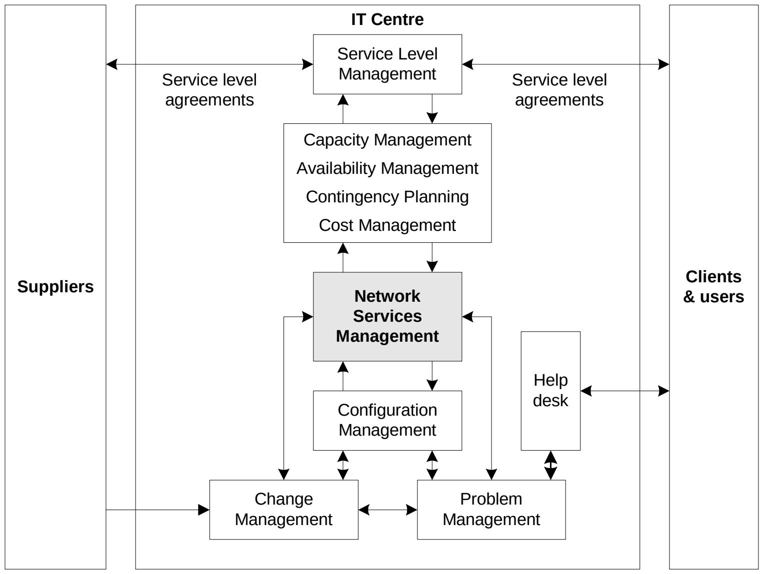

Figure A.14: Network Services Management in relation to other ITIL subjects (source: [Loo98, p. 257]).

A network service is a central point of attention within the NSM. It is emphasized, that network services should be managed in the same was as any other services with the customer needs being the most important; the means of providing the service is of little consequence provided business needs are met, as a cost that the business can afford. Additionally, NSM describes the application of other ITIL subjects such as Capacity, Change and Configuration Management, to the management of network services.

The NSM 7-layer model is the central topic of the NSM. It uses a top down layered approach with the emphasis placed on satisfying the business needs of an organization via the provision of network services. This ensures that the NSM staff, tools and procedures work in harmony with the network and its technology rather than fighting against it ([RS94, p. 29]). The whole area of NSM is represented as seven separate layers of functionality as shown on Figure A.15. This model in essence works in a similar fashion to other models that use a principle of layers, such as the TMN Logical model: each layer relies upon a service provided by the layer underneath and is a service provider to the layer above.

Let's give a brief overview of the seven NSM-layers starting from the top to the bottom. *The seventh layer Business Management* represents the functions needed by business managers such as accounting, billing, design, development, operations and planning and control. *The sixth layer Network Services Management* is responsible for coordinating the activities of the four supporting disciplines in layer 5. The major tasks of this layer are configuration control, cost management, fault management and prevention, enhancement programmes, quality of service, resource optimization,

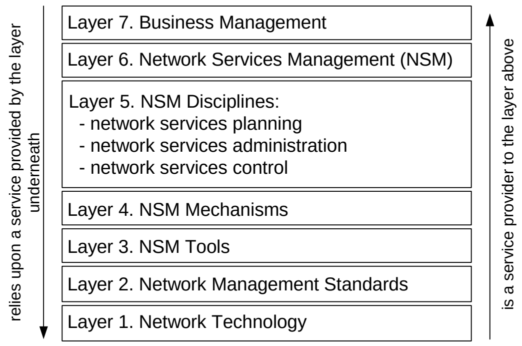

Figure A.15: The Network Services Management 7-layer model (source: [RS94]).

and security control. *The fifth layer NSM Disciplines* distinguishes three distinct, yet interrelated, disciplines: planning, administration, and control. These disciplines supply the reports and information that the NSM require to function in a cost-effective manner and to provide the required level of service. *The fourth layer NSM Mechanisms* defines mechanisms and procedures that the NSM disciplines are dependent upon. The areas requiring such procedures are, for example, operation and control, configuration maintenance, and statistical analysis. *The third layer NSM Tools* represents the actual tools that are required within the NSM. These are, for example, capacity management tools, database systems, service monitoring tools, and testing tools. *The second layer Network Management Standards* represents network management standards such as OSI (CMIS/CMIP) or TCP/IP (SNMP). *The first layer Network Technology* provides the physical network connections that allow all the layers above to communicate. This layer supplies the technologies such as ISDN, LAN, and WAN.

A.3 Comparison

The models described in section A.2 contain a number of similarities and differences. This section presents a comparison of these models. Firstly, the models are compared using key success factors in section A.3.1. Secondly, the models are compared using a set of criteria in section A.3.2. A similar approach was also used by Van Hemmen in [Hem97].

A.3.1 Comparison using key success factors

Terplan suggested an approach for comparing models supporting the organization of network management. This approach, defined in [Ter88], gives five key success factors that are necessary for an efficient management of computer networks:

1. Architecture

2. Functions/tasks

3. Instrumentation
4. Organizational components
5. Human resources

Each success factor represents an area of activity in which favorable results are necessary for an organization to reach its goals. The goal for managing networks is to maintain service levels and thus ensure that the network is operating effectively and efficiently at all times in order not to cause any problems in the organization's short-, middle-, and long-range operations [Ter92].

The remainder of this section is devoted to analyzing to which extent the models described in section A.2 meet the requirements of every key success factor mentioned above. A similar approach for comparing models was also used by Van Hemmen in [Hem97, p. 46 - 48]. Table A.1 summarizes the results of the analysis presented in this section.

Key success factor	Looijen framework	OSI	Terplan framework	TMN	TM Forum	ITIL
Architecture	+	+	+	++	++	+
Functions/tasks	±	−	+	+	+	±
Instrumentation	±	±	+	+	+	+
Org. components	++	−	−	±	−	±
Human resources	±	−	++	−	−	++

Legend:

++	key success factor suffices very well
+	key success factor is sufficient
±	key success factor is partially sufficient
−	key success factor is not sufficient

Table A.1: Comparison of the models using key success factors.

Architecture

The first success factor *"architecture"* implies that a model should have a framework of subsystems – such as configuration, performance, problem, application, and capacity management – and describe their mutual relationships. This success factor is considered in all models described in section A.2. The Looijen framework divides the management into the task areas such as Technical Support or Operational Control; each task area is further divided into several task fields (see Figure A.2).

The architecture of the Terplan framework, the TMN framework, and the TM-Forum models is largely based on the general architecture of the OSI Management framework. These models expand and detail the OSI framework. The OSI framework gives an overall global picture of five functional areas: configuration, accounting, performance, fault, and security. The Terplan framework adds an extra subsystem "planning" to the OSI framework. The TMN framework, being largely based on the OSI framework, elaborates OSI Management areas into function sets presented on

Figures A.7 and A.8. The TMForum models TOM and NMDOM inherit TMN function sets and define additionally a number of areas and processes depicted on Figures A.9 and A.12.

ITIL uses a complicated architecture of many interrelated and interconnected subjects which are united in sets such as the Service Delivery set, and the Service Support Set (see Figure A.13). Each subject corresponds to a process having the same name. These processes and their mutual relationships comprise the architecture of ITIL (see also Figure A.14).

Functions/tasks

The second success factor *"functions/tasks"* implies that a model should recognize some elementary activities necessary to manage, control, and maintain a computer network. All described models except for the OSI Management framework recognize and describe management functions/ tasks.

The Looijen framework focuses on tasks that apply to the management of information systems in general: computer networks are seen as a part of information systems, and not all the tasks are applicable for computer networks. Therefore, this framework is only partially suitable for supporting the network management.

The Terplan framework, the TMN, the TMForum's TOM and NMDOM models, and ITIL present lists of functions/tasks that must be performed within the area of network management. Often, the tasks are also referred to as activities or responsibilities. The last imply not the responsibilities of a person, but the responsibilities of a management process or a subsystem.

Instrumentation

The third success factor *"instrumentation"* implies that the model should define a set of tools for automating management activities and for supporting them technically. This includes collecting, storing and processing information related to the technical side of network management. For example, such tools support monitoring of the utilization of network resources and forecasting their future loads.

The OSI Management framework is supported by an extensive set of network management standards and protocols such as CMIP/CMIS. However, these standards have not been widely accepted by the networking community.

The TMN models, and the TMForum's models also define a set of technical standards for managing telecommunication networks. These models not only give a detailed specification of such tools, but are also supported by vendors of hardware and software. Specifically, the so-called OSSs (Operations Support Systems) of many telecommunication operators function according to the standards defined within these models.

The remaining models – the Looijen framework, the Terplan framework, and ITIL – do not introduce any specific technical standards and tools supporting network management. However, they give examples of existing tools and the way in which they can be used. The Terplan framework is guided by the network management instrumentation and the information system to be developed from it ([Hen03, p. 46]).

Organizational components

The fourth success factor *"organizational components"* implies that the model should define the organizational structure which has to be put in place for carrying out network management activities. This success factor considers concepts such as departments, teams, and divisions.

Organizational components are not considered in the OSI Management framework, the Terplan framework, and the TMForum models.

The TMN framework and ITIL define organizational components by dividing the management into a number of levels or layers, such as strategic, tactical, and operational. The TMN Logical model distinguishes four layers – business management, service management, network management, and network element management – which can reflect the vertical division of an organization performing the management. Similarly, ITIL defines seven layers which were described in section A.2.6 and depicted in Figure A.15. However, these two frameworks do not give further details of the organizational structure.

The Looijen framework uses an organizational logo defined by Mintzberg in [Min79]. The logo represents the division of an organization into a strategic apex, a middle line, an operating core, a technostructure, and a support staff. Looijen uses this approach for positioning various management tasks within the organizational structure. This approach explains which organizational components should be in place for performing successful management of information systems, including network management. Figure A.4 gives an example of these logo's.

Human resources

The fifth success factor *"human resources"* implies that the model should describe issues such as personnel skills and education that are critical to the successful, long-term operation of human resources in management.

The Looijen framework considers issues related to the personnel skills and education. It presents four types of skills: cognitive skills, administrative skills, social skills, and intellectual skills. Additionally, it gives the list of job functions and responsibilities borrowed out of the report of the Dutch Committee Professional Development [NGI93]. This report describes vocations in the area of automation.

ITIL also gives an overview of issues related to skills and education of the staff responsible for the management of computer networks. It gives specifications for vocations that are necessary for performing successful network management.

The Terplan framework contains an extensive description of job and competence profiles required for performing various network management activities. For each management area depicted on Figure A.5, a number of HR-related topics are discussed such as job profiles, duties, qualifying experience, skills, and responsibilities.

The remaining models (OSI, TMN, and TMForum) do not consider HR-related issues.

A.3.2 Comparison using a set of criteria

Additionally to key success factors, the existing models can be compared using a set of criteria. These criteria were formulated on the basis of a literature study ([Loo98], [Hem97, p. 49 - 50], [Bro99], [TMF99], [TMF00], [Ter92], [Ter95]). The following comparison criteria were identified:

1. Acceptance and application
2. Target business domain
3. Level of specification
4. Extendability
5. Variety of concepts handled
6. Simplicity of using/applying

Table A.2 presents an overview of values of these criteria for each model. The remainder of this section is devoted to describing the values of above-mentioned criteria in relation to the models described in section A.2.

Criterion	Looijen framework	OSI	Terplan framework	TMN	TMForum	ITIL
Acceptance and application	NL	worldwide	worldwide	worldwide	worldwide	worldwide
Target business domain	any	any	any	telecom	telecom	any
Level of specification	average	low	high	high	high	high
Extendability	possible	possible	impossible	impossible	impossible	impossible
Variety of concepts handled	high	low	average	average	high	high
Simplicity of using	average	simple	average	complex	complex	complex

Table A.2: Comparison of the models using a set of criteria.

Acceptance and application

The acceptance and application of a model refers to an extent of its recognition at various geographical levels such as the international (worldwide) recognition, the national recognition, and the local recognition.

Most existing models except for the Looijen framework are internationally recognized, accepted, and used. These models have, therefore, the highest level of acceptance. Although the Terplan framework is also internationally accepted, it is not so widely used as other models. ITIL being originally developed and used in the UK, has become recognized all over the world. It has been adopted by hundreds of organizations worldwide, including such giants as IBM, Barclays Bank, Midland Bank, Guinness, The Proctor & Gamble Company, and British Airways.

The Looijen framework is mainly used only in the Netherlands. However, after the recent translation of the book [Loo98] to other languages, such as Chinese, it is also expected to get wider international recognition.

Target business domain

The target business domain refers to kinds of networks or organizations targeted by a model. The OSI Management Framework, the Terplan framework, the Looijen's framework, and ITIL are not constrained by any specific business domain. These models are applicable for any organization owning a computer network which has to be managed.

Unlike these models, the TMN framework and TMForum models are primarily targeted towards telecommunication companies – organizations whose core business is the provision of the telecommunication and network services.

Level of specification

The level of specification reflects how comprehensive/detailed is a model in its coverage of the issues related to the network management.

The Looijen framework contains several models which are rather abstract. The management paradigm, the state model, and the triple management model need to be first adjusted in order to be practically used for network management. This is because these models are designed for supporting the management of information systems in general.

The OSI Management Framework gives a general division of the management into five areas, and describes briefly the content of these areas. Because this description is only a few pages long, it is far from being comprehensive. Therefore, this framework has a rather low level of specification.

The remaining models are more specific in their presentation of the network management. The TMN framework gives a very detailed specification of management functions (see Figures A.7 and A.8). The TMForum models also contain quite detailed description of various areas and processes within the network management. Terplan also gives a rather extensive description of activities performed within the network management. ITIL provides the most extensive and detailed description of the network management comparing to other models.

Extendability

The model's extendability refers to its ability of being extended with some new concepts and/or constructs.

The Looijen framework is quite extendable and flexible. Its fundamental basis – the management paradigm – is an abstract construction which can be extended with more details. For example, Van Hemmen extended the management paradigm by defining a number of entities and relationships within it ([Hem97]). Also the other two fundamental constructions of the Looijen framework – the state model and the triple model of management – can be extended for more specific situations if necessary.

The OSI Management framework is also easily extendable due to its abstractness. The TMN framework and the Terplan framework are elaborated out of the OSI Management framework. Therefore, it is possible to extend this framework and develop other models out of it.

The remaining models – the TMN framework, the Terplan framework, the TMForum models, and ITIL – are not extendable. They are positioned as ready-to-be-used models. However, the authors of these models are constantly developing new versions of their models. For example, the TMForum has recently developed the so-called "eTOM Business Process Framework" – an extended version of the TOM model.

Variety of concepts handled

The criterion "variety of concepts handled" reflects whether a model recognizes the concepts such as process, task/ function, tool/ instrument, goal/ objective, level/ layer, area/ subsystem, and service.

The Looijen framework handles practically all mentioned concepts, except for the concept "service". Although, the concept of services is recognized here as a part of the service level agreements, it is not specifically defined or modelled. The OSI Management Framework considers only management functional areas: the remaining concepts are not recognized. The Terplan framework consider most of the concepts except for goal/ objective, level/ layer, and service. The TMN framework considers tasks, tools, and four layers (business management, service management, network management, and network element management). The TMForum models consider processes, tasks, levels, and services. ITIL consider all concepts except for task/ function and area/ subsystem. Table A.3 illustrates mentioned overview.

Concepts	Looijen framework	OSI	Terplan framework	TMN	TM Forum	ITIL
Process	+		+		+	+
Task/function	+		+	+	+	
Tool/instrument	+		+	+		+
Goal/objective	+					+
Level/layer	+			+	+	+
Area/subsystem	+	+	+			
Service			+	+	+	+

Table A.3: The variety of concepts handled by the existing models.

Simplicity of using/applying

This criterion reflects the extent in which the model is simple to be used (applied), and easy to comprehend by people that are responsible for the management of computer networks.

The OSI Management Framework is the simplest model due to its conciseness. The Looijen framework and the Terplan framework have an average level of complexity. In order to apply these models, one needs to read and study appropriate books describing these models. The TMN Functional model is rather complex, since it includes several hundreds of management functions which are often interrelated and interdependent. The TMForum models are also rather complex. ITIL is probably the most complex model because it appeals to be universally applicable for any situation involving the management of ICT. However, the part of ITIL responsible for the network management is less complex.

A.4 Suitability for RENs

Section A.2 presented a number of existing models supporting the management of computer networks. This section is devoted to analyzing whether these models are suitable for RENs. This is accomplished by confronting each model with topics depicted in Chapter 2.

Chapter 2 gave an extensive analysis of topics associated with RENs and their management. The topics were grouped into seven areas: (1) user-related topics, (2) topics related to communication links, (3) service-related topics, (4) usage-related topics, (5) organizational topics, (6) financial topics, and (7) environment-related topics. Sections 2.2 – 2.8 described each of these areas correspondingly. Figure A.16 presents these topics graphically.

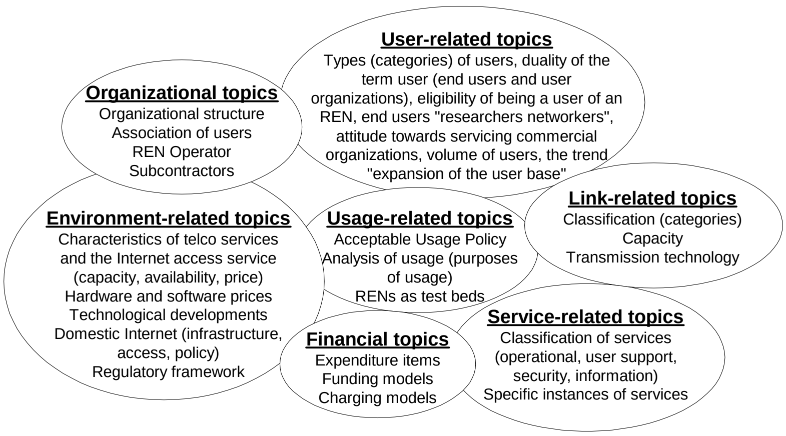

Figure A.16: Topics associated with research and education networks (RENs) and their management.

Sections A.4.1 – A.4.7 present the suitability of existing models for each area described in sections 2.2 – 2.8 correspondingly. Every model is analyzed whether it is able of covering topics which comprise these seven areas.

A.4.1 User-related topics

Although the notion of users is recognized by all existing models, none of them is able of reflecting specific topics related to users of RENs.

The duality of the very term 'user' in relation to the RENs is not handled by most models. This is because these models usually operate within the borders of a single organization. Therefore, the concept "user" usually implies an individual end user. TMForum models use the notion of customers, implying both individual customers and business customers. No specific distinction of the TOM and NMDOM models is made on the basis of this division.

The issue of various categories of user organizations is also not handled by existing models; the same concerns the eligibility of being the user organization. Therefore, an important issue whether commercial organizations should be allowed as user organizations, is also not covered by existing models. Similarly, the models are unable of covering topics related a particular kind of end users such as researchers networkers. The trend "expansion of the user base" is also not covered by the existing models.

A.4.2 Topics related to communication links

Section 2.3 outlined two vital topics related to communication links: the classification of links into a number of categories, and the capacity.

None of the existing models considers the classification of links into international, backbone, user-access, and peering links. This topic seems to be too specific for RENs in order to be considered in existing models which are rather generic models.

The capacity of communication links is considered in most of the existing models. The Looijen framework presents a set of characteristics of information systems' components which also include communication links; the capacity is one of the characteristics along with the speed and the reliability. The Terplan framework considers the capacity of communication links by defining an activity within the management area Planning called "developing the network capacity plan" (see Figure A.5).

The TMN Functional model contains several management functions related to the capacity. For example, the management area Performance Management has a function "traffic capacity analysis". The function set "Network Planning and Engineering" of the Configuration Management also has a number of capacity-related functions (see Figure A.8).

The TMForum models also consider the capacity of communication links: the TOM model has a number of capacity-related processes within the Network and Systems Management Processes such as "Network Planning and Development", and "Network Provisioning" (see Figure A.10). Similarly, the NMDOM model also has functions, processes, and data areas related to the capacity of links.

ITIL defines a separate process called Capacity Management which is meant to consider the capacity of communication links along with the capacity of other IT resources. The OSI Management framework being a very generic model does not specifically consider the topic "capacity".

A.4.3 Service-related topics

Section 2.4 presented an extensive classification of services comprising the service profile of RENs. The notion of services is recognized within the TMN framework, the Terplan framework, ITIL, and the TMForum models (see Table A.3): the remaining models are unsuitable for covering service-related topics presented in section 2.4.

The TMN Functional model provides a function set "Service Planning and Negotiation" within the Configuration Management area. Several important management functions are defined in this set. However, no specific examples or classifications of services are given. Therefore, the TMN framework is not suitable for supporting the topics related to the services of RENs.

ITIL does not give a specific classification of services; it provides the definition of a service as "one or more IT systems which enable a business process". In principle, services provided by RENs also fit in this definition. However, this generic definition cannot capture the specific details of RENs' services and their content. Therefore, ITIL is not suitable for supporting the topics related to the services of RENs.

Although the TMForum models recognize the notion of services, they are unable of supporting specific details of RENs' services. The TOM and NMDOM models do not provide a framework for classifying the services. These models do not give any specific examples of services. Therefore, the TMForum models are also unsuitable for supporting the topics related to the services of RENs.

A.4.4 Usage-related topics

Section 2.5 presented three groups of topics related to the usage of RENs, namely acceptable usage policies (AUPs), analysis of usage, and the usage of RENs as test beds. Let's analyze to which extent existing models presented in section A.2 are able of supporting these topics.

Acceptable usage policies (AUPs) are not handled by most of existing models except for the Looijen framework. This framework refers to the Information Policy and Planning as an important phase in the development of information systems (see the state model on Figure A.3). Since computer networks are seen as a particular case of information systems, this approach is also applicable for networks. Although an AUP is not specifically mentioned, it is implied that it can also be a part of such an information policy.

The analysis of usage is partially covered within the TMN framework, and the TMForum models. This is accomplished by introducing management functions and processes related to the usage measurement. The TMN Functional model contains a number of management functions grouped into a function set "Usage Measurement". Additionally, it also has the management function "customer usage pattern analysis" (the area Security Management, see Figure A.7). However, topics such as the purpose of usage and the usage growth trend are not considered by these models. The remaining models hardly consider the topics related to the analysis of usage.

The usage of RENs as test beds is not considered by either of the models. This topic seems to be very specific for RENs, since it relates to a research nature of such networks. Therefore, it is hardly possible that generic models could support such a topic.

A.4.5 Organizational topics

Section 2.6 described a number of organizational entities which are involved in the management of RENs and the provision of services. It was shown that the most important entities are REN Operator, Subcontractor, and Association of Users. Additionally, Management Board, Advisory Board, and state agencies are also involved in the management of an REN.

Existing models are unable of reflecting the organizational structure of RENs, and various organizational topics described in section 2.6. These models typically operate within the borders of a single organization which owns and manages a computer network. RENs, on the contrary, operate within the borders of many organizations. Firstly, RENs connect and serve a number of user organizations. Secondly, RENs are often managed by a conglomerate of organizational entities with each entity having a specific role. Section 2.6.1 gave an example of SURFnet which until 1999 was managed by several subcontractors. An important topic which is also not considered in any of existing models is the phenomenon that some user organizations are also service providers for other user organizations. Issues of this kind are not considered by existing models. Topics discussed in section 2.6 are too specific for RENs, and, therefore, generic models are unsuitable of supporting them.

A.4.6 Financial topics

Section 2.7 described topics having financial nature such as expenditure items, funding models, and charging models. Let's see to which extent existing models can be used for supporting these topics.

Although financial topics are not explicitly placed within the models comprising the Looijen framework, many of the topics receive attention as part of the economical and juridical aspects ([Loo98]). These aspects are the types of costs, the costs models, and the calculation of tariffs. However, mentioned topics are covered rather briefly, without providing a theoretical framework for modelling them.

The OSI Management framework is hardly able of supporting any of the financial topics mentioned above. This is because this model is very generic. However, it provides a common framework for other models such as the Terplan framework and the TMN functional model. Specifically, the management area Accounting Management is mostly concerned with various financial topics.

The Terplan framework provides some support of financial topics. The expenditure items are supported by a process "identification of cost components" within the management area Accounting Management. Additionally, a special attention is given to the identification of costs, cost components, and the financial analysis of network management ([Ter92, p. 655 - 674]). The charging models are supported by activities "establishing charge-back policies" and "definition of charge-back procedures". Funding models are not supported by this framework.

Similarly to the Terplan framework, the TMN Functional model contains a number of management functions related to economical and financial topics. These functions belong to the area Accounting Management. Various functions within the function set Collections and Finance support the expenditure items; functions of the function set Tariffing and Pricing support charging models; functions of the function set Enterprise Control support funding models. However, this support is not adjusted to specific needs of RENs. For example, the TMN model does not recognize such an income source as state subsidies.

The TMForum models support financial topics by describing activities within some of the processes depicted on Figure A.9, particularly Customer Care processes, and Service Development and Operations processes. The process Invoicing and Collections is related to the charging models and also the funding models. The process Service Planning and Development contains an activity called "setting product or service pricing". Therefore, this process is related to the charging models. The TMForum models provide little support for expenditure items.

ITIL provides the most comprehensive support for financial topics mentioned in section 2.7. It introduces the process "Financial Management for IT services" consisting out of three subprocesses related to financial topics namely Budgeting, IT

Accounting, and Charging. Each of these subprocesses is similar to a financial topic discussed in section 2.7. Because the process IT Accounting enables IT organization to account fully for the way its money is spent, it is able of covering the topic "expenditure items". Since the process Budgeting implies predicting and controlling the spending of money and the setting of budgets, it is able of covering the topic funding models. The process Charging has a similar coverage as the topic "charging models".

A.4.7 Environment-related topics

Section 2.8 presented a number of topics related to the external environment of RENs. These topics include characteristics of telecommunication services, characteristics of Internet access service, hardware and software prices, technological developments, domestic Internet, and the regulatory framework.

Most existing models hardly reflect such environment-related topics. These models normally operate within the borders of an organization that manages or owns a computer network, and often provides services to its customers. The influences from outside of this closed system are usually not considered.

Only the Looijen framework refers to the environment-related issues and to their importance. Such issues are called external influences; they are modelled within the management paradigm (see Figure A.1). However, this framework does not present further analysis of particular examples of external influences: it gives only a brief indication of their importance, and presents their division into economical, informational, technical, and managerial influences. Additionally, the Looijen framework introduces generic situational factors ([Loo00]). Some of these factors are connected with environment-related topics: the legal provisions, the availability of infrastructure facilities, and the digitalization of networks.

A.4.8 Summary

Preceding sections A.4.1 – A.4.7 have shown that the existing models are largely unsuitable for reflecting the topics associated with RENs and their management. Table A.4 summarizes the results of the analysis presented in these sections.

Although some models can partially reflect certain topics, no model is capable of supporting these topics to an acceptable extent. Financial and links-related topics can partially be covered by most existing models. However, none of existing models is able of covering user-related, organizational, and service-related topics. Environment-related topics are also hardly covered by any existing model, except for the Looijen framework.

Topics	Looijen framework	OSI	Terplan framework	TMN	TM Forum	ITIL
User-related	−	−	−	−	−	−
Link-related	±	−	±	±	±	±
Service-related	−	−	−	−	−	−
Usage-related	±	−	−	±	±	−
Organizational	−	−	−	−	−	−
Financial	±	−	±	±	±	+
Environment-related	±	−	−	−	−	−

Legend:
+ the model is suitable
± the model is partially suitable
− the model is unsuitable

Table A.4: Suitability of existing models for supporting topics associated with RENs and their management.

Appendix B

Manual to the model

B.1 Introduction

This document is a part of the dissertation "Modelling Management of Research and Education Networks". It briefly describes a model supporting the management of Research and Education Networks (hereafter – the model). It is a brief manual on how to use/ apply the model in practice. Computer networks and network management are viewed here from technical, organizational, financial, and administrative perspectives.

A Research and Education Network (REN) is a computer network on the scale of a city, a region, a state, or a country (nation) which interconnects campus networks of research and education institutions with each other and with other networks (including the Internet), and provides network services to those R&E institutions. Although RENs are primarily targeted towards R&E institutions, many other kinds of organizations are also users of RENs.

Every REN should be considered within some *geographical boundaries*. The model is primarily concerned with networks operating within the boundaries of a country: the so-called National Research and Education Networks (NRENs). Because often NRENs consist of the networks that operate within the boundaries of regions/ provinces or cities, regional and metropolitan RENs are also considered. *Internal (campus) networks of R&E institutions are out of the scope.*

B.2 Objectives

The model's aim is to support the management of both developed and developing RENs. This aim is fulfilled by analyzing various aspects related to RENs and their management – the real situation, and by identifying ways to improve the real situation. In order to fulfill its aim the model has to meet three *main objectives*. These objectives relate to the model's ability to provide a framework for:

1. Producing a description of the real situation – a REN and its management

2. Identifying gaps in the real situation

3. Developing useful recommendations that could make it possible to eliminate the gaps and to improve the real situation

The main objectives correspond to three documents which represent the results of the model's application. Firstly, a description of the real situation (a REN and its management). Secondly, a description of gaps in the real situation. Finally, a description of recommendations that could help in eliminating the gaps and improving the real situation.

The model also has seven *additional objectives*. The model should be capable of

1. Raising the awareness of stakeholders (see the description of stakeholders in the following section).
2. Facilitating the communication among stakeholders (the model is a common communication language).
3. Improving the effectiveness and the efficiency of management.
4. Providing guidelines for building new RENs; the model can be used as a blueprint of a desirable situation the REN wants to realize (the model is a "cookbook")
5. Assisting in compiling project proposals for further development of the REN, including the applications for grants: state subsidies and/or donor grants.
6. Facilitating the transfer of knowledge between developing RENs and developed RENs.
7. Promoting the use of scientific approaches in the management of RENs as opposed to practice-based approaches (avoiding the use of trial-and-error approaches).

B.3 Primary and secondary users (stakeholders)

The model's users can be divided into two categories, namely primary users and secondary users. *Primary users* are those who apply the model in practice and compile the results of the model's application. The primary users of the model are researchers and middle-line managers. *Secondary users* are those who study (read) the results of the model's application.

The following list presents *examples of the secondary users* of the model; the secondary users are also referred to as *stakeholders*:

1. People directly involved in the management of RENs
    - Staff members of the REN operators (particularly senior executives, and middle-level managers)
    - Strategic decision makers, executives of the Association of Users
2. Parties providing financial and political support to RENs

- Representatives of state authorities such as ministries of education and science, and other governmental officials concerned with funding and policy aspects of RENs
- Representatives of international donor agencies providing financial support to RENs

3. Representatives of the user organizations of RENs

- Senior executives of user organizations
- People responsible for the provision IT services such as chief information officers, managers of campus networks, and technical support staff

B.4 Basis of the model: the management paradigm

In order to understand the model, one must be familiar with the management paradigm – the fundamental basis of the model. This section gives a short introduction to this paradigm and explains that the model is constructed by applying the entity-relationship approach to the management paradigm.

The management paradigm abstracts each set of coherent, dynamic phenomena – each dynamic system such as an organization – into the combination of the real system, the information system, and the management of the information system. These systems are connected by relationships depicted as arrows in Figure B.1. Additionally, there is a number of external influences that affect these three systems and the relationships among them. Let us briefly describe the meaning of each system in case of RENs.

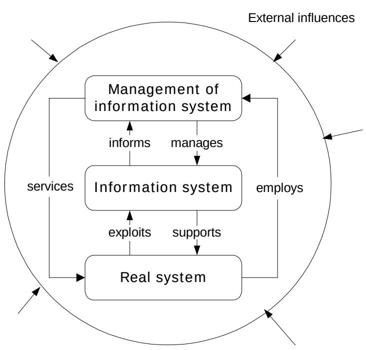

Figure B.1: The management paradigm.

The Real System (RS) is a composition of organizations that need a common network infrastructure and the related services. Although the focus is placed on research and education organizations, other categories of organizations can also be part of the RS. The system of higher education in a country is an example of the RS. Major inputs to such an RS are new entrants to higher education institutions, state funds, external donations, and equipment. Outputs of such an RS are graduates and their knowledge and skills. The system of research activities in a country is another example of the RS. Some inputs into such a system are requests from the industry, state funds, external donations, and equipment. Examples of outputs are discoveries and all other kinds of new knowledge which is typically presented in various scientific publications, reports, and patents. A combination of the two systems described above – the system of higher education and the system of research activities – is also an RS.

The Network System (NS) is a composition of hardware, software, communication links and network services necessary to support the needs and business processes of the RS (NS is a particular instance of the information systems). Examples of components of the NS are backbone links, Internet links, modems, routers, network servers, HTTP servers such as Apache, and operating systems such as Unix and Linux. The NS does not comprise hardware, software, communication links, and network services that are internal to user organizations.

The Management of the Network System (MNS) is the operation, control and maintenance of the NS in accordance with: a) requirements, b) preconditions, c) attributes of the Association of User Organizations, d) goals of the RS, e) aspects of the external environment, f) attributes of hardware/ software resources, communication links, and network services. Secondly, management of the network system offers services to the RS in the most effective and efficient way, and influences goals of the RS in a positive way. *Operation* implies ensuring that the NS is operational, i.e. that hardware and software resources are working properly, and that the network services can be utilized. *Control* implies monitoring and evaluating the performance of the NS and making necessary adjustments in case the performance thresholds are exceeded. *Maintenance* implies making changes in the NS in response to changing requirements and preconditions.

The model presented in this manual is constructed by applying the entity-relationship approach to the management paradigm. The entity-relationship approach is widely used in data modelling and the construction of relational databases. Its main concepts are entities, attributes, and relationships.

Using the entity-relationship approach, each of the three systems RS, NS and MNS is viewed as a set of entities connected by relationships. Each entity possesses several or no attributes. The model describes only the essential attributes of each entity. More attributes can be added to an entity depending on a particular situation. Figure B.2 presents an overview of the entities. Entities are associated with each other by relationships. The detailed description of the relationships will be given in the next section.

B.5 Application guidelines

The application of the model consists of three phases. Each phase is divided into several steps as shown in Figure B.3. Coming sections B.5.1, B.5.2, B.5.3 describe these phases and their underlying steps.

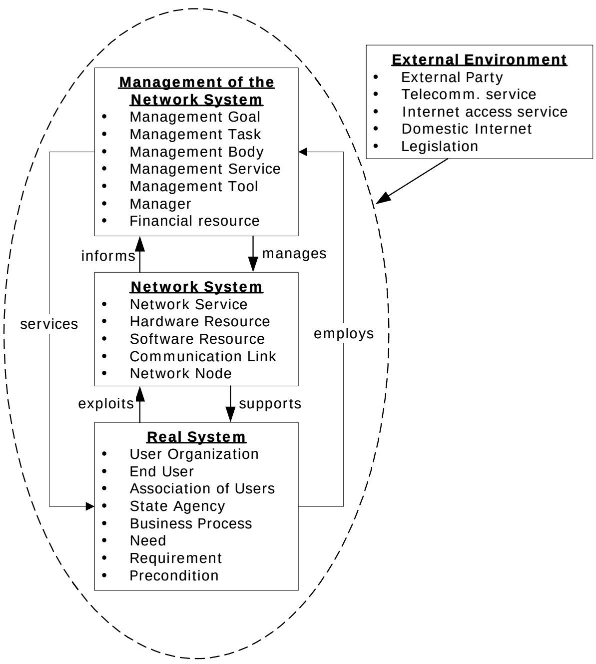

Figure B.2: Entities comprising the model.

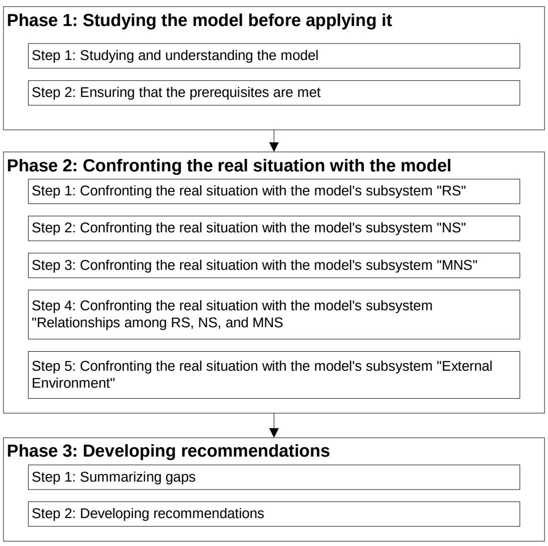

Figure B.3: The graphical depiction of the phases and the steps to be followed in order to apply of the model.

B.5.1 Phase 1: Studying the model before applying it

Step 1: Studying and understanding the model

Before actually applying the model, its primary users must first study it carefully. The following sources can be used for this purpose:

- this manual,
- the detailed description of the model given in Chapter 3,
- the examples of the model's application in real situations such as those given chapters 4 and 5 of this dissertation.

Step 2: Ensuring that the prerequisites are met

Prior to applying the model it is required that the following prerequisites are met:

1. the senior management of the site is committed to support and facilitate the application of the model,
2. the primary users are familiar with the real situation and have access to various kinds of information,
3. the stakeholders are willing to cooperate and share the information,
4. considerable time input is secured.

Firstly, it is required that the senior management of the site is committed to support and facilitate the application of the model. This particularly relates to senior executives of the backbone operator, which usually play a central role in the management of the REN. The role of the senior management includes providing access to the necessary information, supervising activities of those who apply the models (the primary users of the model), and participating in meetings, discussions, and interviews. The knowledge possessed by the senior management is particularly important for dealing with issues that have a strategic or political nature.

Secondly, it is required that the primary users are familiar with the real situation and have access to various kinds of information, including financial and technical information. Information of this kind (such as the precise network configuration or billing information) must sometimes be handled with care because it might be confidential.

Thirdly, it is required that the stakeholders are willing to cooperate and share the information. The data which needs to be collected is often not registered in written documents, but reside in the minds of those involved in the management of the REN. Therefore, various parties must collaborate and share information with each other, and also with the primary users of the models. This prerequisite also implies collaboration with user organizations possessing knowledge about user requirements and preconditions.

Finally, it is required that considerable time inputs are secured. This includes not only the time input from the primary users, but also from the personnel of the

REN operator. Interviews, discussions, and meetings with the staff members of the REN operator and the executives of the REN may require considerable time. It is estimated that depending on the complexity of the real situation, the time necessary for the model's application can range from several weeks up to several months.

B.5.2 Phase 2: Confronting the real situation with the model

The confrontation of the real situation with the model implies the following. The entities and relationships composing the model are filled in with the actual data taken from the real situation. This results in making *a description of the real situation.*

It might appear, that the real situation does not have some elements of the model (entities, relationships, or attributes), or these elements have been improperly developed. Such elements are referred to as *the gaps in the real situation*, see Figure B.4. The search for such gaps is carried out in parallel with making the description of the real situation.

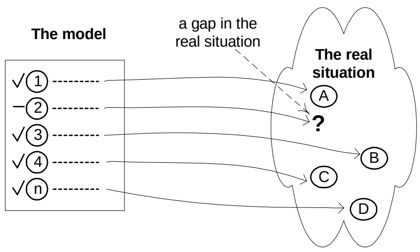

Figure B.4: Visual interpretation of the gaps in the real situation.

The real situation is confronted with each of the following model's subsystems: 1) Real System (RS), 2) Network System (NS), 3) Management of the Network System (MNS), 4) relationships among RS, NS, and MNS, 5) External Environment. This is done in five steps described below.

Step 1: Confronting the real situation with the model's subsystem "RS"

The model's subsystem "Real System (RS)" consists of two parts: 1) the entities of the RS, 2) the relationships among the entities of the RS. The confrontation of the real situation with this subsystem has to be produced according to Chapter 3, section 3.4.

Table B.1 assists in confronting the real situation with the entities of the RS. Besides listing attributes and examples of each entity, this table also presents questions that should be answered. Note the particular nature of the entity Association of Users: although this entity does not always correspond to a legal body, it is defined in such a way that it always exists. This entity normally has only one instance.

Table B.2 assists in confronting the real situation with the relationships among the entities of the RS. It illustrates these relationships by giving their names and posing the questions that should be answered. The relationships marked by "*" are for illustrative purposes only. They are not meant to be filled in with actual data. These relationships, however, assist in understanding the role of the entities they connect and the data which might be necessary for filling in the content of the corresponding entities.

Entity	Attributes	Examples	Relevant questions to be answered
User Organization	Category, size, financial condition	universities, research institutes, libraries, astronomic observatories, colleges, schools, museums, public authorities, ministries, and commercial enterprises.	What kinds of organizations are connected to the REN and utilize its services?
State Agency	none	Ministry of Education and Science	Which state agencies are responsible for R&E networking in the REN's geographical area (country, region, or city)? Which bodies provide financial and regulatory support for the REN on behalf of the state?
Association of Users	mission, size, organizational structure, geographical distribution, legal status, policy	SURF Foundation (NL), DFN Association (DE), the UKERNA (UK)	Are user organizations formally united in an association? What is the mission of this association? How are user organizations geographically distributed? What kind of policies are in place (such as Acceptable Use Policy or Connection Policy)?
Business Process		research process, learning process, knowledge assessment process, enrolment of students, financial administration, HRM	What kind of activities are performed by user organizations (particularly those that are or might be supported by IT)?
End User	category, scientific field, IT literacy	students, teachers, researchers (scientists), technicians, clerks, and administrators	Who are end users of the REN?
Need	nature (private/ professional)	searching and accessing scientific articles, publishing papers, communicating with colleagues, listening to the music, playing games, booking tickets, reading the latest news	What are the reasons for end users to utilize the network and its services (purposes of usage)? What is the relationship between private needs and professional needs (what needs dominate)?
Requirement	none	availability, compatibility, security, continuity of data processing and information management, flexibility, performance, reliability	What kind of services do users need (the assortment of services)? What are the required characteristics of these services (service levels)?
Precondition	none	(de)centralization of activities, (de)centralization of hardware and software, constrains of financial resources (approved budget), hardware and software supplier lines, personnel allocation, and standardization directives	What kind of conditions constrain (limit) user organizations, the association of users, or the state agencies?

Table B.1: Entities comprising the Real System.

Step 2: Confronting the real situation with the model's subsystem "NS"

The model's subsystem "Network System (NS)" consists of two parts: 1) the entities of the NS, 2) the relationships among the entities of the NS. The confrontation of the real situation with this subsystem has to be produced according to Chapter 3, section 3.5.

Table B.3 assists in confronting the real situation with the entities of the NS. Besides listing attributes and examples of each entity, this table also presents questions

Relationship		Relevant questions to be answered
ID	Full text	
r1	Precondition limits Requirements	How (in which way) do the identified preconditions constrain the the identified requirements?
r2	User Organization defines Requirements	How (in which way)are the identified requirements distributed among user organizations? Do certain user organizations have specific requirements?
r3	End User defines Requirements *)	
r4	User Organization formulates Preconditions	How (in which way) are the identified preconditions distributed among user organizations? Do certain user organizations have specific preconditions?
r5	End User has Needs *)	
r6	End User belongs to User organization *)	
r7	End User is involved in Business Processes *)	
r8	Business Process causes Needs	How (in which way) are the identified professional needs related to business processes?
r9	User Organization executes Business Processes	How (in which way) are identified business processes distributed among user organizations? (which user organizations perform each type of business processes?)
r10	User Organization is a member of Association of Users	Are all user organizations a member of the Association? How is the membership in the association formally regulated?
r11	State Agency formulates Preconditions	Which of the identified preconditions are formulated by state agencies?
r12	State Agency participates in or patronizes Association of Users	Does a state agency participate in (or is a patron of) the Association of users? If yes - in which way? (for example, representatives of this state agency may take part in the management board, or they may supervise meetings of the members)
r13	Association of Users formulates Preconditions	Which of the identified preconditions are formulated by the Association of Users?

Table B.2: Relationships among the entities of the Real System.

that should be answered.

Table B.4 assists in confronting the real situation with the relationships among the entities of the NS. It illustrates these relationships by giving their names and posing the questions that should be answered.

Entity	Attributes	Examples	Relevant questions to be answered
Network Service	service level, costs	transmission service, messaging services, the Internet access service, the news service, the domain name service, the IP multicast service	What kind of network services are provided to users? What is the service level of each service?
Communication Link	category, capacity, transmission technology, scale, costs	leased lines, digital channels, Ethernet links, Frame Relay links, ATM links, satellite links	What kind of hardware is used for the transmission of data? What are the acquisition/installation and the recurrent costs?
Hardware Resource	Capacity, costs	Routers, network servers, modems	What hardware is used for the provision of network services (hardware upon which network services are based)? What are the acquisition/installation costs and the recurrent (maintenance) costs?
Software Resource	Status, costs	operating systems (Cisco IOS, Unix, Linux) and service-support software (BIND, Apache, squid)	What software is used for the provision of network services (software which network services are based upon)? Is it commercial or freeware software? What are the acquisition/installation costs and the recurrent (maintenance) costs?
Network Node	none	backbone nodes, access nodes	What are the physical sites (locations) where the hardware resources are located?

Table B.3: Entities comprising the Network System.

Relationship		Relevant questions to be answered
ID	Full text	
n1	Network Service is based on Software Resources, Hardware Resources, and Communication Links	What are hardware and software resources upon which each of the network services is based? (which network services does each hardware/ software resource support?)
n2	Hardware Resource is located in Network Node	Where is each hardware resource physically located?
n3	Network Node is connected to Network Node via Communication Link	What is the topology of the network? (physical or logical arrangement of network nodes, especially the relationships among the network nodes and communication links that connect those nodes)

Table B.4: Relationships among the entities of the Network System.

Step 3: Confronting the real situation with the model's subsystem "MNS"

The model's subsystem "Management of the NS (MNS)" consists of two parts: 1) the entities of the MNS, 2) the relationships among the entities of the MNS. The confrontation of the real situation with this subsystem has to be produced according to Chapter 3, section 3.6.

Table B.5 assists in confronting the real situation with the entities of the MNS. Besides listing attributes and examples of each entity, this table also presents questions that should be answered.

Table B.6 assists in confronting the real situation with the relationships among the entities of the MNS. It illustrates these relationships by giving their names and posing the questions that should be answered.

The relationships marked by "*" are for illustrative purposes only. They are not meant to be filled in with actual data. These relationships assist, however, in understanding the role of the entities they connect and the data which might be necessary for filling in the content of these entities. These relationships reflect obvious associations between the management goals on the one hand, and management tasks and management services on the other hand. They originate from the generic theory of the management, control, and maintenance of information systems.

Entity	Attributes	Examples	Relevant questions to be answered
Management Goal	none	Theoretical management goals: 1. to operate, control and maintain the NS in accordance with requirements, preconditions, attributes of the RS components, aspects of the external environment, and attributes of the NS components; 2. to offer services in the most effective and efficient way 3. to influence goals of user organizations in a positive way	Are there well-formulated goals related to the management of the REN? Are they in line with the theoretical goals stated by the model (see the examples)? To what extent are the theoretical goals fulfilled?
Management Task	none	usage measurement, facility management, security response, router management, DNS management, fault monitoring, IP addresses management	Which activities are performed for fulfilling the management goals? (such as activities aimed at ensuring that the network services are operational)
Management Service	service level, costs	fault handling service, network status information service, naming domain administration service, help desk, provision of documentation, training, technical assistance, security monitoring service	What services provided to users are the result of carrying out management tasks? (and not a capability provided by the network hardware or software)
Management Tool	none	system monitoring tools (such as syslog), web server checking tools, disk space guards, uptime and CPU usage monitors, HP OpenView, Cisco Works, MRTG	Which hardware and software resources are used to perform, support and/or automate management tasks?
Manager	education, competence, salary	network technicians, system administrators, network engineers, network designers, help desk employees, a director, bookkeepers	What kind of people are responsible for the management? Who do actually perform and/or control management tasks, and deliver management services to users?
Financial resource	frequency, size	donor grants, state subsidies, user fees	Which financial means are used to cover the costs of hardware resources, software resources, communication links, network services, managers, and management tools?
Management Body	size, category, org. structure	backbone operator, regional operator	What organizations or org. units actually manage the network and its services?

Table B.5: Entities comprising the Management of the Network System.

Relationship		Relevant questions to be answered
ID	Full text	
m1	Manager is responsible for Management Tasks	How are management tasks distributed among managers (staff members of management bodies)? What are the responsibilities of each manager?
m2	Manager uses Management Tools	Which management tools does the manager use for fulfilling his/her duties?
m3	Manager belongs to Management Bodies	Which organization does the manager work for? (the employer of every manager)
m4	Financial Resource covers the costs of Managers and Management Tools	How are financial resources distributed for covering the salaries of managers and costs of management tools? (In which way are corresponding budget items distributed?)
m5	Management Body executes Management Tasks	How are management tasks distributed among management bodies? (relevant for RENs managed by several bodies: for example, regional operators and backbone operators)
m6	Management Body provides Management Services	Which management services does each management body provides? (how provided management services distributed among management bodies?)
m7	Management Tool supports or automates Management Tasks	Which management tasks does the management tool support and/or automate?
m8	Management Service is based on Management Tools	Which management service does each management tool support?
m9	Management Service is derived from Management Goals *)	
m10	Management Service is a result of carrying out a sequence of Management Tasks	What are the management tasks which result in the provision of the service? (What are management tasks whose results are useful/ interesting to users?)
m11	Management Task is derived from Management Goals *)	
m12	Management Task depends on Management Task	How do management tasks depend on each other?
m13	Management Body has a contract with Management Body	Are there contractual relationships among management bodies? What are the characteristics of these contracts?

Table B.6: Relationships among the entities of the Management of the Network System.

Step 4: Confronting the real situation with the model's subsystem "Relationships among the RS, the NS, and the MNS"

The confrontation of the real situation with the model's subsystem "Relationships among RS, NS, and MNS" has to be produced according to Chapter 3, section 3.7. Table B.7 assists in doing this. It illustrates sixteen relationships by giving their names and posing the questions that should be answered.

Let us make several remarks concerning some relationships out of this table. The relationship `e1` "Management Body is a subdivision of State Agency of User Organization" is optional. The relationships `e4` "Management Body provides Network Services to User Organizations" and `e8` "Management Body provides Management Services to User Organizations" are relevant in case of multiple management bodies. The relationship `e10` "Requirement specifies the assortment and the characteristics of Network Services and Management Services" is not meant to be filled in with actual data because it reflects the definition of the entity Requirement.

Step 5: Confronting the real situation with the model's subsystem "EE"

The confrontation of the real situation with the model's subsystem "External Environment (EE)" has to be produced according to Chapter 3, section 3.8. Table B.8 assists in doing this. Besides listing attributes and examples of each entity, this table also presents questions that should be answered.

B.5.3 Phase 3: Developing recommendations

Step 1: Summarizing gaps

This step is necessary to bring the gaps identified during the preceding phase together. One or more of the following kinds of gaps in the real situation might be found:

1. an entity does not have instances,
2. an entity does not possess an essential attribute,
3. a relationship does not exist, or it has been improperly developed,
4. not enough knowledge is available about a certain entity or relationship.

If *an entity does not have instances*, it means that the corresponding concept of the model does not exist in the real situation. For example, if there are no requirements, this may mean that users do not need any services, or that they do not care about the characteristics of the services. Another example is the nonexistence of state agencies: this may imply that the REN is not supported by the state. Such situations indicate serious deviations of the real situation from the model, and, therefore, they must be carefully investigated.

If *an entity does not possess an essential attribute*, it means that the corresponding concept of the model does not exist in the real situation. Consecutively, the value of such an attribute cannot be identified. This particularly relates to the entities Network Service and Management Service, which both have the attribute "service

Relationship		Relevant questions to be answered
ID	Full text	
e1	Management Body is a subdivision of State Agency or User Organization	Is the management body a subdivision of a state agency or a user organization? (this relationship is optional in many cases)
e2	User Organization or State Agency provides Financial Resources	Who provides funding for the REN? How is this funding distributed among the state and the user organizations? How much funds does every user organization pay periodically?
e3	Financial Resource covers the costs of the Network System (Hardware Resources, Software Resources, and Communication Links)	How are financial resources used for covering the costs of the network?
e4	Management Body provides Network Services to User Organizations	How is the provision of network services distributed among management bodies? (this relationship is more relevant for multiple management bodies than for a single management body)
e5	Management Goal is based on the characteristics of the Network System, Requirements, Preconditions, and the attributes of the Association of Users	Are all mentioned aspects taken into account by the management (characteristics of the Network System, requirements, preconditions, and the attributes of the association of users)?
e6	Management Task is related to Hardware Resources, Software Resources, and/or Communication Links	How are management tasks related to the hardware/ software resources of the network?
e7	Network System reports to Management Tasks	How does each component of the NS (hardware, software, comm. link) report its status/ state to a corresponding management task responsible for this component? (for example, a communication link might be (1) up and running, (2) down, or (3) congested)
e8	Management Body provides Management Services to User Organizations	How is the provision of management services distributed among management bodies? (this relationship is more relevant for multiple management bodies than for a single management body)
e9	Network Service supports Needs and Business Processes	How do network services support business processes? Are network services useful for research, educational, and other processes within user organizations?
e10	Requirement specifies the assortment and the characteristics of Network Services and Management Services *)	(this relationship reflects the definition of requirements)
e11	End User utilizes Network Services	What kind of policies relating to the use of the network are available? (for example, ethical rules)
e12	User Organization utilizes Network Services	Is there statistical information concerning the utilization of network services by user organizations? (for example, graphs showing the load of access links)
e13	User Organization utilizes Management Services	Is there statistical information concerning the utilization of management services by user organizations? (for example, the number of calls to the help desk)
e14	Management Body provides Network Services to Management Body	Does any management body provide services to other management bodies? (for example, a backbone provider that provides services to regional providers)
e15	External Party supplies hardware and software resources to Management Body	Who are external suppliers of hardware and software resources? Are there contracts and long-term agreements between the suppliers and each of the management bodies?
e16	External Party provides Network Services to Management Body	Who are external suppliers of network services? (for example, a telecom operator may provide transmission services to the backbone operator)

Table B.7: Relationships among the entities of the RS, the NS, and the MNS.

Entity	Attributes	Examples	Relevant questions to be answered
External Party	none	suppliers of hardware or software resources, ISPs (Internet service providers), telecommunication operators, donor agencies	Who are the suppliers of hardware/ software? Which ISPs does the REN cooperate with: which ISPs provide the Internet connectivity? which ISPs does the REN peer with? Who provides the transmission services and comm. links? Which international agencies provide funding?
Telecommunication service	Capacity, area of availability, price	ISDN, xDSL, PDH/SDH, ATM, X.25, Frame Relay, FDDI	What are the data transmission services upon which the network is based? What are their characteristics (what do they cost, where are they available, what is the transmission capacity)?
Internet access service	Capacity, area of availability, price	Internet access via satellite, leased lines, dialup access, broadband access, cable access.	What are the tariffs? Is there a choice of providers (ISPs)? Is Internet access is available everywhere in the country/ region served by the REN?
Domestic Internet	Number of: Internet hosts, PCs, Internet users, and Internet service providers in a country/ region	Well developed and competitive Internet market, developing Internet market, non-existing Internet market (no Internet in a country/ region served by the REN)	What is the value of each attribute of the Internet market in a country/ region served by the REN?
Legislation		National ICT policy, the regulatory basis for telecom liberalization	Is there a national ICT policy in country? Is there a national regulatory basis for telecom liberalization? (Is the telecom market liberalized?)

Table B.8: Entities comprising the External Environment.

level". It might be so that the service levels are not recognized as such, or that service levels are recognized only for some instances of the services.

If *a relationship does not exist, or it has been improperly developed*, it means that entities connected by such a relationship do not relate to each other as the model prescribes. This is particularly important for the relationships crossing the borders of the RS, the NS, or the MNS. For example, if the relationship `e9` "Network Service supports Needs and Business Processes" has been improperly developed, it means that the network services are hardly necessary for the RS, and, therefore, it is questionable whether the services provided by the NS and the MNS are useful for the RS.

If *not enough knowledge is available about certain entity or relationship*, it means that people responsible for the management of the REN may not always possess enough knowledge about such entities or relationships. This particularly relates to the entities Requirement, Precondition, Business Process, and Need. This situation generally indicates a gap in the perception of those responsible for the REN management. Gaps of this kind seem to be most common.

Step 2: Developing recommendations

For each kind of gaps in the real situation, a corresponding recommendation can be developed. The realization of these recommendations is expected to improve the real situation.

The development of recommendations is usually straight forward. It is based on the model and the gaps identified at the previous step. The following list gives recommendations for eliminating each kind of gap.

If *an entity does not have instances*, a corresponding object should be created. For example, if no state agency is involved in the support or supervision of the REN, such an agency should be sought to attract state support. If no management goals exist, the theoretical management goals suggested by the model can be used. Alternatively, own management goals can be formulated. In this case it is recommended to base such goals on the theoretical management goals suggested by the model (see Table B.5).

If *an entity does not possess an essential attribute*, the corresponding concept should be introduced. For example, if the service level of a certain network or management service is not recognized, service levels for this service could be introduced.

If *a relationship does not exist, or it has been improperly developed*, such a relationship should be created developed further. For example, if the relationship `e9` "Network Service supports Needs and Business Processes" has been improperly developed, meaning that certain network services are not necessary any more, termination of such services is recommended. Let us give an example of the creation of a relationship. Suppose that the relationship `e7` "Network System reports to Management Task" is not implemented for certain hardware resources. This means that the status of such resources is not known to the management. Therefore, this relationship should be created for such resources; in practice, this means setting up some monitoring tools, for instance, SNMP-based tools, which would constantly guard the status of such hardware resources.

If *not enough knowledge is available about a certain entity or relationship*, additional investigations should take place. The compilation of the description of certain entities or relationships may require questioning user organizations. This particularly relates to the entities Requirement, Precondition, Business Process, and Need. Because the people responsible for the management of the REN may not always possess enough knowledge about these entities, additional investigations should be made. Questions from the last column of tables B.1 – B.8 can be used as a basis for investigations.

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Samenvatting (Dutch Summary)

Samenvatting van het onderzoek

Introductie

Computernetwerken zijn een onmisbaar stuk gereedschap geworden voor onderzoek en onderwijs. De interne computernetwerken van onderzoeks- en onderwijsinstellingen (O&O instellingen) – ook vaak intranets of campusnetwerken genoemd – zijn een belangrijk platform voor het automatiseren van de bedrijfsprocessen van deze instellingen. Naast de netwerken binnen de O&O instellingen zijn er ook netwerken tussen deze instellingen: de netwerken die de instellingen met elkaar en ook met andere netwerken verbinden, inclusief het Internet. Dit soort netwerken, ook wel Research en Education Networks (REN's) genoemd, leveren netwerkdiensten aan O&O instellingen binnen geografische gebieden van verschillende grootten, zoals een stad, een regio, een land, of een continent. REN's zijn te vinden in vele landen en overal ter wereld. Europa, Noord Amerika en Oost Azië zijn de delen van de wereld waarin de meest ontwikkelde REN's zich bevinden.

Om een succesvol platform voor hun diensten te kunnen zijn, moeten REN's, net als andere computernetwerken, beheerd worden. Ze hebben continu ondersteuning nodig gedurende hun hele leven: fouten en storingen ontstaan, de prestatie verslechtert, hardware en software moeten geïnstalleerd en onderhouden worden.

Het beheer van REN's omvat een breed scala van activiteiten, zoals het monitoren van prestatie, het verhelpen van fouten en storingen, het afrekenen met en factureren aan gebruikers, het onderhouden van software en hardware, het werven van personeel, het binnenhalen van financiering, het vaststellen van prijzen, het promoten van diensten, het onderhandelen met leveranciers en het ontwikkelen van beleidsdocumenten. Daarom vereist het beheer van REN's ook verschillende soorten van kennis, zoals technische, administratieve, organisatorische, financiële/ economische, en juridische kennis. Hoewel de meeste aandacht vaak naar de technische kennis uitgaat, zijn andere typen van kennis ook van belang.

Om de efficiëntie en de effectiviteit van het beheer te waarborgen, dient er rekening gehouden te worden met een aantal zaken zoals de besturingsstructuur van de netwerken, financieringsmodellen, factureringschema's, verbruiksbeleid, capaciteiten en technologieën van de communicatieverbindingen, netwerkverkeer, karakteristieken van hardware en software, scala en kwaliteit van diensten, personeel, en helpdesk. Het volume en de complexiteit van deze en vele andere zaken maken het beheer van REN's een grote uitdaging, die ook nog wordt gecompliceerd door het feit dat er veel partijen bij betrokken zijn, zoals overheidsinstanties, gelddonoren, gebruikersorganisaties, netwerkoperators, software- en hardwareverkopers, en aanbieders van Internetdiensten.

Kennis over REN's en het beheer daarvan wordt meestal aangeboden in de vorm van een aantal beschrijvingen van bestaande praktijken. Er zijn geen effectieve manieren om deze kennis uit te wisselen of over te dragen, bijvoorbeeld vanuit ontwikkelde REN's naar de in ontwikkeling zijnde REN's. Het resultaat is dat de kennis typisch geconcentreerd blijft op de plaatsen (REN's) waarin deze aanvankelijk was verkregen.

Het beheer van REN's was tot nu toe genegeerd door onderzoekers. Er waren een paar onderzoeken die slechts gedeeltelijk gingen over het beheer van REN's, en deze richtten zich op het brede scala van kwesties gerelateerd aan REN's. Het bestuderen van de literatuur heeft geen voorbeelden van wetenschappelijke onderzoek opgeleverd die als doel had het bestuderen van de kennis over het beheer van REN's.

Conclusie Er is behoefte aan een model die de kennis over het beheer van REN's formaliseert. Wij hebben deze behoefte ontdekt, niet alleen in de literatuur, maar ook in de praktijk, in een project gericht op het opzetten van een REN in de Oekraïne, namelijk het Ukrainian Research and Academic Network (URAN). Het in dit proefschrift beschreven onderzoek werd aanvankelijk opgestart als een poging te helpen deze REN op een systematische manier te bouwen, in plaats van op een proefondervindelijke manier.

Onderzoeksprobleem en onderzoeksvragen

De vorige alinea presenteerde de achtergrond van de behoefte aan kennis over het beheer van REN's. Om aan deze behoefte te voldoen werd het volgende onderzoeksprobleem gedefinieerd:

Onderzoeksprobleem *Hoe kan de kennis over REN's en het beheer ervan geformaliseerd worden in een model dat in staat is om zo'n beheer te ondersteunen?*

Het onderzoeksprobleem werd benaderd allereerst middels het bestuderen van de kennis over het beheer van REN's, daarna werd een model ontwikkeld, en vervolgens werd dit model gevalideerd in de praktijk. Ten behoeve van deze doelstelling werden drie onderzoeksvragen geformuleerd:

Onderzoeksvraag 1 *Wat zijn de relevante onderwerpen die betrekking hebben op REN's en het beheer ervan?*

Onderzoeksvraag 2 *Hoe kunnen wij een model bouwen dat gebruikt kan worden voor de ondersteuning van het beheer van in ontwikkeling zijnde en reeds ontwikkelde REN's?*

Onderzoeksvraag 3 *Hoe kan het ontwikkelde model gevalideerd worden in praktijksituaties?*

Omdat de term "kennis" een brede en wat meerduidige betekenis heeft, zou het te ambitieus zijn om te zeggen dat wij alle aanwezige kennis gerelateerd aan het beheer van REN's proberen te bestuderen. Daarom werd in de definitie van de eerste onderzoeksvraag deze term vervangen door een wat meer concrete term, namelijk "onderwerpen die betrekking hebben op de REN's en het beheer ervan". Het is de bedoeling dat deze onderwerpen de meest belangrijke aspecten van alle kennis vertegenwoordigen.

De hierna volgende paragrafen beschrijven de bevindingen van het onderzoek en schetsen de antwoorden op de onderzoeksvragen. Elke paragraaf beantwoordt één van de onderzoeksvragen en presenteert hieraan gerelateerde bevindingen.

Bestuderen van onderwerpen gerelateerd aan REN's en het beheer ervan

De eerste onderzoeksvraag, *"Wat zijn de relevante onderwerpen die betrekking hebben op REN's en het beheer ervan?"*, wordt beantwoord in Hoofdstuk 2.

Onderzoeksantwoord 1 Onderwerpen gerelateerd aan REN's en het beheer ervan kunnen worden verdeeld in organisatorische, gebruikersgerelateerde, omgevingsgerelateerde, gebruiksgerelateerde, verbindinggerelateerde, financiële, en dienstengerelateerde onderwerpen. Hoofdstuk 2 beschrijft deze onderwerpen uitgebreid.

De bevindingen gerelateerd aan dit antwoord worden hieronder beschreven.

1. REN's worden vaak niet alleen gebruikt om diensten te produceren, maar ook om de mogelijkheden van de nieuwe netwerktechnologieën, diensten en applicaties te onderzoeken. Daarom worden REN's vaak gebruikt als proefopstellingen voor innovatieve technologieën. Dit maakt ze tot de pioniers onder de netwerktechnologieën, en hierdoor kunnen ze worden gebruikt om de allernieuwste netwerkdiensten en applicaties te ontwikkelen. Dergelijke innovatieve projecten vereisen vaak een vergroting van de transmissiecapaciteit, en vereisen daarom grote investeringen.

2. Vele REN's worstelen om meer transmissiecapaciteit te krijgen. Het verschil tussen de transmissiecapaciteit van REN's in ontwikkelingslanden en REN's in ontwikkelde landen is enorm; het is het verschil tussen het verzenden van kilobits (2^{10}) en gigabits (2^{30}) per seconde. Financiële, technologische, en politieke aspecten spelen hierbij een rol.

3. De diensten geleverd door REN's zijn grotendeels gelijk aan die geleverd door verschillende commerciële netwerkdiensten leveranciers, zoals aanbieders van Internetdiensten. De meeste REN's zijn gericht op het aanbieden van operationele diensten, zoals dataverzendingsdiensten.

4. Hoewel de organisatorische structuren van REN's heel divers zijn, kan er een aantal generieke elementen geïdentificeerd worden. Deze zijn REN Operator, Subcontractor, Association of Users, Management Board, Advisory Board, en State Agency.

5. De REN Operator (de exploitant van een REN) is meestal een organisatie die speciaal is bedoeld voor het vervullen van deze taak. Het is zeer onwaarschijnlijk dat REN's worden beheerd door commerciële organisaties die zich richten op het verkrijgen van winst uit het verlenen van diensten aan de onderzoeks- en onderwijsinstellingen. Subdivisies van overheids-instanties of gebruikersorganisaties zijn vaak de exploitanten van REN's.

6. REN's zijn vaak zeer afhankelijk van subsidies van de overheid of van gelddonoren, vooral tijdens de initiële fase van hun ontwikkeling. Tijdens de ontwikkeling van de REN wordt echter geleidelijk meer financiering door de gebruikers geïntroduceerd.

7. Het is discutabel op welke wijze de periodieke kosten van de exploitatie van REN's gedekt dienen te worden. Zowel het gebruiksgebaseerde (usage-based) als vasttarief (flat-rate) factureringsmodellen hebben hun voordelen en nadelen. Echter, het gebruiksgebaseerde factureringsmodel is meer wenselijk indien de middelen schaars zijn en duur.

Ontwikkelen van het conceptuele model

De tweede onderzoeksvraag, *"Hoe kunnen wij een model bouwen dat gebruikt kan worden voor de ondersteuning van het beheer van in ontwikkeling zijnde en reeds ontwikkelde REN's?"*, wordt beantwoord in Hoofdstuk 3.

Onderzoeksantwoord 2 Het conceptuele model dat het beheer van REN's ondersteunt is ontwikkeld met het gebruik van het beheerparadigma en de entity-relationship aanpak. Hoofdstuk 3 presenteert een uitgebreide beschrijving van dit model.

Bestuderen van bestaande modellen

De tweede onderzoeksvraag werd allereerst benaderd via een literatuurstudie van bestaande modellen die netwerkmanagement ondersteunen. Omdat REN's in feite ook computernetwerken zijn, zouden sommige van deze modellen ook geschikt kunnen zijn voor het ondersteunen van het beheer van REN's. In zo'n geval zou het onnodig zijn om een nieuw model te ontwikkelen, omdat dan een bestaand model gebruikt kan worden.

Bestaande modellen die het beheer van computernetwerken ondersteunen (OSI, Terplan framework, Looijen framework, TMN, TM Forum, en ITIL) bleken niet zonder meer geschikt te zijn voor het ondersteunen van het beheer van REN's. Dit is gedemonstreerd in Bijlage A. Het beheer van REN's omvat een aantal zeer specifieke onderwerpen, behandeld in Hoofdstuk 2. Omdat de bestaande modellen generiek zijn, behandelen ze dergelijke onderwerpen niet. Deze conclusie rechtvaardigt de behoefte aan de ontwikkeling van een nieuw model.

Ontwikkelen van een nieuw model

Een model dat het beheer van REN's ondersteunt werd ontwikkeld aan de hand van twee fundamentele theoretische raamwerken, namelijk het beheerparadigma en de entity-relationship (ER) aanpak. In overeenkomst met het beheerparadigma werden vier systemen bestudeerd, namelijk het reële systeem (RS), het netwerksysteem (NS), het beheersysteem (management of the network system – MNS) en de externe omgeving (external environment – EE). Gebruikma-kend van de ER aanpak werd elk systeem ge- modelleerd als een verzameling van entiteiten die verbonden zijn via een aantal relaties. Daarnaast werden er zes algemene relaties tussen de systemen gemodelleerd (RS exploits NS, NS supports RS, MNS manages NS, NS informs MNS, MNS services RS, en RS employs MNS) als een aantal relaties tussen de entiteiten van de overeenkomstige systemen. Figuur B.5 presenteert een vereenvoudigd overzicht van het conceptuele model.

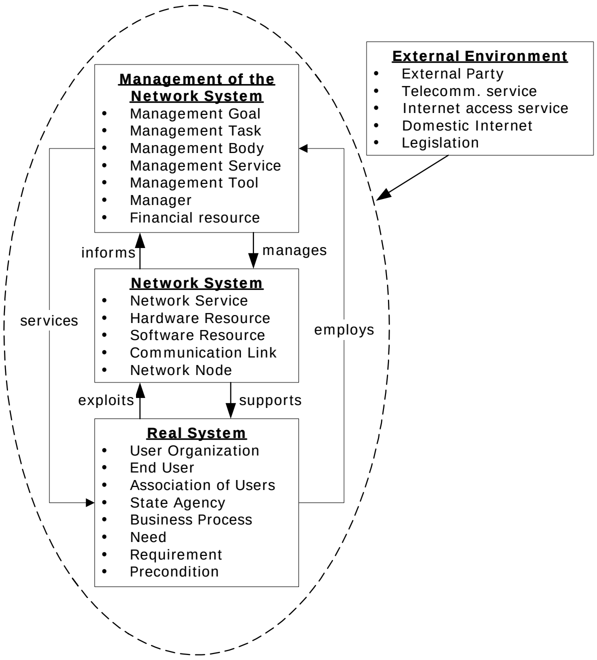

Figure B.5: Vereenvoudigd overzicht van het conceptuele model.

Valideren van het conceptuele model

De derde onderzoeksvraag, *"Hoe kan het ontwikkelde model gevalideerd worden in praktijksituaties?"*, wordt beantwoord in de hoofdstukken 4, 5, en 6.

Onderzoeksantwoord 3 Het conceptuele model werd gevalideerd in de praktijksituaties van twee sites (REN's), namelijk de Ukrainian Research and Academic Network (URAN) en de Swedish University Network (SUNET). Hiervoor werd gebruik gemaakt van een aanpak bestaand uit drie stappen: 1) wederzijdse confrontatie van het model en de praktijksituatie, 2) aanpassen van het model en ontwikkelen van aanbevelingen, 3) evalueren van het model door vertegenwoordigers van de sites. Hoofdstukken 4 en 5 presenteren de resultaten van de eerste twee stappen voor elk site. Hoofdstuk 6 presenteert de resultaten van de derde stap voor beide sites.

Hieronder wordt elk stap kort beschreven samen met de gerelateerde onderzoeksbevindingen.

Stap 1. Wederzijdse confrontatie van het model en de praktijksituatie

In Stap 1 werd het model toegepast om de beschrijvingen van de sites te maken. De entiteiten en relaties van het model werden ingevuld met de actuele gegevens van de sites.

Door het toepassen van het model op de praktijksituaties leerden we dat er aan enkele voorwaarden voldaan moet worden. Ten eerste dient de top van het management van de site het op zich te nemen om de toepassing van het model te ondersteunen en te faciliteren. Ten tweede dienen degenen die het model toepassen bekend te zijn met de praktijksituatie, en dienen ze ook toegang te hebben tot verschillende soorten informatie, inclusief financiële en technische informatie. Ten derde dienen alle belanghebbenden bereid te zijn om samen te werken en informatie te delen. Als laatste is er een aanzienlijke tijdsinvestering vereist. Dit betreft niet alleen de tijd van degenen die het model toepassen, maar ook de tijd van het personeel van de site. Afhankelijk van de complexiteit van de praktijksituatie kan de tijd nodig voor het opstellen van de beschrijving van de deze situatie variëren tussen enkele weken tot enkele maanden.

Tijdens het opstellen van de beschrijvingen constateerden wij dat het de praktijksituaties ontbrak aan bepaalde elementen van het model (entiteiten, relaties, of attributen), of dat deze elementen onvoldoende waren ontwikkeld. Degelijke ontbrekende elementen noemden we *lacunes in de praktijksituatie*. De sites hadden de volgende lacunes:

- Het management kent eisen en randvoorwaarden van gebruikersorganisaties niet (URAN, SUNET)
- Gebrek aan service levels van de netwerkdiensten (URAN, SUNET)
- Gebrek aan beheerdoelen (URAN, SUNET)
- Gebrek aan het geaccepteerde gebruiksbeleid (URAN)
- Beperkt aantal fout- en veiligheidsbeheertaken (URAN)
- Beperkt aantal beheerdiensten (URAN)
- Gebrek aan service level agreements (SLAs) (SUNET)
- Gebrek aan de wettelijke basis voor de liberalisering van de telecommarkt en het monopolie van Ukrtelecom op de provisie van de grond telecommunicatiediensten (URAN)

Op grond van de bevinding dat beide validatiesites soortgelijke lacunes vertoonden zouden we kunnen concluderen dat deze lacunes nogal vaak bij REN's voorkomen. Op basis van onze verkenning in Hoofdstuk 2 verwachten wij dat andere REN's ook soortgelijke lacunes vertonen, dus dat ze, bijvoorbeeld, de eisen van hun gebruikers niet kennen, en dat ze geen beheerdoelen hebben. Daarnaast dient de betekenis van de in dit onderzoek gebruikte term een "lacune in de praktijksituatie" uitgelegd te worden. Het feit dat zo'n lacune bestaat, betekent dat een geschikt element van het model (entiteit, attribuut, of relatie) niet in de praktijksituatie aanwezig is. Het model is primair voortgekomen uit twee bronnen: de REN-onderwerpen en de MCMIS theorie. Het is waarschijnlijker dat er een lacune in de praktijksituatie wordt ontdekt als gevolg van de confrontatie van de praktijksituatie met de MCMIS theorie. Met andere woorden, het ligt meer voor de hand dat het niet de REN-onderwerpen zijn, maar dat het de MCMIS theorie is die iets voorstelt dat niet aanwezig is in de praktijksituatie.

Tijdens het opstellen van de beschrijvingen constateerden wij ook dat het model bepaalde aspecten van de praktijksituatie niet kon weergeven, of, met andere woorden, dat deze aspecten niet overeenkwamen met welke entiteiten, attributen, of relaties van het model dan ook. Dergelijke aspecten noemde we *lacunes in het model*. Het model bleek niet in staat te zijn om de volgende aspecten weer te geven: 1) de contractuele relaties tussen veelvoudige beheersinstanties (management bodies), en tussen deze instanties en de externe partijen (URAN), 3) de relaties tussen verschillende beheertaken (URAN), 4) de verdeling van eindgebruikers in intensieve en minder intensieve gebruikers (SUNET).

Stap 2. Aanpassen van het model en ontwikkelen van de aanbevelingen

De volgende aanbevelingen werden gedaan om de lacunes in de praktijksituaties op te vullen:

- Onderzoek de eisen en randvoorwaarden van gebruikersorganisaties (URAN, SUNET)
- Introduceer service levels voor netwerkdiensten (SUNET, URAN)
- Definieer beheerdoelen en controleer hun realisatie (SUNET, URAN)
- Introduceer nieuwe fout- en veiligheidsbeheertaken (URAN)
- Introduceer nieuwe netwerkdiensten (URAN)
- Sluit SLAs af (SUNET)

Paragrafen 4.9 en 5.9 geven gedetailleerde beschrijvingen van deze aanbevelingen.

De lacunes in het model werden ongedaan gemaakt door het model zelf aan te passen.

Stap 3. Evalueren van het model door de sites

Stap 3 was bedoeld om de kwaliteit van het model te evalueren volgens de mensen die bij het beheer van de sites betrokken zijn. Hoofdstuk 6 presenteert de resultaten van deze stap. Zes criteria die de kwaliteit van het model weerspiegelen werden geïntroduceerd, namelijk de geschiktheid, nauwkeurigheid, begrijpelijkheid, leerbaarheid, operabiliteit, en aantrekkelijkheid. De vertegenwoor-digers van de sites werden gevraagd om deze criteria te evalueren conform drie kwaliteitsniveaus: 'zeer goed', 'enigszins goed' en 'slecht'. De resultaten van de evaluaties laten zien dat de meerderheid van reacties tot de kwaliteitsniveaus 'zeer goed' en 'enigszins goed' behoort.

Een belangrijk resultaat van deze stap was de ontwikkeling van een handleiding voor het model, zie Bijlage B. Deze handleiding beschrijft richtlijnen voor het gebruik van het model in de praktijk. De handleiding stelt de gebruikers van het model in staat om het model beter te begrijpen dan op basis van de academische beschrijving van het model uit Hoofdstuk 3.

Aanbevelingen voor nader onderzoek

Deze paragraaf presenteert voorgestelde richtingen voor nader onderzoek op het gebied van het modelleren van het beheer van R&E netwerken.

Een veelbelovende richting voor nader onderzoek is het bestuderen hoe het model ontwikkeld in dit onderzoek kan worden uitgebreid met een aantal meetbare variabelen of parameters. Invoer- controle- en uitvoervariabelen kunnen worden gedefinieerd. Op deze manier kan het model kwantitatiever worden gemaakt en beter programmeerbaar, zodat het geautomatiseerd kan worden, bijvoorbeeld door middel van het gebruik van kunstmatige intelligentie en/of simulatietechnieken. Het gebruik van simulatietechnieken zou ook betekenen dat men het gedrag van een gemodelleerde situatie zou kunnen voorspellen, en de visuele weerspiegeling van praktijksituaties en processen zou kunnen zien.

De mogelijkheid om simulatietechnieken te gebruiken maakt het ook mogelijk om de dimensie "tijd" aan het model toe te voegen. Dit houdt in dat het gedrag van entiteiten, attributen en relaties wordt gemodelleerd door de tijd heen. Een dergelijke verbetering zou het model dynamischer maken: het in dit onderzoek ontwikkelde model ondersteunt slechts statische situaties. De toevoeging van de dimensie "tijd" zou de kwestie van de overgang vanuit de huidige situatie naar de toekomstige situatie kunnen oplossen – dit probleem wordt beschreven in Hoofdstuk 5, paragraaf 5.3.1. De overgang vanuit de ene netwerkinfrastructuur naar een andere infrastructuur (in het geval van Hoofdstuk 5: de overgang van SUNET naar GigaSUNET) lag buiten het bestek van het model dat in dit onderzoek werd ontwikkeld omdat dit model niet bedoeld is voor het ondersteunen van dynamische processen. Het model is primair bedoeld voor het ondersteunen van het beheer van een REN op een bepaald willekeurig moment, inclusief de toekomstige situaties. Het bouwen van nieuwe REN's lag buiten het bestek van dit onderzoek.

Wij bevelen aan om de toepassing en het gedrag van het model te onderzoeken buiten de in dit onderzoek beschouwde omgeving. De voorgestelde omgevingen zijn computernetwerken van de aanbieders van Internetdiensten die hun diensten aan bedrijven leveren, en computernetwerken van grote multi-organisatie concerns.

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Dmitry Galagan
Rotterdam, June 2004

About the author

Dmitry Galagan was born on 9th July 1973, in Kiev, Ukraine. In 1996 he graduated from the National Technical University of Ukraine "Kiev Polytechnic Institute" with two diplomas of higher education: that in Applied Mathematics (with distinction), with a specialization in "Intelligent Systems of Information Processing and Decision-making", and that in Management and Marketing, with a specialization in "Industrial Marketing" (evening course). After finishing university, he worked as a software developer at the joint stock bank "AGGIO", and the Research Institute of Systems' Technologies in Kiev.

In 1997 Dmitry started to become involved in activities aimed at building up a computer network among the R&E organizations in Ukraine, URAN. This was the starting point of the research project described in this dissertation. Because there was a lack of experience in building and managing such networks in Ukraine, the following question had to be answered: how can networks of this kind be managed in a systematic way, rather than in a trial-and-error manner? The idea to investigate this issue was supported by the Delft University of Technology, and its Center for International Cooperation and Advanced Technologies (CICAT). The research project described in this dissertation was entirely financed by the Dutch state.

In March 1998 Dmitry moved to the Netherlands and began working on the research project. Apart from this, he was also involved in activities such as creating and supporting the website of URAN, managing a contract between URAN and a North American Internet Service Provider (ISP), conducting a marketing analysis of Ukrainian ISPs, and developing a project proposal regarding the creation of a national R&E network in Vietnam; the funding of the project (˜1 million EUR) was approved by a donor agency. He was also a guest lecturer at several workshops and conferences in Ukraine.

In March 2002, Dmitry started working for Ordina, which is one of leading players on the market for information and communication technology in the Netherlands. At the present, he is working there as an information analyst and software designer.

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List of abbreviations

ATM	Asynchronous Transfer Mode
AUP	Acceptable Usage Policy
BPR	Business Process Re-engineering
CEENet	Central and Eastern European Networking Association
CEI	Center of European Integration
CEO	Chief Executive Officer
CERT	Computer Emergency Response Team
CPU	Central Processing Unit
DNS	Domain Name System
DRC	Digital Rendered Channel
EE	External Environment
ER	Entity- relationship
FDDI	Fiber Distributed Data Interface
FR	Frame Relay
FTP	File Transfer Protocol
HDD	Hard Disk Drive
HDSL	High-speed Digital Subscriber Line
HEI	Higher Education Institution
HTTP	Hyper Text Transfer Protocol
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IOS	Internetworking Operating System
IP	Internet Protocol
IS	Information System
ISDN	Integrated Services Digital Network
ISO	International Standard Organization
ISP	Internet Service Provider
IT	Information Technology
ITIL	Information Technology Infrastructure Library
ITU	International Telecommunication Union
IX	Internet Exchange
JANET	Joint Academic Network (UK)

KTHNOC	Kungliga Tekniska Högskolan (Royal Institute of Technology) Network Operation Center
LAN	Local Area Network
LDAP	Lightweight Directory Access Protocol
MBONE	Multicast Backbone
MCM	Management, Control and Maintenance
MCMIS	Management, Control and Maintenance of Information Systems
MNS	Management of Network System
MRTG	Multi Router Traffic Grapher
NATO	North Atlantic Treaty Organization
NMDOM	Network Management Detailed Operation Map
NREN	National Research and Education Network
NS	Network System
NSM	Network Services Management
NTUU "KPI"	National Technical University of Ukraine "Kiev Politechnical Institute"
OSI	Open Systems Interconnection
PC	Personal Computer
RAM	Random Access Memory
REN	Research and Education Network
RIPE	Réseaux IP Européens
RS	Real System
SDH	Synchronous Digital Hierarchy
SLA	Service Level Agreement
SUNET	Swedish University Network
TCP	Transport Control Protocol
TERENA	Trans European Research and Education Networking Association
TMN	Telecommunication Management Network
TOM	Telecom Operations Map
UNESCO	United Nations Educational, Scientific, and Cultural Organization
URAN	Ukrainian Research and Academic Network
WDM	Wave Division Multiplexing