

# Availability Management of Complex Technical Systems

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*This work presents basic elements of availability management methodology in complex technical systems according to the business and user perspectives. The methodology primarily relates to Information Technology (IT) systems, and the presented availability perspectives are based on parameters resulted from the exploitation conditions, according to analysis of the Tax Administration Information System of the Republic of Serbia – DIS 2003. The result of the implemented technology enhances the availability level through the clear identification and elimination of critical elements that affect the stability of IT infrastructure and ensures a continuing service provided by the system. The criteria of the optimization applied within the implementation of the availability enhancing process present a relation between the cost price of service provided by the system and expenditures of investments in improvements. Considering the established business requirements through the system, the availability management process should be given an appropriate level of service.*

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## 0 INTRODUCTION

From a theoretical and practical perspective, maintenance includes a set of activities and procedures that ensure a proper functioning of a technical system and a level of functioning safety and reliability that meets the established function of objective. The type of a maintenance system, determined by conception, organization and features of maintenance procedures (maintenance technology), as well as by relation between certain levels at which maintenance is performed, is the maintenance strategy. From the perspective of dynamics and content of implementation, the maintenance has to be assessed carefully and harmonized strictly with the real needs [1].

Strategies and models of maintenance rely upon reliability indicators and optimization criteria, more often upon minimal costs and maximal availability or upon a compromise thereof [2]. Technical systems have to be approached systemically, taking into consideration the entirety of all features and mutual relations and facts of influence. It is usually a set of scientific and engineering activities that have to provide the required exploitation features of technical system [3].

The entire strategy may rely upon technical system availability management, unavailability risk management, identification and elimination of critical elements and

optimization of the process in relation to maintenance costs.

This paper presents, the theoretical bases of technical systems availability management process, with special emphasis on methodology applied to complex systems, the elements of which according to the own technical features are based on information technologies [4]. Through the availability management process, it is possible to identify the critical elements of the system, as well as to apply the methodology of identification and risk management [5]. The bases of the methodology and cost management process shall also be presented, as they form a basis for optimization and can be applied within the complex technical systems [6].

The implemented and presented methodology of availability management relies upon the recommendations and procedures from the “best practice” of management of IT systems and services provided by the system [6]. The obtained results of applied methodology and manners of obtaining the results can be measured, compared and harmonized with the results of the latest research within this field, presented in cited literature [7] to [9].

Availability or unavailability is the key indicator of service quality provided by the IT system, which is required as the support to business processes or by the user [10]. Availability is underpinned by the reliability

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and maintainability of the IT Infrastructure and by the effectiveness of IT organization. The IT system availability depends on:

- availability of components,
- level and risk of failure,
- quality of maintenance and support,
- quality, pattern and extent of implementation, of operational processes and procedures,
- security, quality and availability of data.

The goal of the IT System Availability Management process is to optimize the capability of IT Infrastructure, IT service level and IT organization in order to deliver a cost effective and sustained level of Availability that enables a business success and meeting of business objectives [6].

The availability management shall be implemented through several phases: projecting, implementation, measuring and IT infrastructure availability management, in order to ensure the established business requirements.

## 1 THEORETICAL RUDIMENTS

### 1.1 Availability Designing and Implementation

The inception of designing process implementation relates to identification of availability requirements for the real system (*Tax Administration Information System of the Republic of Serbia – DIS 2003*) in exploiting conditions.

It is important to point out that the business system needs cannot be expressed in technical terms. Therefore, the Availability Management, as a process, provides an important role in being able to translate the business and User requirements into quantifiable and exact terms of needs. This is an important input to IT Infrastructure design and IT organization in the meeting of Availability business requirements.

The role of Availability Management within the design activities of availability requirements shall be obtained through:

- specification of Availability requirements for hardware and software,
- requirements for Availability measurement points (instrumentation and tools),

- the requirements for new/enhanced systems management,
- participation in IT Infrastructure Design,
- specification of reliability, maintainability and serviceability requirements for the IT system components,
- validation of a designed minimum of business requirements to meet the required level of the IT System Availability.

The Availability Management process should be utilised to design the requirements that will consist of:

- minimal levels of Availability business requirements for IT system and business processes,
- identification of internal and external suppliers,
- minimal reliability, maintainability and serviceability levels for each component of IT Infrastructure,
- preparation of tools for an Availability modelling,
- ability to test or simulate the new component within the designed and specified requirements.

### 1.2 Availability Measurement and Reporting

A key output from the IT System Availability Management Process is measurement and reporting which provides the basis for:

- establishing measures of Availability and harmonization of Availability and business objectives,
- monitoring the actual Availability delivered versus a set of objectives,
- identifying unacceptable levels of Availability that affect the business processes and Users,
- reviewing Availability with the business and User representatives,
- reviewing Availability with the IT support organisation,
- continuous improvement activities to optimise the Availability.

"What to measure and how to report it" inevitably depends on which activity shall be supported, who the recipients are and how the information shall be utilised. The importance of measuring and reporting in order to improve the

availability shall be reflected in the following perspectives and meeting of various needs:

- the IT Support Organisation perspective considers IT component Availability with regard to Availability, Reliability and Maintainability,
- the User perspective considers IT Service Availability as a combination of three factors: frequency, duration and scope of impact, i.e. all Users or some Users, all Business functions or certain business functions,
- the Business perspective considers IT System Availability in terms of its contribution or negative impact on the implementation and realization of business processes.

In order to satisfy the differing perspectives of System Availability and Availability Management needs, it is necessary to provide a wide range of methods and techniques of measurement and reporting according to different availability parameters [11]. The Availability Management Process takes into consideration both the IT Service and IT Infrastructure component perspectives where the focus is completely different, but the concepts of measurement and reporting are similar.

The IT support organisations have mostly measured and reported for the previous periods of system functioning time according to Availability parameters. Traditionally, these measures have been based on the IT Infrastructure component Availability and have somehow not been related to business requirements and Users.

While the traditional IT Availability (Fig. 1) measurement and reporting methods can be considered as appropriate for internal IT reporting, the disadvantages of this approach are that they:

- fail to reflect IT Availability as experienced by the business process and the User
- can conceal an increasing User's dissatisfaction with the level of IT Service, although the availability level of IT Infrastructure enhances
- do not easily support continuous improvement opportunities of IT System to drive improvements that can benefit the business and the User

- can mask the benefits from availability improvements for business and users.

On the other hand, when measuring and reporting from the User perspective, on the basis of results the relation with and an impact on the business processes, IT service level and service users can be established. Furthermore, this method of measuring and reporting in most cases discovers benefits for business processes and users resulting from the IT system availability and IT Infrastructure improvements [12].

### 1.3 Availability Management of the IT Infrastructure

The availability management should have a proactive role in identifying opportunities and improving IT infrastructure availability in relation to the optimal costs. To implement this, applying appropriate reliable methods of measurement and reporting from the system, in accordance with the predefined criteria is needed. In order to improve the system from availability perspective, it is important that the measuring and reporting from the system shall not be related only to the IT Infrastructure components availability, but to business operations and outputs toward users as well [13].

The Availability management process of the IT Infrastructure relies upon permanent improvement of the performances, based on the measurement results and identification and elimination of the critical elements.

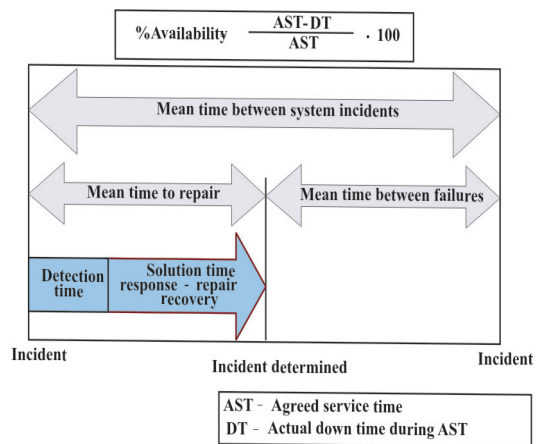


Fig. 1. Availability Measurement

The process is shown in Figure 2 and can be based on widely known Deming Cycle, in coordinates of availability level and duration time of the process [6].

In order to meet the business requirements to enhance the availability level, it is necessary to ensure the financial investments for the purposes of improving the IT Infrastructure and enhancing the IT organization capacities.

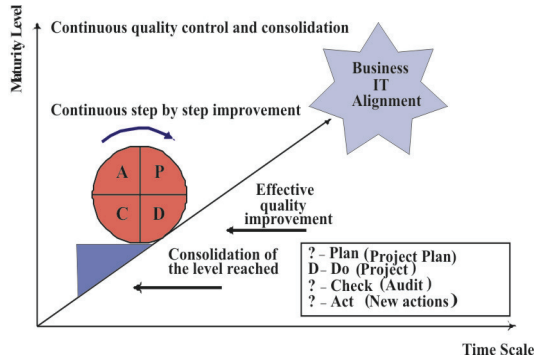


Fig. 2. Principles of Availability Management of the IT Infrastructure

## 2 IMPLEMENTED METHODOLOGY AND RESULTS

### 2.1 Functional and Technical Features of the Real IT System

The Information System of the Tax Administration (DIS 2003 – Distributed Information System) as a means of business support as distributed system with the central records has been designed. From the perspective of function, the system consists of two parts, mutually integrated and connected by the network infrastructure.

Information and technical support to the information system's functioning has been implemented through three basic levels:

- Central computer system;
- Transport;
- Local computer systems in dislocated organizational units.

The basic infrastructure of the Tax Administration's information system presents the Information and Telecommunication network (ITC). ITC network is a highly distributed and complex technical system with

respect to the high degree of organizational units' dislocations because the management, maintenance and improvement methodologies are very complex.

The Tax Administration's ITC network architecture was built in a manner to prevent the system from being dependent on the organizational units' network or the their internal functional organization. Currently, the system provides services for 234 information "addresses" on 167 locations that represent the organizational units of Tax Administration, where 7457 workstations or system users are placed.

The global structure of the Tax Administration's ITC network is shown in Figure 3. All dislocated organizational units analyzed from the perspective of communication channels and connections can be categorized in two groups: connected and unconnected.

The connected organizational units, regardless of the level of organization's hierarchy, have the direct (on-line) connection with the Central Computer System.

The local servers of unconnected organizational units are connected with the central servers through the periodical (Dial-up) connection.

### 2.2 Implemented Methodology of Availability Measurement

Availability, when measured and reported to reflect the experience of the User [1], provides a more representative view of the overall IT Service quality. The User view of Availability is influenced by the following factors:

- frequency of downtime,
- duration of downtime,
- scope of impact.

Where the number of users impacted by an IT failure is known, this information can be used to report the user availability as:

- Report on user impact - as an absolute value per Incident or reporting period;
- User productivity loss - as a time based value per Incident or reporting period;
- User availability - as an availability percentage (%) for the reporting period.

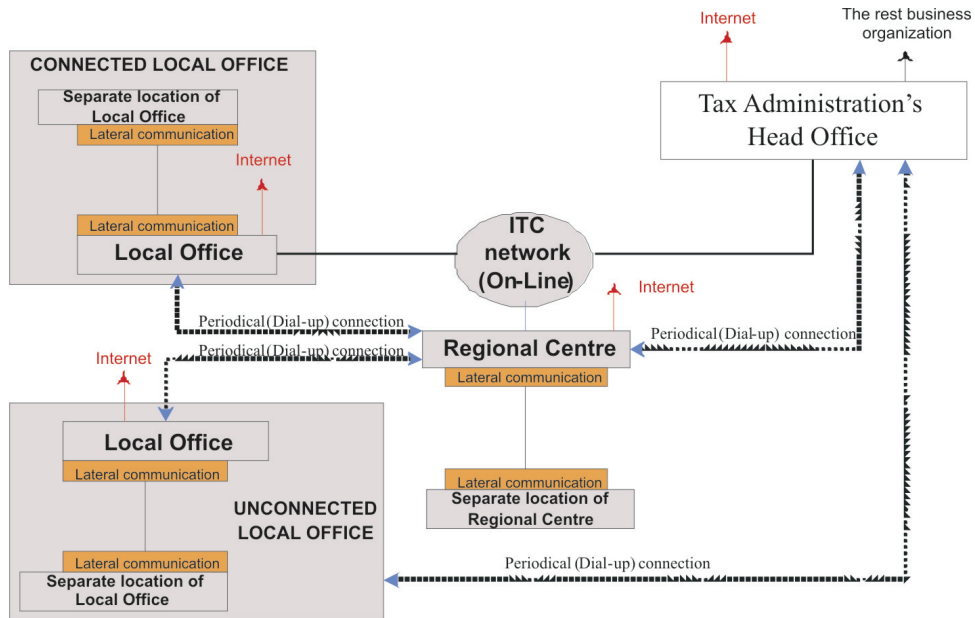


Fig. 3. ITC Network Infrastructure

End-User Availability (EUA) can therefore be calculated in a reporting period based on the following calculation:

$$EUA(\%) = \frac{(EUP - EUDT) \cdot 100}{EUP} \quad (1)$$

Where:

- The user processing time (EUP) - This is to base calculation on the Agreed service time AST multiplied by the total number of users (Nuser);
- End User Downtime (EUDT) – This is to base calculations on the duration of Downtime (DT) multiplied by the number of hit users (Npuser) and by summarizing all downtimes within the measured period.

Within the implementation of measurement methodology the method of Component Failure Impact Analysis (CFIA) is used as a support to foresee and assess the impact of component failures on the IT system availability. This aspect of the problem offers a possibility for availability calculation to be based on the number of influenced users and/or lost user's working hours.

The DIS 2003 is designed to have a separate reporting system for processes relating to its functioning. Within the reporting system, there is information on the implemented

processes relating to the regular functions of the system, as well as on extraordinary processes mostly relating to the system component failures. For the methodology to be implemented, the other type of system reporting that relates to the identification of the system component failures and identification of the delivering service failures provided by the system, are important.

To evaluate an impact of local subsystems on availability of the entire system, at first step, it is necessary to implement the method of Component Failure Impact Analysis (CFIA). The implemented analysis indicates that, in a concrete case, local subsystem failures have an irrelevant impact on the availability of the entire system.

According to previous analyses, it may be concluded that, for the real system shown, in the implementation of the methodology for user availability determination, the key assumptions and restrictions are as follows:

- Needed input data are received from the central system reporting on extraordinary processes.
- Connections of local systems with the central system do not affect availability of the entire system.

- With an analysis it was identified that the failures in local dislocated subsystems had an irrelevant influence over the user availability of entire system.
- The time frame of the system duration of failure shall be determined from the system for reporting on extraordinary processes.
- Due to the existence of the timeframe for reporting failures defined in reporting system, the results from measurements will be expressed with the presupposed error.
- Input restrictions and assumptions are necessary due to the lack of availability and defects of input data needed for the determination of system availability.
- Input restrictions and assumptions are defined in a manner to prevent the summarizing of errors or incorrectness of the received results.

Results from the implemented procedure of User availability determination are shown in Table 1. The analysis was performed for the period between 02.08.2005 at 00:00 and 31.05.2006 at 24:00, amounting to 302 days or to 434,880 minutes. In the Table 1 row 133 and column 2 and 3 the date and time (29.05.2009 at 13:10:12) of the last known failure in the abovementioned period are presented.

According to calculations, the value of user system availability (in percentage [%]) with the absolute error is as follows:

$$[EUA] \pm [\Delta EUA] = 98.157 \% \pm [0.435] \% ;$$

or if considered the relative error:

$$[EUA] \pm [\Delta rEUA] = 98.157 \% \pm [0.443] \% .$$

The absolute error expressed in percentage [ $\Delta EUA(\%)$ ] and the relative error expressed in percentage [ $\Delta rEUA(\%)$ ] are calculated according to the following formulas:

$$\Delta EUA(\%) = \frac{(EUP T \cdot \Delta(\Sigma EUD T) + \Sigma EUD T \cdot \Delta EUP T) \cdot 100}{(EUP T)^2} \tag{2}$$

$$\Delta rEUA(\%) = \frac{\Delta EUA \cdot 100}{EUA} . \tag{3}$$

The initial assumptions and restrictions in the implementation of the User system availability determination point out a lack of development of tools for availability management. In the current system of failure recording, it is necessary to enhance the data availability level, as well as to design and implement the tools for analysis.

Table 1. Results from the implemented procedure of User availability determination

No	System failure description				Failure duration		User impact		End User Downtime	
	Date	Time	Incident description	Failed comp.	[DT]	±[ΔDT]	[Npuser]	[ΔrNpuser]	[EUDT]	±[ΔEUDT]
	(dd.mm.yyyy)	(hh:mm:ss)			(min)	(min)	(%)	(%)	(min)	(min)
1	2	3	4	5	6	7	8	9	10	11
1	02.08.2005.	11:44:06	Problem of Orion from the Process 5	Process 5, C2	30	14	6,325	1	189,750	89,499
2	02.08.2005	11:45:29	Problem of dns.it.pu	DNS	30	14	7,457	1	223,710	105,517
3	04.08.2005	16:47:18	Problem of dns.it.pu	DNS	30	14	7,457	1	223,710	105,517
..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
132	29.05.2006	09:35:32	Problem of dns.it.pu	DNS	30	14	7,457	1	223,710	105,517
133	29.05.2006	13:10:12	Problem of FTP	DPO	240	60	1	1	240	61



Table 1.1 *Sum of results from the implemented procedure of User availability determination*

Agreed service time		Total number of users		End user downtime-sum		User processing time		End-user availability		
[AST]	±[ΔAST]	[Nuser]	[ArNuser]	[ΣEUDT]	±[ΔΣEUDT]	[EUPT]	±[ΔEUPT]	[EUA]	±[ΔEUA]	±[ArEUA]
(min)	(min)		(%)	(min)	(min)	(min)	(min)	(%)	(%)	(%)
12	13	14	15	16	17	18	19	20	21	22
434,880	0.5	7,457	1	59,775,082	13,815,178	3,242,900,160	16,218,229	98.157	0.435	0.443

In accordance with the initial assumptions applied, the preciseness of resulting issues might be considered as a satisfactory one, but the conclusions about confidence level cannot be drawn. If we analyze the resulting value, with respect to a high level of complexity and distributiveness of the system, we can conclude that the system actually has a high User availability level.

The greatest benefit of the methodology applied is an opportunity to identify the critical elements of a system, by the technical improvement by which it shall be possible to affect the availability level. By reapplying methodology, after technical and technological system improvements have been implemented, the impact on changes of availability level can be identified.

### 2.3 Identification of Critical System Elements

By an analysis applied and the implementation of the presented methodology, the most critical elements from the availability perspective have been identified. Here, these elements will be listed logically, starting from the most critical one:

- *ITC network*  
A high percentage (46%) of the system “addresses” is connected by the periodical modem communications. This is very unfavorable from the perspective of availability of data incorporated into the system. By an increase of the level of business requirement for a shorter timeframe of data availability from all the “addresses”, both critical and risk level of the ITC network shall increase.
- *Computer and communication equipment*  
From the total number of workstations and servers, 54% belong to an older

technological generation, older than three years or more. Replacement of this equipment by a new one shall be very important from the reliability perspective, and most important is to have equipment of the latest technological generation in the central computer system. The risks result from the lack of reliability of old equipment and from difficult maintenance.

- *IT organization*  
The critical and risk issues result from the lack of development of IT organization. It is caused by the absence of clearly defined business processes and procedures, which need to be implemented in operations. There are neither clearly defined standards for the development of the technical support system nor the development of tools for availability management.
- *Tools for availability management*  
The risks result from the inadequacy or absence of automated tools for data collection, which contain criteria for tracking, analyzing and managing of the system availability.

With an identification and analysis of the critical elements of system, the conditions for the implementation of technical and technological improvements that will provide the implementation of availability management processes have been met.

### 2.4 Improvement of the System

Here all the technical and technological improvements of system that are implemented on the basis of availability analysis and identification of critical elements shall be presented. The improvements were implemented within a one-year period, and the impact on the availability level shall be seen on the basis of a renewed analysis.

The implemented system improvements that relate to technical and technological perspectives are:

- Unique information and telecommunication network of the Tax Administration (on-line) has been built, so that all the organizational units were connected.
- Computer and communication – old generation equipment (older than 3 years) has been replaced by the latest technological generation equipment.
- Central computer system was established on a new location and built by the latest technological generation equipment.
- IT organization has been improved by establishing a new organizational structure and training of personnel.
- New Division for technical support has been established, the work of which has been supported by new communication technologies and a high level of automation.
- Establishment of a separate IT organizational part has been initiated, and will deal with equipment maintenance.
- Constant training within the IT organization from the field of technical support in system functioning, equipment maintenance, service delivery, as well as in the field of system Users from the user perspective have been performed.

## 2.5 Repeated Measurement of Availability

The procedure of determining the user availability is presented in 2.2 by the application of which the results for the real system were obtained. A repeated analysis for the following timeframe has been implemented in the course of which all improvements of the system previously presented were implemented.

The applied methodology is identical with the previous one presented in 2.2, where all the defined restrictions were considered.

The analysis was performed for the period between 01.06.2006 at 00:00 and 28.02.2007 at 24:00, and lasted 273 days or 393,120 minutes.

According to calculations, the value of the user system availability with the absolute error is as follows:

$$[EUA] \pm [\Delta EUA] = 98.905 \% \pm [0.458] \% ;$$

Or if the relative error is considered:

$$[EUA] \pm [\Delta rEUA] = 98.905 \% \pm [0.463] \% .$$

According to the obtained results, it can be concluded that the User availability level was increased by 0.748%, with absolute error of:  $\pm [0.023] \%$ , and relative error of:  $\pm [0.030] \%$ .

## 2.6 Optimization Criteria

The applied model of the technical system availability management relies upon optimization criteria, the most important of which are the *cost price of service provided by the system* and the *costs of investments in improvements*. It is very difficult in practice to apply a model which connects criteria of availability to the costs, so the principle being mostly applied is a compromise or a relation where the advantages or disadvantages are balanced. If it is required that the criteria of both maximal technical system availability and minimal costs have to be met simultaneously, then a problem will arise and cannot be resolved mathematically, regarding that both criteria have to be met. Instead of this, it is possible to obtain:

- Maximal availability according to the set costs of investment in improvements and the price cost of service provided by the system, or
- To minimize the costs of investment in improvements and the price cost of service provided by the system according to the set availability.

Therefore, one of criteria has to be set in advance and expressed as a restriction, on the basis of which the other one could be optimized.

The information required for optimization of the system availability, which is very extensive, might be provided by the continuous monitoring of system operations together with the application of updated information technologies.

The cost of service provided by the system shall be determined by the implementation of the budgeting process where the precise financial indicators on funds available for IT service delivery and on funds that may be spent within the budget period shall be provided, and the spending of budget funds during the year shall be monitored as well.



In Figure 4 the structure of the cost of the service provided by the system, annually, according to the budget items is shown. In the calculations of the budget for the precisely determined timeframe, within which the improvements of real system were implemented, the following costs of IT system elements were considered:

- IT equipment costs – hardware;
- IT applications costs – software;
- Costs of employees;
- Costs of business premises;

- Costs of external services.

Figure 5 shows the structure of implemented investments in technical and technological improvements of the real system, implemented on the basis of previous identification of critical elements, for the purposes of enhancing the user availability level. On the basis of previously implemented analysis, the conclusions drawn in 3.

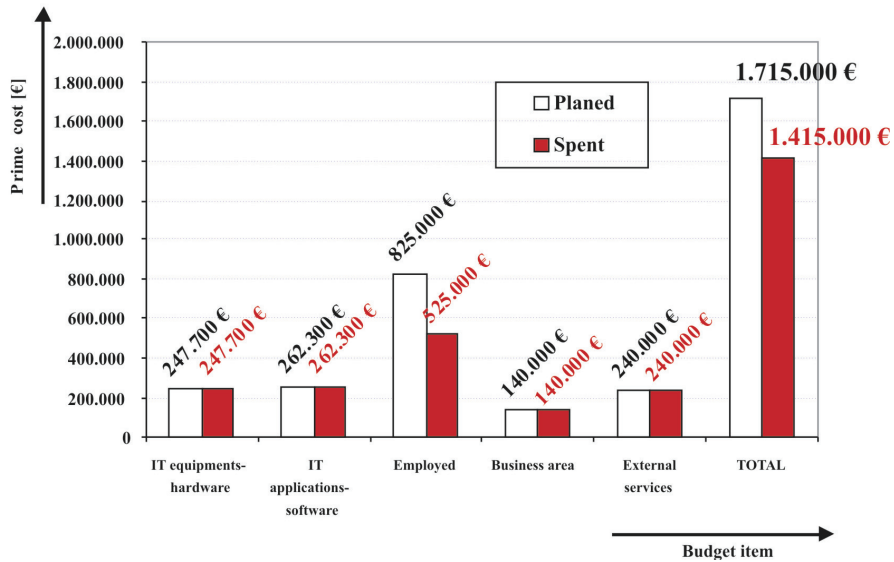


Fig. 4. Structure of annual price cost of the real system service

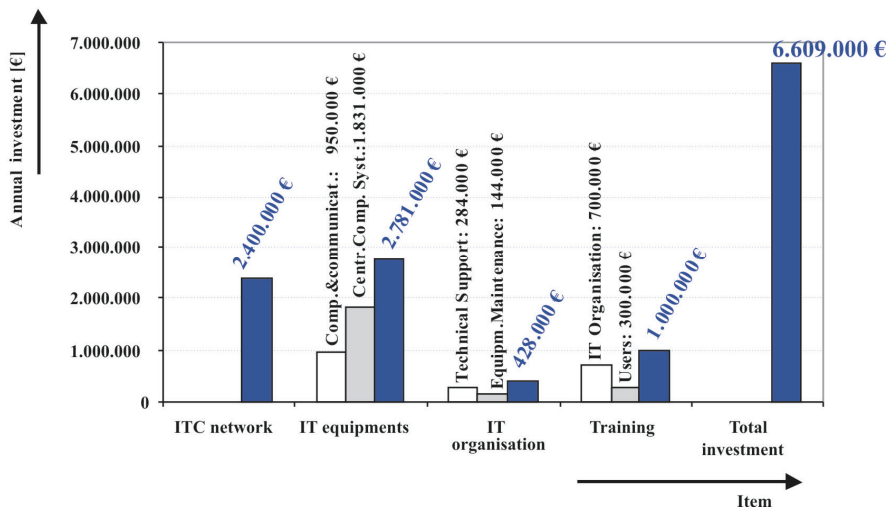


Fig. 5. Structure of costs of investment in the real system improvements

The models of management of real system outgoing performances rely upon reliability indicators and optimization criteria mostly of the minimal costs or maximal availability, or on the basis of compromise thereof. The complex technical systems have to be analyzed and resolved in order to meet all the business requirements set, to ensure all the necessary features and characteristics, high quality in use, high dependability and low life cycle costs.

The implemented strategy of availability management is based on the risk management, identification and elimination of critical elements and optimization of the process according to the price of the service provided by the system and costs of investment in improvements.

The basic optimization criteria in the implemented methodology is the cost price of the service provided annually by the system, on the basis of which a maximal value of investment costs in improvements and the elimination of critical elements are defined. With respect that the cost of the service of the system amounts to € 1,415,000 (Figure 4), and that the investments in information system amounts to € 6,609,000 (Figure 5), the result is a relation according to which the investments are 4.67 times higher in comparison to the cost of service. Having in mind that according to international IT standards and recommendations, the amount of investments in improvements in relation to the annual cost of service should not be higher than 5 times ([9] and [13]), the results obtained from analysis indicate that one of the set optimization criteria has been met.

Considering the obtained results (investments are 4.67 times higher in comparison with the cost price of service and their value is real in relation to the annual cost price of service), it could be said that the impact of investments on increase of the user availability level of the real system is extremely high and that it amounts to 0.75% approximately.

It could also be concluded that by the methodology implemented, critical elements of the system were precisely and regularly identified, since, as the final result of

investments in elimination of critical elements and improvement of critical business processes, an increase of user availability level of the entire system was obtained.

#### 4 CONCLUSION

In IT systems with a high availability level, it is necessary to make great efforts and obtain high costs in order to provide an insignificant improvement of availability. To overcome these problems, it is needed to permanently optimize the IT Infrastructure availability, which is the key activity of availability management. In this manner, it is possible to improve the availability level by more reasonable costs.

To meet the business requirements for the enhancement of availability level, it is necessary to ensure the financial investments for the purposes of improvement of IT Infrastructure and enhancement of the IT organization capacities. It is important to justify each additional investment for improvement of the availability level of system from the perspective of costs in relation to the obtained results. With the implementation of availability management methods and techniques it is possible to identify the potentials for the maximal improvement in relation to the optimal costs.

The availability management and planning should make an impact within the IT organization on providing continuity of availability and stability of IT Infrastructure. The continuous improvement is the key element of "quality-management" and provides the "value added" and favorable prerequisites for both the business and users.

#### 5 NOMENCLATURE

DT	- Downtime, min
$\Delta$ DT	- Absolute error of the Downtime, min
N <sub>user</sub>	- Number of users
$\Delta$ rN <sub>user</sub>	- Relative error of the Number of users, %
EUDT	- End User Downtime, min
$\Delta$ EUDT	- Absolute error of the End User Downtime, min

AST	- Agreed Service Time, min
$\Delta$ AST	- Absolute error of the Agreed Service Time, min
Nuser	- Total numbers of users
$\Delta$ rNuser	- Relative error of the Total numbers of users, %
$\Sigma$ EU DT	- End User Downtime-sum, min
$\Delta$ $\Sigma$ EU DT	- Absolute error of the End User Downtime-sum, min
EUPT	- User processing time, min
$\Delta$ EUPT	- Absolute error of the User processing time, min
EUA	- End-User Availability, %
$\Delta$ EUA	- Absolute error of the End-User Availability, %
$\Delta$ r EUA	- Relative error of the End-User Availability, %

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