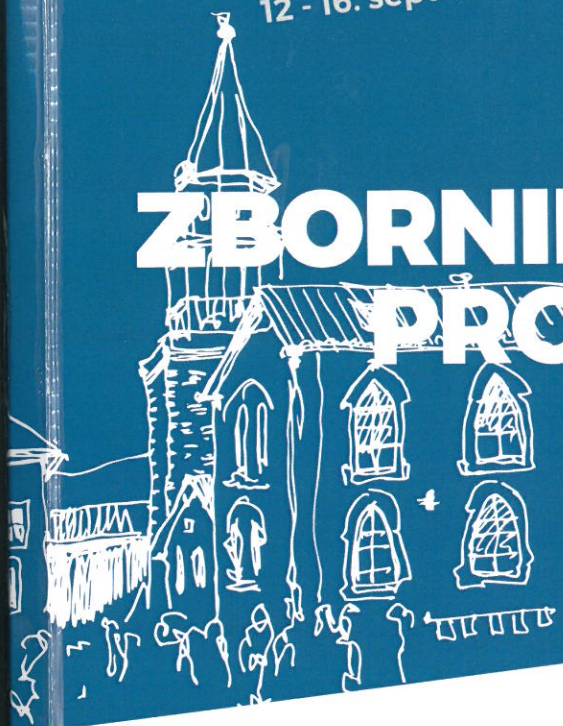
ISSN 1986-583X

7. KONFERENCIJA
7TH CONFERENCE

# ODRŽAVANJE 2022

Budva, Crna Gora
12 - 16. septembar 2022.

# MAINTENANCE 2022



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**7. Konferencija „ODRŽAVANJE 2022“ / 7 th Conference „MAINTENANCE 2022“**
**12 - 16. septembar / september 2022., Budva, Crna Gora**

**Urednici / Editors:**
v. prof. dr. Fuad Hadžikadunić
r. prof. dr. Darko Petković

**Izdavač / Publisher:**
University of Zenica, Fakultetska 3, 72000 Zenica
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Faculty of Mechanical Engineering in Zenica, Fakultetska 1, 72000 Zenica
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**Za Izdavača / For publisher:**
Prof. dr. Jusuf Duraković

**Lektor / Lector:**
Mr. sc. Branka Petković, prof. bhs jezika i književnosti

**Tehnička priprema / Technical assistance and DTP:**
mr. Emir Đulić, Emir Čaplja

**Štampa / Printed by:**
GRAFORAD Zenica

**Za štampariju / For printing shop:**
Pero Letić

**Izdanje / Issue:**
200 primjeraka / copies



**ISSN 1986-583X**

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**Dear Sir / Ms,**

The Proceedings of the 7th Conference 'MAINTENANCE 2022' is in Your hands.

We want to believe that this Proceedings finds You in good health and in an even better mood. In this sense, we believe that You will find a lot of interesting things in it for yourself, your organization, colleagues, students or friends.

We also hope that the pandemic adversities and unpredictability, at least in the form of a significant disruption of life and activity, are behind us and that with significant energy and further hopes we continue the tradition of realizing the Conference, which has been going on for the 14 years, as well as our other activities from domain of personal and professional life.

This year 2022, we have the special honor of having renowned academic Institutions participate in the organization of the 7thconference 'MAINTENANCE 2022': Faculty of Maritime Studies Kotor - University of Montenegro; Engineering faculty - Harran University, Şanlıurfa in Turkey; Faculty of Mechanical Engineering - University of Maribor; Faculty of Technical Sciences - University in Novi Sad and Faculty of Mechanical Engineering - University of Slavonski Brod. We kindly thank the Deans and Management of the Institutions for this honor and contribution, and certainly also the contribution of authors and co-authors with very high-quality papers.

Also, in efforts to strengthen the connection between academic institutions and the industry sector of the European region, a certain number of business entities participate in the Conference through published papers and other forms of support. This strengthens mutual cooperation between Universities and Faculties, strengthens cooperation between the academic and industry sectors, and makes a huge contribution to the exchange of knowledge, experience and information from the domain of the most modern methods and technologies in the field of maintenance of various complex systems.

In the total process, 76 papers were submitted, and 64 peer-reviewed and proofread papers were accepted. Given that the process included vacation periods in one part, although abstracts were submitted, some papers did not reach the final version, and we hope that these quality papers will soon be published in one of the next conferences or publications.

The realization of the Conference itself, among other things, is planned through 'face-to-face' and 'on-line' presentation of papers. The implementation of Keynote papers, peer-reviewed papers by section is planned, and we expect that through quality discussions, questions and answers, a significant contribution will be made to the exchange of modern information, methodologies and technologies in the field of maintenance of complex systems, with special reference to practical experiences from the industrial environment. A certain number of papers and the planned 'round table' will try to shed light on the need for a more significant realization of 'dual education', as one of the forms of stronger connection of students' output competencies and the needs of the real industry sector in the area of complex systems maintenance. There is hope that the overall activities and contents realized in Budva, Kotor and Tivat will meet the expectations of the participants of the Conference.

Once again, we sincerely thank the Deans and Management of the respected co-organizing Institutions, all authors and co-authors of papers, reviewers, industry entities, and all meritorious others, for their extremely significant contribution to the realization of the Conference and Proceedings.

With the wish for good health and further joint successes, we want the Conference 'MAINTENANCE 2022' to be successfully realized through joint efforts, and the next one in 2024 - even more successful.

**Sincerely,**

assoc. prof. dr. Fuad Hadžikadunić - President of the Organizing Committee
prof. dr. Darko Petković - President of the Scientific Committee
senior assit. mr. Emir Đulić - secretary

Budva/Kotor/Tivat, September 2022.

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## UVODNI REFERATI / KEYNOTE PAPERS



## SEKCIJE / SESSIONS

# ANALIZA OBLIKA I UČESTALOSTI KVAROVA KORISNIČKE INFORMACIJSKE I KOMUNIKACIJSKE OPREME

# ANALYSIS OF THE FORM AND FREQUENCY OF FAILURES OF USER INFORMATION AND COMMUNICATION EQUIPMENT

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## ABSTRACT

*The use of modern information and communication services (ICS) is conditioned by using advanced information and communication equipment (ICE). The provision of the ICS can be achieved through various transmission technologies. The key factors for the ICS provider are the decision-making processes adopted for various types of ICE, the type of supporting technology and the type of ICS. Failure analysis makes it possible to obtain a broader view which ultimately reduces the risk and increases the reliability of ICS delivery. This paper presents an analysis that provides insight into the forms and frequency of failures on ICE at the level of the selected telecommunications operator.*

**Keywords:** information and communication equipment, network monitoring, failure analysis, reliability, lifecycle

## REZIME

*Korištenje suvremenih informacijsko-komunikacijskih usluga (ICS) uvjetovano je korištenjem suvremene informacijsko-komunikacijske opreme (ICE). Pružanje ICS-a može se postići različitim tehnologijama prijenosa. Ključni čimbenici za pružatelja ICS-a su procesi donošenja odluka usvojeni za različite vrste ICE-a, vrste prateće tehnologije i vrste ICS-a. Analiza kvarova omogućuje dobivanje šireg pogleda što u konačnici smanjuje rizik i povećava pouzdanost isporuke ICS-a. U radu je prikazana analiza koja daje uvid u oblike i učestalost kvarova ICE-a na razini odabranog telekomunikacijskog operatora.*

**Ključne riječi:** informacijska i komunikacijska oprema, nadzor mreže, analiza kvarova, pouzdanost, životni ciklus

## 1. INTRODUCTION

Monitoring of the electronic communications network and of the maintenance process through failures is an important factor in the informational, technical, functional, and operational work of the public communication network operators, i.e. the telecommunication operator, as a link between the users i.e., control of the operation of the user service, operational management and the entire control of the network operation and planning. This has also been regulated legislatively [1, 2]. In accordance with the operational processes of managing the user ICS, the solving of the faults on the users' equipment is affected proactively through the control of the network, and this acts at the users' satisfaction [3]. Real-time failure monitoring is operationally critical in order to properly allocate the resources to resolve ICE issues and affect the improvement of the existing failure resolution processes.

In this paper, the emphasis is placed on the traffic network of operators of public communication networks through which the telecommunication traffic takes place, and it is monitored from 0 to 24 hours. The system of network and failure monitoring is used to describe the method of monitoring traffic and the operation of the network elements as well as the users' equipment as the end point of the access network. The process of system operation has been shown structurally at the moment when the end user's ICS stops working. In that case, the monitoring system is used to proactively diagnose the fault and the ICE of the user is replaced, with the aim to ensure that the user is without ICS for as short as possible. Due to the shortening of the period of inability to use the ICS, there is special effort to replace the ICS as quickly as possible in situations when the number of failure reports increases. Fast detection through the network monitoring system, fast diagnostics and speed of action, i.e. troubleshooting, ultimately increases the user satisfaction.

The current research is mainly related to the issue of the impact of the lifecycle and service life of the network equipment and the components regarding the selected information and communication technology (Internet technology, smart grid, etc.) [4]. The authors in papers [5, 6] deal with the analysis of the methods of strengthening the LAN (Local Area Network) maintenance and reducing the computer network failures. The operator of public communication networks apart from the obligation of delivering the network equipment to the user (ICE), continuously monitors the reliability and the lifecycle of ICE, considering the maintenance issues at several levels [7]. The reliability and the lifecycle of ICE of the telecommunication operator, observing the maintenance issue through the dynamics of failures, the time of resolution, and call, are the subject of research and standardization [8, 9]. The results of the study show that inappropriate maintenance models affect the reduction of continuous operation of the equipment, which eventually results in the dissatisfaction of the end users [10]. A well-maintained communication network requires less corrective maintenance and becomes more cost-effective and reliable for the work and provision of ICS. Preventive or predictive maintenance in the context of a telecommunication network is a set of predefined strategies aimed at reducing the impact of component damage in the communication network. [11].

The purpose of this research is to conduct an analysis of the occurrence of failures on the ICE of the public communication network operators. The goal of the analysis is to correlate the causes, i.e. the type of infrastructure, service provided, equipment, number of users, etc., and the consequences, which in this case is the occurrence of ICE failures. The paper is structured in five chapters which provide the insight into the system of control and monitoring of the failures of the telecommunication operators, and the implementation of the monitoring of the network, and control of the ICE operation. The telecommunication operator's network monitoring system, analytics (from data collection to data processing), and data correlation, as well as specific ways of detecting certain types of failures and real-time monitoring, are

explained. Chapter 2 describes the standardization of the monitoring and management of telecommunication systems by the public communication networks. Chapter 3 describes the control of the public communication networks operator systems, monitoring of the user equipment and monitoring of the failures. In Chapter 4 the types of failures are defined, and the analysis of the failures is performed on the example of a selected telecommunications operator. Chapter 5, the conclusion, summarizes all the information collected and processed during the work on this paper. The paper includes graphical presentations of the method of monitoring certain relevant statistical elements and indicators of failures and disturbances at the level of the selected operator of the public communication networks in Croatia.

## 2. STANDARDIZATION OF MONITORING AND MANAGEMENT OF TELECOMMUNICATION SYSTEMS

The concept of the Telecommunications Management Network (TMN) was brought by the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T), intended for the standardization of the control and management of telecommunication systems [12]. As a follow-up on TMN, the Tele Management Forum (TMF) organization developed the concept of eTOM (enhanced Telecommunication Operations Map) which focuses on the management of ICS and of end users [13].

With these concepts the building of a special network is recommended for collecting data from every single element of the network in the operational systems which are processed and made available to the users at workstations. Also recommended is the protocol standardization in order to enable the introduction of a unique system for monitoring and management, regardless of the function of the element in the electronic communication network and regardless of its manufacturer. Apart from standardization of interfaces between single network elements, the areas of application of monitoring and managing in the electronic communication network, i.e. the databases and types of data required for certain areas, have also been standardized. This is applied in the following areas:

- Data Base Management;
- Configuration Management;
- Fault Management;
- Security Management;
- Performance Management, and
- Billing Management.

## 3. OPERATOR NETWORK MONITORING, USER EQUIPMENT MONITORING, AND FAILURE MONITORING

In order for the network to be sustainable and complete, the monitoring of the network is a necessary segment through which the network is managed [14]. The communication between network elements is performed by means of different and mutually compatible protocols. The monitoring of the entire telecommunication system is done by means of the interface which is used to manage all network elements and their links, and the interface displays: live monitoring of the operation of all network elements, a system for displaying the operation of all network elements through graphs, system of displaying the operation of all connections, alerting system, announcement of works, a list of active / inactive faults, on-call calendar, display of tables and maps, maps with GEO locations of all users, statistical data and the overview of all historical events [12, 13]. The monitoring and management system has the task to monitor the state of all network elements and services in the network and send timely information in case an individual network element has operational problems. The management of user equipment monitoring functions takes place through the interface, and for high-quality monitoring and management systemic communication with the network

elements is required, so that the system would collect information on the operation of single elements, process them, and analyse them. Network monitoring and failure monitoring by the telecommunication operators is done at the following levels: network elements, connections between network elements, the entire network on the transit, interurban, and urban (metro network) levels, user equipment and user services.

The network monitoring system has the feature of detecting all the problems in the network. By collecting the data from network elements and monitoring the operation of the users' service, their systematic analysis results in timely reaction. For the purpose of faster resolution of the failure, interruption of the operation of the customer service, which occurred due to the technical fault, through the CRM (Customer Relationship Manager) system and the system for monitoring, management and diagnostics of broadband services, a rapid identification of the users and the diagnostics of the failure are possible. By monitoring the network in the function of detecting and resolving the failures we want to achieve proactivity. This is achieved by using the system for monitoring, managing and diagnostics of broadband services to identify the service operation interruption, and to diagnose the failure. Regarding its purpose, the system has an indisputable technical advantage of detecting and correlating the data of other systems, but the advantages in the reaction and proactivity are the crucial elements, and the drawbacks are unfavourable in terms of finances.

Maintenance management is defined as a function related to the maintenance technologies, equipment design regarding reliability and sustainability, sustainability research and reliability regarding improving operations. Proper and functional user network equipment is the basic precondition for access and use of the service by the service provider. The telecommunication operator must ensure adequate user network equipment. Also, they can increase the level of reliability in the equipment performance by predicting the failure probability and the conditions necessary to maximize the lifecycle of the equipment.

The user support uses requests to log reported issues. For each problem reported by the user, one request is created, with the associated problem area. This means that if a user during one call reports several problems, several requests need to be entered in CRM and they will all be connected to the same call. The connection with CRM system allows activation of the troubleshooting process regarding user problem, and the procedure of replacing the equipment and returning the defective equipment, and the interruption of the operation of a certain ICS is most often seen as an example of the failure.

## 4. ANALYSIS OF ICE FAILURES ON AN EXAMPLE OF PUBLIC COMMUNICATION NETWORK OPERATOR

Analysing various statistical data about the distribution of failures on the network equipment of the chosen telecommunications operator, it is possible to distinguish the failures regarding: sort of failure, type of failure, network infrastructure, access technology, failure report, recurring failure and failure logout report and failure location. When reporting malfunctions, the task of the telecommunications operator is to keep a detailed record of reporting difficulties in using the services and diagnostics of the network infrastructure and the user equipment (CPE, Customer Premises Equipment, and STB, Set-Top Box). Early diagnostics and preventive diagnostics allow the operators of public communication networks a faster access and method of solving the problems, and monitoring and control of the failures in the function of failure detection is performed by means of the system for monitoring and diagnostics. In order for the network of the telecommunication operator to be complete and sustainable, functional and operational, it is necessary to connect the network monitoring system with other systems in the network so that network monitoring becomes an indispensable segment which is used to manage the telecommunication network and user services. Failure monitoring is performed through a series of parameters in order to monitor

the technical stability of the network and the operation of the user equipment (at the same time also the service provided through the equipment, CPE and STB), and also to influence the future failures and operational organization in elimination of failures. With this, the failures can be monitored according to the status (open or closed faults), time of fault removal, geographic distribution, type of network equipment, level of resolution (remote access at the level of user support, on-the-field activity, replacement of equipment, problem on the network part), service, user segment, etc. The analysis of the failures of the public communication network operators has been made for the three observed years (2020, 2021 and 2022), i.e. the comparative presentation refers to the following periods: 1 January 2020 – 31 May 2020; 1 January 2021 – 31 May 2021 and 1 January 2022 – 31 May 2022.
Figure 1 shows the level of troubleshooting in the observed period. The analysis found that almost 55% of all failures are eliminated through communication with the end user for the purpose of resolving the failures at the first level. At the second level, almost 33% of failures are eliminated, which include solving by remote access and going out to the field by a technician. Almost 12% of all failures are solved by direct equipment replacement, and the public communication network operators replace the equipment for which the failure is detected immediately through delivery services, due to the price i.e. costs.

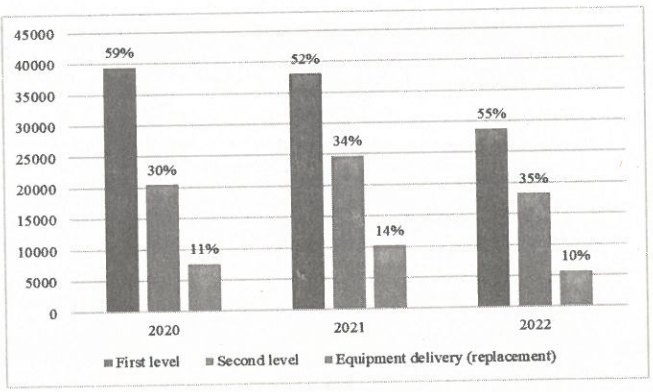


*Figure 1 – The level of troubleshooting in the observed period*

The analysis gives insight into the forms and frequency of ICE failures through the following parameters: fault resolution level, sort of failures, type of failure, and the user equipment. Table 1 shows the types of failures for the observed period of time.

*Table 1. Types of failures for the observed period*

| Type of failures | 2020 | 2021 | 2022 |
|---|---|---|---|
| Internet connection failure | 19% | 20% | 24% |
| Network infrastructure failure | 19% | 17% | 18% |
| Impossibility of establishing an xDSL connection | 17% | 17% | 17% |
| Interruption ("bursting") of the line | 16% | 16% | 15% |
| IPTV quality problems | 7% | 8% | 7% |
| IPTV is not working | 7% | 6% | 5% |
| Faulty CPE equipment | 5% | 5% | 4% |
| Defective STB equipment | 4% | 4% | 4% |
| Problems with xDSL quality | 4% | 4% | 3% |
| Voice service problem | 4% | 4% | 3% |

The analysis of the failures of the telecommunication operator regarding the type of failure found that the biggest problem generators are the quality of the network infrastructure which affects the Internet connection, establishment of xDSL connection, and the physical problems

in the very infrastructure. Line quality failures, i.e. line interruptions are the second most common group of problems that depend again on the quality of the network infrastructure (in Croatia 76% is copper public communication network). Defective equipment represents 4-5% of all failures reported by the end users while using the service.
Figure 2 shows the types of failures for the observed period. The analysis per type of failure of the telecommunications operator gives us an overview and the relation between three key variables: service degradation (the service works, but with reduced quality and with frequent interruptions on the line), failure (when the service does not work at all), and force majeure (failures that are under the influence of weather or other weather conditions).

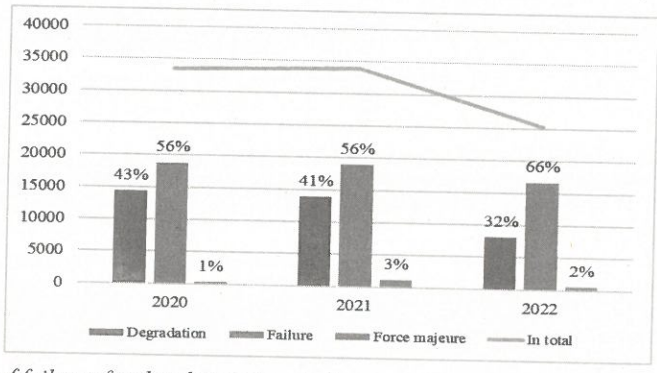


*Figure 2 – Types of failures for the observed period*

Table 2 shows the failure report or the location of the failure for the observed period. The analysis of failures by check-out i.e. by location of the failure where by the detection upon resolving the problem the failure had occurred, shows that almost 36% of all failures occur on the network infrastructure which is the consequence of reduced quality of service, load, and absence of maintenance of the existing copper access network.

*Table 2. Failure report/failure location for the observed period*

| **Failure report / failure location** | **2020** | **2021** | **2022** |
|---|---|---|---|
| Network infrastructure failure | 36% | 36% | 36% |
| Failure solved by changing profile | 15% | 11% | 11% |
| Failure in responsibility of the user (home installation, connection of equipment) | 13% | 11% | 10% |
| Modem failure (replacement) | 10% | 15% | 17% |
| Failure was solved on the second level (remotely; by upgrading the modem and stabilizing the line) | 7% | 10% | 10% |
| Defect on the output cabinet | 6% | 4% | 4% |
| STB failure (replacement) | 5% | 7% | 4% |
| Replacing the remote control | 5% | 3% | 2% |
| Application cancelled; the user solved the problem according to the instructions | 4% | 4% | 5% |

If we add the end point of the network (outlet cabinets) to the network infrastructure, almost 41% of failures occur on the network part. DSLAM (Digital Subscriber Line Access Multiplexer) profiles and line stabilization make up 13% of all failures and are resolved by remote access, and if other faults are added that are solved by remote access, such as device upgrade and additional stabilizations of the user line, the percentage of 22% is reached, of failures that are resolved remotely. Equipment replacements (CPE, STB) account for a total of 20% of all failures. Also, by analysing the failures that are generated by the user, incorrect connection of the equipment, home installation, careless manipulation of the equipment, etc. it results that these are the causes of almost 15% of all failures.

Figure 3 shows the logging of malfunctions (service) for the observed period.

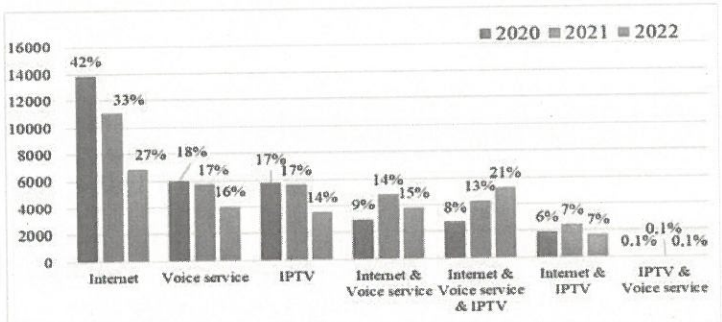


*Figure 3 – Logging of malfunctions (services) for the observed period*

The analysis of failure logging at the level of service for which the failure is reported, the Internet connection and the quality of Internet operation have the highest share of 34%, and for the reduction over the three years the selected telecommunications operator argue that this is due to better monitoring, following the trends by introducing new user equipment and ultimately by stabilizing the line on DSLAM. After the Internet, the share of voice services and IPTV that are reproduced in real time, is relatively the same and ranges between 14% and 17%.

*Table 3. Modem replacements due to failure for the observed period*

| Modem replacements due to failure | 2020 | 2021 | 2022 |
|---|---|---|---|
| Iskratel Innbox v45 VDSL AnnexB | 43% | 72% | 76% |
| Iskratel Innbox v45 POTS | 40% | 0% | 0% |
| TP link TP8961 ND ADSL AnnexA | 7% | 11% | 9% |
| Iskratel Innbox v51 VDSL AnnexB | 4% | 6% | 6% |
| TP link TDW8951 ND ADSL AnnexA | 3% | 5% | 3% |
| ZTE H108L ADSL AnnexA | 1% | 2% | 2% |
| Iskratel Innbox v51 POTS | 0% | 0% | 1% |
| Sagem 1704 | 1% | 2% | 1% |
| TBAND TB9600A1 ADSL AnnexA | 1% | 1% | 1% |
| TBAND TB9600A1 VDSL AnnexB | 1% | 0% | 0% |

Table 3 shows the percentage of modem replacement due to failure for the observed period. The public communication network operators follow the trends and introduce new user equipment. According to the data presented in Table 3, it is evident that there is periodic mass replacement of services and the interruption in their distribution in the coming years (e.g. Iskratel Innbox v45 POTS is not being used after 2020 anymore). Also, one can see which ICE is more represented in the replacements, and the lifecycle of ICE is monitored in order to realistically plan the purchase of new and repair of the existing equipment.

## 5. CONCLUSION

Network control and real-time failure monitoring is an important and necessary factor in the entire telecommunication system and very significant for the integrity, stability of network and user experience. The monitoring system is used at all network levels, from network elements in the very network of the telecommunications operator to the control of user equipment and collection and analysis of data. From the aspect of user experience, proactive action is a factor that has impact on the lifecycle of the user, which, for the telecommunications operator means the realization of profit. Today's trend is that the systems for monitoring and control have the analytics, and that the system and the data are accessed

through the interface, and the emphasis is placed on proactive action. The systems for monitoring and control are very complex systems with the aim of being oriented to business efficiency, data analysis and proactive action. After the performed analysis, the correlation between the occurrence of failures and the quality of the public communication network can be seen. The development of advanced ICS and the increase of the base of the end-users show that the occurrence of failures is more frequent on the copper communication network. Wider introduction of FTTx (Fiber to the x) technologies represents an assumption that the failures in the communication segment will be less frequent. The end goal is to increase the reliability and availability in providing ICS to the end user. The future research expects the implementation of Weibull distribution by using specialized programming tools in the function of higher quality in determining the reliability and lifecycle of ICE.

## REFERENCES


[1] Croatian Parliament.: Law on Electronic Communications, NN 76/22. Zagreb, Croatia, EU; 2022.

[2] HAKOM.: Ordinance on Amendments to the Ordinance on the Ways and Conditions of Conducting Activities of Electronic Communication Networks and Services, NN 68/2019. Zagreb, Croatia, EU; 2019.

[3] Grgurević I, Jović I, Jasak M, Brodarić A.: Reliability and Lifecycle of User Network Equipment for Provision of Telecommunication Services. In Održavanje 2020 - Maintenance 2020; 2020; Zenica, BiH. p. 15-22.

[4] Itten R, Hischier R, Andrae ASG, Bieser JCT, Cabernard L, Falke A, et al.: Digital transformation—life cycle assessment of digital services, multifunctional devices and cloud computing. The International Journal of Life Cycle Assessment. 2020; 25: p. 2093-2098.

[5] Liu J.: Analysis of Computer Network Maintenance Strategy Based on Lan. Journal of Physics: Conference Series; 2021; 1744: p. 1-4.

[6] Duan J.: Computer network fault analysis and maintenance research. Science and fortune. 2015; 7(2).

[7] Aleksic S, Mujan V.: Life Cycle based Analysis of ICT Equipment for Advanced Metering Infrastructure. In 13th International Conference on Telecommunications (ConTEL); 2015; Graz. p. 1-7.

[8] ETSI.: Environmental Engineering (EE); Life Cycle Assessment (LCA) of ICT equipment, networks and services; General methodology and common requirements. Sophia Antipolis Cedex: European Telecommunications Standards Institute; 2011; Report No.: ETSI TS 103 199 V1.1.1.

[9] ITU-T.: End of Life Management for ICT Equipment. Geneva: International Telecommunication Union Telecommunication Standardization Sector; 2012.

[10] Kareem JAH, Saeed KFA, Faraj OMM.: Maintenance Practices in Poor Uptime of Operating Equipment Toward Dynamic of Business Issues. International Journal of Innovation and Technology Management. 2018; 16(2): p. 1-21.

[11] Hossain K, Shahrir MS, Yusof MIM, Yusof Z, Asraf NM.: Predictive Maintenance of Network Elements using Markov Model to Reduce Customer Trouble Tickets. In IEEE 2nd International Conference on Big Data Analysis (ICBDA); 2017; Beijing. p. 31-36.

[12] ITU-T.: Recommendation M. 3100 and M. 3400. Geneva, Switzerland; 2000.

[13] TM Forum.: Enhanced Telecom Operations Map (eTOM), The Business Framework. London, UK; 2010.

[14] Salau A, Yinka-Banjo C, Misra S, Adewumi A, Ahuja R, Maskeliunas R.: Design and Implementation of a Fault Management System. In Abraham A, Gandhi N, Pant M, editors. Advances in Intelligent Systems and Computing, Innovations in Bio-Inspired Computing and Applications (IBICA 2018). Cham: Springer; 2019, p. 495-505.

**Budva, Crna Gora**
**12 - 16. septembar 2022.**

ISSN 1986-583X