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Editor's note

We are delighted to present Vallis Aurea (Journal of Sustainable Development and Innovation) due to successful cooperation between the School of Industrial Fisheries, Cochin University of Science and Technology and the Faculty of Tourism and Rural Development. The Journal **Vallis Aurea** (*Journal of Sustainable Development and Innovation*) is devoted to multidisciplinary research in the fields of management, economics, entrepreneurship, tourism, sustainable development, gastronomy, food safety, quality control and innovation, addressing complex issues that are closely intertwined with other disciplines such as information and communication sciences, law, sociology, psychology, and other relevant fields.

The journal aims to foster an integrative approach to understanding the dynamic and interconnected nature of economic and entrepreneurial activities, the evolving trends in tourism, the principles and practices of sustainable development, and the role of innovation in driving societal progress.

The journal focuses on a wide range of topics, including but not limited to economic theories and models, entrepreneurship and its impact on society, sustainable and responsible tourism development, innovative practices in business and management, the role of technology and information systems in economic and social development, the legal and regulatory environment of business, societal and psychological aspects of entrepreneurship and economic behaviour, the impact of innovation on competitiveness and growth, sustainable business practices, and the integration of environmental and social considerations into economic and business strategies.

By emphasising a multidisciplinary perspective, the journal aims to contribute to the development of knowledge and understanding that supports the advancement of sustainable and innovative economic and business practices, the promotion of entrepreneurship, the enhancement of tourism, and the achievement of a more sustainable and prosperous society.

Vallis Aurea (Journal of Sustainable Development and Innovation) is a biannual journal that affirms an integral, holistic view of interdisciplinary research. It aims to unite academic methodology and sincerity with professional focus and practices.

We are dedicated to achieving and maintaining this journal's high standards. All articles submitted for publication in this journal are subjected to a double-blind review process performed by at least two academics from the Editor's Board. Reviewers stay anonymous.

With all our hearts and sincerity, we express our deepest gratitude to all the authors, reviewers, and editorial board members for their valuable contribution to this journal. We look forward to successful cooperation.

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IMPROVING ACCESSIBILITY OF E-LEARNING SYSTEMS FOR VISUALLY IMPAIRED STUDENTS IN SRI LANKA

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Abstract: *Purpose: This study aims to investigate the means to improve the accessibility of e-learning systems for visually impaired students in Sri Lanka. It focuses on addressing the challenges these students face, particularly during the shift to online learning brought about by the pandemic.*

Design: The study builds on the Web Content Accessibility Guidelines (WCAG), utilizing the POUR principles, Perceivable, Operable, Understandable, and Robust as the conceptual framework.

Methodology: A quantitative design was employed to examine the impact of these principles on learner satisfaction.

Approach: The sample consisted of 150 visually impaired students from the Ceylon Deaf and Blind School, selected through purposive sampling.

Findings: The analysis revealed that both the Perceivable and Understandable factors had a positive and significant impact on learner satisfaction. However, the Operable and Robust factors did not show a significant impact, indicating areas that require enhancement.

Originality/Value: This research contributes to the field by providing empirical insights into the accessibility challenges faced by visually impaired students in Sri Lanka. It underscores the need for improvements in e-learning system design, particularly in operability and robustness, to ensure equitable access.

Keywords: *Accessibility, E-learning, Visually Impaired Students, WCAG, POUR Principles, Learner Satisfaction.*

1. Background of the Study

Technology is a fundamental aspect of contemporary society, it significance is prevalent in all industries including the education system. Information Technology cannot be simply dissociated from pedagogical practices and educational progress. The role of technology is critical in our livelihoods that it is vital for students to develop problem-solving, organizational and crucial skills to meet the demands of an increasingly technology-oriented workplace and become fully integrated members of society. Thus, education is heavily influenced by the emergence of new information and

communication technologies. One such development within the field of education is the concept of e-learning. Since the mid-1990s, within the educational sphere, the number of universities or colleges utilized e-learning to provide high school education, degrees, and courses has grown exponentially. E-learning is a learning/teaching approach that may make up all or a portion of the educational model adopted. It substantiates on the use of electronic devices and media to improve access to interactions and discussions that facilitate the establishment of a new way of learning and comprehending. Accordingly, e-learning has a direct relationship with novel technologies which support the concept of online learning platforms as a conducive means to improving the accessibility of education in terms of providing instruction where students can access wherever and whenever they want. Additionally, it is hoped that students who cannot attend formal education will be able to complete their programs with the aid of remote learning programs. Therefore, it can be claimed that the concept of distant learning is to make education more accessible. However, there are also concerns about how accessible online learning settings are for students with disabilities. (Burgstahler, 2004) assert that the ultimate purpose of distance learning to make education accessible to everyone which cannot be simply achieved unless the course design is inclusive of all students, including those with disabilities. However, accessibility is rarely a top consideration for those who create online courses, and those who have impairments are not thought of as a significant category of students (Treviranus, 2006). Visually impaired students or learning system users are a group that has the greatest barriers to accessing and utilizing educational technologies. Statistics show that there are more blind students enrolling in schools and universities each year, but technological advancements have not kept up. The Ceylon School for the Deaf and Blind (CSDB) was established in the year 1912 with the objective of making education accessible for the disabled students particularly with hearing and sight impairments (Padmasiri, S., 2013). Around 1.7% of Sri Lankans are blind approximating to 364,000 people being blind. Thus addressing the socio-economic needs of the blind is an important factor given the considerable numbers. There are approximately 600 students currently enrolled at the CSDB (Padmasiri, S., 2013). However, these students were significantly challenged with the onset of the pandemic where remote or e-learning became a prevalent form of education amidst concurrent lockdowns. These e-learning systems are of little relevance to the visually impaired. To avoid a decline in social mobility these inequalities in the education system need to be mitigated (Pendigrast, R., 2021). It is crucial to make sure that those with vulnerabilities can access and use instructional materials, particularly those provided through online learning management systems for equality in education systems. Thus, the purpose of this study is to improve the accessibility of e-learning systems for students with visual impairments. Therefore, the researcher intended to test an online learning management system with learners who are end users of the tool. The outcomes would then generate useful design insight for the development of a suitable e-learning system for the visually impaired in Sri Lanka.

Problem Statement

Online or e-learning has partially contributed to the massification, internationalization, and universalization of education (Karkouti., B., 2021). It has also transformed the concept of learning and teaching mechanisms, student evaluations, and professional development of faculty. With the onset of the pandemic, over 1.6 billion students were subjected to a temporary discontinuation of education (United Nations (UN), 2020), whereby educational institutions had to utilize technology to continue to provide education despite the adversities created by the pandemic. This transition ignited the importance of online education in terms of its accessibility to students. Though the prevalence of online learning in Sri Lanka is unknown, according to (Fazlulhaq, 2021) report,

only 30% of Sri Lankan students were able to migrate to online study during the pandemic. The inclusion of visually impaired students in the e-learning context in Sri Lanka is even more uncertain. Considering that United Nations Sustainable Development Goal number 4 and the accessibility offered by e-learning through ICTs, it may seem that no person willing and able to learn is left behind. The inclusion of visually impaired students (VIS) in online learning, however, has not been acknowledged. The few other related studies (Teklu A.,Samuel A., 2022) focused on the experiences of visually impaired students participating in traditional classroom settings. This is in contrast to a study (Amponsah, 2012) that focuses on the experiences of visually impaired students participating in online learning. Students with visual impairments have been generally disregarded in web-based learning in scholarly research. There is a dearth of research on the pedagogical aspects of course design at the nexus of accessibility and online learning. Moreover, there are little to no studies within the context of Sri Lanka considering the novelty of e-learning. Although web accessibility specifications and related guidelines have been elucidated and examined previously, it is difficult to deduce that these specifications have helped in solving all accessibility issues in an online context for the disabled, especially those that are visually impaired. Contextual differences can alter the experience and outcomes of the use of websites. There is an evident gap in the literature considering accessibility to e-learning for visually impaired students particularly in the context of Sri Lanka. To extend understanding and better inform web designers and other stakeholders, this study addresses the literature gap by identifying the features that need to be improved in e-learning systems for the inclusion of visually impaired students in online learning contexts.

2. Research Objectives and Questions

Research Objectives

1. To identify the accessibility problems related to e-learning systems for Sri Lankan students with visual impairments.
2. To recommend e-learning systems improvement mechanisms for better accessibility for the visually impaired students in Sri Lanka.

Research Questions

1. What accessibility problems in e-learning systems exist for Sri Lankan students with visual impairments specifically?
2. How can e-learning systems be improved for better accessibility for visually impaired students in Sri Lanka?

Research Significance

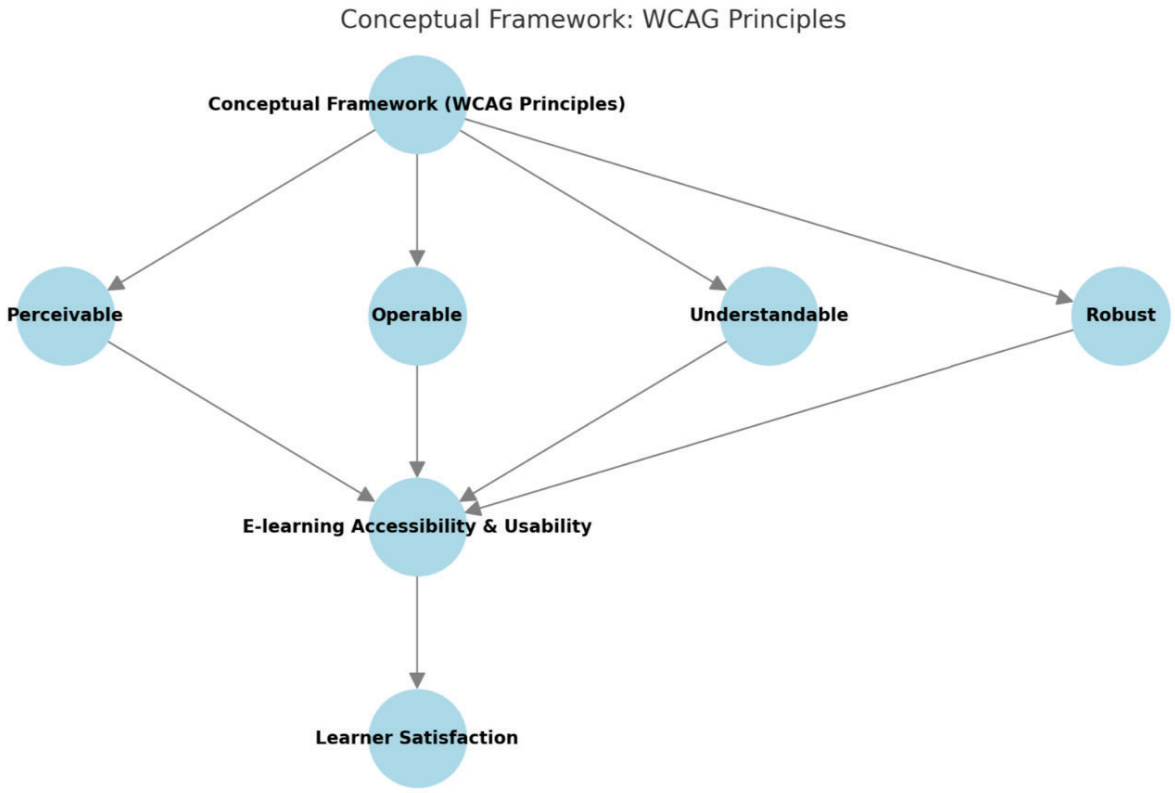
The available literature does not sufficiently examine how visually impaired students interact with e-learning systems, nor the problems typically encountered. In order to design e-learning systems to effectively support visually impaired users, it is important to first identify the design elements that are currently lacking within the e-learning system and how these could be improved for ease of use. The findings of the study will be particularly useful for the Ceylon Deaf and Blind School and the Ministry of Education of Sri Lanka, in ensuring inclusive as well as accessible education. This study will be particularly useful for website designers and developers in obtaining important information related to user experience and design especially related to the education of the visually impaired learner. The findings of this study will also be important to the management of the educational institution on how they could integrate assistive technologies in teaching. Moreover, the study would also contribute to

the body of knowledge on accessibility of e-learning systems for those with disabilities. The study would form a basis for further research in inclusive online learning more specifically in developing countries such as Sri Lanka.

Conceptual Framework

The conceptual framework representing the conceptual framework for your study. Each WCAG principle (Perceivable, Operable, Understandable, Robust) contributes to the accessibility and usability of e-learning systems, which in turn impacts learner satisfaction.

Fig. 1: Conceptual Framework: WCAG Principles



Hypotheses of the Study

The study is guided by the following hypotheses, developed based on the conceptual framework and literature review:

Hypotheses 1

H01: The perceivable factor of the e-learning system has a significant impact on learner satisfaction of visually impaired.

H11: The perceivable factor of the e-learning system has a significant impact on learner satisfaction of visually impaired .

Hypotheses 2

H02: The understandable perceivable factor of the e-learning system has a significant impact on learner satisfaction of visually impaired.

H12: The understandable perceivable factor of the e-learning system has a significant impact on learner satisfaction of visually impaired students.

Hypotheses 3

H03: The operable factor of the e-learning system has a significant impact on learner satisfaction of visually impaired.

H13: The operable factor of the e-learning system has a significant impact on learner satisfaction of visually impaired.

Hypotheses 4

H04: The robust factor of the e-learning system has a significant impact on learner satisfaction of visually impaired

H14: The robust factor of the e-learning system has a significant impact on learner satisfaction of visually impaired

3. Literature Review

Rapid advances in technology have created new possibilities in education, including e-learning, which provides flexible and accessible learning for students of all ages and backgrounds. However, not everyone, especially visually impaired students, has access to these tools. Accessibility to e-learning is an important issue to be addressed in Sri Lanka, where the prevalence of blindness is high. This literature review will review current research on e-learning access for students with visual impairments, focusing on the situation in Sri Lanka. The problems faced by visually impaired students in accessing e-learning and the strategies to solve these problems will be examined. Additionally, the review will identify gaps in the current literature and suggest future research directions. Overall, the purpose of this literature review is to provide insights and recommendations to assist educators and policymakers in improving the accessibility of e-learning for visually impaired students in Sri Lanka and other students who may face similar challenges.

This chapter sets the theoretical basis for the study. Initially the key definitions for this study are reviewed which includes the conceptualization of visual impairment and e-learning. The challenges encountered by visually impaired students in e-learning contexts is then evaluated by investigating prior studies. After which the web accessibility standards and principles are reviewed. Finally empirical evidence related to web-accessibility and implications on visually impaired is reviewed.

According to the World Health Organization (WHO), an impairment is any aberration or loss of anatomical, physiological, or psychological function or structure. This definition encompasses a broad range of conditions. Accordingly, a visual impairment is defined as any chronic visual defect that makes it impossible to carry out everyday duties and that cannot be corrected with standard eyeglasses or contact lenses. In other words, a visual impairment prevents a person from functioning normally in society. According to Holbrook (1996), a visual impairment is a loss of sight that makes it difficult or impossible to carry out everyday duties without the use of specialized tools or assistance. The World Health Organization (WHO) developed the International Statistical Classification of Diseases and Other Health Problems (ICD-10), which categorizes visual impairments into four primary forms: mild impairment, moderate impairment, severe impairment, and blindness. The definition of mild vision impairment states that a person's better eye must have a visual acuity of 6/18 or better. Visual acuity of less than 6/18 but equal to or greater than 6/60 in the better eye is what's considered to be a moderate kind of visual impairment. If a person has a visual acuity of less than 6/60 but greater than

3/60 in their better eye, they are deemed to have severe visual impairment. Visual acuity that is less than 3/60 or concomitant visual field loss in the eye that is considered to be the better eye is what is considered to be blindness.

Visual impairment in a learning environment affects a student's requirement for instructional resources that are not visually focused. This need is taken into consideration while selecting appropriate course materials. In the context of education, "visually impaired" is defined by (Bishop, 2004) as the need for tactual and/or aural channels for learning. This can be developed further, where some visually impaired students have some degree of vision for the sake of movement, while other visually impaired students might build up outlines or faces but find it impossible to read print in any size, and they will be real or auditory learners instead. Children who are visually impaired in their education mostly rely on tactile and auditory input to learn. A visually impaired student needs braille and similar media that can be perceived without the use of vision (Halliday, 2001).

E-learning is described as an alternative means to teaching and learning (Govindasamy, 2002). The basis for e-learning stems from the inclusion of electronic media including internet, extranet, intranet, audio/video tape, interactive video to deliver instructions. It can be viewed as a means of using multimedia, hypermedia and simulation (Maddux, C., 1997). Based on the definition of education and learning wales (ELWA, 2004), e-learning is the use of electronic technology to enhance, deliver and support learning and teaching. E-learning has the ability to transform learning and is effective through various modes including learning in the presence of a lecturer, trainer or teacher, whose delivery is enhanced and supported by electronic materials and media. It also enables the learner to directly interact with the teacher or mentor remotely through electronic media such as videoconferencing. Additionally, learners can learn independent through electronic means with access to online support. Peer assistance has the potential to underlie the learning process in all circumstances, which will rely increasingly on electronic technology the more physically distant the learner is. E-learning, also known as electronic learning or online learning, is the process of acquiring information using electronic technology and media. E-learning is defined simply as "learning that is facilitated electronically."

One of the main senses required for effective learning and development is vision (Cooper, M., Sloan, D., Kelly, B. and Lewthwaite, S., 2010). Access to information is one of the significant issues with low eyesight, and adopting to new technology simply makes exacerbates this issue (Permvattana, 2013). The visually impaired students experience challenges in their daily life, and in their studies, which requires them to frequently use assistive technologies and tools (Creed, 2016).

The difficulties that visually impaired students face are not the same as those that are often experienced by others. The majority of the time, e-learning platforms are developed for students who do not have any issues with their eyesight. Because these systems are predicated on the utilization of visual pictures and interactive activities, it might be challenging for those who have severe visual impairments to use them. They must therefore rely on applications that enables the conversion of screen content and information into more accessible formats (Permvattana, 2013). Some of the challenges that are commonly experienced by the visually impaired are the unavailability of learning materials and special learning or assistance required by these students, (Kesic, 2010) pointed some of the main barriers experienced by visually impaired students as follows: small fonts, evaluation in traditional forms is difficult or impossible, unable to hear lecturer due to lack of clarity in sounds and unable to see clearly what is in the presentation or blackboard. Whilst e-learning may be able to address some of these issues through enlargement of content, adjusting volume or using text to audio applications. Some e-learning systems may still lack these features making accessibility a challenge for visually impaired students. Hence, ensuring website accessibility is imperative in these scenarios.

Web accessibility refers to website development in a way that all users can access it including those with disabilities (Power, 2012). This suggests that any user should have the ability to navigate, perceive, comprehend, interact and contribute in the site without any accessibility challenges to content that is multimedia, text, video, audio, images (Goette, 2007). To address accessibility challenges, accessibility guidelines emerged. The accessibility guidelines is a set of technical requirements that need to be adhered in to ensure the accessibility of digital content for varied users. These guidelines set out the requirements to eliminate barriers to access that may delimit users from perceiving, accessing, interacting or using the website. The Web Content Accessibility Guidelines (WCAG) established the World Wide Web Consortium (W3C) is the most recognized web accessibility standards adhered to globally (Cooper, 2008). Up to now there have been three releases of the WCAG which includes WCAG 1.0 in 1999, WCAG 2.0 in 2008 and WCAG 2.1 in 2018. Every time a new version of WCAG is released, more features, technical standards, technological platforms, and target demographics are covered. The reason for this is that both technology and content are constantly evolving. At present, the valid standard is WCAG 2.0 and WCAG 2.1. Both standards provide accessibility specifications through a set of regulations centered on four core principles: perceivable, operable, understandable, and robust (POUR) (Caldwell, 2008). There are three conformance levels in the guidelines, Level A being the lowest, Level AA being intermediate and Level AAA being the highest. As it reflects the fundamental and minimum accessibility standards that developers should try to conform to, Level A is the easiest to accomplish and complete. In comparison, Level AAA is the most challenging to earn since it has more stringent standards, some of which might be challenging to meet. A website should conform to at least WCAG 2.0 level AA to ensure accessibility for majority of users with disabilities (Power, 2012). 2.5 Web Accessibility Features for Visually Impaired: POUR Principles of WCAG According to the POUR principles, web content should ideally meet the following criteria: (1) it should be completely perceivable by using different senses and ways that users opt for (perceivable), (2) it should be easy to operate with varying user interaction modalities (operable), (3) it should be easy to understand for the widest possible audience (understandable), and (4) it should be robust for use with various platforms along with various assistive technologies (Robust). These fundamentals will be discussed in further depth below

Perceivable refers to the ability for an individual to understand using their senses such as hearing and sight. This means that no information or functionality may be obscured from view or unavailable to a person's other senses. Perceivability is determined through the provision of suitable replacement text, provision of subtitles, provision of clear instructions, perception of content irrelevant to color, etc. Users should be able to hear, see or feel about the information provided. In the case of visually impaired students, if the content cannot be seen, the user must be able to hear or feel it for instance through a connected braille display or text to speech (Evett, 2005). Regardless of the method of access, all content must be readable and perceivable by users (keyboard, mouse, screen reader, etc.). Every text and text function should have a non-text equivalent. For example, alternatives of text for images and captions on videos, color contrast measures such not using red text against green backgrounds (Hyun, 2008). To address this gap, it is important to raise focus approximately the significance of e-learning platform accessibility and the precise wishes of visually impaired college students within the Sri Lankan context. this may involve providing schooling and sources for e-studying developers and educators on how to design and supply available content, in addition to advocating for accelerated availability and accessibility of assistive technologies and sources for visually impaired students.

Operable means that users should be able to easily operate the user interface of the website. The content of the website should be not presented in a form that is difficult for users to operate. Operable factor of a website can be determined through guaranteed use of keyboard, controlled response-time, focused movement, providing stop-function, restrictions of sparkling and flickering (to avoid

seizures), provision of titles by page, repeated region skipping and appropriate text links (Gibson, 2007). Ideally buttons should function irrespective of whether an individual is using a joystick, touchscreen, mouse, keyboard or any other input medium.

The University of Colombo has implemented a screen reader software called NVDA (Non-Visual Desktop Access) that allows visually impaired students to access e-learning content (NVDA, 2011). One major gap is that a website should be functionally usable irrespective of how it is evaluated and users should be able to navigate the content easily (Shrepp, 2006). The website should provide sufficient time for users to react to the presented information, even if their impairments can slow their response.

Understandable refers to the user's ability to easily conceive the content presented on the user interface of a website. Information must be easy to grasp, as well as how the user interface works. This implies that users must be able to comprehend both the material and how the user interface works (the content or operation cannot be beyond their understanding). The understandable factor of a website can be determine through expression of basic language, executing based on user requirement, configuration of tables, provision of labels and content linearization (Albusays, 2016). Content should not difficult or complex for the user to decipher and draw inferences from.

Robust as part of the WCAG principles, is also expressed as progressiveness of technology. This indicates that regardless of what technology may be created in the present or the future, people should be able to access the contents provided by an existing site using it. In other words, consumers should be able to view website content regardless of their browser or device (Baker, 2019). For this, markup language grammar and web application accessibility must be followed in web contents.

The information should work with a range of assistive and non-assistive technologies and continue to work as technology advances. For instance, a video should function no matter the browser or platform an individual is using to view it. Another illustration is the fact that many websites are just inoperable on smartphones, thus mobile viewing should also be accounted for. Content needs to be reliable enough to be understood by a wide range of user agents, including assistive technology (Stefik, 2011).

Rarely are studies available that examine how adhering to online accessibility standards affects user experience. Eleven blind individuals were invited to engage with a variety of websites that varied in their degree of standard compliance by (Aizpurua, 2015). They came to the conclusion that consumers' real perceptions of online accessibility do not always match compliance, and that elements like preconceptions, recollections, expectations, and trust in a website play a significant influence. In addition, the researchers look at how assessments of pragmatic and hedonic characteristics link with perceptions of web accessibility (Aizpurua, 2015) and they suggested using those metrics as a proxy to gauge compliance with web accessibility requirements. Results have revealed that users with visual impairments have a beneficial impact on the scales for affect, the user experience and aesthetic (Schmutz, 2017) as well as on mood (Pascual, 2014). Regarding usability-related outcomes, research methods that included non-disabled subjects have demonstrated that this influence on experience is not just beneficial to users with disabilities but also to users without impairments (Schmutz, 2017). Overall, the majority of recent research have shown a favorable impact of adherence to online accessibility standards on user experience-related metrics.

4. Methodology

Study Design

This chapter is concerned with making philosophical decisions that guide the data collection. In this chapter, the many philosophical considerations that should be taken into account before beginning the process of data gathering and analysis are discussed. This chapter details the procedures that must be followed in order to carry out a scientific investigation.

Research_Philosophy

Research philosophy elaborates on the development of knowledge and guiding ideologies. The study is founded on positivist philosophy, which holds that reality can be viewed via an objective lens, and is hence acceptable for scientific investigation. This viewpoint conforms to observation- and measurement-based scientific knowledge (Bryman, 2007). It asserts that reality is composed of observable, separate elements from an ontological standpoint. The job of the researcher is confined to the collection of data and its impartial evaluation. Consequently, study findings are often apparent and quantitative.

Research_Approach

The research methodology emphasizes the practice that incorporates the broad assumptions into the data collecting, analysis, and interpretation methods. Positivists advocate a deductive research methodology (Tashakkori, 2010). Beginning with an evaluation of current theories of a particular phenomenon, the researcher next tests the hypotheses derived from these theories to reflect the causal linkages between the identified variables, in order to support empirical evidence and validate these ideas (Bryman, 2007).

Research_Strategy

According to (Creswell, 2016) the nature of the study's aims dictates the research design and approach employed to achieve the objectives and answer the research questions. Consequently, the following study follows a case study research approach and focuses largely on the students at Ceylon Deaf and Blind School. This approach provides a comprehensive analysis of a confined system based on a large quantity of data. This is a cross-sectional research design in which data is collected at a certain period in time across a sample population due to time and resource constraints in study administration.

Data Collection Methods

Choice of Methods Mono-method, mixed-method, and multi-method are the three available options for the study's research design (Saunders, 2009). Accordingly, the following study employs a mono-method, which focuses on a single application approach. In accordance with positivist ideology and logical research methodology, the phenomenon is represented quantitatively using correlation to determine the link between the independent and dependent variables. Consequently, the study employs quantitative techniques.

Instrument

A systematic questionnaire was utilized to collect the primary data. At the Ceylon Deaf and Blind School, visually impaired children were given the questionnaire. It is important to highlight that the questionnaire was read aloud to elicit replies. The questionnaire had closed-ended questions,

and its organized design facilitated administration, standardization, and retrieval of quantitative data (Kothari, 2004).

Additionally, while the oral administration of the questionnaire was necessary due to the participants' visual impairments, it introduces potential limitations. These include interviewer bias, variations in tone or emphasis that could influence responses, and reduced privacy, which may affect the authenticity of participants' answers. These limitations should be considered when interpreting the findings. Information such as the age range, gender distribution, educational levels, and the number of participants should be clearly outlined.

Data Analysis Techniques

Data Analysis

The study supports quantitative approaches, which need quantitative analysis in which descriptive statistics are used to describe data in a comprehensible manner. In addition, correlation and regression analyses were employed to establish the significance of the link between the independent and dependent variables.

Reliability and Validity

When the data-gathering instrument measures what it is intended to measure, it is considered legitimate (Kothari, 2004). The supervisor of the study ensured the validity of the research instrument. Reliability is a measure of the consistency of the research's results, and a study is considered trustworthy if its results are consistent when recorded again (Caldwell, 2008). Using the Cronbach Alpha coefficient, the results' dependability is examined.

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While the study employed a quantitative research design, alternative methods such as mixed-methods were considered during the planning phase. However, the decision to proceed with a purely quantitative approach was based on the nature of the research objectives, which focused on measuring the strength and significance of relationships between variables. A mixed-methods approach, while valuable for exploring deeper contextual insights, was not deemed necessary as the research did not require qualitative data for interpretation or theory generation. The quantitative method provided the most efficient and objective way to analyze the structured data collected for this study.

5. Analysis

The importance of technology in modern life is pervasive throughout all sectors, including the educational system. It is impossible to separate information technology from instructional methods and academic advancement. Given how important technology is to our daily lives, it is fundamental for students to acquire problem-solving, organizational, and other essential skills in order to fulfill the demands of a workplace that is becoming more and more technologically oriented and to successfully integrate into society. Thus, the advent of new information and communication technologies has a significant impact on education.

The research was conducted in order to evaluate the e-learning system. The research was conducted under the objectives of identifying the accessibility problems existing for users with visual impairments

and identifying methods for improving the e-learning system for better accessibility. This chapter focuses on analyzing the research data collected during the data collection process. The research was conducted as a quantitative study, and SPSS software was used for analysis. The reliability analysis, regression, and correlation tests were conducted to analyze and test the research variables.

Reliability Test

The reliability test was conducted to ensure and evaluate the accuracy and reliability of the dataset. Cronbach Alpha values were used to assess reliability. According to (Malhotra, 2015), a Cronbach Alpha value greater than 0.7 is considered reliable. The results are shown in the table:

Table 1: Reliability Test

Variable	Cronbach's Alpha
Perceivable	0.833
Understandable Perceivable	0.946
Operable	0.851
Robust	0.760
Learner Satisfaction (Dependent)	0.871

The results indicate that all variables, both independent and dependent, are reliable based on their Cronbach Alpha values exceeding the 0.7 threshold. To provide greater clarity and reproducibility, the structure of the survey instrument should be explicitly stated. The questionnaire consisted of closed-ended questions measured using a Likert scale, typically ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). This type of response scale allows for standardized quantitative analysis and supports the use of Cronbach Alpha to assess internal consistency. Including such details helps contextualize the reliability results and strengthens the methodological transparency of the study.

Correlation Analysis

The correlation analysis was conducted to examine relationships between independent and dependent variables. The results are presented below:

Table 2: Correlation Analysis

Variables	Pearson Correlation	Sig. (2-tailed)
Perceivable → Learner Satisfaction	0.812	0.003
Understandable → Learner Satisfaction	0.897	0.034
Operable → Learner Satisfaction	0.283	0.001
Robust → Learner Satisfaction	0.183	0.004

- **Perceivable**: High correlation (81.2%) and significant (p = 0.003).
- **Understandable Perceivable**: High correlation (89.7%) and significant (p = 0.034).
- **Operable**: Weak correlation (28.3%) but significant (p = 0.001).
- **Robust**: Weak correlation (18.3%) but significant (p = 0.004).

While Perceivable and Understandable dimensions show strong, significant correlations with learner satisfaction, the relatively low correlations for Operable and Robust suggest potential usability and technical concerns. This finding warrants further exploration. It may indicate that users do not find the system sufficiently interactive, navigable, or technically reliable. Follow up qualitative feedback or observational studies could help uncover specific usability challenges or system limitations that affect user engagement. Addressing these issues could enhance overall learner satisfaction and system performance.

Regression Analysis

The regression analysis results are summarized in the tables below:

Table 3: Regression Analysis

Model Summary	**R**	**R Square**	**Adjusted R Square**	**Std. Error**
Model 1	0.803	0.709	0.997	0.07561

ANOVA	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	7.933	4	2.594	421.459	0.002
Residual	1.184	363	0.004		

Coefficients	**Unstandardized Coefficients**	**t**	**Sig.**
Perceivable	0.758	1.274	0.013
Understandable Perceivable	0.856	-12.041	0.022
Operable	0.226	9.041	0.053
Robust	0.243	13.335	0.061

The regression analysis indicates that Perceivable and Understandable variables have a more significant impact on learner satisfaction, while Operable and Robust factors show relatively lower influence, as reflected in their higher p-values and lower coefficients. This suggests that learners may not view system usability (Operable) or technical strength (Robust) as primary contributors to their overall satisfaction. It is important for the study to explore possible reasons behind this, such as whether learners place more value on content clarity and accessibility over interface interactions or system reliability. These findings highlight a potential gap in the system's usability features that may not align with learner priorities or expectations, which could be explored further through user feedback or qualitative studies.

Summary of Hypotheses Testing

Table 4:Summary of Hypotheses Testing

Hypotheses	Result
H11: Perceivable → Learner Satisfaction	Accepted
H12: Understandable Perceivable → Learner Satisfaction	Accepted
H13: Operable → Learner Satisfaction	Rejected
H14: Robust → Learner Satisfaction	Rejected
Learner Satisfaction (Dependent)	0.871

The rejection of hypotheses H13 and H14 suggests that the Operable and Robust factors have limited or no significant influence on learner satisfaction within this context. This warrants further investigation. For instance, the weak impact of the Operable dimension might indicate that users found interaction elements such as keyboard navigation, responsiveness, or accessibility aids insufficient or unintuitive. Similarly, the lack of impact from the Robust factor could point to possible shortcomings in the underlying technological infrastructure, such as slow loading times, compatibility issues, or limited support for assistive technologies. Exploring these aspects more deeply through user interviews or usability testing could provide valuable insights and guide improvements to better meet learner needs.

6. Conclusion

The importance of technology in modern life is pervasive throughout all sectors, including the educational system. It is impossible to separate information technology from instructional methods and academic advancement. Given how important technology is to our daily lives, it is fundamental for students to acquire problem-solving, organizational, and other essential skills in order to fulfill the demands of a workplace that is becoming more and more technologically oriented and to successfully integrate into society. The aim of conducting this study was to identify ways to improve the accessibility of e-learning systems for the visually impaired students in Sri Lanka. Accordingly, the objectives of the study were to identify the accessibility problems related to e-learning systems for Sri Lankan students with visual impairments and to recommend e-learning system improvement mechanisms for better accessibility for the visually impaired students in Sri Lanka.

Researchers developed the research objectives with the perspective of finding solutions to the existing problems in society, and the hypotheses were developed accordingly. The findings suggest that each user must be able to understand the information presented in an e-learning system. The material should not be overly challenging to learn or comprehend, as it may hinder users from effectively utilizing the system. For instance, forms must be easy to understand and complete, and language must be as comprehensible as possible. Consistency in labeling and interactive elements is also essential. For example, the same term should be used for similar functions across the platform, such as using “buy” instead of “add to cart” in different sections. The language programmed into the

website and the one visibly displayed should align to ensure that screen readers interpret it correctly. Ensuring that these elements are addressed can enhance the usability of e-learning platforms for visually impaired students.

When testing the hypothesis regarding the perceivable factor of e-learning systems, the study found a significant positive relationship between the perceivable factor and learner satisfaction of visually impaired students, with a coefficient of 0.758 and a p-value of 0.013. This demonstrates that the perceivable factor has a substantial impact on user satisfaction. Perceivability implies that no information or functionality can be hidden or unavailable to a person's other senses. Content must be accessible through alternative means, such as being audible or tactile, ensuring that all users can engage with the material regardless of their method of access. Examples include providing alternative text for images and captions for videos. This aligns with the need for inclusive practices, such as avoiding color combinations that are challenging for colorblind users and ensuring content is compatible with Braille displays.

The understandable factor also showed a significant positive relationship with learner satisfaction, with a coefficient of 0.856 and a p-value of 0.022. Understandability emphasizes that the system's content and operation must be clear and comprehensible. This ensures that learners can navigate and engage with the system effectively, fostering better learning outcomes. The findings support the notion that e-learning systems must use accessible fonts, logical formatting, and comprehensible instructions to improve user experience.

The operable and robust factors, however, showed weaker correlations with learner satisfaction. Although these factors are important, the results indicate that their current implementation in the analyzed systems does not significantly impact learner satisfaction. This highlights areas for further improvement, such as ensuring keyboard navigation, providing sufficient time for users to interact with content, and enhancing compatibility with assistive technologies like screen readers.

The study highlights the need to address these issues to improve the accessibility of e-learning systems for visually impaired students. Recommendations include implementing WCAG accessibility practices, such as alternative text, keyboard navigation, and descriptive links, to enhance usability. Additional measures, such as labeling forms correctly, providing text equivalents for multimedia content, and ensuring sufficient color contrast, can further improve accessibility. Training programs for educators and developers can build awareness of accessibility standards, and policy advocacy can drive compliance with these standards. Integrating assistive technologies into e-learning platforms is crucial to ensure that students with visual impairments have equal access to education.

The findings of this study will be especially valuable for the Sri Lankan Ministry of Education and the Ceylon Deaf and Blind School in promoting inclusive education. They also provide critical insights for website developers and designers, helping them create more accessible systems. This study contributes to the understanding of accessibility in e-learning and provides a foundation for further research in inclusive online learning, particularly in developing countries like Sri Lanka. It emphasizes that perceivable and understandable factors are crucial and should be prioritized to ensure that e-learning systems effectively support visually impaired users.

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THE INFLUENCE OF FUNCTIONAL, HEDONIC AND SOCIAL ASPECTS ON SATISFACTION OF SMARTPHONE USERS IN TANZANIA

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***Abstract**: Despite the usage of smartphone to grow exponentially, the satisfaction and factors influencing it are less explored. The literature suggests functional, hedonic and social values to be possible predictors of satisfaction with smartphone. Using a self administered structured questionnaire, a convenient sample of 270 university students that yielded 247 dully filled questionnaires with data subjected to partial least square path modeling using SmartPLS 3 to test both the measurement and structural models. The results indicate all the hypothesized antecedents to be significant predictors of satisfaction with smartphone. The functional value of smartphone was observed to be the leading contributor to satisfaction while hedonic value to be the least significant contributor in satisfaction. Theoretically the finding suggests modification in the models explaining satisfaction with electronic gadgets like smartphone by incorporating hedonic and social values together. Practically, the results provide marketing insights on how smartphone can be marketed to the youth by including all the four predictors in marketing communications as well as in the design of smartphone.*

Keywords: *Functional, Hedonic, Social, Smartphone, Satisfaction*

1. Introduction

The number of smartphone mobile network subscriptions worldwide reached almost seven billion in 2023, and is forecast to exceed 7.7 billion by 2028 with China, India, and the United States being the countries with the highest number of smartphone mobile network subscriptions leaving Tanzania with approximately 105 mobile cellular subscriptions per 100 inhabitants (Statista, 2024). The escalating number of smartphone users emanate from the utility of the gadget in voice, data, e-mail, social networking and myriad internet applications. People began to like smartphones as they can purchase, order, pay, and consume online products (Kennedy, 2015). People use smartphone for different purpose example they can use smartphone for traveling purpose especial those who like to take video capture and map services and others use for Instagram and playing games (Meng et al., 2014). Some of the smartphone users are very selective in picking out different functionalities of their devices. Users need to have knowledge of obtaining of a certain application and using them in a right way (Park et al., 2012). Smartphone usage in educational science environments has the

potential for rather positive effects, such as an increase in learning achievements or an increase in motivation, and smartphone usage rarely leads to detrimental effects (Ubber et al., 2023).
The continuous popularity of smartphone usage has led into a stream of research appraising the antecedents of smartphone usage. Lusekelo and Gervas (2015) urged that students used smartphones for relaxation or leisure purpose, and not for academic purpose or developmental function. Despite of the growing interest in smartphones uses but a few research has been done and little is known on how people uses their smartphones, is it for functional, social or hedonic use? Also if they get satisfaction by using it and in order to understand that research is needed. Kong and Tan (2023) indicated that hedonic motives were positively linked with problematic smartphone use. With the social use; Rotondi et al. (2017) suggested that, due to its intrusiveness, the smartphone reduces the quality of face-to-face interactions and, as a consequence, their positive impact on well-being. The aware smartphone mode of use reflects an active lifestyle, while the unaware mode of use reflects the use of the smartphone in conjunction with other activities (Sela et al., 2022). This study helps to know how people use the smartphones whether it is for functional, social or of hedonic use. This study helps developer of smartphones application or mobile application specialists to understand not only the need of the uses but also decision of marketers to develop and promote a specific functionality of smartphone based on the interest of the users. Thus, the specific objectives of this study are to determine the influence of functional use, social use and hedonic use on smartphone users' satisfaction.

2. Literature review

2.1 Functional use of smartphone

Ochs and Sauer (2022) studied on the disturbing aspects of smartphone usage behaviors by using the method of 'thematic analysis' and discovered eight themes. Five themes related to reasons for use, including inevitability, habitual use, avoiding unpleasant circumstances, need satisfaction and fulfilling social expectations. Three themes referred to consequences of smartphone usage (life management, social life, and online life). The study of users and non-users of smartphones for travel done by Meng et al. (2014), was develop for the aim of understand the individual process to adopt the smartphone for travelling purpose. They categorized smartphone user into user and non-user according to their use of their smartphone. The study revealed that smartphone user for travelling purpose are very high although not all the user of smartphone use their device for travelling. And there is no difference in general use of smartphones in terms of length and daily use. The study by Zhao et al. (2015) explained about the usage of smartphone for unmanned aerial vehicle (UAV) where this method helps the user of smartphone to detect the smartphone sensor accuracy without using any special instruments and the result was reveal that using the smartphone for UAV are found to be both indoor and outdoor effective of the boundary condition for localization condition. On the other hand the study of Nyheim et al. (2015) explained that the smartphone used in advertisement and the study wanted to personalized smartphone advertising avoidance in a restaurant context and the result reveal smartphone advertising irritation has direct relation with advertising avoidance.
Although on the study of smartphone effect on academic performance on higher learning students done by Lusekelo and Gervas (2015), reveals that small percent of students are using the smartphones for education purpose but majority of them use the smartphones for social use such as Twitter, WhatsApp, Facebook and Instagram. Ahmed (2012) indicated that all students at college use their smartphones for texting massaging, while nine in ten of the students use their smartphones for email and for finding coupons and deal. Eight in ten of students use their smartphones for GPS navigation,

checking news and making voice call. Seven in ten of students use their smartphones for checking weather and concluded majority of the students at collage have positive perception that smartphone will help them in their academic performance. Amez and Baert (2020) reviewed the scientific literature to date on the relationship between smartphone use and academic performance in tertiary education and revealed a predominance of empirical results supporting a negative association.

Also the study by Tsai and Ho (2013) explained how the design affordance affect the usage of smartphone in terms of design feature, functional affordance, descriptive belief and inferential belief and the result revel that diversity has a direct relationship with the perceived ease of use and perceived usefulness on the use of smartphone although intuition has a relation with perceived ease of use and not perceived usefulness. A study by Abeynaike (2012) on the application of the smartphone in medical research indicated that most of the researcher become more productive as they use smartphone however most of them they did not utilize application and none utilized field specific application in the laboratory, also concluded that smartphone are not used to their full potential in the laboratory. Jeong et al. (2024) investigated the serial mediating effects of depressive symptoms and cognitive function on the relationship between smartphone usage and life satisfaction among older people and found that the status and level of smartphone usage had significant positive impacts on cognitive function and life satisfaction, and negative impacts on depressive symptoms.

People can use smartphone to conduct online survey and there are different ways in which user of smartphone can deploy an online survey depend on the type of smartphone they use (Buskirk & Andrus, 2014). Also Kennedy (2015) said that smartphone user use their smartphone to access the internet where they will use to make a purchase and even to make a transaction without going to bank also shift of money from one bank account to another by using smartphones, all this payment are done online. In the study of Park and Chen (2007) tried to look how human motivation can affect the decision of adopting smartphone for doctors and nurses. The result indicated that the intention of using smartphone is much influenced by the perceived ease of use (PEOU) and perceived usefulness (PU) of adopting smartphone for doctors and nurses. And both PEOU and PU were positive related to the adaptation and the usage of smartphone. Nautiyal et al. (2024) aimed to investigate the perspectives of older Indian adults regarding smartphone adoption and its usage in healthcare services and the findings revealed that older adults have adopted smartphones for various purposes after initially facing hindrances, often with assistance from family members. However, the use of smartphone-based healthcare applications remains minimal.

Smartphone has been increase the level of internet literacy and usage of internet for old people as the results found on the study which tries to see the effect of smartphone on the internet literacy (Hong et al., 2016). Valenti and Faraci (2024) highlighted the conceptual overlap between Internet and smartphone addiction by investigating whether the Internet Addiction Test (IAT) and the Smartphone Addiction Scale-Short Version (SAS-SV) capture separate Internet-related disorders findings suggested that they do not effectively capture two distinct constructs. By considering the use of smartphone application to order food and drinks in restaurant, smartphone has been used to promote healthy eating behavior by proving a range of services that can be used to improve daily habit of the users, also smartphone help its users to keep with their diet and daily exercise routine (Okumus & Bilgihan, 2014). Beaulieu-Bonneau et al. (2024) studied the use of mobile devices after acquired brain injury (ABI), from the perspectives of injured individuals and significant others, and also examined factors associated with mobile device use for cognition. I was found that mobile device use for cognition was common (64%), predicted in a regression model by lower subjective memory and more positive perception of the psychosocial impacts of technology, and also associated in univariate analyses with younger age, lower executive functioning, and greater use of memory strategies.

2.2 Hedonic use

Hong et al. (2023) explored the role of social presence, hedonic value, perceived value, and learning outcome, and their correlates and results showed considerable efficacy of the learning outcomes, revealing a positive correlation between social presence, hedonic value, perceived value, and learning outcomes. Kim et al. (2014) tried to explain the antecedent affecting application usage among the smartphone users. The study revealed that users tend to use the application for informative, entertaining needs and they did not use smartphone for communication purpose. While the study of why do people play mobile social games? an examination of network externalities and of uses and gratifications which was done by Wei & Lu (2014), showed that users play social interactive game on their smartphone for enjoyment. Enjoyment has been an important variable which make user to play a social game on their mobile. Some users use the smartphone for enjoyment where most of the people tend to download and play game, most of the game players prefer the social games due to social interaction and enjoyment they get when they are using smartphones (Wei & Lu, 2014). On the other hand the studies of Meng et al. (2014) and Turel et al. (2010) indicated that others use smartphones for listening to the music through downloading different applications and get access to the music, as most of the people gets enjoyment when they are listen to the music. While Ahmed (2012) said that college students use their smartphones devices for enjoyment where about eight in ten of the students use their device for playing music. Ie Roux et al. (2024) studied the effects of smartphone use during play on performance and enjoyment among recreational golfers and results indicated that smartphone use for work-related purposes has a small negative effect on performance; but that smartphone use for personal purposes has no effect. They further found no direct relationship between smartphone use and round enjoyment, but proposed that it may indirectly impact enjoyment through its impact on performance.

2.3 Social use

Sun et al. (2023) investigated the correlation between smartphone usage patterns and social capital among Chinese college students, while also examining the moderating effect of sociability revealed that college students' mobile phone usage can be classified into five distinct patterns which are low entertainment usage, balanced low-frequency usage, social and convenience-centric usage, balanced high-frequency usage, and entertainment and convenience-centric usage. They further pointed out that social interaction ability had a positive moderating function in the association between social and convenience-centric and balanced high-frequency usage and social capital levels. The study of Lusekelo & Gervas (2015) tried to understand the smartphone effect on academic performance of high learning student find out that most of the student use their smartphone for social where by majority of student were addicted to the application which are found on their smartphone like twitter, WhatsApp, Facebook and Instagram, also student spend most of their time in accessing the social media chatting and socialize with their friend and get new relationship. Also on the study of Mansour (2016) showed that social application like Facebook and twitter were most popular for students as they spent more time on social application and for professional most students use their smartphone more for communication purpose other than learning and have positive feeling with the applications which they have less negative concerns. A study by Vorley and Williams (2016) indicated that smartphones have been used in teaching as a tools to understanding and increase entrepreneurial confidence as well as skills. This is supported by Chou and Lin (2023) who urged that implementing effective social entrepreneurship can result in a better redistribution of wealth and well-being in society; social mediating technologies are digital transformation tools that can fulfill specific goals and the success of social entrepreneurship.

While on the study of millennial generation performance and usage of mobile device in the US which was done by Ahmed (2012) indicated that all student at college use their smartphone for texting messaging and eight in ten use their smartphones for functional use like email and GPS. About seven in ten of the students at college are using their mobile device for accessing the social media. Park and Lee (2015) studied the usage of smartphone in a new dimension as the level of usage, awareness and usability conducted for college students. Findings indicated that more people who are using smartphone had more online friends and most of them spent their time online for social network such as twitter and Facebook. Tufan et al. (2024) examined how smartphone-related behaviours, such as phubbing and smartphone addiction (SPA), are associated with fear of missing out (FoMO), being phubbed (BP) and friendship satisfaction (FS). The study surveyed 811 university students and the findings showed that FoMO positively correlated with phubbing, with SPA as a partial mediator, suggesting that reducing SPA could mitigate phubbing. Results also showed that BP moderated the relationship between these variables, influencing the effects of phubbing on FS.

Lusekelo and Gervas (2015) investigated the effect of using smartphone in academic performance in Iringa, Tanzania and results indicated that there was a negative effect of using smartphone in academic performance. About 48% of the total respondents were found to spend most of their time like 5 up to 7 hours per day in social communication sites such as Facebook and twitter without considering that they could use that time for academic issues like searching for information on the websites for academic purposes (Lusekelo & Gervas, 2015). On the other hand the study of why do people play mobile social games which was done by Wei and Lu (2014) it was revealed that users use their smartphones to play social games because of the social interaction with other users and networks. It was observed that social interactions have been the major variable for play social game. Cabezas-González et al. (2024) explored whether the use made by children of video games, social media, and smartphones in their free time influences the development of digital competence as regards safety; they found that while students enjoy playing video games and using certain social media, mainly through smartphones, they are not digitally competent.

Borrowing from the Theory of Planned Behavior (TPB), particularly the social norm factor, it can be argued that social norm can be a possible factor influencing smartphone user satisfaction. Subjective norm can be defined as the perceived social pressure to perform or not to perform a certain behavior. Subjective norms are practically independent of attitude toward the behavior, people can perceive favorable attitude toward a certain behavior and yet can perceive social pressure not to perform it (Ajzen, 1991). By applying the protection motivation theory and theory of planned behaviour in understanding the parental mediation strategy, Sharma and Lee (2024) explored parents' perception of their own responsibilities and the development of appropriate policies and legislation to curve the risk of digital media in their children's lives; they reveal that the fundamental variables of protection motivation theory and the theory of planned behaviour are mostly held to explain the psychological and external-environmental factors that impact parents' digital media mediation strategy.

Derived from the literature, the following hypotheses were proposed:

Hypothesis 1*: Functional use of smartphone has a significant influence on customer satisfaction*

Hypothesis 2*: Hedonic use of smartphone has a significant influence on customer satisfaction*

Hypothesis 3*: Social use of smartphone has a significant influence on customer satisfaction*

3. Methods

Data for this study was collected using structured questionnaires distributed conveniently in two college campuses in the University of Dar es Salaam. Potential respondents were approached and requested to participate in the study. Upon agreeing to participate in the study, the respondents were given the questionnaire to fill in. The questionnaire had 2 sections; the first section captured demographic variables using nominal and ordinal scale questions while the second section captured the functional, hedonic, social use of smartphone and the social norms factors in the usage of smartphone and satisfaction with the use of smartphone. The second part of the questionnaire was composed of 5 point Likert scales with 1 indicating strong disagreement, 5 for strong agreement and 3 for neutral. In order to ensure reliability and validity, the items were adapted from previous studies that obtained reasonable validity and reliability of the scales. Prior to the final data collection, the questionnaire was piloted with 50 respondents with the factor and reliability analyses indicating the factors to load into their respective dimensions and Cronbach alpha exceeded 0.6.

Out of the 270 distributed questionnaires, 247 were dully filled and used in the final analysis. Among 247 responses, 52.2% were males; 38.9% belonged to the age group of 25 or less; 38.8% were between 26 to 40 years of age and the rest were above 40 years. About half (49%) of the respondents were college students while 12.6% were self-employed while the remaining being employed. To test the hypotheses, Structural Equation Modelling Approach was employed using Smart PLS 3 tool. The use of Smart PLS is recommended when sample sizes are small to medium and when the data are non-normal (Hair et al., 2017). Two steps approach to assess the measurement and structural model was adopted (Anderson and Gerbing 1988).

4. Results

Measurement model was first appraised for reliability and validity using Smart PLS 3.0. The reliability of the reflective indicators for the constructs used in this study was appraised using Cronbach's alpha, Composite reliability and outer loadings with results indicating all to be the recommended levels (Hair et al., 2017) as shown in Table 1. The convergent validity was assessed using the Average Variance Extracted (AVE) with values for the entire construct crossing the recommended mark of 0.50.

Table 1: Validity and Reliability of Constructs

Construct and Item	Outer Loading	Cronbach's alpha	CR	AVE
Functional		.797	.881	.712
F1-smartphone improves my information-seeking performance	**0.789**			
F2-smartphone makes it easier to seek informtion	**0.875**			
F3- I find smartphone useful in seeking information	**0.866**			
Hedonic		.736	.850	.653
H1- smartphone allows me to be more entertained	**0.823**			
H3-smartphone makes life to be more fun	**0.796**			
H4- smartphone is a source of entertainment	**0.805**			
Social Value		.690	.828	.616
SU2- smartphone improves my social life	**0.759**			
SU3- smartphone makes it easier for me to communicate with friends and relatives	**0.818**			

SU5- smartphone add value to social media	**0.777**			
Satisfaction		.704	.871	.773
Overall, I am happy to use smartphone	**.882**			
Overall, I am satisfied with the benefits I obtain from using smartphone	**.875**			

The discriminant validity using Fornell-Locker criteria was used. Specifically, the criteria require the AVE of each construct to be larger than square correlations between the constructs (Hair et al., 2017). Results in Table 2 indicates all the AVE to be well above the squared correlations indicating the measurement model to have a higher discriminant validity.

Table 2. Discriminant validity

	Functional	Hedonic	Satisfaction	Social usage
Functional	0.844			
Hedonic	0.352	0.808		
Satisfaction	0.499	0.408	0.878	
Social usage	0.423	0.478	0.479	0.785

Structural model and path analysis

The validation of the measurement model was followed by the evaluation of the structural model with 5000 iteration bootstrapping procedure. The results with path coefficients are presented as Table 3 which show all the four predictors to have a significant impact on satisfaction with smartphone, thus supporting all the hypothesized relationships. In total, 41.3% of the variations in satisfaction with smartphone is explained with the four predictors (Adjusted R^2 = 40.3%). Using blindfolding technique to assess the predictive relevance of the model, the resulting Q^2 was .289. Using Hair et al., (2017) criteria for R^2 and Q^2 the model moderately predicts satisfaction with smartphone.

Table 3. Estimated results of the structural model and hypotheses test outputs

Hypothesized relationships	Path coefficient	SE	t-value	P-value	Results
Functional→ Sat.	0.277	.073	3.988	.000	Supported
Hedonic →Sat.	0.158	.059	2.419	.008	Supported
Social usage → Sat.	0.203	.085	2.299	.017	Supported

5. Discussion

The first objective was to determine the influence of functional use of smartphone on user satisfaction. What has been found and observed from the research findings is that there is a significance influence of functional use on the usage of smartphone and user satisfaction. A positive relationship confirmed between the functional use and the user satisfactions; the more the people use their smartphone for functional use the more satisfaction they will get. Also people tend to use their smartphone more for functional use than hedonic and social uses.

Functional use of smartphone has more significance influence on the customer satisfaction than other variables as it contributes 34.7% to the customer satisfaction. This result is very similar with other studies which found that smartphone has been used for functional usage but none of them has mentioned how users of smartphone get satisfaction by functional use of smartphone so this stud has a contribution that users of smartphone they get satisfaction by using the smartphone (Abeynaike, 2012; Ahmed, 2012; Buskirk & Andrus, 2014; Kennedy, 2015; Lusekelo & Gervas, 2015; Meng et al., 2014; Nyheim et al., 2015; Park & Chen, 2007; Tsai & Ho, 2013; Zhao et al., 2015). The results also indicate that there is no demographic variation on the usage of smartphone for functional use in terms of age and gender while on the study by the Teh et al., (2014) found demographic variation in terms of age where youth consider convenience as the primary factor for them to use NFC SES while adult found to consider intuitive and perceived usefulness as the determinant of their individual behavior to use NFC SES.

The second objective was to determine the influence of hedonic use of smartphone on user satisfaction. Rresults indicate that there is a significance influence of the hedonic use of smartphone and user satisfaction. Results suggest that the more the people use their smartphone for hedonic purposes the more the satisfaction they will get due to the positive relationship between hedonic use and user satisfaction of smartphone. It has been further observed that the hedonic use of the smartphone has a small significance influence compare to the other variables as it contributes 11.2% to the customer satisfaction. Results further indicate that there is a demographic variation in terms of gender on the usage of smartphone for hedonic purposes where female has been found to use their smartphone more for hedonic purposes than male and found no demographic variation on the hedonic use in terms of age. The current study findings do support previous findings (Apaolaza-Ibáñez et al., 2011; Hanzaee & Rezaeyeh, 2013; Nejati & Moghaddam, 2013; Ryu et al., 2010; Ying et al., 2016) showing that there is a significance influence of hedonic use to the customer satisfaction where by the more hedonic use has been applied the more the satisfaction they will get.

The third objective was to determine the influence of social use of smartphone on user satisfaction. The observed result from findings indicate that there is a significance influence of social use of smartphone and user satisfaction which means that there is a positive relationship between the social use of smartphone and user satisfaction. The more people spend on using their smartphone the more the satisfaction they will get. People who use their smartphone for social use as Facebook, twitter and WhatsApp contributes to about 18.3% to the customer satisfaction. This result is also similar with the studies (Ahmed, 2012; Kim et al., 2014; Meng et al., 2014; Turel et al., 2010; Wei & Lu, 2014) which found that smartphones have been used for social proposes although none of them indicated the satisfaction users of smartphone they get by social usage of smartphone. This study has a contribution that users of smartphone they get satisfaction by social usage of their device and the more they use the more satisfaction they get. But it has been also observed that there is no demographic variation in terms of gender and age on the usage of smartphone for social use.

6. Conclusion

The research problem for this study was to determine the influence of hedonic, functional and social value on smartphone customer satisfaction. How do people use their smartphone? Do they use their smartphone for social, hedonic or functional? And do they get satisfaction from using it? From what is seen in the above findings is that people use their smartphone for functional use than any other use as they searching for information. The rank in the usage of smartphone for the three variables starts with functional, social and lastly is hedonic use. This leads to conclude that many people are using their smartphone for information seeking and the people who are using more smartphone are the people with the age less than 41 and male tend to use smartphone than females as male are so much interested in new technology than female. Governments and other stakeholders should encourage females to engage more in technology as it shows that female and older people are not much interested in technology than males, youths and teenagers. So the priorities should include the policies and regulatory guidelines that encourage female to engage more in technology the same as male.

It is evident that there are rapid technological changes around the world smartphone has been gaining its popularity day by day as time goes on. Before developing the system or application for smartphone users then the programmer should seek the information first on what users of smartphone wants, which will help to give the programmer a clear picture of what to develop or to program for the user of smartphone. As from this study it shows that more people use their smartphone for functional use so if the programmer invent more on the application which deals with the functional use the more customer will be satisfied. There exist lack of literature and little is known on demographic variation on the usage of smartphone for functional, social and hedonic. Therefore, area for further study would be assess the level of demographic variation on the usage of smartphone for functional, social and hedonic uses as this study found no demographic variations in terms of gender and age in the functional and social use as opposed to hedonic use.

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PUBLIC INTEREST LOST IN UGANDA'S EDUCATION SECTOR DURING COVID-19

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Abstract: *The global spread of COVID-19 brought to the lime light the lack of public goods in Uganda during the fight against this contagious virus. The public servants demonstrated selfishness at the expense of fostering services for the majority of Ugandans. Thus, a cross-sectional qualitative approach was used to collect data from the private primary school teachers. Data were collected from 12 participants using an interview guide. The study findings demonstrate how public interest was lost during attempts to curb the spread of the pandemic. Researchers call for additional scholarship pertaining to reviving the lost common preferences in times of pandemics, particularly the coronavirus.*

Keywords: *COVID-19, Coronavirus, Public interest, Uganda*

1.Introduction

This article has one main aim. To examine how public interest was lost in Uganda's education sector during Covid-19. The arrival of COVID-19 on the African continent in Egypt in February 2020 led to fundamental transformations (such as shock to human life, shattered businesses, feelings of uncertainty, school closures, reduced human contact, and adoption of online learning, among others). This threatened the lives and normality of humankind. As elsewhere, the free flow of people, products, and ideas in East Africa was affected by the new global turmoil. Ugandans were not spared ever since the president announced the country-wide lockdown on March 18th 2020 and eventual

reporting of the first corona case on March 21, 2020 *'a 36-year-old businessman from Kampala, who had travelled to Dubai'.* From 23rd July when the first death was recorded from the contagious pandemic, the Pearl of Africa has been seriously affected and hit by this highly infectious disease with reported 121,984 cases, 3,119 deaths and 95,835 recovered people (Ministry of Health Report, June 2021), while the rising cases are alarming. The government, desperately looking for ways to flatten the infection curve and reduce total fatalities from the disease, came up with a number of measures. These were termed standard operating procedures (SOPs) and numbered 34 in number. They were largely to confine people to their respective homes in the form of a lockdown and limited social gatherings to halt the spread of COVID-19.

As the corona cure was causing havoc across Italy, France, Spain, and the UK, the Ugandan government closed all teaching and learning institutions with their respective buildings. Thus, rendering a number of Uganda jobless, for example, over 140,000 private primary and secondary teachers became jobless immediately in Uganda (Kanywa, 2020). Since then, schools have remained closed to date (22/10/2021), Uganda remains the only country globally whose schools are still shut yet person-to-person classes were cancelled, face-to-face lectureships were no longer, and exams and school activities were put on halt. This led to the creative idea and action of teaching remotely to continue learning as a response to the 'external shock' of the pandemic. The abrupt change in learning approaches from physical to online teaching comes with a number of challenges, especially the remote assessment of learners/students. Again, communal prayers in all religious places of worship were suspended, parties were postponed while burials would be conducted with utmost 10 people strictly observing the established SOPs, public political gatherings were stopped (much as it was an election/political season), monthly markets like cattle auction markets were halted, banned movement of public and private cars, social contact restrictions locally termed as 'tonsembelera,' mask-wearing, 'working from home,' curfew time maintained at 7:00pm among other SOPs as elements of a 'new normal. ' This increased economic insecurity, as businesses, both formal and informal, came to a standstill.

Much as pandemics are part of the history of life on Earth (for example, the Spanish flu at the beginning of the 20th century and HIV-AIDs) (Grek & Landri, 2021), COVID-19 has triggered the lives of normal everyday routines in terms of contact, travel, and activities so as to diffuse its spread. Health care systems, economies, and the lives of mankind changed in unnumbered ways that were unimaginable at the beginning of 2020. Specifically, the education sector was profoundly disrupted by the pandemic. Schools that convene large groups of people have become a go-no area to foster precautionary measures to minimize the rapid spread of the deadly virus. The International Association of Universities (2020), an independent global organization affiliated with UNESCO, initially reported that more than a billion and a half of students across the world are affected by school closures due to the COVID-19 outbreak. The imposed lockdowns resulted in the immediate closure of schools, thereby affecting over 63 million teachers worldwide (UNESCO, 2020).

This pandemic has created an unprecedented crisis in most sectors across Uganda, especially in education. Schooling learners at primary, secondary, and tertiary institution levels have been in their homes for so long (close to two years), while a number of these students had paid school fees at the time of closure. This has affected learners by missing two academic learning years, while most of their parents or guardians lost employment or income with the arrival of the global pandemic. A number of candidates are required to pay examination fees to complete high school, secondary, and primary categories of education, respectively. This increases the chance of not completing different levels of education. Private schools that have been enhancing literacy rates are being sold largely because they are surviving on loans, as they cannot survive the pressure from financial institutions and money leaders that need their money. The academic calendar will be interrupted for many

months and years as Uganda tries to bridge the lost education years. It is disturbing that presently; the education sector appears not to be clear on the dates for reopening. This study questions the reading materials distributed in confinement via online communication systems in response to the COVID-19 pandemic. These did not reach all the common Ugandans; the materials ranging from Maths, Literacy, English, Geography, Entrepreneurship, and other subjects were not delivered to a number of ordinary learners. Not all communities in this country can afford/access online classes; ordinary pupils lack access to phones, computers, and the Internet, and even charging these gadgets is a luxury in a typical Ugandan setting. The cost of buying batteries is unsustainable in many rural villages. The government looking for a way into automated learning promised radio to all households across the country and TV learning. This was fora for model teachers to prepare lessons and air lessons on radio and television stations across the country. To the detriment of the populace, Ugandans are yet to receive the promised radios.

On the contrary, a number of learners, students, and lecturers responded positively, with huge adaptability to online learning. A number of school buildings are closed, and online learning takes place via digitalization. However, learning institutions that have attempted to adopt knowledge sharing remotely in a bid to refrain from social gatherings/contacts, such as Christian University Mukono and Uganda Management Institute, have faced challenges, especially the examination of learners electronically. So far, they have started two semesters (two academic terms) without conducting the end of the model examinations to assess whether learning has occurred. Schools and institutions of learning realized that they could not keep teaching while cancelling or postponing examinations. Teachers lack a clear understanding of how to give out exams online, which has halted grading and promoted students from one class to another. The poor Internet connectivity in most parts of Sub-Saharan Africa, few computers/phones to use, and how to invigilate, especially detecting fraud during examination, as some learners may hire others to sit for them, frustrate electronic examination. At the time of writing this paper, the Uganda Management Institute (UMI) had not yet succeeded in an online assessment approach; however, online learning has been ongoing for nearly two years.

The pandemic has overwhelmingly polished the financial gap between the government and private teachers. At the beginning of the lockdown, public teachers continued to earn, while private teachers' salaries were reduced. In the long run, private teachers lost jobs, had no salaries, and currently had no pay at all. As both categories of teachers teach Ugandan students, public teachers have continued to receive salaries to date, yet their counterparts last received wages a year plus ago, much as they have families and dependants to take care of. Teachers struggle with financial stress, thereby suggesting the need to rethink how to cater to private teachers as public officers. Through the Ministry of Education's national database, the government of Uganda is aware of the number of private schools and their respective teachers. This ought to act as a basis to guide the government on how to assist teachers in prevailing catastrophic times.

According to Mbah et al. (2021), Covid19 has been less deadly in Africa than in other regions for five reasons. These include drastic actions taken by many nations to halt or slow the spread of the virus, wide public support for different measures, characteristics of the population being mostly young people, favorable climate, and good community health systems. Maeda and Nkengasong (2021) also capture a limited testing regime, pre-existing immunity, and genetic factors. Tembo et al. (2021) also suggests that there is evidence of possible underreporting. Surprisingly, there are countries that did not go into lockdowns, including Sweden, which is recognized worldwide for its approach in dealing with the COVID-19 pandemic. Thus far during COVID-19, life in Sweden has remained relatively unchanged, with some recommendations in place, such as maintaining social distance, limiting social gatherings, and, whenever possible, working from home. However, no lockdown regimes have been

implemented (Kamoga & Varea, 2021). Irrespective of these critical incidents, the government of Uganda seems to have neglected the common man during these trying moments of the pandemic.
Prior crisis-response studies have largely focused on firm survival and adaptation efforts (Novelli et al., 2018; Rapaccini et al., 2020). Relatedly, recent empirical studies on COVID-19 have tended to concentrate on its impact on the economy, oil price, stock volatility (Albulescu, 2020; Estrada et al., 2020), biosecurity risk management (Melly & Hanrahan, 2020) and the expansion of the disease (Chinazzi, 2020; Gilbert et al., 2020) amongst however, little is known about the concept of public interest, particularly during the outbreak and control of COVID 19. Drawing from grounded theory, this paper the objective of this study was to examine how public interest was lost in Uganda's education sector during Covid-19.

2. Theoretical Predictions

2.1 Grounded Theory

This study adopted a qualitative research approach based on Grounded Theory founded by Glaser and Straus (1967). This theory is underpinned by symbolic interactionism, which focuses on the nature of social interaction and is essentially a theory of human behavior that sees humans as both actively creating the social environment and being shaped by it. A person's response to an event is determined by understanding and interpreting the meaning of the event and their ability to communicate this meaning using language (Blumer, 1969). Specifically, the model rests on collecting, examining, and checking data (Charmaz, 2015). It is a systematic method aimed at theory construction that relies on rigorous analysis and conceptualization of data. This theory is iterative, comparative and interactive. The theory involves coding different processes that imply abstracting and relating categories in the data analysis. This supports the systematic procedure of data analysis, which enhances the ordering of data by offering traceability between the data and categories (Pries-Heje, 1992). It is emphasized that category development should be unprejudiced and open-minded (Charmaz & Belgrave, 2018). Similarly, Orlikowsky (1993) asserted that the ability to incorporate unique insights during the course of the study is one of the benefits of this model. It is also credited for its theoretical power in the sampling process, whereby new data are gathered to enrich the evolving theory (Dey, 1999).
COVID 19 is a complex, dynamic, and fluid phenomenon that is transferred in diverse and often conflicting ways. To make sense of this, this complexity can be appropriately examined using grounded theory. This paradigm of choice allows themes to emerge inductively from data, culminating in data-driven but abstract theoretical understanding of social reality (Charmaz, 2014). This enhances the discovery and generation of new knowledge regarding the pandemic by being central to organizing concepts that serve to both direct the research process and provide a heuristic for data analysis and interpretation. The adoption of GT stems from the need for theory development and creative perspectives, generating powerful insights into the unique deadly corona that caused crisis, and the human race is failing to return to normality. Almost all individuals, communities, societies, and countries are caught off guard, and they appear to fail to understand what can be done to control this catastrophic phenomenon from different viewpoints.

3. Literature review

Public interest, Covid-19 and Education

It is difficult to define the construct of public interest because it is socially constructed and meanings attached to the term by governments, regulators, and other stakeholders (that include a range of groups and organizations representing the public and its views) have varied across time and place (Myles et al., 2023). For example, in the nineteenth-century in Canada, the public interest pertained to service provision by qualified (ie, trained and educated) individuals to lessen patient or client harm, ensure adequate health service access, and practise ethically and competently (Wei et al., 2021). By the late twentieth century, understandings of the public interest had shifted to place more emphasis on cost containment and efficiency in service provision (Adams, 2020). More recently, Kwemarira et al., (2025), has conceptualized the global construct of public interest to include the dimensions of citizens will, egalitarianism and common good.

Public interest has been advanced in response to curbing COVID19 though the use of new technologies and socio-technical landscapes while altering work practices and service in the education sector (Casey, 2019). This was evidenced in the widespread shift to virtual education provision (). Again, technology, increased mobility and easy access of education provision to many learners and students while in their different homes thus serving the public interest (Sweatman & McDonald, 2022). Relatedly, in the spring of 2020, public schools across the United States were forced to close their campuses due to an emerging public health crisis caused by the detection of the first cases of the COVID-19 virus. Although schools closed their buildings, the delivery of educational services did not stop. This included the ongoing provision of services mandated by federal law to ensure that learners continued to attain education (Jameson et al.,2020).

Education is traditionally a domain of the government, where public authorities determine how education is organized and quality assured. This is in line with a rights-based approach: governments are the duty-bearers and as such, are responsible for ensuring the right to education. While governments have succeeded in making education more accessible over the past decades, the role of the government has also been changing as public budgets were shrinking and the private sector encouraged and facilitated to play a new and expanded role in providing public education (Wulff, 2021).

Researchers have argued that there can be no doubt that the crisis caused by the COVID-19 pandemic will be looked back on as a historic moment – one that could come to be seen either as an important turning point for humanity or as a huge missed opportunity, a mile stone in the story of our deterioration and mismanagement of the planet. How we respond and the actions we take now will have a profound impact on the society of the future, including the future of education. It will determine whether we continue on our current course, leading, as it would appear, to increasingly brutal, authoritarian and inequitable forms of capitalism, or whether we recognise the profound dysfunction at the heart of our socio-economic arrangements and try to create something better. To do so, we must be sure to act on the basis of values and principles that can enable us not only to build back better but to build back fairer and in a more inclusive, democratic and sustainable way. Education, of course, has a critical role in all of this, as it helps to mould these formative values while at the same time being moulded by them (Stanistreet et al., 2020).

Globally, the last 50 years have seen serious huge growth worldwide in the provision of education at all education levels. COVID-19 is the greatest challenge to humanity that these expanded national education systems have ever faced. Many governments from low to developed countries have ordered institutions to cease face-to-face instruction for most of their students, requiring them to switch, almost overnight, to online teaching and virtual education (Daniel, 2020). This shows the

need for governments to offer online platforms to foster the continued provision of education services to their publics, teachers, institutional heads and state officials who must manage the educational consequences of this crisis (Kwemarira et al., 2025a).

4. Methodology

This study adopts existential phenomenology. Existential-phenomenology is a paradigm that blends the philosophy of existentialism with phenomenological methods of phenomenology (Valle & King 1978). In existential phenomenology, the human being is understood as essentially embodied, and the body 'is a physical thing, an object that can be weighed, measured and described using purely physical or naturalistic terms. However, it is also the source of subjective feelings, perceptions, and sensations; it is the seat of subjectivity and the place where consciousness occurs. As such, the body is a subject object, a unique being that can be experienced both from a first and a third person's point of view' (Carel, 2011). For example, existential-phenomenological methods have been employed in research concerning the experiences of anxiety and depression (Fischer 1978) which are closely associated with the study of COVID 19 and its related predictors or outcomes. Researchers have adopted this paradigm because it focuses more on ontology or what it means to be (Heidegger, 1962/1999) in the context of the COVID-19 pandemic.

5. Research design

This article used a qualitative method with a case study research type. The purpose of this study was to examine how public interest was lost in Uganda's education sector during Covid-19. This study was conducted at the lead author's residence in Nakinyuguzi village, located in Salaama-Munyonyo in Uganda's capital city, Kampala. Data were collected using interview techniques by selecting specific informants to obtain relevant primary data. The selected informants were 12 private teachers who had not received any salary since the closure of schools, in line with the lockdown. These 12 participants are consistent with the concept of saturation was originally developed by Glaser and Strauss (1967) to qualitative research, which focuses to the point in data collection when no additional issues or insights emerge from data and all relevant conceptual categories have been identified, explored, and exhausted. These respondents had been seriously negatively affected since the declaration of the corona quarantine. This study sought to gain insight into each of the severely impacted teachers through the use of interview procedures and thematic analysis. Following social distancing, sanitizing, and masking, interviews were conducted. This was to control the spread of the coronavirus by abiding by set SOPs (MoH, 2020). The researchers further interpreted the experiences of the affected teachers through a thematic analysis. This theme is the main product of this analytical technique (Green et al., 2007).

6. Participants

The participants were notified and invited to participate in the interviews by the lead scholar (Kwema) a week prior via telephone calls. The intention of the visit was made thorough to the interviewees (the purpose was made clear that it was only for scientific purposes). Informed consent was obtained verbally before conducting interviews. All the teachers spoke and understood English, which was used as a communication model. This was intended to understand how public interest was lost from interviewees' perspectives. Using semi-structured interviews, each of the authors interviewed four participants to collect the qualitative data. As opined by Qu and Dumay (2011), a

semi-structured interview involves questioning, which is guided by identified themes in a consistent and systematic manner interposed with probes to elicit more elaborate responses. All interviews were audio-recorded with the oral permission of the **respondents,** all the interviews were audio recorded. Each experiment lasted for approximately 1 h. The responses generated were analyzed using the QSR*NVIVO qualitative data software program for data management (Kwemarira et al., 2021). Thereafter, the generated responses were analyzed to obtain the emerging themes and sub-themes indicated in the NVIVO outputs.

Table 1: Showing Profile of informants

Cases	Age	Gender	Marital status	Education Level	Years	Way of survival
1	35-46	Male	Married	Diploma	11	Went into Peasantry
2	26-35	Male	Married	Degree	10	Self-employment/ Fruits
3	36-45	Female	Married	Diploma	15	Self-work/Bakery
4	Below 26	Female	Single	Degree	4	Settling into corporate
5	26-35	Female	Married	Degree	6	Teaching via Zoom
6	26-35	Female	Single	Single	9	Massage parlour
7	36-45	Male	Married	Diploma	12	Gardening
8	Above 46	Male	Married	Certificate	16	Awaiting for reopening
9	36-45	Female	Married	Certificate	15	Operating a salon
10	36-45	Male	Married	Diploma	7	Car wash
11	36-45	Female	Separated	Certificate	16	Pool Table
12	Above 46	Male	Divorced	Diploma	10	Waiting for re-opening

Source: Primary Data; September 2021

7. Emerging themes

After data analysis stemming from information gathered from respondents in Table 1, nine critical themes were generated from the master transcript of the responses of the participants in line with public interest being lost during the coronavirus. The results are presented and discussed below.

Critical theme 1: The lockdown

During the first wave of the coronavirus, the government of Uganda imposed a lockdown where the cessation of stay-at-home orders was undoubtedly enforced. The study reveals that this was a challenging decision where, for the first time in the history of Ugandans, people were to stop working and be confined to their homes to curb the spread of the virus. In effect, this involved isolation and loss of physical contact, which frustrated the wider social bonds that threatened the core of our Ugandan social human existence. The researchers noted increased challenges in a number of Ugandans' mental health due to the lockdown brought in by physical isolation and loss, combined with fear of unpredictable threats and economic hardship. This affected the income of the citizenry, especially the urban Ugandans. The lockdown immediately ushered in unemployment; thus, poor or questionable feeding became inevitable, implying a lack of home materials. This points to the failed government provision of basic commodities during the lockdown, ranging from food and medical insurance (participants argue that a number of people with HIV/AIDS died due to failed access

to ARVs). It is important to note that the government's emphasis was seemingly on security for citizens to abide by curfew guidelines at the expense of providing basics in communities. A number of patients who were on motorcycles, locally termed boda bodas, were not given a chance to proceed to hospitals to receive medical care. The security officers dehumanized the citizens by beating them in the evening to enforce the lockdown directives. The lockdown was extremely expensive, and many citizens questioned its relevance in fostering the common good. Again, urban dwellers were highly affected; they were forced to stay in their homes, unlike their counterparts in rural areas, who continued to cultivate their land and farming continued normally, while the government ignored this disparity.

Viewpoint 2: The standstill of formal schooling

School closures were a difficult decision. School activities mobilize many people: teachers, head teachers, students, parents, and other staff. While Covid-19 was soon revealed to be more dangerous for the adult population (notably for older age groups), school closures were considered one of the most effective measures for containment and prevention of the disease because different learners congregate from different homes, and in the evening, they could transfer the virus to their parents.. This paved way for the viewpoint of closing schools and those that attempted to teach online was challenged by the high costs and challenging access to the Internet in almost all regions of Uganda. The transformation from traditional education to online via zoom in the context of Uganda faces a number of challenges, especially inadequate facilities and electricity coverage, to charge these gadgets, which are viable enough to replace the traditional system. The informants indicated that learners who were to be promoted are yet to be promoted at another level of education. Schools have been sold off in a bid to clear proprietor loans, leaving learners wondering where they are going for studies as soon as schools reopen. At the reopening of schools, learners will pay afresh irrespective of what they had paid before the closure of the schools, to the detriment of parents and guardians. Additionally, masks would have been made compulsory and put on every time while on school premises and emphasized again while talking in class plus other SOPs. Participants argued that washing hands, social distancing, and isolating sick learners and teachers suffering from flue was the best alternative for averting the spread of the virus. This would have kept schools open at the same time without frustrating the learning process. It appears that the government rushed to close schools. When schools closed, everything came to a standstill, girls became pregnant, unemployment rose, and teachers went into a miserable life; they could not provide basics for themselves or their families. Participants informed the researchers that for close to two years, private teachers are yet to receive salaries, and a number of them have been sent out of houses for failure to pay rent. One interviewee said,*'two meals are a luxury in this lockdown, we only survive on posho and beans once a day. I am intending to take my family to the village. Only if I can get someone to buy my computer such that I get transport money. I am very sure of not going back to teach, the school would have given me some relief in form of food and accommodation fees. I have been a laughing case in my neighbourhood. To hell with teaching again in my life time'.* Teachers, especially private, did not receive salaries throughout the lockdown and no savings, yet they needed to pay for accommodation, food, and medication insurance for their family members as the government kept a deaf ear, yet they offered their services to the entire public.

Emerging theme 3: Online education

The world, inclusive of Uganda, witnessed a rapid transformation of the education system with the coming of COVID 19 and subsequent closure of schools. Online education gained wind in its sail during this pandemic event now more than ever. Previously, online-based education was (mostly)

limited to pre-recorded videos and online courses (both using institutional learning management systems and massive open online course platforms), but in the desperate times of the pandemic, it transformed physical classrooms into virtual classrooms, connecting the teachers and students to live through the Internet and necessary devices. For a lower-middle-income developing Uganda, which is going through a transforming period to officially achieve the status of a developing country, this seemed like a desperate measure without deliberate consideration to maintain educational quality, similarity or resemblance, reach, and interaction, or the same teaching method of the live online classes made the virtual classes parallel to physical ones.

However, COVID 19 did not present a chance for Ugandan teachers to reap from the benefits of online teaching by being trained in appropriate approaches to convert traditional methods to online learning. This greatly affects the understanding of the use of available technologies. The reality is that it is much harder to transfer a number of subjects online, for example, practical subjects such as agriculture and biology. Virtue learning requires significantly more motivation and attention, while the screen creates an emotional removal that makes it difficult to have dialogue or feedback without feeling as if you are speaking into a void. Interviewees suggested that this kind of teaching required a great deal of resources and careful planning. Moreover, a huge change in the mindset of students and teachers is required to play new roles in the educational process. In Uganda, another major challenge for online learning is the limited coverage of electricity to charge computers, and the limited funds to buy these gadgets as the government keeps increasing taxes on computers and the Internet instead of subsiding or providing them freely.

Due to the lockdown and resultant closure of schools, the government would have rushed to avail learning gadgets at subsidized or no cost and even provide free internet. Instead, the government hiked the costs of the Internet, frustrating common learners. Instead, it would have gone on to avail learning video recordings of what was to be taught in the communities, to be accessed freely. In contrast, it promised free radios that we are yet to receive. The reading materials provided in the media were not afforded by the majority of common Ugandans. Relatedly, the study questions the availability of teachers after the lockdown, high dropout of learners, and the fact that a number of girls have had unwanted pregnancies, while all the Ugandans are disturbed by the loss of academic two years while at home.

Theme 4: Social distance

"Social distancing" was an essential element SOP announced by the president of Uganda a global recommendation to mitigate the community from the spread of the deadly coronavirus. It was conceived from the perspective that the emergence of social distancing was an effective measure to curb the spread of the virus. The idea of social distancing brought forth working from home (remote work), virtual courts, online classes, and greeting from friends and close relatives at a distance against the Ugandan culture of hugging without engaging socially to prevent the virus from spreading. The COVID-19 outbreak had a devastating impact on Ugandans and shattered the social system with a massive jolt to hugging and partying culture, both in villages and urban areas. The COVID-19 pandemic quickly led to the closure of universities, colleges, and secondary and primary schools with government instructions to follow social distancing, which could help to flatten the infection curve and reduce total fatalities from the disease. The most important pandemic precaution called "social distancing" or "physical distancing" has attempted to reduce interpersonal contact and thereby minimize the kind of community transmission that could develop quickly in dense social networks like the school campuses.

Critical incidence 5: The new normal

During the COVID-19 outbreak, new habits and practices that were previously considered normal came into being and have been termed the 'new normal. ' The interviewees observed "new normal" as they lived day to day in the times of lockdown. The participants noticed that some changes in their routines, both positive and negative, occurred. For example, cooking their own food in people's respective homes as all restaurants and hotels were closed, sleeping as much as they could because people had a lot of idle time. However, on a positive note, the Ugandans are now minding about their cleanliness, especially washing their hands regularly. The participants are sure that even after the demise of corona virus this culture of washing hands and sanitizing will stay that will keep the populace from a number of diseases. The public has adopted a good culture of nutritious foods, especially fruits, to boost immunity.

Emerging theme 6: Inequality between public and private teachers

Between March and May 2020, 132 countries, including Uganda, implemented country-wide school closures affecting hundreds of millions of students worldwide (United Nations Educational, Scientific and Cultural Organization, 2020). As part of the unprecedented societal and economic effects associated with the COVID-19 pandemic, national education systems face short- and long-term negative effects spanning from the detrimental social and health conditions of vulnerable children and families to exacerbating social and educational inequalities (Van Lancker & Parolin, 2020). In Uganda, private and public education systems have witnessed high inequalities during the lockdown. This originated from the immediate closure and subsequent cessation of receiving salaries and wages among teachers and other employees of private learning institutions at all levels. The lives of private teachers were turned upside-down, while the government demonstrated that it could not assist these teachers and instead focused on only public teachers, as the private teachers served all Ugandan learners. This appears to be illogical, paying government teachers for two close years, yet their counterparts have never been paid since the closure of schools. The corona crisis shrewdly demonstrates that much as private teachers offer their services to the Ugandan populace and even pay taxes, the government of Uganda does not care about their wellness.

Emerging theme 7: Financial stress

From the beginning of the pandemic in March, the suffering of private teachers, each and every month that passed, became more significant. Private teachers suffered from financial stress, but the majority of the Ugandans faced financial setbacks. For example, the transport system, agriculture, manufacturing and production, hotels, games, sports, and the music and entertainment industries were extremely halted, which affected the incomes of the citizenry. Financial setbacks among the populace were largely a result of the immediate stay home to implement the set guidelines from the Ministry of Health, as forwarded by the president of Uganda. For private teachers, having no cash to use stemmed from the government completely ignoring them financially as if they did not teach Ugandan pupils. The interviewees noted that disrespectfulness emerged from the learners towards the teachers as they were found doing indecent work like brick lying and hawking different food items, which greatly affected them psychologically.

Emerging theme 8: Cars movement put on standstill

Since the announcement of the lockdown, the livelihoods of the citizenry have changed, especially from the transport perspective. One measure to stop the spread of the contagious virus during the lockdown was to halt the use of public transport. This has pushed the populace towards the use of private cars and individual means of transport. Transport is crucial to connect communities but was

highly challenged as cars were packed, walking long distances (to and from markets and hospitals) became the new normal, bicycles and motor bicycles (Boda bodas) were also used in trying to reduce the spread of the pandemic, and a few citizens could afford to hire pickups and motorcycles. The interviewees noted that the sick suffered more while others died, as they could not afford transport to access hospitals for medication.

Emerging theme 9: Domestic violence

During the lockdown, a number of incidents of domestic violence were witnessed during isolation and forced stay at home. The husbands, wives, children, and relatives were fighting and abusing each other largely because of a lack of resources. The lockdown frustrated the intimate relationships, and the family institution was largely torn apart, largely as a result of fathers failing to provide as a result of being rendered jobless. One participant asserted that without financial resources, staying at home can be dangerous, as the number of requests continues to accumulate without being sorted. This was not the intent of restricting people to their homes per se. The forced stay at home was intended to curb the spread of corona virus yet it made domestic violence inevitable as a result of accumulated unmet needs in homes. The researchers note that any teachers to teach in private schools are, in most cases, registered/examined and passed by the Ministry of Education (MoE). They even pay taxes to schools, especially their respective schools, and thus this was the basis for the government to come in and assist financially so as to keep earning even in times of pandemic, like the ongoing situation.

8. Concluding remarks

In the first and second waves of the pandemic, Ugandans, particularly teachers, faced significant challenges as a result of the COVID-19 pandemic that came with the closure of schools. The impact of the pandemic on the population would have been neutralized by the government. However, the regime demonstrated egoism to the detriment of citizenry. It is important to change the trend of handling the interests of the public with those of authority. This study notes that public servants tend to remain blind to the desires, needs, and preferences of their citizens. They have only cared for their selfish interests at the expense of what benefits most Ugandans. This stems from the poor-quality masks, and questionable food in terms of quality and quantity (the beans and posho) were extremely not in lieu of the public value of the taxpayers' money spent. In addition, Ugandans collected staff and money during the lockdown to act as relief for vulnerable Ugandans; surprisingly, those who were supposed to receive emergency facilities have never received the collected money and materials, while no clear accountability has been provided to that effect.

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APPLICATION OF SMART TECHNOLOGIES IN THE INTEGRATION OF LOCAL RESOURCES FOR SUSTAINABLE DESTINATION MANAGEMENT

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Abstract: *The research has shown that smart technologies can significantly improve the integration of local resources into sustainable destination management, but this potential depends on strategic alignment, digital infrastructure readiness, and stakeholder coordination.*

Practical implications point to the need for continuous training of destination managers, investment in digital tools tailored to local specificities, and adaptive governance frameworks.

The study's limitations include a limited geographic sample and reliance on secondary data for benchmarking, while future research should expand on empirical fieldwork and explore comparative cross-country models.

Lessons learned suggest that smart solutions should not be treated as universal tools, but as contextual instruments aligned with the social, ecological and technological maturity of each destination.

Keywords: *smart technologies, sustainable management, local resources, smart destination, tourism, collaboration*

1. Introduction

1.1. Context and Importance of the Research

This paper was created as part of the project "Smart Destinations: Integration of Local Resources and Sustainable Tourism, whose overall goal is "to explore and apply the concepts of smart destinations for the sustainable use of local resources, with an emphasis on reducing the negative impacts of tourism on the environment and strengthening the social capital of the local community. Application of Smart

Technologies in the Integration of Local Resources for Sustainable Destination Management directly encourages all the specific objectives of the project by: ensuring an overview, preservation, and high-quality use of existing local resources, providing methods and tools for reducing tourism's negative impacts through technology-assisted planning, generating new insights that can be shared through scientific publications and conferences, and strengthening cooperation and involvement of the local community, thus making tourism sustainable and socially responsible. This paper investigates how smart technologies can support the integration of local tourism resources in sustainable destination development. The research problem lies in the underutilisation of such technologies at the local level, particularly in regions with fragmented governance and limited digital literacy. The significance of the study is in exploring the feasibility and context-specific mechanisms of such integration, aiming to fill a gap in applied models and policy approaches post-COVID. The topic directly aligns with the journal's focus on sustainable development and innovation, as it explores technological enablers of green transformation and local resource optimisation in tourism.

1.2. The Problem and Current Situation

A fundamental problem regarding smart technologies for the integration of local resources for sustainable destination management, as cited in the literature, is: "Insufficient coordination between local stakeholders, such as residents, the public sector, the private sector, and civil society organizations, remains common and hampers sustainable destination management" (Marasco et al., 2018:65). "Despite the existence of numerous strategies and plans, their implementation is often delayed or absent due to a lack of financial resources, specialist knowledge, or political will" (Ivars-Baidal, Celdrán-Bernabeu & Mazón, 2019:91). In this context, smart technologies can provide a platform for better connectivity and transparent information sharing in real time.

"In Croatia and many other Mediterranean countries, tourism often represents the main source of income but also poses a risk for the overexploitation of local resources (UNWTO, 2018:23). This is especially true regarding seasonality, uneven distribution of revenues, pressure on infrastructure, and the preservation of natural and cultural attractions" (Zhang et al., 2019:5). Smart technologies in this case offer the possibility of better visitor distribution, crowd management, energy efficiency, and environmental monitoring.

1.3. Research Objectives and Hypothesis

The main objectives of this paper are to: 1.) investigate how smart technologies can facilitate the integration of local resources and improve sustainable destination management, 2.) identify key stakeholders and mechanisms of cooperation that ensure successful practical implementation of smart technologies, and 3.) analyze best-practice examples and compare various destinations that have already implemented smart management models to derive recommendations and guidelines for improving Croatian destinations. From these objectives, the following research hypothesis was formulated:

> ***H1****: The introduction of smart technologies into integrated management of local resources positively impacts the sustainability and competitiveness of a tourist destination while simultaneously preserving the quality of life of the local community.*

1.4. Structure of the Paper

The structure of this paper consists of several interconnected sections. After the introductory part, the research methodology follows, explaining the quantitative and qualitative methods used, the

sample of respondents, and the description of the questionnaire. Next is the theoretical framework of smart destinations and sustainable management of local resources. The comparative analysis section presents best-practice examples and compares different models of implementing smart technologies. This is followed by the testing of the hypothesis and presentation of the research results, together with identified risks and mitigation measures. The final section provides the discussion, conclusion, and list of references.

2. Research Methodology

2.1. Research Design and Approach

The design of this research is based on a mixed-method approach that encompasses quantitative and qualitative methods. This design enables a comprehensive examination of the phenomenon of smart technologies and their role in integrating local resources, providing not only statistical indicators but also deeper insights from the perspective of key stakeholders.

Quantitative approach – based on a survey of a larger number of respondents to determine attitudes, perceptions, and experiences regarding smart technologies and sustainable destination management (Buhalis & Amaranggana, 2013). **Qualitative approach** – includes in-depth interviews with a smaller number of informants (representatives of local authorities, tourist boards, experts, NGOs, etc.), providing a deeper analysis of institutional, organizational, and socio-cultural aspects. **Comparative analysis** – comparison of a local smart destination model with examples from other countries to identify best practices and guidelines for improvement (Marasco et al., 2018). This combined approach allowed the hypothesis to be tested from different perspectives and contributed to the reliability and validity of the research findings.

2.2. Quantitative Methods

2.2.1. Survey Questionnaire

The main research instrument was a survey questionnaire constructed according to recommendations for studies in the field of sustainable tourism and technology (Hall, Gössling & Scott, 2015; Gretzel et al., 2015). The questionnaire consisted of three main parts: 1) **Socio-demographic indicators** – gender, age, education level, relationship to the destination (tourist, local resident, representative of local authorities/business, etc.); 2.) **Attitudes toward sustainability** – assessment of the importance of sustainable management, personal awareness of tourism impact, perception of stakeholder cooperation; 3.) **Perception and experience of using smart technologies** – attitudes about the benefits of technology for local resources, willingness to invest, evaluation of existing solutions.

"Most questions used a Likert scale from 1 (strongly disagree) to 5 (strongly agree)" (Buhalis & Amaranggana, 2013:558), which enabled statistical comparison among different groups of respondents.

2.2.2. Sample of Respondents

The survey was conducted on a total of 300 respondents (N = 300). After reviewing and cleaning the data, 290 questionnaires were deemed valid and included in the analysis. The sample included tourists, local residents, representatives of local government/tourist boards, and representatives of local businesses (Table 1).

The aim was to capture different perspectives and levels of involvement in destination management (Hall, Gössling & Scott, 2015).

Table 1. Structure of respondents by group (N = 290)

Group of respondents	Number of respondents	Percentage (%)
Tourists	85	29.3%
Local residents	110	37.9%
Representatives of local government/tourist boards	45	15.5%
Representatives of local businesses	50	17.2%
Total	290	**100%**

"When selecting the sample, a convenience sampling procedure was used, aiming to capture as wide a spectrum of socio-demographic characteristics as possible. Given that this was a mixed-method study, the primary goal was to collect sufficiently diverse responses to gain a realistic insight into perceptions of sustainability and the role of smart technologies" (Dwyer, 2018:152).

2.2.3. Data Processing and Analysis

The SPSS software package was used to process the quantitative data. The analysis included: 1.) **Descriptive statistics** (means, standard deviations, minimum, maximum) to describe variables and check the distribution of responses; 2.) **Inferential statistics** (ANOVA, Tukey post hoc test, Pearson correlation, linear regression) to test differences among groups and verify the research hypothesis as well as relationships among variables (Marasco et al., 2018). Before conducting the main statistical analyses, the reliability of the measurement instruments (Cronbach's alpha) and potential data outliers were checked. Normality was tested using the Kolmogorov–Smirnov test and visual inspection of histograms.

2.3. Qualitative Methods

2.3.1. In-Depth Interviews

The qualitative part of the research was realized through 20 (semi-structured) interviews.
Interviews were based on a thematic guide, which included questions about strategic planning, institutional and operational challenges, stakeholder collaboration, and the application of specific smart solutions. Interview participants included representatives of: 1.) local government and tourist boards (mayors, municipal heads, heads of tourism departments), 2.) the private sector (hotel and restaurant owners, tech companies specializing in IT solutions for tourism), and 3.) NGOs and civil initiatives (environmental protection associations, cultural promotion, etc.).
Each interview lasted on average 40–60 minutes and was audio-recorded with the interviewee's consent. Data analysis was conducted in NVivo software using thematic analysis. This method identified the main categories based on which the results were interpreted and compared with the quantitative findings.

2.4. Comparative Analysis

The methodology also included a comparative analysis with the aim of comparing the local model of implementing smart technologies with practices in other countries. Secondary data were collected from scientific publications, international reports (e.g., UNWTO, WTTC), and case studies. The focus was on: 1.) regions with a longstanding tradition of implementing smart technologies (e.g., Spain, some Asian destinations) and 2.) similar Mediterranean countries (Italy, Greece) for comparison of institutional frameworks and seasonal challenges (Ivars-Baidal, Celdrán-Bernabeu & Mazón, 2019). The analysis consisted of reviewing key parameters (institutional framework, financial mechanisms,

level of collaboration, technological maturity), and the results are presented in tabular form in the main body of the paper (Section 4). This provided insights into existing models and practices and identified possible opportunities to improve the local model.

3. Theoretical Framework

The theoretical foundations of smart destinations, sustainable management, and stakeholder collaboration form the backbone of the empirical part of this paper.

Combining quantitative and qualitative methods allowed for an in-depth examination of the hypothesis that smart technologies have a positive effect on the sustainability and competitiveness of a destination, but only with adequate institutional support and the involvement of local stakeholders (Boes, Buhalis & Inversini, 2016; Koo, Shin & Gretzel, 2017).

Recent research emphasises the transformative potential of smart technologies in tourism, particularly in the context of post-COVID recovery and digital resilience (Gretzel et al., 2020; Koo et al., 2021; Sigala, 2023). The literature has increasingly focused on how artificial intelligence, big data, and mobile platforms shape destination management systems.

3.1. The Concept of Smart Destinations and Sustainable Management

The concept of smart destinations "is based on the idea that modern information and communication technologies (ICT) are integrated into the comprehensive management of a tourist destination, with a special emphasis on stakeholder collaboration and the preservation of local resources" (Buhalis & Amaranggana, 2013:553–554). The term "local resources" refers to the natural, cultural, social, human, and infrastructural resources that a destination possesses, which form the basis of sustainable development (Boes, Buhalis & Inversini, 2016:405). This concept implies the synergistic use of modern ICT to achieve more efficient and sustainable destination management, where stakeholders (public sector, private sector, local residents, and tourists themselves) are actively involved in all phases of the process. By using large amounts of data from sensor systems and internet platforms, smart destinations aim to optimize resources, monitor the impact of tourism on the environment, and enhance visitor experiences.

Theoretically, smart destinations arise at the intersection of several key areas: 1.) **Smart city technologies** (Internet of Things, big data analytics, artificial intelligence, mobile apps, and sensor systems), 2,) **Sustainable resource management**, involving strategies to reduce the negative impact of tourism on nature and society while fostering economic growth and preserving local identity, 3.) **Stakeholder collaboration and participation**, including the public and private sectors, local residents, and visitors, with open platforms and transparent information sharing (Gretzel et al., 2015)

Research confirms that the concept of smart destinations can be viewed as a broader ecosystem solution, where coordinated collaboration between various actors and the intelligent use of digital technologies play a primary role (Koo, Shin & Gretzel, 2017). According to some recent studies, "this ecosystem approach reduces overlap in activities and enables faster adaptation to local needs" (Egresi & Polat, 2019). On the other hand, "sustainable tourism management involves balancing economic gain, respecting social values, and preserving the environment in the long term. In practice, this includes equitable distribution of tourism benefits and costs, involving the local community in decision-making, and protecting natural and cultural attractions" (Hall, Gössling & Scott, 2015:8–9).

Some authors (Koo, Shin & Gretzel, 2017; Egresi & Polat, 2019) point out that "smart technologies serve as a catalyst for change because they facilitate the real-time collection and analysis of data, thereby enabling data-based decision-making in destination management." Ongoing sustainable management implies promoting economic efficiency, social equity, and environmental conservation

in the long term" (Hall, Gössling & Scott, 2015). In the context of tourism, "this means equitable distribution of benefits and costs, involving local communities in decision-making, and preserving ecosystems and cultural heritage" (UNWTO, 2018:23).

3.2. The Role of Smart Technologies in Integrating Local Resources

"Integrating local resources, which include natural, cultural, social, and infrastructural foundations, is increasingly important in the context of the global demand for authentic and sustainable tourism experiences" (Boes, Buhalis & Inversini, 2016:405). Smart technologies play multiple roles here and contribute to the integration of local resources through several mechanisms: 1.) **Real-time visitor monitoring and analysis**: IoT sensors and big data tools provide destination managers with insights into visitor numbers, movements, and infrastructure load, facilitating more effective planning and redistribution of tourist flows (Zhang et al., 2019); 2.) **Digital collaboration platforms**: Through common internet portals or mobile apps, different stakeholders can exchange information, coordinate activities, and promote sustainable practices (Buhalis & Amaranggana, 2013; Hribar et al., 2021); 3.) **Resource optimization**: Implementing smart systems for energy, traffic, and waste management reduces consumption and enables more eco-friendly development (Zhang et al., 2019). Because of these advantages, "many destinations are adopting smart technologies to promote sustainability, especially those with pronounced seasonality or sensitive ecosystems" (Ivars-Baidal, Celdrán-Bernabeu & Mazón, 2019). Newer studies indicate that "the application of IoT solutions is increasingly spreading to rural areas, where indicators of the preservation of natural and cultural heritage are monitored, and tourists are guided to less-known attractions to alleviate pressure on main destinations" (Tomljenović, 2021:15–17). This approach can help avoid the negative effects of mass tourism and encourage more evenly distributed development across the entire region.

3.3. Stakeholder Collaboration and the Institutional Framework

Stakeholder collaboration is considered one of the main prerequisites for the success of any sustainable and smart destination management strategy.

According to Egresi and Polat (2019), stakeholders must share a common vision and have a unified digital platform for information exchange for smart technologies to truly operate on a practical level. "The degree of success in implementing smart technologies depends on the quality of stakeholder collaboration: the public sector, private companies, NGOs, local communities, and even tourists" (Marasco et al., 2018:66–67). Without a clear vision and strategic plan at the institutional level, pilot projects usually remain isolated, and local resources are not fully integrated (Dwyer, 2018).

Systematic planning, which includes defining long-term goals, financial mechanisms, and success metrics, greatly influences the level of acceptance of smart technologies in the local community.

Examples of good practice abroad (e.g., Barcelona, Seoul) demonstrate that policy continuity, public education, and supportive regulations are key (Ivars-Baidal, Celdrán-Bernabeu & Mazón, 2019; WTTC, 2017).

However, practical challenges often include insufficient IT infrastructure, lack of financial support, and unadapted legal frameworks, especially in smaller communities or rural destinations.

Vidović (2022) notes that creating a collaborative environment further empowers the local community, as digital platforms can serve as a mechanism for voting, planning, and transparent monitoring of decisions about resource use.

"Establishing clear strategic plans and long-term financial projections is crucial for integrating smart solutions into everyday management. At the level of local governments and counties, coordinated regulation that encourages innovation and attracts private-sector investment in technological solutions is needed" (Gretzel et al., 2015:185).

3.4. Integrating Theoretical Assumptions into the Research

The conducted research (see Sections 6 and 7 of the paper) is based on the assumption "that the systematic application of smart technologies and stakeholder collaboration positively influences sustainable tourism destination management" (Buhalis & Amaranggana, 2013). Quantitative findings showed that attitudes toward smart technologies correlate significantly with the perception of sustainable management, while qualitative analysis highlighted the crucial role of strategic planning and education.

Thus, the theoretical assumption of technology's importance as a catalyst for sustainability is confirmed, along with the recognition of obstacles such as insufficient institutional support and limited financial resources.

Some recent studies in Croatia (Hribar et al., 2021; Tomljenović, 2021) indicate that pilot projects—such as smart parking systems, interactive digital maps, or platforms promoting less-known locales—can enhance the visitor experience and reduce congestion in city centers. However, as Vidović (2022) points out, the success of such initiatives largely depends on local stakeholders' capacities and willingness to collaborate.

In conclusion, an analysis of theoretical and empirical insights indicates that smart technologies significantly contribute to integrating local resources and managing destinations sustainably, but only in synergy with an effective institutional framework, ongoing education, and solid stakeholder collaboration (Egresi & Polat, 2019; Koo, Shin & Gretzel, 2017).

To ensure scientific relevance, this study builds upon up-to-date insights from key authors in smart tourism and destination innovation (Mariani & Baggio, 2022; Sigala, 2023), linking technology adoption with sustainable development objectives.

4. Comparative Analysis

The comparative analysis included an overview of several examples of implementing smart technologies for sustainable destination management in Mediterranean areas, as well as in destinations globally recognized for advanced "smart" solutions. This allowed for a comparison of the local (Croatian) model with international practices as a learning opportunity from proven concepts.

Table 2. Comparative analysis of smart destination models

Destination	Institutional Framework	Smart Technologies	Stakeholder Collaboration	Results / Best Practices
Local Model (Croatia)	National and regional tourism strategies; lack of an integrated "smart" strategy	Pilot projects: smart parking, digital maps, crowd tracking solutions (primarily in city centers)	Limited; projects often depend on the will of individual city/ municipal authorities	Growing awareness of the importance of smart technologies, but insufficient financial and institutional support
Spain (e.g., Barcelona)	Strong public-sector support, clear "Smart City" strategy	IoT networks, digital platforms, big data analytics for crowd control and energy efficiency	Highly developed—tech companies, universities, and public institutions all actively involved	Successfully reduced traffic congestion, increased satisfaction among residents and tourists
Italy (Tuscany)	Regional strategy focused on digital transformation of tourism	Platforms for promoting cultural heritage, mobile apps for interpreting local attractions	Solid—emphasis on collaboration between SMEs and local authorities	Increased visibility and distribution of tourist flows, reduced pressure on main city centers

Destination	Institutional Framework	Smart Technologies	Stakeholder Collaboration	Results / Best Practices
Asia (Seoul, South Korea)	Long-term "Smart City" strategy at the national level, incentives for innovative solutions	Integrated public transport systems, smart cards, artificial intelligence for predictive capacity management	Very strong—partnerships between the government, major IT companies, and academia	High digital literacy and efficiency, reliable tracking of flows, and rapid service adaptation

From Table 2, it is evident that "the local model in Croatia, despite initial pilot projects, lags behind in coordinated strategy and financial sustainability. In more advanced examples (Barcelona, Seoul), there are robust state and regional incentives and systematic investments in infrastructure and education of the population. Italy, on the other hand, demonstrates the advantages of cooperation between SMEs and local authorities, especially in promoting cultural heritage, which could be beneficial for Croatian destinations."

In conclusion, the comparative analysis shows that local destinations need stronger institutional support, strategic planning, and investments in digital infrastructure, with the critical involvement of all stakeholders (the private sector, local community, academia) from the start of the process.

5. Examples of Good Practice

Below are three concrete examples, together with a description, key benefits, and applicability, illustrating how smart technologies can improve sustainable destination management and integrate local resources:

1. **Digital Cultural Routes and Interactive Maps**: **Description**: A platform and mobile app offering real-time displays of historical trails, museums, and cultural events; **Key Benefits**: Better visitor guidance, reduced congestion at the most popular attractions, and increased visibility of peripheral areas; **Applicability**: Particularly useful in destinations with rich cultural and historical heritage (Hribar et al., 2021).
2. **Smart Traffic and Parking Management Systems: Description**: Sensors on parking spaces, information boards at city entrances, and apps guiding tourists to free parking spots; **Key Benefits**: Reduced traffic congestion, economic savings due to better traffic organization, improved satisfaction among local residents; **Applicability**: Suitable for city centers and popular tourist locations where traffic congestion is a significant problem (Gretzel et al., 2015).
3. **Big Data Analytics for Resource Management**: **Description**: Using large datasets (number of visitors, energy consumption, water resources) to predict peak times and allocate services accordingly; **Key Benefits**: Optimization of consumption, preservation of natural and infrastructural capacities, reduced seasonal peaks; **Applicability**: Destinations with pronounced seasonality and limited capacities (Zhang et al., 2019).

All these examples emphasize the importance of stakeholder collaboration and continuous education as fundamental conditions for success. Good practice shows that technology without adequate organizational and financial support often remains at the pilot-project stage.

6. Hypothesis Testing

The research set forth the hypothesis:

H1: The introduction of smart technologies in integrated local resource management positively influences the sustainability and competitiveness of a tourist destination while simultaneously preserving the quality of life of the local community.

Quantitative research results (see Table 6) showed that attitudes toward smart technologies significantly predict perceived sustainable destination management ($\beta = 0.39$; $p < 0.01$), as reflected in a positive correlation ($r = 0.56$; $p < 0.01$). Qualitative findings further confirm that properly planned technology implementation can facilitate cooperation, transparency, and more efficient use of resources.

Despite positive indications, institutional and financial barriers can slow down or hinder the long-term application of smart solutions (Dwyer, 2018). However, a comparison with foreign models (Table 2) indicates that destinations systematically investing in smart infrastructure and educating residents more quickly realize the benefits in terms of visitor distribution, environmental protection, and better traffic management.

Based on integrated findings (both quantitative and qualitative), it can be concluded that Hypothesis H1 is confirmed.

Nevertheless, "for a sustainable and long-term effect, strategic plans, greater financial support, and the strengthening of stakeholders' digital competencies are needed. Only then can smart technologies act as a catalyst for sustainable destination management" (Boes, Buhalis & Inversini, 2016:406–407).

7. Research Results

7.1. Quantitative Analysis Results

As described earlier, the quantitative part of the research involved data collected from a survey of 300 respondents (N = 300), of which 290 valid questionnaires were included in the analysis. Statistical programs (SPSS) were used for data processing and analysis.

7.1.1. Descriptive Statistics

To gain insight into the main variables (e.g., perception of sustainability, stakeholder cooperation, attitude toward smart technologies), descriptive analysis was conducted. Table 3 shows key indicators—minimum, maximum, arithmetic mean, and standard deviation—for the main variables measured on a Likert scale (1 = strongly disagree, 5 = strongly agree).

Table 3. Descriptive statistics for key variables (N = 290)

Variable	Min.	Max.	M	SD
Perception of the importance of sustainability	2.0	5.0	4.4	0.68
Attitude toward smart technologies	2.0	5.0	4.1	0.74
Stakeholder cooperation	1.5	5.0	3.1	0.94
Local government support for sustainability	1.0	5.0	2.8	1.02
Willingness to invest in technologies	2.0	5.0	4.3	0.60

The table shows that respondents rate the importance of sustainability (M = 4.4) and the usefulness of smart technologies for destination management (M = 4.1) very highly. However, the average rating of stakeholder cooperation (M = 3.1) and local government support for sustainability (M = 2.8) indicates room for improvement.

7.1.2. Differential Analyses for Hypothesis Testing

The research hypothesis (H1) states that introducing smart technologies into the integrated management of local resources positively impacts the sustainability and competitiveness of a tourist destination, while preserving the quality of life of the local community.

Using ANOVA—differences between respondent groups were compared in terms of their average attitude scores toward the importance of smart technologies among four groups (tourists, local residents, representatives of local government/tourist boards, and representatives of local businesses). Table 4 shows the results of the one-way ANOVA for the variable "Attitude toward smart technologies."

Table 4. ANOVA results for comparing attitudes toward smart technologies among groups

Source of Variation	**SS**	**df**	**MS**	**F**	**p**
Between Groups	4.33	3	1.44	4.21	0.006 *
Within Groups	96.77	286	0.34		
Total	101.10	289			

p < 0.01

The Tukey post hoc test revealed a statistically significant difference ($p < 0.05$) between representatives of local government and the other two groups (tourists and local residents): tourists and local residents show greater enthusiasm for introducing digital solutions compared to government representatives. Respondents from businesses lie between these two extremes.

Table 5. Correlation matrix of key tourism development indicators

Indicator	**Smart Infrastructure**	**Digital Skills**	**Tourism Demand**	**Sustainability Index**
Smart Infrastructure	1.000	0.78	0.66	0.71
Digital Skills	0.78	1.000	0.60	0.69
Tourism Demand	0.66	0.60	1.000	0.52
Sustainability Index	0.71	0.69	0.52	1.000

Source: Author's calculation based on regional development datasets (2024)

As presented in Table 5, all indicators demonstrate strong interdependence, particularly between digital skills and sustainable management perception ($r = 0.69$), highlighting the significance of human capital in digital transitions.A correlation analysis using Pearson's coefficient indicates a moderately positive relationship between attitude toward smart technologies and perceived sustainable destination management ($r = 0.56$; $p < 0.01$). Stakeholder cooperation also exhibits a positive correlation with the perception of sustainable management ($r = 0.48$; $p < 0.01$), confirming the importance of a coordinated approach.

A regression analysis was conducted to formally test Hypothesis H1. A linear regression model was used where the dependent variable was "perceived sustainable destination management," and the main independent variable was "attitude toward smart technologies" (with control variables such as respondent age, education level, and group affiliation). The results (Table 6) show that attitude toward smart technologies significantly predicts perceived sustainable management ($\beta = 0.39$; $p < 0.01$).

Table 6. Regression analysis summary (dependent variable: sustainable destination management)

Variable	β	SE(β)	t	p
Attitude toward smart technologies	0.39	0.08	4.88	<0.01
Stakeholder cooperation (control)	0.22	0.05	2.95	<0.01
Age (control)	0.01	0.01	0.73	0.468
Education level (control)	0.07	0.04	1.64	0.102
(Constant)	2.12	0.31	6.84	<0.01

$R^2 = 0.32$; $F(4,285) = 12.65$; $p < 0.01$

It is evident that attitude toward smart technologies (β = 0.39) significantly contributes to explaining perceptions of sustainable management after controlling for age and education. These findings support Hypothesis H1 and underscore the importance of technological innovation as one lever of sustainable destination management.

7.2. Qualitative Analysis Results

In the qualitative part of the research, data were gathered from 20 semi-structured interviews with key stakeholders (representatives of local authorities, tourist boards, businesses, and NGOs). The analysis was conducted in NVivo software using thematic analysis.

7.2.1. Thematic Categories

Through open and axial coding, four main thematic categories emerged (Table 7). Each category shows how many references were coded (i.e., how many times a particular topic appeared in the interview transcripts).

Table 7. Main thematic categories derived from NVivo analysis

Thematic Category	Examples of Codes	Number of Coded References
1. Strategic planning and vision	"lack of strategic plan," "long-term goals"	42
2. Institutional and operational challenges	"financial barriers," "lack of IT specialists"	37
3. Stakeholder collaboration and education	"workshops for local residents," "collaboration platforms"	51
4. Examples of innovative practice	"digital maps of cultural routes," "real-time crowd tracking"	28

Regarding strategic planning and vision, interviewees frequently stressed the need for long-term strategic documents and clear performance indicators. Some interviewees noted complicated tender procedures that slow down implementation. Stakeholder collaboration and education generated the largest number of references, focusing on the need for stronger collaboration between the private and public sectors and the necessity of ongoing communication and education for the local community regarding the benefits of digital solutions.

Examples of innovative practice show that multiple interviewees mentioned concrete pilot projects, such as smart parking systems and digital guides, which helped spread out visitor numbers and reduce crowds.

7.2.2. Key Insights from the Interviews

Key insights from the interviews include: 1.) **Potential of smart technologies**: Interviewees generally believe that technology can enhance sustainability, but only with adequate organizational support and funding; 2.) **Need for an integrated platform**: Many interviewees spoke of the need for a single digital platform encompassing data on traffic, accommodation, and events, accessible to all stakeholders; 3.) **Education of the local community**: This involves strengthening digital literacy and reducing resistance to change. The introduction of new solutions could face distrust or insufficient usage if not properly supported.

These qualitative results provide a deeper context to the quantitative findings—particularly regarding the reasons why stakeholder collaboration and institutional support are not always at the desired level.

8. Discussion

Combining the quantitative (survey data) and qualitative (interviews) results, it can be concluded that there is a high level of awareness of the importance of sustainability and the potential of smart technologies among tourists, local residents, and the private sector, but that institutional and operational obstacles are the main factors slowing down local resource integration.

First, the quantitative analysis (Table 6) clearly shows that attitudes toward smart technologies are positively linked to the perception of sustainable destination management ($\beta = 0.39$; $p < 0.01$). This finding confirms the stated hypothesis (H1) and aligns with existing literature emphasizing the transformative effect of digital solutions on tourism management.

Second, the qualitative section (Table 7) highlights the importance of strategic planning and clearly defined goals, especially at the level of public institutions. Without such support, pilot projects and applications can remain isolated initiatives, as has been noted in some Croatian coastal destinations.

Third, the results indicate the critical role of stakeholder collaboration (local government, private sector, civil organizations, and residents). Although the average survey score for collaboration (3.1) is not below the neutral value, respondents still perceive significant room for improvement.

Interviewees also noted that, without sufficient education and clear benefits, local communities can remain on the sidelines or skeptical about "technologization."

Fourth, insufficient financial and human resource support appears as a recurring problem. Several interviews revealed that even when there is interest in implementing smart technologies (e.g., for crowd monitoring or environmental indicators), outlying areas often lack the infrastructure or personnel to maintain these systems.

Considering all the above, it can be concluded that H1 is accepted, but introducing smart technologies alone is not a "magic wand." It requires a comprehensive strategy, financial support, and capacity-building to ensure that digital innovations can be sustainably integrated into destination management (WTTC, 2017; Zhang et al., 2019). Based on the findings, one possible solution is the introduction of smart platforms to support local SMEs in rural destinations. These platforms should be tailored to regional digital maturity and integrated with local tourism strategies. To address this imbalance, mobile tools and smart signage can be deployed in neglected micro-regions, improving navigation and visitor experience.

9. Conclusion

To summarize the key findings, this study was based on the hypothesis that introducing smart technologies into integrated local resource management positively affects the sustainability and competitiveness of a tourist destination (H1). The results obtained by combining quantitative and qualitative methods support this hypothesis: 1.) **Quantitative data** (290 survey respondents) showed a statistically significant relationship between a positive attitude toward smart technologies and the perception of sustainable management ($\beta = 0.39$; $p < 0.01$), with stakeholder collaboration playing an important moderating role; 2.) **Qualitative insights** (20 in-depth interviews) underscored the need for clear institutional support, strategic planning, and ongoing education of the local community. Without these, innovations tend to be sporadic.

The **implications for practice** are closely related to strategic planning results, indicating that it is essential to develop a long-term vision at the local and regional government levels, encompassing clear goals, financial instruments, and success metrics. Without a systematic approach, pilot projects can remain isolated and underutilized.

Regarding **stakeholder collaboration and education**, there is a strong need for more intense engagement of local residents and both public and private sectors in planning and implementing smart solutions. Regular workshops, open data, and knowledge-sharing platforms can facilitate the acceptance of innovations.

With respect to **technological infrastructure and adjustments**, while smart technologies can be successfully implemented in urban centers, rural and less-developed areas still require substantial investments in basic digital infrastructure.

Limitations of the research include: 1.) the temporal and spatial constraints of the sample: the survey and interviews were predominantly conducted in several coastal destinations, which may affect the generalizability of the findings, and 2.) reliance on self-reporting: the quantitative results are based on respondents' perceptions rather than on objective indicators of destination management performance.

Recommendations for future research focus on: 1.) **longitudinal studies**, where long-term monitoring of the results of implementing smart technologies is necessary to determine their real impact on destination sustainability, 2.) **comparative studies**, examining various regions and countries with similar characteristics (e.g., the Mediterranean) that could contribute to a better understanding of success and failure factors, and 3) a **multidisciplinary approach**, integrating knowledge from economics, sociology, environmental management, and information technology to provide broader insight into the complex relationships among tourism, local communities, and smart technologies.

In conclusion, the research confirms the significant potential of smart technologies to improve sustainable management and integrate local resources while highlighting that their success depends on stakeholder collaboration, strong institutional support, and ongoing education of the local community. Examples of good practice from abroad reinforce this argument, pointing to the need for a clearly defined strategy and adequate funding. Thus, smart technologies should be viewed as a catalyst that accelerates and facilitates the sustainable growth of a destination, but not as the sole solution to the deeper structural challenges that destinations face today.

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ANALYSIS OF COMPUTER NETWORK USER'S ACTIVITIES USING SUPPORT VECTOR MACHINE (SVM) AND LONG SHORT-TERM MEMORY (LSTM) NETWORK

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Abstract:

The rapid growth of number of network users have led to a significant rise in network traffic. Analysing user activities within computer networks is essential for optimizing performance, enhancing security, and improving user experience. This study explores the application of machine learning techniques, specifically Support Vector Machine (SVM) and Long Short-Term Memory (LSTM) networks, to analyse computer network user activities. SVM is employed for its effectiveness in binary classification tasks and its ability to handle high-dimensional data, making it suitable for identifying distinct user activities based on network traffic

patterns. Conversely, LSTM networks was utilized to capture temporal dependencies in sequential data, allowing for the prediction of future user actions based on their historical activities. The precision, recall, FI-score and accuracy results for SVM model for analysing computer network user's activities are 96.00, 99.00, 98.00 and 95.40 respectively. While the precision, recall, FI-score and accuracy results for LSTM model for analysing computer network user's activities are 90.00, 91.00, 91.21 and 93.50 respectively. Trailing to this, the SVM has a better performance than the LSTM model. Therefore, this research contributes to the field of network analytics by offering insights that will improve network management strategies, resource allocation, and security measures.

***Keywords**: network, user, activities, SVM, LSTM, management.*

1. Introduction

The dramatic surge in the demand for internet and multimedia services, alongside the exponential growth in the number of internet users throughout the years, has made the management of network resources increasingly complex. (Rodjas, 2020: 431). In other to meet the increasing demand to ensure a good quality of service, managing network resources has become a continuous struggle for network providers due to the aforementioned factors (Rodjas, 2020: 436). The outbreak of COVID-19 also contributed significantly to the explosion in digital media consumption all over the world in conjunction with both wired and wireless Internet connectivity speeds and bandwidth. Due to the restrictions on both indoor and outdoor activities imposed by COVID-19, there was a notable increase in the demand for video streaming services following the shutdown of movie theaters. This surge has provided consumers with greater ease of access to the media content they desire, available at any time and place, typically at reduced prices (Rodjas, 2020: 446). Over-the-top (OTT) applications have swiftly become a primary tool through which consumers now have access to these media contents. This has drastically influenced user's behaviour as users are now in high demand for services that are more user-friendly and respond to their desires. Users no longer depend on their television sets for entertainment rather, with OTT applications, a new era of binge-watching has become a preferred choice. OTT applications have supplanted traditional television as the primary means of delivering media content via the internet, utilizing the infrastructure established by network operators. (Elijah et al., 2024: 238). The services provided by these applications utilize a significant amount of network resources, resulting in a substantial impact on the operation and administration of the network (Jain, 2021: 260).

Telecommunication providers typically offer data plans with consumption limits, and service degradation is a common strategy employed to regulate the volume of data users can transfer over time. Upon exceeding their allocated data limit, the network provider will curtail the user's bandwidth based on their consumption to ensure the network operates efficiently (Rodjas, 2020: 440). This mechanism in itself does not apply limit with an exception, rather the limit applied affects the overall activity such a user might be performing on the network. And this makes this mechanism less efficient. The utilization of substantial network resources by OTT applications to provide services like audio, video, and various other functionalities significantly affects network operation and management due to the high volume of traffic generated (Rodjas, 2020: 438). Utilizing service degradation as a strategy to mitigate the excessive traffic produced by a specific OTT application impacts the performance of all other applications utilized by the user, without considering the user's behavior regarding which OTT application is causing the high traffic. Therefore, the execution of service degradation might lead to infringements of the service level agreements that the Internet Service Provider may have with other OTT service providers (Rodjas et al., 2019: 582). Due to the large consumption of network resources of OTT applications, efficient management of the available resources based on the data usage behaviour of users becomes a necessity (Cisco, 2017: 1). Studying the user's preference and

usage behaviours trend on the computer network to decipher the OTT application which consumes beyond the limit of the allocated network resources to perform informed service degradation to the OTT application without affecting other OTT applications as the traditional service degradation would, will ensure that the service level agreement between OTT application providers and ISPs is not breached. Machine learning algorithms can predict future network demands, allowing for practive resources allocation and capacity planning, which minimizes overprovision and downtime. Aditionally, ML can automate tasks like anomaly detection and security treat identification, reducing manual effort and improving response time. Hence, this study performed a comparative profiling of network user's activities using Support Vector Machine (SVM) and Long-Short-Term Memory (LSTM) Network for effective selective OTT application network resources consumption management.

1.1 Support Vector Machine (SVM)

A support vector machine (SVM) is a type of supervised machine learning model that utilizes classification algorithms to solve problems involving two categories (Okpor et al., 2024: 218). The SVM algorithm is founded on the idea of decision planes, employing hyperplanes to differentiate between a set of objects. After being trained on a labeled dataset, SVM can classify new data effectively. The primary objective of the SVM algorithm is to establish a decision boundary that divides n-dimensional space into distinct classes, facilitating the accurate categorization of future data points. This optimal decision boundary is known as a hyperplane, which is determined by selecting the extreme points or vectors that contribute to its formation. These critical instances are termed support vectors, which is the origin of the algorithm's name, Support Vector Machine. The classification of two different categories using a decision boundary is illustrated in Figure 1. In contrast to more recent algorithms such as neural networks, SVM has two key advantages: faster processing speed and better performance with a limited number of labeled samples (Madugu et al., 2023:108).

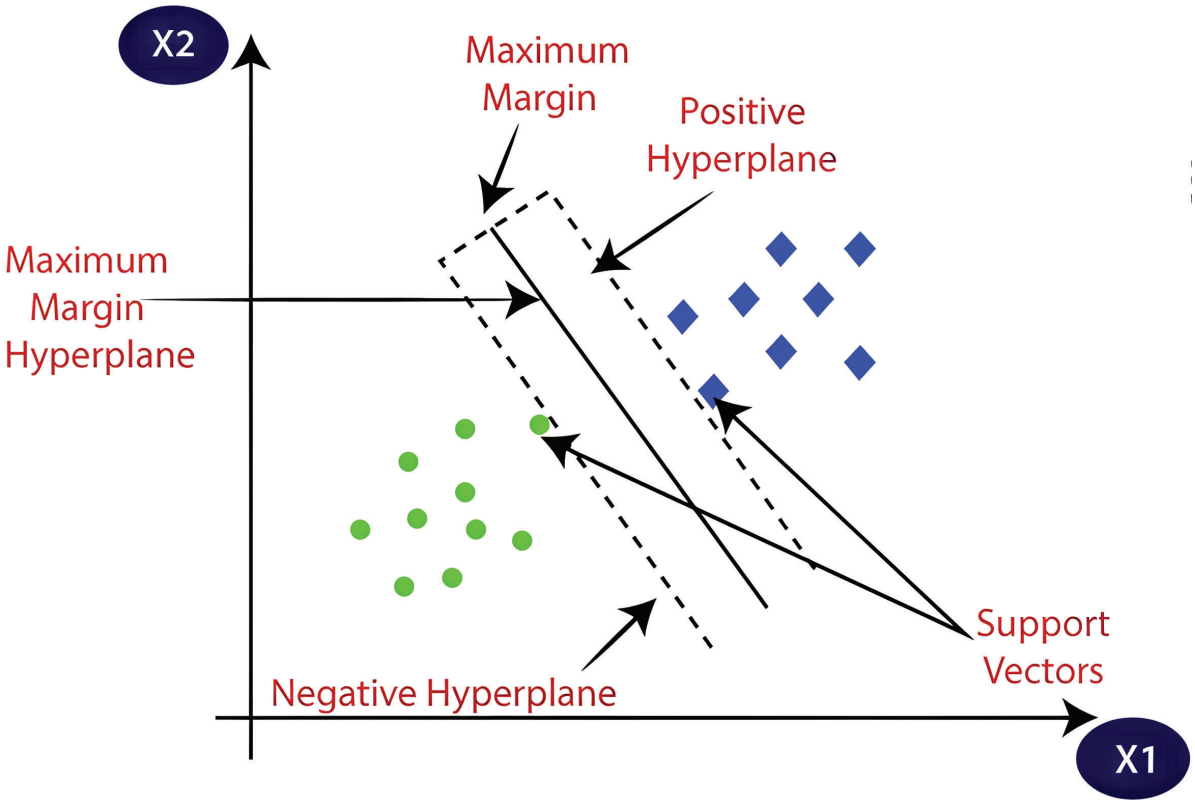

Figure 1: Classification using a decision boundary (Madugu *et al.*, 2023:108)

1.2 Long Short-term memory (LSTM) Network

The Long Short-Term Memory is an extension of the Recurrent Neural Networks (RNNs) in which the output processed from the previous layer is fed back to the current time stage layer enabling the model to learn while maintaining long-term dependencies. Hence, recalling past information for long periods is the default behaviour of Long Short-Term Memory (Olajide *et al.,* 2024: 755). In order to boost performance, the RNN utilizes the Long Short-Term Memory (LSTM) concept, which is a refined RNN network that incorporates memory cells to ensure the retention of cell state when processing sequential data (Okpor et al., 2023: 60). Therefore, the LSTM model proposed is crafted to process dataset elements one at a time while preserving the information state through its memory state (Oluranti et al., 2023: 8). This mechanism successfully mitigates the vanishing gradient problem. The behavior of an LSTM cell is defined by the following equations:

$$c_{in}^{t} = \tanh(W_{xc}x^{t} + W_{hc}h^{t-1} + b_{c}) \quad (1)$$

$$i^{t} = \text{sigmoid}(W_{xi}x^{t} + W_{hi}h^{t-1} + b_{i}) \quad (2)$$

$$o^{t} = \text{sigmoid}(W_{xo}x^{t} + W_{ho}h^{t-1} + b_{o} + b_{forget}) \quad (3)$$

$$f^{t} = \text{sigmoid}(W_{xf}x^{t} + W_{hf}h^{t-1} + b_{f}) \quad (4)$$

$$c^{t} = f^{t}c^{t-1} + i^{t}c_{in}^{t} \quad (5)$$

$$h^{t} = o^{t}\tanh(c^{t}) \quad (6)$$

where $W \in \mathbb{R}^{ls \times ls}, x^{t}, h^{t}, o^{t}, f^{t}, c^{t}, b \in \mathbb{R}^{ls}$. ls is a hyperparameter, called the LSTM size, and is defined upfront by design as constant among all cells.

2. Literature Review

Vinupaul et al. (2016: 4) presented the notion of flow-bundle-level features, which can be derived from packet-level and flow-level characteristics typically gathered by flow probes, based on the assessment of flow features. They identified a set of flow-bundle-level attributes capable of accurately recognizing users. This set comprises two distinct types of features: user-features, which pertain to the specific activities of a user, and host-features, which relate to the characteristics of the user's host platform. They further argue that as the use of personal mobile devices increases, one host, one-user systems will become more prevalent, thereby enhancing the user identification model through the integration of host features. The model was validated through the application of four distinct supervised learning techniques on a dataset comprising 65 user flow data, achieving a peak accuracy of 83%. Furthermore, Rojas et al. (2019: 590) presented a performance comparison of traditional and incremental machine learning algorithms applied to data regarding users' Over-The-Top consumption to see which approach is capable of a continuous model adaptation while maintaining their usefulness over time. For the tests, two datasets are used: the first is made up of 1,581 instances from a genuine network experiment, while the second has 150,000 instances that were created artificially. Upon reviewing the results, it was concluded that the Support Vector Machine excelled in the traditional method, whereas the optimal classifier for the incremental approach was an ensemble method combining the K-Nearest Neighbor algorithm with Oza Bagging.

(Radha, 2013: 10) proposed a method for quantifying YouTube usage, primarily focusing on the analysis of encrypted network traffic. An Android application named YouQ was developed to facilitate the creation of a training dataset derived from monitored client-side application layer KPIs. The dataset, which comprised 1060 video streaming instances, was subsequently divided into two subsets: the reduced dataset and the full dataset. Five machine learning algorithms were employed to construct a model, including OneR, Naive Bayes, SMO, J48, and Random Forest. The reduced dataset emphasized realistic network conditions without significant fluctuations in bandwidth. The Random Forest algorithm achieved an accuracy of 80.18% on the full dataset, while the Naive Bayes algorithm yielded the highest accuracy of 83.94% on the reduced dataset. (Goeffery *et al.,* 2014: 26) Employed an unsupervised machine learning method using a clustering algorithm based on Expectation Maximization (EM) to identify Internet traffic, comparing it with a supervised Naïve Bayes classifier. The unsupervised method achieved 91% accuracy, exceeding the supervised method by 9%. (Oluranti *et al,* 2021: 8) The study illustrated the classification of network traffic through machine learning techniques from two distinct viewpoints: one incorporating feature selection and the other excluding it. The experimental findings reveal that the classification method without feature selection achieved an average accuracy of 94.14% and a runtime of 0.52 seconds. Conversely, the approach utilizing feature selection recorded an accuracy of 95.61% with an average runtime of 0.25 seconds. (Juan *et al.,* 2020: 25) established an OTT consumption analysis model utilizing Incremental Learning algorithms, which include Naive Bayes, K Nearest Neighbour, Adaptive Random Forest, Leverage Bagging, Oza Bagging, Learn++, and Multilayer Perceptron. The results indicate that the Adaptive Random Forest and a combination of Leverage Bagging and Adaptive Random Forest deliver the highest performance, achieving classification precision and recall exceeding 90%. Based on these findings, they proposed personalized service degradation policies to aid decision-making in mission-critical systems. (Jeffery *et al.,* 2007: 28) utilized two unsupervised clustering techniques, specifically K-Means and Density-Based Spatial Clustering of Applications with Noise (DBSCAN), to categorize network traffic. The performance of these algorithms was assessed and compared against the established AutoClass algorithm found in existing literature, using empirical Internet data. The results indicated that their methods outperformed AutoClass in both speed and efficiency. Additionally, the research highlighted that while DBSCAN exhibited lower accuracy than K-Means and AutoClass, it produced superior clusters. Conversely, AutoClass was noted for its significant time consumption during model construction, which discourages system developers from adopting this algorithm, despite the infrequent need for model retention.

3. Research Methodology

The SVM and LSTM models for analyzing user activities on a computer network are developed on a 64-bit Windows OS with an Intel Core i5-3630QM CPU at 2.40GHz and 4GB RAM. The development environment is Anaconda, using Python 3.8, the Sklearn API, and essential libraries like NumPy, pandas, TensorFlow, and Matplotlib. The research consists of three phases: data pre-processing, model implementation, and model evaluation. In the data pre-processing phase, the Universidad Del Cauca network dataset from Kaggle, containing packet captures from April to June 2019, is utilized. A total of 2,704,839 flow instances dataset having 50 features detailing IP address flows from a network device, such as source and destination IPs, ports, flow durations, inter-arrival times, packet sizes, and the layer 7 protocol for classification was used. Data filtration addressed missing values, and scaling converted non-numeric data to numeric format. The Spearman rank correlation coefficient was used for feature extraction, suitable for non-linear correlations in large

datasets. The implementation phase involved splitting the pre-processed dataset into a 70:30 training and test set. The dataset was then used in two deep learning algorithms: Support Vector Machine (SVM) and Long Short-term Memory (LSTM) network. Parameter tuning was performed for both algorithms to optimize performance, with configurations detailed in Tables 2 and 3.

Table 1: Dataset Feature descriptions

Dataset feature name	Feature description	
flow_key	Flow identifier through a hash algorithm	
src_ip_numeric	Source IP in decimal format	
src_ip, dst_ip	Source and destination IP in network format	
src_port, dst_port	Source and destination port number	
Proto	Transport protocol number according to IANA (e.g., 1 for ICMP, 6 for TCP, 17 for UDP)	
pktTotalCount	Total number of packets in both directions	
octetTotalCount	Total number of bytes exchanged in both directions, focusing on the IP payload only	
min_ps, max_ps	Minimum and maximum packet size on the flow, in both directions	
avg_ps	Average packet size on the flow, in both directions	
std_dev_ps	Packet size standard deviation, in both directions	
flowStart	Flow start time in seconds using UNIX time format	
flowStart, flowEnd, flowDuration	Flow start time, flow end time, and total flow duration time in seconds using UNIX time format	
min_piat, max_piat, avg_piat	Minimum packet inter-arrival time, maximum packet inter-arrival time, and average packet inter-arrival time on the flow, in both directions	
std_dev_piat	Standard deviation of packet inter-arrival times, in both directions	
f_pktTotalCount	Total number of packets, in the forward direction	
f_octetTotalCount	Total of bytes exchanged in the forward direction, focusing on the IP payload only	
f_min_ps, f_max_ps, f_avg_ps, f_std_dev_ps	Minimum packet size, maximum packet size, average packet size and packet size standard deviation on the flow, in the forward direction	
f_flowStart, f_flowEnd, f_flowDuration	Flow start, flow end, and total flow time in seconds using UNIX time format, in the forward direction	

Table 2: Parameter Set for SVM model for User's Network Resources Use Analysis

SVM Parameter	Value
Kernel	Linear
Probability	True
Degree	3
Cache-size	200

Table 3: Parameter Set for LSTM model for User's Network Resources Use Analysis

LSTM Parameters	Value
Max-Batch Size	5
Max epochs	20
Initial learn rate	0.0001
Optimizer	Adam
Drop-out	0.2
Activation	Relu and Softmax

The maximum batch size indicates how many input instances are processed per layer. Maximum epochs define the total number of complete passes through the training dataset. The learning rate controls the size of updates to the model's parameters during training. The optimizer adjusts the model's weights and biases to improve accuracy and performance. The activation function determines when an input is activated. For LSTM and MLP algorithms, RELU (Rectified Linear Unit) is used in input and hidden layers, while SoftMax is used in the output layer for multiple class labels. The Kernel Cache Size has a strong impact on run times for the applied Support Vector Machine (SVM) algorithm. It determines the cache size needed for the program in the RAM (Random Access Memory), the cache size used for SVM was set to 200. Considering that the variables from the dataset are linear, the linear kernel was used. In the final stage of model evaluation, this study employed three performance metrics to assess the two developed models: accuracy, precision, F-score, and recall. Accuracy indicates the classifier's recognition rate, while precision measures the exactness of the classifier's predictions. Recall reflects the sensitivity of the classifier. The F-score represents the harmonic mean of precision and recall, thereby integrating both values into a single score. The equations for accuracy, precision, recall, and F-score are presented as equations 7, 8, 9, and 10, respectively (Okpor *et al.,* 2024: 222).

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN\ (total\ sample)} \tag{7}$$

$$precision = \frac{TP}{TP+FP} \tag{8}$$

$$Recall = \frac{TP}{TP+FN} \tag{9}$$

$$F1_{-Score} = 2 \times \frac{Precision \times Recall}{Precision + Recall} \tag{10}$$

Where; P is the total positive predictions, N is the total negative predictions. True Positive (TP) are correctly identified positives, True Negative (TN) are correctly identified negatives, and False Positive (FP) are incorrectly classified positives, which are negative tuples that are incorrectly labelled as positive, and False Negative (FN), which are positive tuples that are incorrectly labelled as negative (Olajide and Andrew, 2023: 63).

4. Results and Discussion

During the training of the developed models aimed at analyzing user activities within computer networks, this study divided the dataset into two distinct segments: training and testing. The training segment was specifically used for the purpose of model training, while the testing segment was utilized to evaluate the performance of the models. Out of a comprehensive total of 26,014 records, 30%—which equates to 7,805 records—were set aside for testing and validating the performance of each model through various evaluation metrics. Conversely, the remaining 70%, amounting to 18,209 records, was allocated for the training of the models. To enhance the feature selection process, the Spearman rank correlation coefficient technique was applied to the dataset, with the outcomes depicted in Figure 2

```
Out[153]: Index(['src_ip', 'dst_ip', 'proto', 'pktTotalCount', 'octetTotalCount',
                 'min_ps', 'max_ps', 'avg_ps', 'std_dev_ps', 'flowStart', 'flowEnd',
                 'min_piat', 'max_piat', 'avg_piat', 'std_dev_piat', 'f_pktTotalCount',
                 'f_octetTotalCount', 'f_min_ps', 'f_max_ps', 'f_avg_ps', 'f_std_dev_ps',
                 'f_flowStart', 'f_flowEnd', 'f_flowDuration', 'f_min_piat',
                 'f_max_piat', 'f_avg_piat', 'f_std_dev_piat', 'b_pktTotalCount',
                 'b_octetTotalCount', 'b_min_ps', 'b_max_ps', 'b_avg_ps', 'b_std_dev_ps',
                 'b_flowStart', 'b_flowEnd', 'b_min_piat', 'b_max_piat', 'b_avg_piat',
                 'b_std_dev_piat', 'flowEndReason', 'category', 'application_protocol',
                 'web_service'],
                dtype='object')
```

Figure 2: Selected Features from the Dataset

Table 4 illustrates the results obtained from the SVM and LSTM models employed to assess user activities within computer networks. Both algorithms delivered commendable outcomes, with performance metrics exceeding 90%. However, the SVM model outperformed the LSTM models in several key areas, including precision, recall, F1-score, and overall accuracy. To be specific, the SVM model achieved impressive values of 96.00 for precision, 99.00 for recall, 98.00 for F1-score, and 95.40 for accuracy. In contrast, the LSTM model recorded lower performance metrics, with precision at 90.00, recall at 91.00, F1-score at 91.21, and accuracy at 93.50.

Table 4: Results of the SVM and LSTM Models for Analysing Computer Network User's Activities

Algorithm	Precision (%)	Recall (%)	Fl-score (%)	Accuracy
Support Vector Machine (SVM)	96.00	99.00	98.00	95.40
Long Short-Term Memory (LSTM)	90.00	91.0	91.21	93.50

5. Conclusion and Recommendation

This study has performed a comparative analysis of the performance of two developed models for analysing computer network user's activities. The two models were developed using
Support Vector Machine and Long-Short-Term Memory. The study classified the OTT application of a particular user according to the data consumption rate of each application so that the service degradation mechanism can be applied to the particular application generating the traffic instead of a generalized degradation approach which is not the most efficient. The dataset employed in this research was sourced from the Kaggle machine learning repository, a well-known platform for data science and machine learning resources. Specifically, the data was collected from the network of Universidad Del Cauca, located in Popayán, Colombia. This collection involved capturing packets from real users who were utilizing Over-The-Top (OTT) applications, leading to a substantial dataset comprising 2,704,839 individual data instances. These instances were gathered at various times throughout the day to ensure a comprehensive representation of user activity. To evaluate the performance of each machine learning model developed in this study, several metrics were utilized, including accuracy, recall, precision, and the F-measure, which collectively provide a robust assessment of model effectiveness.. The experimental result showed that the SVM model performed as the best model to analyzing computer network user's activities with an accuracy of 95.4%. It is therefore recommended that this work be implemented on live computer networks to evaluates its credibility for carrying out smart service degradation on user-by-application basis.

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TECHNICAL AND ECONOMIC ASPECTS IN THE DEVELOPMENT OF ADDITIVE TECHNOLOGY

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Abstract:

This paper studies the importance and development of additive technology through technical and economic aspects. The technical aspect includes research about the influence of surface inclination and layer thickness on the surface roughness of the produced test samples. Two AM technologies or processes (FDM and SLS) were used, with the use of three different materials (PLA, PETG and PA12) and two subsequent treatments (compressed air and glass bead blasting). Surface roughness parameters (R_a, R_z and R_{max}) were measured and analyzed after different manufacturing conditions. Their variability and statistical analysis are presented. From the obtained results, it is evident that with increasing slope (from 0° to 90°) the values increase to a maximum (between 10° and 40°), after which they decrease (from 50° to 90°), while increasing the thickness of the layer causes higher values of roughness parameters. Also, the aim of the paper is to determine the economic profitability of the used procedures, that is, the impact of the manufacturing procedures on the price of the product. Modern and innovative materials and technologies are used in the research. By using innovative technologies, we influence on sustainable development, which speaks of the fact that we need to meet our needs with quality, while taking care that the generations that come after us also have this opportunity.

Keywords: *additive technologies, surface roughness, costs, economic aspect, sustainable development .*

1. Introduction

Additive manufacturing or three-dimensional (3D) printing is the controlled addition of materials, carried out by successively applying layers of materials until a predefined shape is formed. It enables the creation of objects of different complexity and size. 3D printing, transforms traditional manufacturing by building objects layer by layer from digital designs. It enables rapid prototyping, customization, and efficient production of complex geometries while minimizing material waste. (Šimunić, Kostadin, Stipaničić and Grgurić, 2024.)

Unlike traditional processes such as injection molding, milling or casting, which use a top - down principle, with additive technologies, the reverse principle is present: bottom - up. (Badiru, Valencia and Liu, 2017.)

Additive technology includes the following steps: CAD model creation, CAD model conversion to STL file, STL file transfer to AM machine, AM machine parameters adjustment, prototyping, prototype removal, post-processing (if needed) and use. (Gibson, Rosen and Stucker, 2015.)

Surface roughness is, in a general sense, a micro-geometric irregularity of the surface, which occurs during processing procedures or other influences. Surface roughness in certain cases significantly affects the working properties of machine parts, especially at the points of mutual connection of individual elements (friction, clearance, lubrication...). In general, machined parts with lower roughness have higher dynamic strength, higher corrosion resistance, higher fitability, better heat transfer, etc. As achieving a low degree of roughness is always connected with longer and more expensive machining processes, it results in an increase in the price of the machined part.

The main goal of this paper is to evaluate and investigate the primary factors of AM production in terms of quality and surface roughness based on test samples. In this work, the surface roughness parameters are measured: R_a, R_z i R_{max}. (Feketić, 2022.)

Also, the aspect of economic profitability of the application of the processed procedures is dealt with, and after the analysis of the obtained results, the main conclusions are drawn.

2. Theoretical elaboration

Today, additive manufacturing has developed a lot, and is widely used, and thus the materials used are gaining more and more importance.

As materials and their selected properties are subject to constant improvements and rapid changes, it is difficult to keep track of their classifications. It is important to note that the material only partially determines the result of the AM process, and the overall quality of the products is influenced by various parameters. Thus, in addition to choosing the optimal material, it is important to take care of the selected additive manufacturing process and construction solution.

With additive manufacturing, which is carried out in layers, there is a recognizable difference in properties. In this case, we speak of anisotropy, i.e. that the properties vary in different directions and values. Layer-oriented production, assisted by AM processes, actually generates anisotropic formations. The degree of anisotropy can vary; from barely recognizable to a degree that has a significant impact on stability. Although mainly dependent on the AM process, the orientation of the part being made and the design solution also play an important role. (Gebhardt, 2012.)

For special applications, AM compounds are usually post-processed to improve microstructure, reduce porosity and improve surface quality, reduce roughness and meet geometric tolerances.

Today, AM enables the processing of materials of all classes, i.e. polymers, metals and ceramics, and their combinations in the form of composites.

Special importance should always be given to the costs, i.e. the economic profitability of production, and for this reason, new materials and technologies are being researched.

The first group of materials used in additive manufacturing are polymer materials, which are still the most common today.

For selective laser sintering (SLS), the preferred materials are polyamides (PA). Although polyamides are often used for injection molding, they differ significantly from those used in AM processes. Primarily, even if the material were chemically identical, the final products would be very different. The material that is completely melted and injected into the mold under high pressure shows different properties compared to the same one that is locally melted under atmospheric pressure, and is

deposited in layers and solidified by thermal conductivity. Industrial products are typically made of PA6, while SLS mainly uses PA11 or PA12.

Compared to other methods, FDM (fused deposition modeling) technology has its advantages, such as the variety of production and low material costs, which is why it is the most commonly used method. (Šančić and Tomašić, 2022.)

For FDM processes, the base material is acrylonitrile/butadiene/styrene (ABS). Because ABS is often used as an injection molding material, it is considered a standard engineering material.

As the development and production of new products requires high-quality polymer materials, materials such as polyphenylsulfone (PPSF / PPSU) and polyetheretherketone (PEEK) appeared on the market. PEEK has excellent chemical properties, is resistant to flame and high temperature, is light and has high tensile strength. Also, the materials come in different colors, but it is easier to use with AM processes that have the supply of materials from a special container (eg FDM process). The reason for this is the need to replace the entire material stored in the machine and to make the product from the treated color in processes that store the material inside the manufacturing chamber (e.g. SLS process). (Gebhardt, 2012.)

In conclusion, it can be said that the variety of polymer materials that can be used in additive manufacturing is increasing.

The examined parameters of roughness [in μm] in this paper are: R_a (arithmetical mean deviation of the profile), R_z (mean height of roughness) and R_{max} (highest height of roughness).

Surface roughness is the result of surface irregularities inherent in the machining process, not the machine, but which does not include waviness, deviation from form, and surface defects. Roughness includes short-wave surface irregularities. It is generally a consequence of the production process.

It is quantified by vertical deviations of the actual surface from its ideal shape. If these deviations are large - the surface is rough, and if they are small - the surface is smooth.

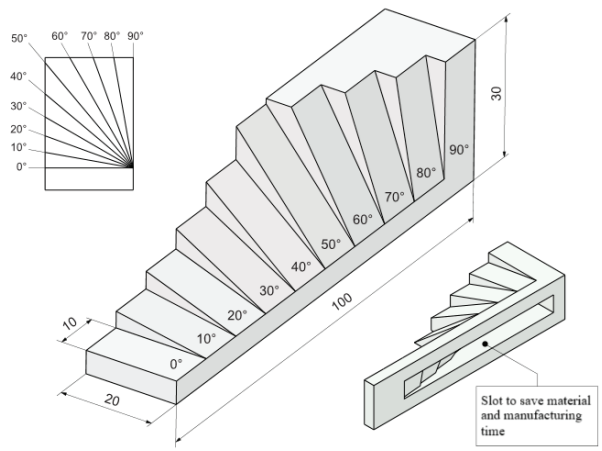
3. Materials and methods

The materials, methods, equipment and used test procedures are listed below.

Test sample is created using software CATIA V5-6R2019 (Dassault Systèmes), and the final 3D model is exported in the form of an STL file, which enables import into a program for cutting layers, connected to an AM machine.

The sample consists of a square block with dimensions of 100x20x30 [mm], which is divided into ten equal surfaces inclined from 0° to 90° to the horizontal plane, in steps of 10°, as shown on Figure 1. (Feketić, 2022.)

Figure 1 Test sample



In this way, ten simple design surface configurations were achieved on the sample, which can be examined from the top side. The lining on the bottom serves as a support and prevents deformation during the time of use, which is limited by the characteristics of the material.
A slot is placed on the back side in order to save material and manufacturing time, and it also does not require the use of a support structure and its subsequent removal. It is dimensionally large enough to provide good access for roughness testing by contact methods, and allows repeatability of measurements.
An auxiliary device and a device for measuring the surface roughness were used from the equipment, and after the measurement the results were statistically processed and analyzed.
The materials used are: PLA - polylactic acid - a biopolymer produced from renewable and natural raw materials such as corn starch and sugar cane, then PETG (polyethylene terephthalate glycol) - which has good physical properties and durability, and PA12 (polyamide) - better known as nylon, which is an engineering plastomer for functional prototyping and end-use manufacturing.
Figure 2 shows the test samples with characteristics for carrying out the measurements, Figure 3 shows roughness measurement procedure, while Table 1 lists the characteristics of the test samples. (Feketić, 2022.)

Figure 2 Test samples with characteristics for carrying out measurements

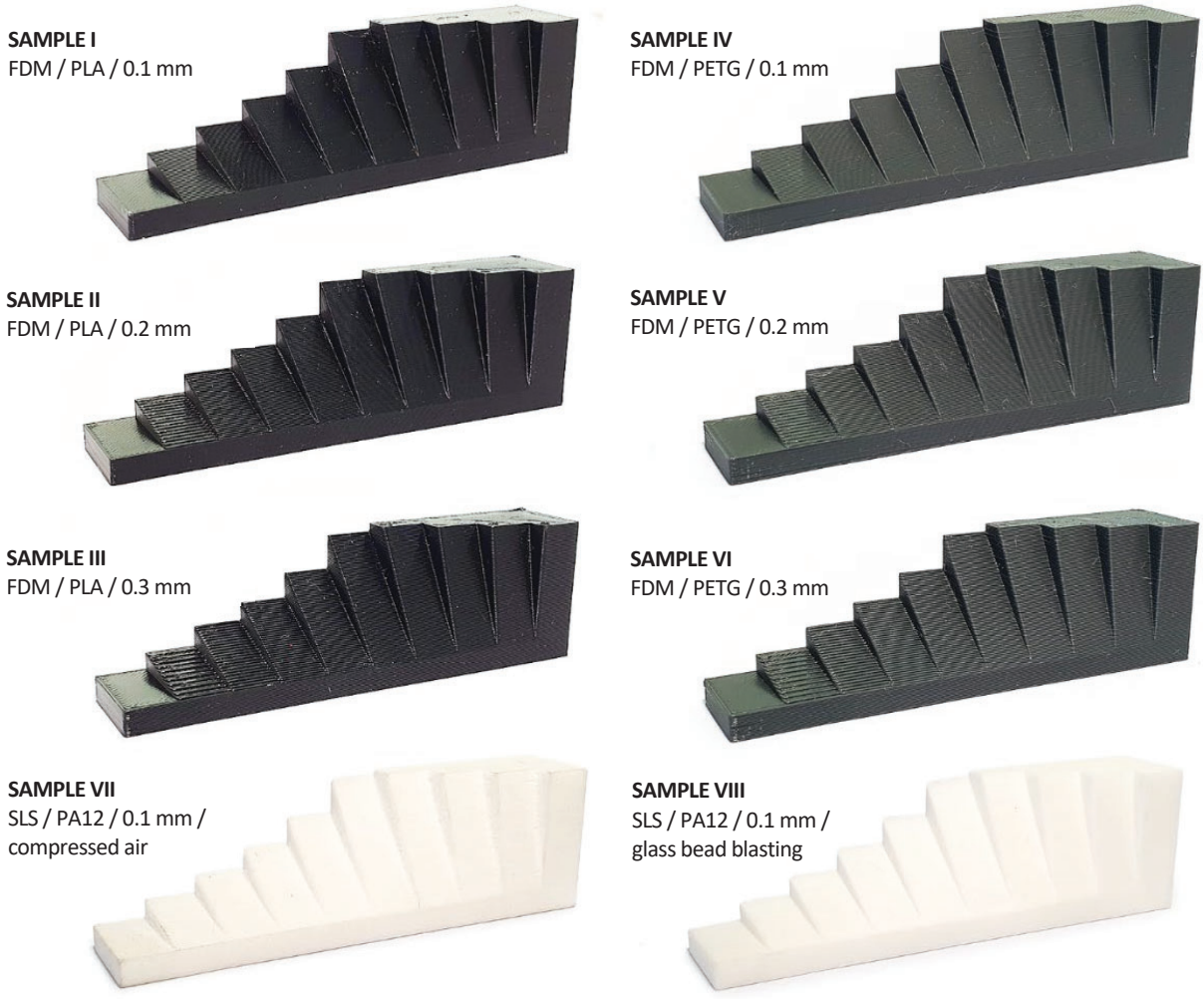


Figure 3 Roughness measurement procedure

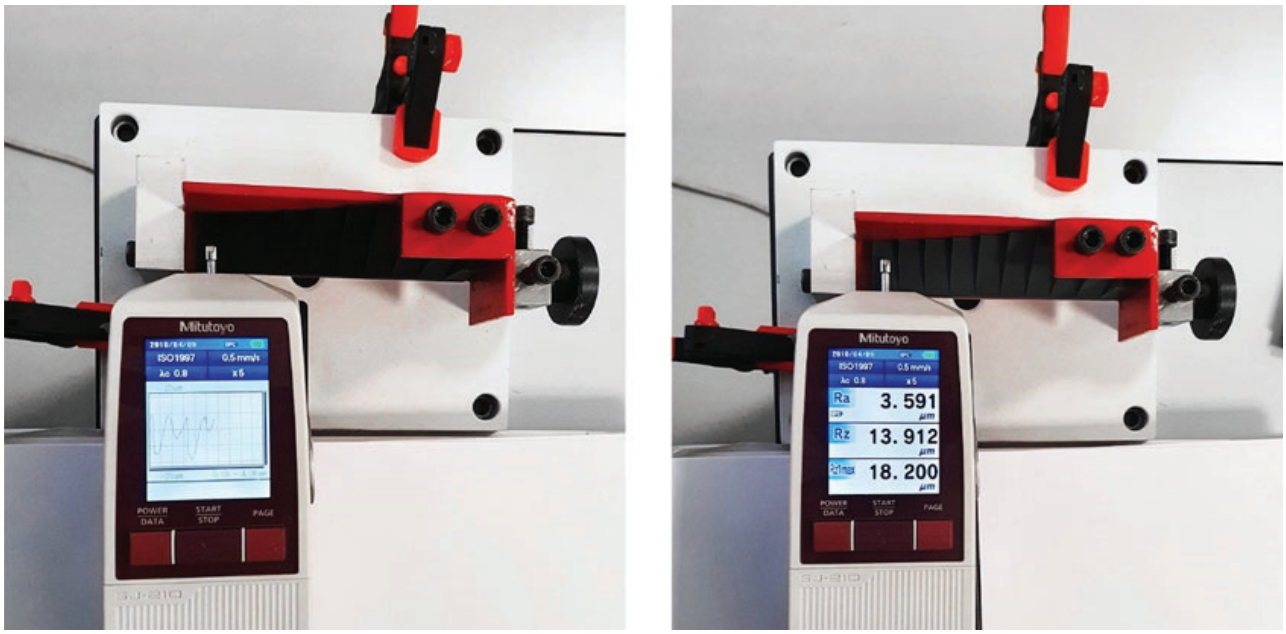


Table 1 Characteristics of the test samples

Sample	Technology/ process/ machine	Material	***Layer thickness*** *(mm)*	Subsequent treatments
I	Material extrusion / FDM / Prusa i3 MK2	PLA	0.1	Not used
II			0.2	
III			0.3	
IV		PETG	0.1	
V			0.2	
VI			0.3	
VII	PBF / SLS / Eos Formiga P110	PA12	0.1	Compressed air
VIII				Glass bead blasting

4. Results and analysis

Here are the test results for all three tested materials (PLA, PETG i PA12). (Feketić, 2022.)

Table 2 Measurement results of samples made by FDM process for PLA material

Surface incline	Surface roughness parameters (μm) / Standard deviation								
	SPECIMEN I *Layer tickness: 0.1 mm Material: PLA*			**SPECIMEN II** *Layer tickness: 0.2 mm Material: PLA*			**SPECIMEN III** *Layer tickness: 0.3 mm Material: PLA*		
	$\overline{Ra}$	$\overline{Rz}$	$\overline{Rmax}$	$\overline{Ra}$	$\overline{Rz}$	$\overline{Rmax}$	$\overline{Ra}$	$\overline{Rz}$	$\overline{Rmax}$
	σ_{Ra}	σ_{Rz}	σ_{Rmax}	σ_{Ra}	σ_{Rz}	σ_{Rmax}	σ_{Ra}	σ_{Rz}	σ_{Rmax}
0°	4,138	17,796	22,254	5,913	25,920	29,498	5,573	25,073	28,179
	0,131	0,399	0,879	0,078	1,646	2,550	0,125	0,468	0,589
10°	15,382	79,819	83,394	14,421	83,216	112,400	14,007	82,192	142,910
	0,965	3,034	4,645	0,293	5,011	0,521	0,705	1,141	6,475
20°	20,978	79,385	82,362	25,384	113,857	122,507	21,783	116,467	128,720
	0,319	0,981	2,445	1,512	3,806	4,833	1,252	5,013	1,908
30°	18,151	73,683	79,962	30,769	116,300	121,880	31,423	130,947	139,570
	0,795	2,237	3,195	1,321	2,283	5,573	2,225	4,866	15,411
40°	13,866	64,254	72,286	26,039	106,163	110,250	29,363	127,570	144,653
	0,302	0,471	4,744	0,681	2,504	3,349	1,210	5,032	22,878
50°	11,821	62,536	67,320	20,016	88,950	95,063	25,842	116,417	131,080
	0,235	1,006	2,730	0,471	0,635	2,469	0,526	2,501	13,479
60°	9,511	49,078	56,005	17,265	77,309	80,952	23,546	102,980	110,027
	0,214	1,287	1,196	0,234	2,564	4,088	0,424	2,176	6,387
70°	8,605	43,856	51,840	14,457	66,167	72,206	21,490	95,244	103,289
	0,342	1,644	4,317	0,371	2,822	5,806	0,405	2,482	5,949
80°	8,596	42,933	52,609	13,817	63,119	68,340	19,758	88,532	94,025
	0,295	0,870	7,730	0,162	0,648	2,007	0,216	1,260	2,163
90°	7,565	39,155	44,054	13,562	62,206	65,151	19,301	85,415	91,008
	0,162	1,724	3,897	0,208	1,829	2,296	0,624	0,844	2,969

Table 3 Measurement results of samples made by FDM process for PETG material

Surface incline	Surface roughness parameters (μm) / Standard deviation								
	SPECIMEN IV *Layer tickness: 0.1 mm Material: PETG*			**SPECIMEN V** *Layer tickness: 0.2 mm Material: PETG*			**SPECIMEN VI** *Layer tickness: 0.3 mm Material: PETG*		
	$\overline{Ra}$	$\overline{Rz}$	$\overline{Rmax}$	$\overline{Ra}$	$\overline{Rz}$	$\overline{Rmax}$	$\overline{Ra}$	$\overline{Rz}$	$\overline{Rmax}$
	σ_{Ra}	σ_{Rz}	σ_{Rmax}	σ_{Ra}	σ_{Rz}	σ_{Rmax}	σ_{Ra}	σ_{Rz}	σ_{Rmax}
0°	3,577	15,306	20,157	5,622	24,999	29,737	4,560	22,877	27,086
	0,297	0,189	0,418	0,112	1,306	4,882	0,183	0,929	0,725
10°	13,610	72,041	83,020	14,548	87,346	121,977	15,850	88,768	145,510
	0,764	6,544	0,652	0,206	0,107	4,308	1,167	7,729	1,781
20°	21,641	81,345	85,434	26,253	121,110	126,127	23,659	133,907	150,257
	0,157	0,610	3,925	0,417	2,098	2,960	0,135	12,294	4,457
30°	18,569	73,462	77,423	30,445	116,857	120,103	26,071	126,023	128,190
	0,201	1,498	1,606	0,431	0,637	0,067	0,738	2,620	3,044
40°	14,779	69,360	76,742	28,161	109,513	116,130	29,804	125,207	128,880
	0,150	2,439	1,655	0,248	3,782	3,068	0,180	0,701	2,121
50°	11,496	59,903	70,124	23,744	98,318	106,193	27,862	118,010	121,583
	0,230	3,322	10,336	0,322	2,202	4,774	0,920	1,747	1,789
60°	9,926	53,390	60,739	18,576	84,806	90,549	25,944	110,023	116,097
	0,604	2,060	7,154	0,101	0,197	4,027	0,224	1,357	3,577
70°	8,357	41,740	46,733	16,913	77,036	81,029	22,955	100,520	103,983
	0,455	3,115	6,915	0,308	1,442	1,849	0,142	0,519	2,237
80°	8,208	40,802	47,479	14,954	66,937	70,801	21,231	94,095	98,529
	0,581	2,502	7,909	0,301	1,162	3,089	0,294	1,779	1,828
90°	7,839	39,154	44,674	14,030	64,071	66,900	20,647	91,938	96,014
	0,440	2,236	0,282	0,064	1,473	2,439	0,150	0,753	1,758

Table 4 Measurement results of samples made by SLS process for PA12 material

Surface incline	Surface roughness parameters (μm) / Standard deviation					
	SAMPLE VII *Layer tickness: 0.1 mm* *Material: PA12* *Subsequent treatment: Compressed air*			**SAMPLE VIII** *Layer tickness: 0.1 mm* *Material: PA12* *Subsequent treatment: Glass bead blasting*		
	$\overline{Ra}$	$\overline{Rz}$	$\overline{Rmax}$	$\overline{Ra}$	$\overline{Rz}$	$\overline{Rmax}$
	σ_{Ra}	σ_{Rz}	σ_{Rmax}	σ_{Ra}	σ_{Rz}	σ_{Rmax}
0°	11,923	62,793	75,747	6,979	33,830	44,334
	0,191	5,368	7,197	0,192	2,402	5,954
10°	16,643	87,230	106,670	15,874	72,896	94,029
	0,471	2,238	6,601	1,124	6,061	2,252
20°	14,451	79,353	90,776	16,367	73,269	90,220
	0,587	1,218	3,112	0,184	1,400	5,340
30°	13,874	75,144	89,814	13,904	59,927	78,846
	0,665	5,100	7,539	1,487	3,855	0,599
40°	12,854	67,782	87,609	11,846	52,503	66,163
	0,655	4,787	14,674	0,872	2,931	5,834
50°	12,432	69,802	83,594	9,290	45,860	64,911
	1,216	7,307	5,627	0,139	2,444	6,696
60°	12,372	70,346	82,140	8,788	42,756	53,433
	1,551	11,804	14,152	0,255	2,915	2,044
70°	12,841	70,551	88,172	8,445	39,342	50,853
	0,888	4,309	12,018	0,453	2,490	2,753
80°	12,891	71,141	87,774	7,853	40,093	57,378
	1,055	4,176	3,821	0,756	4,531	16,175
90°	11,511	65,375	79,023	6,844	35,655	48,780
	0,835	2,459	0,282	0,074	3,394	6,836

By analyzing and comparing the results based on the used AM technologies, it is evident that the SLS process has a much smaller dependence on the surface inclination, as far as the influence on the roughness is concerned, compared to FDM.

Thus, the range between the maximum and minimum values of the R_a parameter, for all slopes of inclination and layer thickness, in the SLS process is between 5,132 – 9,523 μm, while in the FDM process it is 16,840 – 25,850 μm. The same applies to the parameters R_z and $R_{max.}$

This means that with the SLS process, roughness variations can be reduced, i.e. it is possible to achieve somewhat approximate results regardless of the slope of inclination, unlike the FDM process, where the dispersion is relatively greater.

As expected, the best minimum roughness values were achieved at slopes of inclination of 0° or 90°. With the FDM process, the results show the best values at 0°, followed by those obtained at 90° or 10°. Their range is quite large, so for the R_a parameter it is 3,427 – 11,290 μm.

Comparatively, the SLS process achieves the best values at 90°, then at 0°, where the range is very small and amounts to 0,136 – 0,412 μm. The similarity was also observed for the parameters R_z and $R_{max.}$

The analysis of these data shows the influence of the chosen orientation of the product, which is more pronounced in the application of the FDM process. (Feketić, 2022.)

Table 5 shows the maximum and minimum values of the surface roughness parameters, while Figure 4 shows surfaces of specimens during the visual inspection . (Feketić, 2022.)

Table 5 Maximum and minimum values of the surface roughness parameters

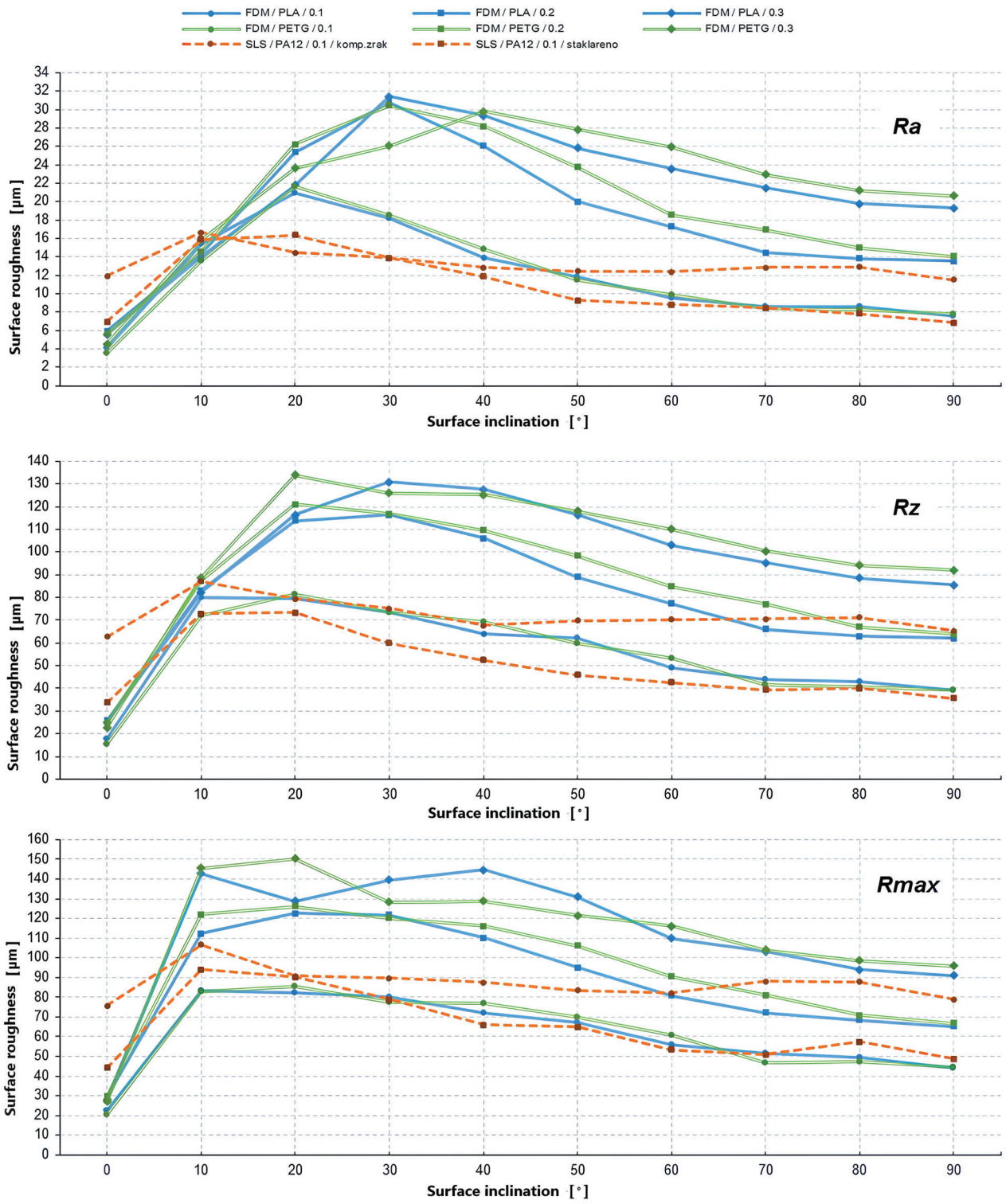
Specimen	Surface roughness parameters (μm)								
	R_a			R_z			R_{max}		
	Surface incline		Difference	Surface incline		Difference	Surface incline		Difference
	MIN	MAX		MIN	MAX		MIN	MAX	
I	0°	20°	16,840	0°	10°	62,023	0°	10°	61,140
	4,138	20,978		17,796	79,819		22,254	83,394	
II	0°	30°	24,856	0°	30°	90,380	0°	20°	93,009
	5,913	30,769		25,920	116,300		29,498	122,507	
III	0°	30°	25,850	0°	30°	105,874	0°	40°	116,474
	5,573	31,423		25,073	130,947		28,179	144,653	
IV	0°	20°	18,063	0°	20°	66,039	0°	20°	65,277
	3,577	21,641		15,306	81,345		20,157	85,434	
V	0°	30°	24,823	0°	20°	96,111	0°	20°	96,390
	5,622	30,445		24,999	121,110		29,737	126,127	
VI	0°	40°	25,244	0°	20°	111,029	0°	20°	123,170
	4,560	29,804		22,877	133,907		27,086	150,257	
VII	90°	10°	5,132	0°	10°	24,437	0°	10°	30,923
	11,511	16,643		62,793	87,230		75,747	106,670	
VIII	90°	20°	9,523	0°	20°	39,439	0°	10°	49,696
	6,844	16,367		33,830	73,269		44,334	94,029	

Figure 4 Surfaces of specimens during the visual inspection

Also from an economic point of view, it should be said that it is important to investigate the possibilities of individual materials and additive technologies to achieve the lowest possible values of surface roughness parameters, because this reduces the costs of possible subsequent processing, which favorably affects both the quality and the final price of the product.

Finally, Figure 5 graphically shows the comparison of the results according to the roughness parameters R_a, R_z and R_{max}.

Figure 5 Comparison of the results according to the roughness parameters



5. CONCLUSION

Additive technologies are used to produce products with a certain surface quality, which results from the characteristics of the process, given that it is about stacking materials layer by layer, i.e. the bottom-up principle.

The geometric 3D model does not include surface defects, but they arise from the manufacturing process, depending on the technological parameters.

It is very important to examine and analyze the surface roughness when creating products using additive technologies, in order to obtain products of the highest quality, without the need for subsequent treatment, which will favorably affect the reduction of costs, that is, the economic profitability of the described processes.

In this paper, an examination of the surface roughness parameters (R_a, R_z and R_{max}) of test samples, which were made using FDM and SLS processes from three different materials: PLA, PETG and PA12, was carried out. Two types of subsequent treatment were used: compressed air and glass bead blasting. The influence of the slope of the surface and the thickness of the layer is observed.

The results were presented and statistical processing and analysis was done, after which the following conclusions and recommendations for further research were made.

There is a need for further improvement of surface quality for additive manufacturing.

Further experimental research needs to be carried out in response to industrial needs, along with standardization of roughness measurements and test samples for different AM technologies and processes.

Increasing the thickness of the layer results in a worse quality of the processed surface (worse surface roughness).

There is a clear mutual connection with the geometric feature of the slope of the surface, i.e. the increase in thickness shifts the slope angle where the critical value of roughness is achieved. As the slope increases (from 0° to 90°), the values reach their maximum from 10° to 40°, after which they decrease with a further increase in the slope from 50° to 90°.

As a criterion for improving surface quality in the FDM process, it is recommended to use reduced layer thickness values and avoid using surface slopes from 10° to 40° to reduce the stairs effect and reduce oscillations between the minimum and maximum roughness values. By using PETG material, better results are achieved compared to PLA material.

The SLS process produces products of better quality, reduced stairs effect and reduced roughness variations, compared to the FDM process, i.e. achieving somewhat approximate roughness results regardless of surface inclination. In order to improve the quality of the surface, the use of slopes from 10° to 40° should also be avoided with the use of subsequent treatment (compressed air, glass bead blasting and others). On average, 21% - 32% better results of the roughness parameter were achieved by glass bead blasting. (Feketić, 2022.)

In conclusion, additive manufacturing techniques offer enormous potential because they adapt well to the geometric complexity and design of the product being made.

The advantages are numerous, such as: lighter and more ergonomically acceptable products, products made of more materials, short production cycles, fewer assembly errors resulting in lower associated costs, lower investment costs in tools, combination of different production processes, optimal use of materials and sustainable production. Conventional production is mainly limited by the size and geometric complexity of the products, with the frequent use of processes and tools that increase the final price of the product.

On the other hand, the disadvantages of additive manufacturing are: the finish of complex surfaces can be extremely rough, long manufacturing times, materials with limited mechanical and thermal

properties that limit performance under stress, and greater tolerances than with other manufacturing methods, such as methods based on material removal .

However, regardless of all the limitations, additive manufacturing can be applied in many sectors where it is easily adapted to the requirements of each of them. Designing and manufacturing using 3D printing is considered one of the biggest industrial revolutions of the last few years, and its use is predicted to increase in the future.

In conclusion, it is necessary to emphasize the economic aspects of the application of the described processes. First of all, the lower costs of tools should be highlighted. Also, by achieving a lower surface roughness, which is obtained with AM products, the need for subsequent treatment is reduced, which reduces the price of the product. As the materials used in the FDM process are also cheaper, this also contributes to economic profitability, so this can also be added to the previously described advantages of additive manufacturing.

This work contributes to the research of new, modern and innovative technologies and materials, and their properties.

PLA material for example is a biopolymer, while PA 12 is biocomatible material and these properties are very important in modern technologies.

By using new and innovative materials and technologies, we also influence on sustainable development, which speaks of the fact that we need to meet our needs with quality, while taking care that the generations that come after us also have this opportunity, that is, that we leave a quality place for living, for the generations behind us.

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- ***Review article* –** A review paper is a scientific paper that contains an original, concise and critical presentation of an area or part of it in which the author actively works. The role of the author's original contribution in the field must be emphasized, considering the already published works and the review of those works. The review also contains the latest information on the current state of development and direction (so-called state-of-the-art reviews). They can be written by one or a group of authors and are usually written at the request of the editor.

The peer review process is an independent quality control procedure for articles submitted to journal. Because it is so difficult for authors to be objective about their own writing, they benefit greatly from having someone else read and comment upon their work. Peer review is vital for enhancing the quality, credibility and acceptability of published research and practice papers

Please observe carefully the following *guidelines* on the role of the reviewer:

- **Expertise:** Papers are not always sent to a reviewer whose field is identical to the subject matter of that paper. You do not have to be precisely qualified in a field to be a constructive reviewer. In fact, quite the contrary, an excellent paper will speak beyond its narrowly defined field. If, however, a paper is so distant from your field that you do not feel qualified to judge its merits, please return it to the publishing manager for the journal, who will locate another reviewer.
- **Confidentiality:** Reviewers receive unpublished work which must be treated as confidential until published. Reviewers must not disclose to others which papers they have reviewed; nor are they to share those papers with any other person.
- **Conflict of Interest:** Reviewers must declare any conflict of interest or any other factor, which may affect their independence – in cases for instance where they have received a paper of a colleague or an intellectual opponent. In cases of conflict of interest, please notify the editorial team of your inability to review a particular paper.
- **Intellectual Merit**: A paper must be judged on its intellectual merits alone. Personal criticism or criticism based solely on the political or social views of the reviewer, is not acceptable.
- **Full Explanation:** Critical or negative judgments must be fully supported by detailed reference to evidence from the paper under review or other relevant sources.
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- **Responsiveness:** Reviewers are asked to return their reports within four weeks.

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