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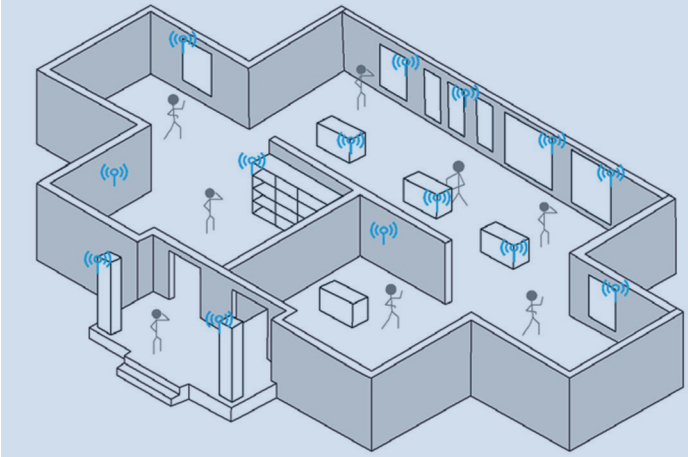

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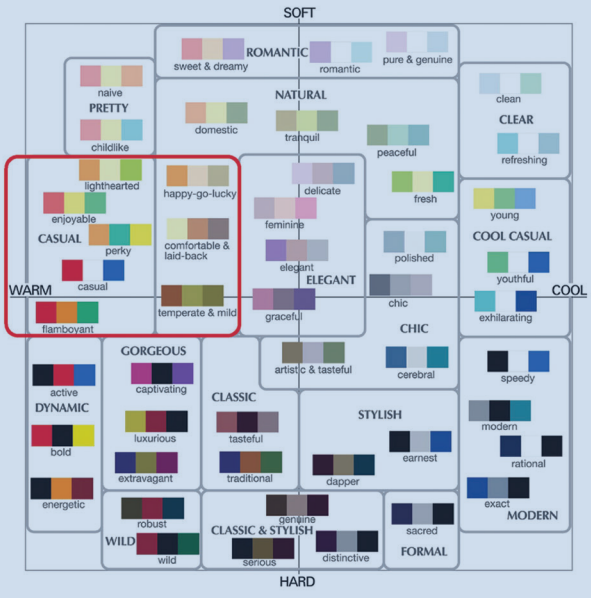

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The design of a model for providing information at local museums through mobile devices with Beacon technology

ABSTRACT

This research aimed 1) to study the information and information system of the museum, 2) to create a system for providing information within the museum via mobile applications, and 3) to assess the satisfaction of the users of information system within the museum via mobile devices by using Beacon technology. First, the data were collected from related documents and interview with experts, and the obtained data were then used for the design of a system and an application called MUCON which is Beacon technology for providing information within the museum. The designed information system and MUCON application were then tested and assessed by visitors at Ja Thawee Folk Museum in Thailand in terms of their satisfaction towards the performance of the information system and mobile application design, including additional comments and feedback by using questionnaire. The results showed that the system for providing information within the museum via mobile applications and MUCON application were successfully designed and created. Moreover, the satisfaction with the performance of the information system and mobile application design was also assessed and proved that they were suitable for use. Limitations of the study are discussed, and recommendations for further research are also made.

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Information system, Beacon technology, MUCON application, local museums

Introduction

According to the current changes in terms of the development and driving global economy, Industry 4.0 has an important role in these changes. It focuses on bringing the world of manufacturing to connect with the network in the form of Internet of Things (IoT), which makes the production process connected with digital technology (Mourtzis, Milas & Vlachou, 2018).

Thailand has a policy of Thailand 4.0 as a guideline for national development by focusing on the use of digital technology innovation and creativity to develop and propel the country (The Secretariat of The Prime Minister, 2017). This is in line with the Industry 4.0 development framework that demonstrates the importance of information and communication technology (ICT) to drive economic and industrial development, especially the deal with Big Data which is one of the key drivers of Industry 4.0 (PwC, 2016; Salkin et al., 2018). Information system is another important factor that needs to be developed in order to provide complete information to receivers. The study of the needs, place, and time of receiving information should be conducted and developed so that the system can provide information appropriately according to the needs of receivers (Chingchuang, Ono & Watanabe, 2021; Chingchuang et al., 2020; Sofia & Mendes, 2019). Especially in the situation of the outbreak of Coronavirus Disease 2019 (COVID-19), people are now required to keep social distancing, and they are also necessary to search for information and/or study by themselves when they access information. As a result, this may cause confusion in finding information (Spring, 2021). Nowadays, there is the use of communication technology, providing and receiving information, or positioning through tracking devices in various organisations. It is essential that every organisation or

various agencies take these technological advancements into account and use them to provide information and communication services. These organisations include shopping malls, stores, airports, tourism industry, and museums (Casano et al., 2022; Đurdević et al., 2022; Katchwattana, 2020; Ko, Kim & Jwa, 2022; Komianos, 2022; Vo et al., 2021; Wattanacharoensil, 2019).

Technologies used in positioning are both for outdoor and indoor uses. For outdoor use, satellite system (e.g., Global Positioning System (GPS)) is mainly used. The function of GPS is positioning via satellite systems, which is suitable for outdoor use. As for indoor use, Line-of-sight (LOS) is more suitable. These technologies used for indoor positioning include Wi-Fi, ZigBee, Radio Frequency Identification (RFID), and Bluetooth Low Energy (BLE) which are the technologies that allow smartphones, tablets, and other mobile devices to position for indoor use effectively. It is important to note that BLE is well-known, and it is applied in many devices such as iBeacon technology (As et al., 2022; Dalkılıç et al., 2017).

As mentioned above regarding the importance of using communication technology to manage information systems, the technology called Beacon technology is another technology that can be applied in the development of information systems that are accessible to users effectively. It is an Internet of things (IoT) technology that can be used to connect to communication devices by transmitting a Bluetooth signal. It can be used both indoors and outdoors to determine the signal distribution point and location for receiving the signal in order to receive information as set (Kumkrua, Chokchaisri & Boonsomtob, 2020). In addition, the use of Beacon technology can reach all groups of people, including children, adults, and groups with physical disabilities such as blind people and deaf people so that they can use this application as an effective warning/alarm signal (Ruffa et al., 2015).

According to relevant research studies, it was found that many organisations have realized the importance and have used Beacon technology to develop information systems. For example, many airports have used this technology for tracking, positioning, and providing information systems to passengers (Katchwattana, 2020). Applying Beacon technology to educational institutions to benefit students helps students become more involved in learning (Zorić et al., 2019). Moreover, this technology can be used for positioning locations to promote tourism, provide interesting information, and create a comfortable experience for tourists (Ko, Kim & Jwa, 2022; Vo et al., 2021). Additionally, nowadays, museums have applied modern technology to keep up with the modern world and create interest, and Beacon technology is used as a navigation device that reduces confusion in route finding (Braidotti et al., 2021). It is a good substitute for public relations or location guidance. This will encourage visitors to do various activities on their own, known as self-service, to maintain social distancing and reduce unnecessary close contact with others (Casano et al., 2022; Komianos, 2022).

It can be said that the museum is a good source of learning with various information and is divided into many different exhibition areas. Properly organised information according to the visitor's needs will reduce the confusion of walking through the different areas in the museum. Also, the visitors can access/reach information of the whole building/area smoothly and effectively according to the objectives of the museum. Inside the museum building, Beacon technology can be applied/set and send information in terms of texts, images, and animation to the visitor's mobile devices according to the predetermined point. The researchers were therefore interested in conducting research on the design of information provision system and the application of modern technology in a museum via mobile devices. The researchers hope that the findings of this study will be useful to the relevant agencies and can be used as a guideline for future research for the most benefit.

The significance of the study

Regarding the expected benefits from this research, in addition to the expected success, the museum will be able to manage its information system for large numbers of visitors. It can also reduce the need for museum staff to encounter visitors. This can maintain social distancing in the era of COVID-19. It also reduces the problem of confusion among visitors within a large museum building in which there are a lot of details provided and be able to send alert messages/notification to reach all groups of museum visitors. In particular, people with physical disabilities such as blindness and deafness can use this communication device as an assistive device in the museum. Additionally, it can make museum visitors feel interested and fun with the design of information and enjoy provided information in the museum as well. Moreover, the findings of this research can be used as design guidelines for relevant agencies, further study, and information system development in the future.

Research objectives

1. To study the information and information system of the museum.

2. To create a system for providing information within the museum via mobile applications.

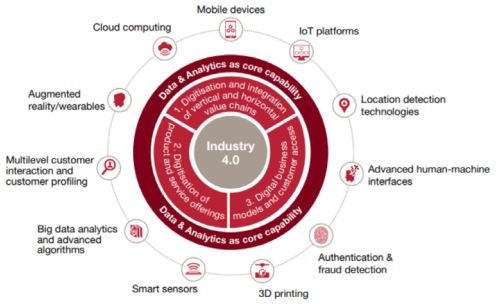
3. To assess the satisfaction of the users of information system within the museum via mobile devices by using Beacon technology.

Literature Review

The design of the information system in the museum through mobile devices by using Beacon technology can be divided into two main theoretical frameworks: 1) the Information Architecture Theory by taking time and place into account and providing information according to people's behavior and appropriateness (Fischer, 2012) and 2) the User Experience (UX) Theory and User Interface (UI) Theory to study the application design process, information display format, and appropriate use (Galitz, 2017; Treder, 2013) for museum visitors.

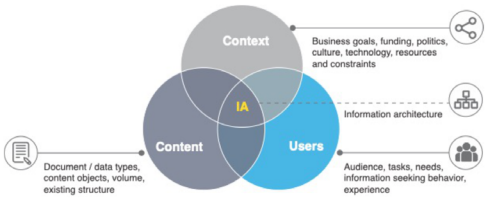
From the study of relevant research on the importance of managing the information system, it was found that the information system is crucial. The use of modern technology to keep up with the rapid changes in today's world can support the growth of the economy and society (Kutzner, Schoormann & Knackstedt, 2018), especially in the era of the epidemic of the Coronavirus (COVID-19) that makes everyone want fast and clear information (Gómez-de-Gabriel et al., 2022). Moreover, there is a matter of social distancing, so self-service in which service users can do every step of the process by themselves without touching or relying on others is required (Wang et al., 2022). Therefore, bringing technology that can provide information to meet the needs of the visitors or information receivers quickly and accurately is needed since it will be able to facilitate even more (Little, Pell & Blondel, n.d.).

For the policy of Industry 4.0, it focuses on the use of modern technology, especially communication technology used to develop industries in various forms (PwC, 2016; Salkin et al., 2018) as shown in Figure 1 below.



» **Figure 1:** *Industry 4.0 framework and contributing digital technologies (PwC, 2016)*

From Figure 1 above, it can be seen that the management of Big Data system, the application of mobile devices, and the Internet of Things (IoT) are applied to the development of various agencies around the world. Therefore, to make the design of information classification based on user needs (i.e., Information Architecture) efficient, three important elements that must be taken into account are context, content, and users (Gearon, 2022; Morville & Rosenfeld, 2007) as shown in Figure 2 below.

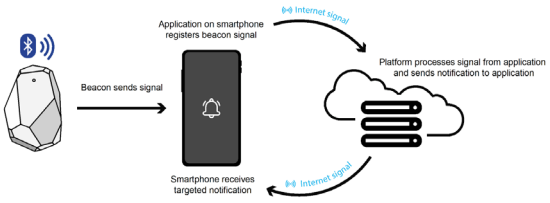


» **Figure 2:** *The infamous three circles of information architecture (adapted from Gearon (2022) and Morville & Rosenfeld (2007))*

Beacon technology

The Bluetooth Low Energy (BLE) Beacon is a small and lightweight device that is widely used in indoor positioning (Dhanyatha et al., 2019; Wong, She & Jeon, 2023). It is designed to automatically transmit BLE signals to receiver's mobile devices. These mobile devices are, for example, smartphone, tablet, or smartwatch of the user who is in the area where the Beacon signal can be reached. The signal will be set and sent out in the radius specified by the sender. It transmits at intervals of frequency and the number of times per second, depending on the developer. In this present study, BLE Beacon Version 4.0 was employed. Although it was introduced in 2009, and there have been later versions that have been developed and available in the market, it has been widely used till these days (Molina-Gil et al., 2022).

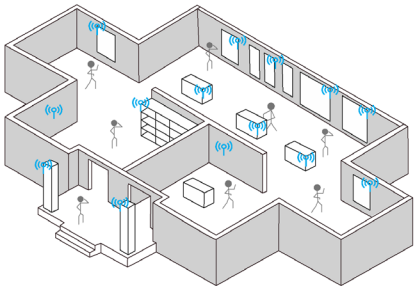
As for the activation process of Beacon in smartphones, tablets, and other devices, Beacon devices send a Bluetooth signal to the user's smartphone or device in the radius that the signal reaches. If the Bluetooth receiver on the user's smartphone is turned on, there will be a notification/information sent to the user immediately (Đurdević et al., 2022) as shown in Figure 3 below.



» **Figure 3:** *The Beacon activation process*

In addition, a number of studies have shown that the application of Beacon technology in sending messages can bring great user satisfaction. Although at present there is still not being applied in Thailand as much as it should be, it is of great interest to messaging developers across industries (Kumkrua, Chokchaisri & Boonsomtob, 2020).

Ruffa et al. (2015) conducted research on the use of Beacon technology in providing information and being as an assistive tool for blind people. This shows that, in addition to creating benefits for the general public, it can also be used to help visually impaired people as well. To understand more clearly, Figure 4 below shows the Beacon technology in action.



» **Figure 4:** *Beacon technology in action (Brooke, 2017)*

Research method

This research was divided into two phases.
For Phase 1, it was to study related information and find ways to develop the design of the information system.
For Phase 2, it was to design and create the information system at a local museum in Thailand and assess the satisfaction of the users of information system within the museum via mobile devices by using Beacon technology.

Participants

The participants of this study were divided into two groups. For Phase 1, the participants were experts and those who involved in information provision at local museums. They were chosen by purposive sampling. For Phase 2, the participants were 124 visitors at Ja Thawee Folk Museum which was the chosen museum in this study. All participants were Thai visitors, and they were chosen by convenience sampling. Regarding ethical issues, this research was reviewed and approved by the Institutional Review Board (IRB), (IRB No. P2-0424/2564). At every stage, the participants' names would remain confidential, and the results of this study were used for academic purposes only.

Research instruments

In this study, there were three research instruments used to collect data:

1) interview,
2) questionnaire, and
3) MUCON application.

The details of each research instrument will be discussed as follows.

Interview

In this study, interview was used to elicit information about general information about the museum, information system in the museum, the needs and problems of information system in the museum, ways to develop information system and the use of technology in the museum in the future, and other recommendations regarding information system in the museum. The interview was conducted with the participants in Phase 1. Table 1 below shows the interview questions used in this study.

Table 1
Interview questions

Part 1: General information about the museum	
Q1	What is the history of the museum, establishment, and its purposes?
Q2	What kind of the information does the museum provide?
Q3	What is displayed?
Q4	How many visitors per day are there?
Q5	During the day, when do a lot of visitors and fewer visitors come?
Q6	Who are the visitors and how old are they?
Part 2: Information system in the museum	
Q1	In providing information within the museum, what media is used to provide information to visitors, such as print media, LED media, digital media, or other modern technologies?
Q2	What are the criteria for the selection of media used to provide information to visitors at various areas in the museum?
Q3	In providing information to visitors, is there staff available to give advice and is there enough staff?
Q4	Are there any documents such as brochures or maps distributed within the museum to recommend places inside the museum?
Q5	In the COVID-19 era, what measures are there to provide complete information to visitors?
Part 2: The needs and problems of information system in the museum	
Q1	What are frequently asked questions from visitors?
Q2	Where are the important areas in the museum where visitors cannot notice or spend too little time there?
Q3	How should visitors walk inside the museum?
Q4	Where should visitors get the information / Where does it start and end in order to receive complete and continuous information?
Q5	Is there a placement plan and prioritized presentation of information?
Part 4: Ways to develop information system and the use of technology in the museum in the future.	
Part 5: Other recommendations regarding information system in the museum.	

Questionnaire

The 5-point Likert scale questionnaire was used as a research instrument to collect data regarding the satisfaction and the opinions of visitors who had tried using the museum's information system via their mobile devices using Beacon technology at Ja Thawee Folk Museum in Phitsanulok Province, Thailand. The questionnaire was divided into three sections: 1) respondent status, 2) satisfaction with the performance of the information system and mobile application design in terms of content and information provided inside the museum, the design of the application, and the usability of the information system inside the museum, and 3) comments and additional feedback on the information system and application design via mobile devices. The questionnaire was conducted with the participants in Phase 2. The details of the questionnaire are shown in Table 2 below.

Table 2

Questionnaire

Section 1: Respondent status, including gender, age, income, occupation, address, and frequency of visiting	
Section 2: Satisfaction with the performance of the information system and mobile application design	
1. Content and information provided inside the museum	
1.1	There is information provision within the museum covering all important areas.
1.2	There is information available to explain the details of the contents within the museum.
1.3	There is the provision of early warning information at an interesting point or at an area that cannot be easily noticed inside the museum.
1.4	Step-by-step information is provided, and there is a systematic pattern.
1.5	Useful information is provided, and it is easy to access the museum.
2. The design of the application	
2.1	The application has an easy-to-use format.
2.2	The application uses appropriate design colors.
2.3	The application uses suitable designed texts.
2.4	Graphic design and animation in the application are suitable.
3. Satisfaction with the usability of the information system inside the museum	
3.1	It can help to reduce confusion in searching for information within the museum.
3.2	It can provide complete information within the museum.
3.3	It can help to reduce time spent searching for various points within the museum by yourself.
3.4	It can help to create interest and encourage motivation to visit the museum.
Section 3: Comments and additional feedback on the information system and application design via mobile devices	

MUCON application

In this study, the researchers designed MUCON application which is Beacon technology and tested it. The details of this application will be discussed in the following sections.

Data collection procedure

The research procedure was divided into two phases. The details of each phase are discussed below.

Phase 1

It was to study related information and find ways to develop the design of the information system. First, related research studies and theories regarding the design of information system within museums through mobile devices and Beacon technology were studied. This aimed to set research objectives and create a framework for conducting this present research.

The data obtained were then analysed in order to be used to determine research objectives and create interview questions for experts' interviews before conducting a study in an actual museum. After that, a pilot study was conducted in order to test the feasibility and the development of the interview questions used in an actual study. It was conducted with two experts who involved in providing information at Wang Chan Museum and Textile Museum in Phitsanulok, Thailand. The suggestions provided could be categorised and summarised with the interview observation as follows. First, in general, the user groups were divided into three main groups: 1) a group of students aged 18-24 years, 2) working people aged 25-35 years, and 3) people aged over 35 years. Second, the data in terms of needs and problems of information provision were analysed, summarized, and used in creating interview questions in an actual study which included 1) general information about the museum, 2) information system in the museum, 3) the needs and problems of the information system in the museum, 4) ways to develop information system and the use of technology in the museum in the future, and 5) other recommendations regarding information system in the museum.

The complete interview questions, as shown in Table 1, were then employed with three experts in an actual study. The obtained data were analysed and used to create a guideline for developing the design of the information system and creating MUCON application and a questionnaire used to assess the satisfaction of visitors/users.

After that, a local museum that was used to set up a system to provide information via mobile devices using Beacon technology was chosen, and Beacon technology was then installed in that museum.

In an actual study, Ja Thawee Folk Museum in Phitsanulok Province, Thailand, was chosen. The selection criteria are as follows. It is a museum that presents locality and history of the province. Also, it is one of the most famous local museums in Thailand. Additionally, it is a museum with continuous visitors of more than 5,000 people per year and has been open for visitors for more than 10 years. The museum has staff members who give information about the museum and has more than five years of work experience. The pictures of Ja Thawee Folk Museum are shown in Figure 5 below.

» **Figure 5:** *Ja Thawee Folk Museum*

Phase 2

It was to design and create the information system at Ja Thawee Folk Museum and to assess the satisfaction of the users of information system within the museum via mobile devices by using Beacon technology.

The data and design guidelines obtained from Phase 1 were used to create an application called MUCON (Figures 8 and 15) as a prototype for use in testing and assessing information system and the satisfaction of museum visitors. This application was used and tested as the main information system within the museum.

Another pilot study was conducted in order to test and assess the satisfaction of users towards the MUCON application with three users. Also, the questionnaire used in the actual study was assessed through Index of Item – Objective Congruence (IOC) with three experts, and it met the criteria at 1.00. In addition, suggestions for the questionnaire development were also provided.

The obtained data were then used to develop the design and the complete questionnaire. After that, the MUCON application was set up at Ja Thawee Folk Museum. The details showing how to set up are discussed in the following section.

Furthermore, the questionnaire regarding the users' satisfaction was conducted with the 124 visitors at the museum in an actual study from August to October 2022. The data were then collected for further analysis.

Design of the experiment

As for the design and experimental process, the researchers created an application that allows visitors to receive information about the museum through text alerts to their mobile devices using Beacon technology installed at various points/areas inside the museum. The design and installation steps are as follows:

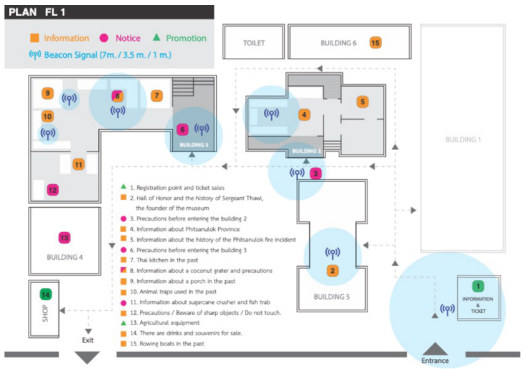
Step 1. Finding information regarding the museum in order to install the equipment.

At this stage, the researchers visited the museum in order to study the information, limitations, and environmental elements of the museum, including a form of providing information to visitors. The obtained details of the museum can be categorised as follows.

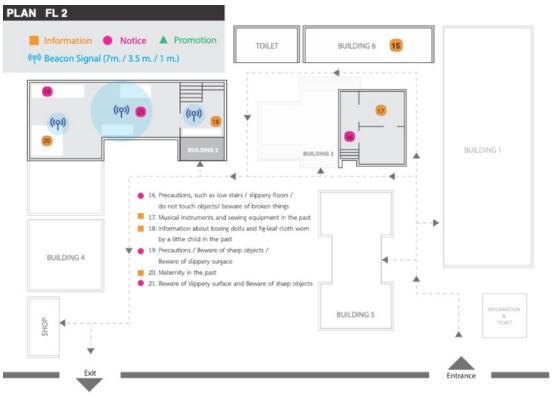
- The museum is a folk museum that presents the lifestyle and past history of the province. The form of information provision is to provide information through museum staff or some printed media.
- There are six separate buildings within the museum, with both one-storey buildings and two-storey buildings.
- Most of the buildings are made of wood and are original buildings that are over 40 years old.
- The information provided within the museum is divided into three categories: 1) detailed information about the history of the museum in different zones, 2) warning information about prohibition and precaution within the museum, and 3) information about sales advertisement.

Based on the above information, the researchers summarised the data and selected Beacon installation points to distribute signals around the museum. In this research, according to budget constraints, the researchers chose to install 11 signal distribution points (in blue circles), considering from the locations that visitors frequently asked staff and the areas that needed to be aware of as presented in Figures 6 and 7 below.

From Figures 6 and 7 below, the information presented in orange color is about the history and the way of life in the past of people in Phitsanulok Province. Pink color is prohibition and precaution inside the museum, green color is advertising information, and blue color is the installation and distribution points of Beacon technology. From the building plans below, the researchers chose to install all 11 signal transmission points by choosing from the areas that were most interesting for the visitors and at the point where the visitors had to be careful about accidents or prohibitions within the museum.



» **Figure 6:** *Building Plan of the 1st floor*



» **Figure 7:** *Building Plan of the 2nd floor*

At each point, signal transmission distance was chosen differently according to the area and the installation restrictions. From Figures 6 and 7, the blue circle shows the distance of signal distribution in various points. The researchers chose three distribution distances as follows: signal at 1 metre, 3.5 metres, and 7 metres. The signal distribution point at 1 metre was used for the areas where information provision was close to each other (i.e., No. 9,10,18, and 20). The 3.5-metre signal distribution point was used for the areas that were far from other signal distribution points, where information covered that area, and where there were no signals from other points to interfere (i.e., No. 2,3,4,6,8, and 21). The 7.5-metre signal distribution point was used for wide-open signal distribution points which were not close to the areas with other signal transmission points, such as a registration point and ticket sales before entering the museum (i.e., No. 1 in Figure 6). As for providing information within the museum, the researchers classified a type of information and its details as shown in Table 3 below.

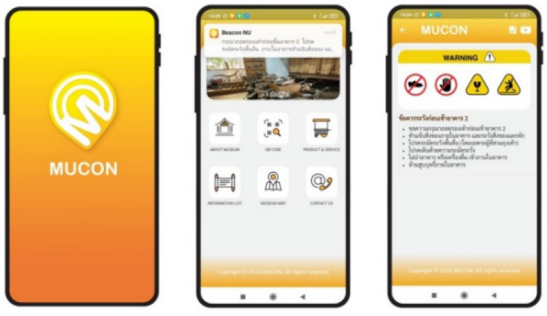
Step 2. Designing an application on mobile devices

Regarding the application design process, the researchers studied relevant documents and research in terms of the color theory used in designing icons, graphics, and arrangements to make it easy for users to use. This application is called MUCON (Figure 8). It should be noted that MUCON application in this present study support only Android system. The design of MUCON application will be discussed in great detail in the Result and Discussion section.

Table 3

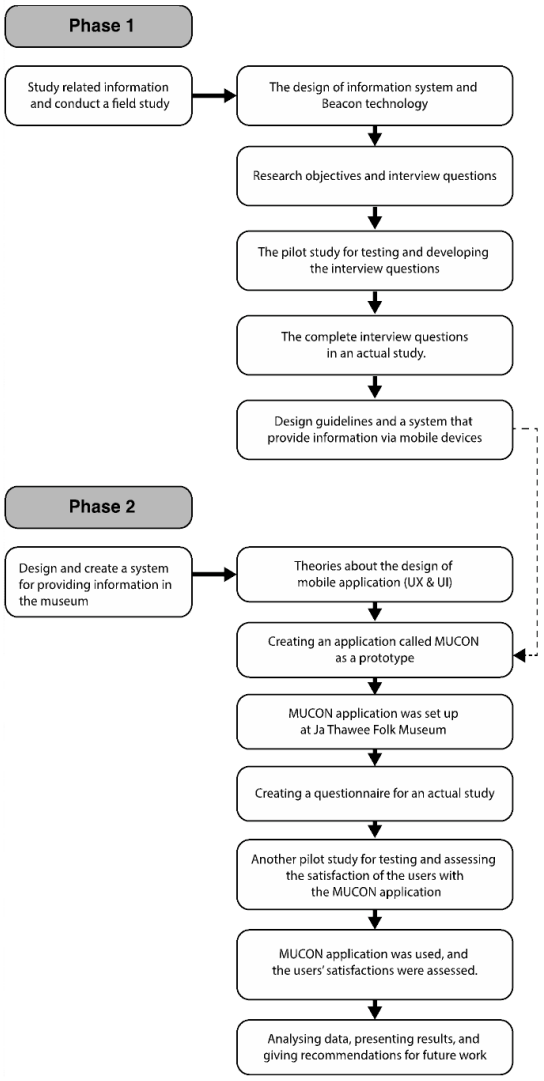
Type of information and its details

Type of information	Details
History	• Hall of Honor and the history of Ja (Sergeant) Thawee, the founder of the museum • Information about Phitsanulok Province • Information about the history of the Phitsanulok fire incident • Thai kitchen in the past • Cooking equipment in the past • Thai houses in the past • Animal traps used in the past • Equipment used for catching fish • Thai children's toys in the past • Agricultural equipment • Weapons in the past • Thai musical instruments • Maternity in the past
Prohibition and precaution	• Precautions before entering the building, such as taking off your shoes, not bringing flammable objects into the building, and not bringing food and drinks into the building • Beware of sharp objects • Beware of slippery surface • Beware of stairs and low ceilings • Do not touch / Do not hold • Do not enter • No smoking
Advertisement	• Registration point and ticket sales • Selling merchandise and souvenirs • Selling food and drinks • Learning promotion activities • A rotation of exhibitions in the museum



» **Figure 8:** *MUCON application*

To understand more clearly, the figure below shows the flow of the research structure in this present study.



» **Figure 9:** *The flow of the research structure*

Data analysis

In this study, since the data were divided according to the two phases of the study, data analysis was also divided into two phases. For Phase 1, the data were knowledge gained from studying related research studies and theories regarding the design of information system and interview data.

The obtained data were analysed by using content analysis. For Phase 2, the data were obtained from questionnaire regarding the satisfaction and the opinions of visitors who had tried using the museum's information system via their mobile devices using Beacon technology at Ja Thawee Folk Museum in Phitsanulok Province.

The data were analysed by using frequency, mean, standard deviation, t-test, f-test, and content analysis.

Results and discussion

The results and discussion of this research are presented according to the three research objectives of this study.

For Research Objective 1 aiming at studying the information and information system of the museum, based on related documents and the interview data, it was revealed that the local museums in this present study were the museums that aimed to reflect the identity and transfer the wisdom of the old lifestyle of Phitsanulok Province. Therefore, the main information provided in the local museums were the information about history, wisdom, way of life in the past of people in the community of Phitsanulok Province, the history of Thai textiles in the past, weapons used in battles in the old days, and biographies of famous people in the past. This information was displayed in the form of photos, home utensils, agricultural equipment, and printings providing information about the history of Phitsanulok Province in the past. They were exhibited for next generations to study.

As for the information system of the museums, it was found that mostly the information was provided through printings, such as maps of the museum, signs telling stories, and brochures that were distributed before entering the museum. Also, there were guides/museum staff who gave information and answered questions from visitors. However, there was only one museum in this area that officially presented the information via animation, video, lighting, light-emitting diode (LED) monitors, and projectors that had touch screens to provide information within the museum.

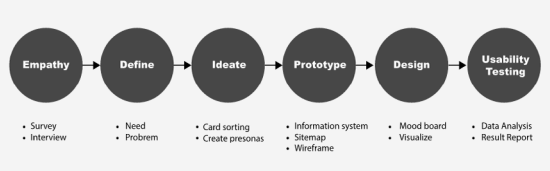
Interestingly, there were three main problems found from the interview data. That is, 1) there were not insufficient officials and guides who provided information and services, 2) the situation of the COVID-19 epidemic made most visitors need to keep distancing, and 3) although the brochures distributed before entering the museum provided information, the information was not detailed and was not grouped according to each particular group of visitors.

Therefore, the museums had a plan to improve and develop museums to meet the needs of information by using more advanced technologies to apply to the museum. Importantly, these technologies must not cause the original image and being the local museum to disappear. However, due to the budget constraint and the COVID-19 epidemic situation, these caused many plans and projects unable to continue. It was believed that setting a good information system could help to reduce the confusion that occurred within the museum and help the limited number of officials to provide information at various important areas where visitors often ask questions or some areas where visitors could not notice or overlook.

Moreover, a good information system could provide precaution notifications and prohibitions in the museum effectively. It is because using too many notification signs within the museum may make the image of the museum become not beautiful, untidy, and not suitable for the museum that looks local and traditional and obscure the displayed objects in the museum. Therefore, the use of media and technology to provide information that did not fade the image of the local museum was crucial.

For Research Objective 2 aiming at creating a system for providing information within the museum via mobile applications, the researchers designed and created the information system at Ja Thawee Folk Museum. This was conducted in Phase 2 of this study as discussed in the Data Collection Procedure section. The main result was the creation of MUCON application as shown below.

As for the application design, the researchers named the application by combining the words “Museum” and “Beacon”, resulting in the name “MUCON”. Regarding the design principles, the researchers drew mainly on User Experience (UX) design, User Interface (UI) design, and usability that affect emotions and feelings of users, for example, the choice of colors in the design, layouts, data locations, graphics, and buttons appearing on the screen for convenience and motivation to use (Khamchan & Kullimratchai, 2022; Kureerung et al., 2022; Mazumder & Das, 2014). The details of the design based on UX and UI are discussed below.



» **Figure 10:** *User Experience and User Interface design process (Adapted from Pacholczyk (2014) and Setiyani & Tjandra (2022))*

User Experience (UX)

The researchers studied the data obtained from Phase 1 in terms of user groups which were divided into three main groups: 1) a group of students aged 18-24 years, 2) working people aged 25-35 years, and 3) people aged over 35 years. The data were then analysed and summarised in terms of needs and problems of information provision. The researchers then designed Personas which is a profile model of a group of users by clearly specifying their age, occupation, needs, and problems in order to make it easier to find a solution in designing a system for providing information through a mobile application further (Adhitya, Andreswari & Alam, 2021). This aimed to define target groups in the design.

After that, the researchers brought the problems and recommendations to determine the direction in the design of information organisation, create the sitemap, and arrange the structure of the MUCON application. Next, it was created in the form of a wireframe for easy understanding and improvement in terms of functionality within the application. Also, this wireframe and design were developed, based on experts’ recommendations. This developed wireframe was then used for designing User Interface (UI) and creating the application for this present study since it allowed the researchers to see the placement and the design better as shown in Figure 11 below.

» **Figure 11:** *A wireframe of MUCON application*

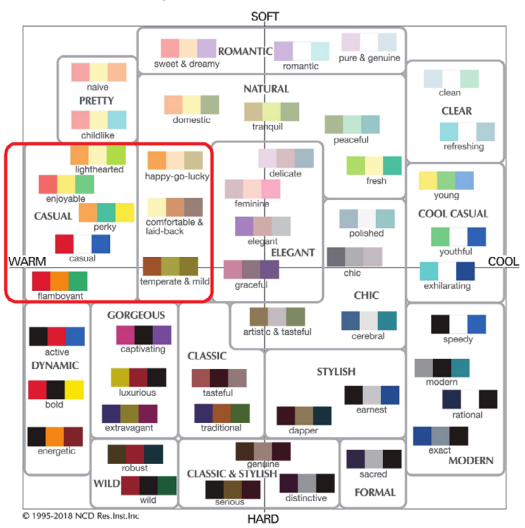
User Interface (UI)

Based on the result of designing the groups of Personas and creating a wireframe to set the direction in the design, the researchers studied and determined the color tone from the personality of Personas and analysed from various media of three main local museums in Phitsanulok Province. It was found that the color tones used were in the Casual and Natural groups based on the concept and theory of Shigennobu Kobayashi's Image Scale (Horiguchi & Iwamatsu, 2018; Kobayashi, 2009) which categorises colors that are suitable for personality as shown in Figure 12. The colors used in this study were the color groups suitable for teenagers, school students, university students, and general public. The colors used are lighthearted, enjoyable, mild, comfortable, friendly, and casual. These colors also communicate culture and nature.

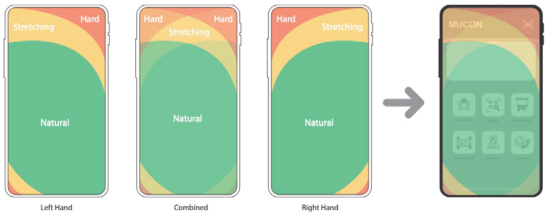
After the researchers determined the colors used in the design, the researchers also studied User Interface (UI) design principles, taking the nature of use into account by placing images and icons in positions that were easy to use with one hand, either left or right, or use with both hands together called “the thumb zone for mobile users” (Knight Design, 2020; Wijs, 2020) as shown in green color in Figure 13 below.

As for designing icons and graphics within the application, the researchers used the lines that looked simple and comfortable and brought some Thai shapes and uniqueness into the design.

This aimed to make it interesting and represent the local museums of Thailand within the application. Figures 14 and 15 show the design of main icons used in the application and the design of using an application to receive information within the museum.



» **Figure 12:** *Image scale for 3-color combinations (1995 to present) (Horiguchi & Iwamatsu, 2018)*



» **Figure 13:** *The thumb zone for mobile users (Knight Design, 2020)*

» **Figure 14:** *The design of main icons used in the application*

Regarding the use and information provision of MUCON application, after visitors successfully downloaded and installed the application, there would be a notification to start using it at the registration point before entering the museum as shown in No. 1 in Figure 15. Users can press to read details about the museum in order to understand before visiting by themselves. Moreover, within the museum, there would be a signal to send messages at various points periodically, such as information about displayed objects, history, prohibition and precaution, and advertisements in the museum.

In the application, researchers categorised information provision according to the needs of users and service providers within the museum. This makes the application easy to use and reduce confusion in use. It was divided into six menus, namely 1) About the museum, 2) QR code scan, 3) Products and services, 4) Information list, 5) Map, and 6) Contact staff. From these six menus, users can click to read information on pages as shown in No. 2 in Figure 15 which shows the detailed map of the 1st floor building of the museum. Within this page, users can zoom in or click to view details later.

The QR code scan function is for scanning to view information in the area where there is no signal. Visitors can scan to read details and can study the information by themselves through the use of this application as shown in No. 3 in Figure 15.

From Figure 15, No. 4 shows detailed information in various points with service information which will present pictures and VDO to provide complete information. Users can select from icons in order to link to different pages as needed. When selecting the picture, in No. 5, the picture will be enlarged and zoomed in to see details clearly. Additionally, when users want to watch a VDO with a lecture from the staff, they can click on the VDO icon to watch or listen as needed.

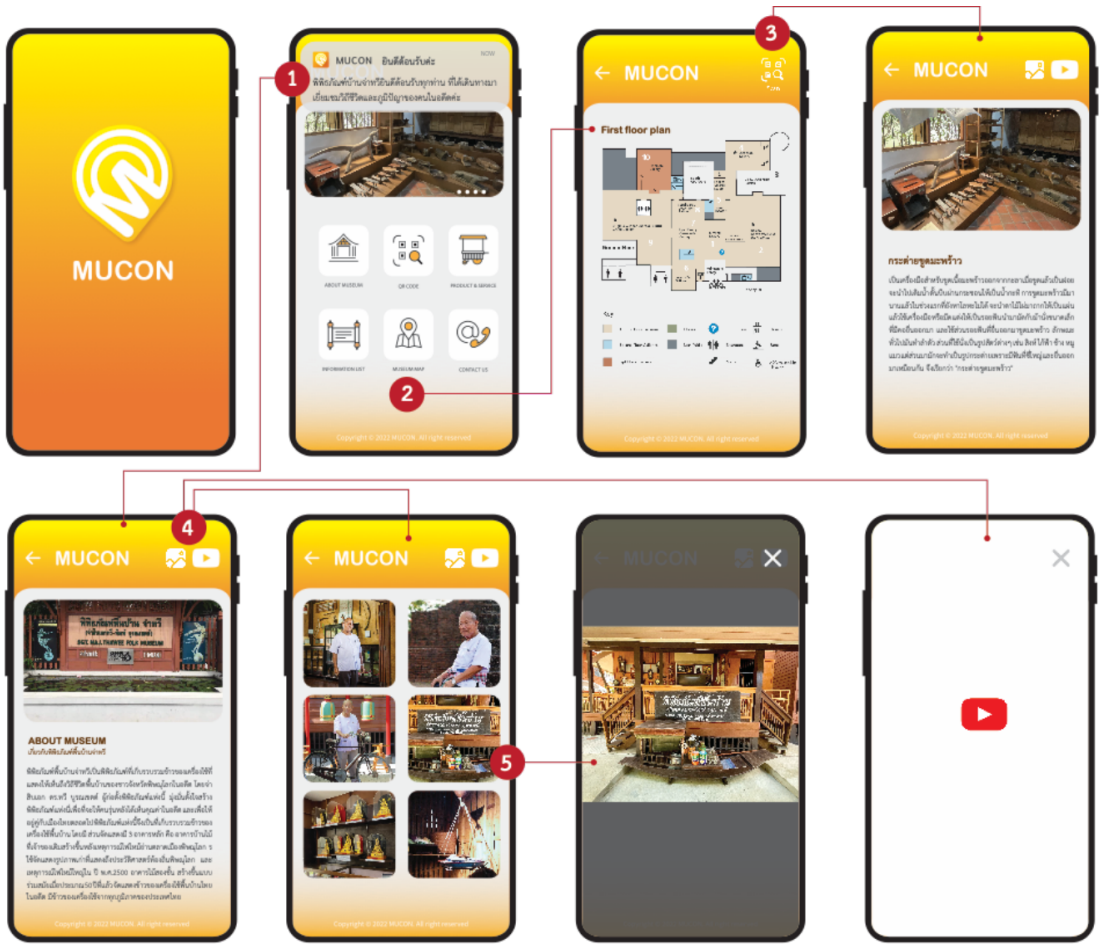
Usability

Based on a study of usability frameworks for user experience (UX) and user interface (UI), it was found that important factors for the usability of MUCON application included learnability, efficiency, memorability, errors, and satisfaction (Kureerung et al., 2022; Mazumder & Das, 2014).

As for learnability, this present study considered the easy-to-learn design. The layout of the position of use had a format that users were familiar and similar to other applications. There were only important and easy menus to use. Also, for the design of the application, the researchers focused on designing the color scheme, text, and icons that are all in the same way for easy understanding and continuous usage.

For efficiency, when using, there was uninterrupted operation and continuous use. Additionally, the user can search for information easily. It included content, images and animations. Also, it reduces designs or the use of unnecessary image files.

Regarding memorability, the user did not need to be trained to use since it was easy to remember its usage patterns. It was designed to have no complicated steps to use.



» **Figure 15:** *The design of using an application to receive information within the museum*

As for errors, there were a few errors in operation, or if an error occurred, the user must know what to do or quickly return to use.

In terms of satisfaction, as discussed in Phase 1 of this present study, there was a study on the related research studies and theories regarding the design of information system within museum through mobile devices to find suitable design guidelines for users' satisfaction.

For Research Objective 3 aiming at assessing the satisfaction of the users of information system within the museum via mobile devices by using Beacon technology, the results of satisfaction assessment can be divided into two parts. The first part is the satisfaction with the performance of the information system and mobile application design in terms of 1) the content and information provided inside the museum, 2) the design of the application, and 3) satisfaction with the usability of the information system inside the museum.

The second part is the comments and additional feedback on the information system and application design via mobile devices. The results are as follows.

1. The satisfaction with the performance of the information system and mobile application design

In terms of the content and information provided inside the museum, the overall satisfaction with this aspect was at a high level ($\bar{x}$ = 4.39, S.D. = 0.11). When looking at greater detail, it was found that the visitors thought that useful information was provided, and it was easy to access the museum ($\bar{x}$ = 4.58, S.D. = 0.61). As for the design of the application, the overall satisfaction was at a high level ($\bar{x}$ = 4.44, S.D. = 0.05). In greater detail, the results showed that the application used suitable designed texts ($\bar{x}$ = 4.52, S.D. = 0.63). Regarding satisfaction with the usability of the information system inside the museum, the overall satisfaction was at a high level ($\bar{x}$ = 4.48, S.D. = 0.05). In greater detail, it was found that the visitors thought it could help to create interest and encourage motivation to visit the museum ($\bar{x}$ = 4.52, S.D. = 0.65), and it could help to reduce time spent searching for various points within the museum by themselves ($\bar{x}$ = 4.51, S.D. = 0.66).

When looking at the differences and significance in use between men and women as well as age ranges, the results of satisfaction assessment with the perfor-

mance of the information system and mobile application design in terms of 1) content and information provided inside the museum, 2) the design of the application, and 3) the usability of the information system inside the museum are presented in Tables 4 and 5, respectively.

As Table 4 shows, there was no statistically significant difference in all aspects of satisfaction assessment between male and female visitors. Both male and female were satisfied with the performance of the information system and mobile application design.

From Table 5, it was revealed that there was no statistically significant difference in all aspects of satisfaction assessment among different age ranges of the visitors. All different age groups were satisfied with the performance of the information system and mobile application design in terms of 1) content and information provided inside the museum, 2) the design of the application, and 3) the usability of the information system inside the museum.

2. The comments and additional feedback on the information system and application design via mobile devices

Based on open-ended question questionnaire data, it can be concluded as follows.

- As for the use of MUCON application by some visitors, there was a delay in receiving the notification signal for up to 1-2 minutes. It is because each mobile phone can receive the signal at different speeds. In addition, each visitor's internet network is from different networks, and it also results in receiving notifications at

Table 4

The results of satisfaction assessment with the performance of the information system and mobile application design between male and female visitors

Satisfaction assessment	Gender				t	P (Sig.)
	Male		Female			
	$\bar{x}$	S.D.	$\bar{x}$	S.D.		
1. Content and information provided inside the museum						
There is information provision within the museum covering all important areas.	4.23	0.83	4.45	0.65	0.22	0.83
There is information available to explain the details of the contents within the museum.	4.23	0.81	4.27	0.59	1.37	0.18
There is the provision of early warning information at an interesting point or at an area that cannot be easily noticed inside the museum.	4.31	0.90	4.36	0.87	0.14	0.89
Step-by-step information is provided, and there is a systematic pattern.	4.33	0.77	4.40	0.64	0.57	0.57
Useful information is provided, and it is easy to access the museum.	4.59	0.69	4.57	0.57	-0.19	0.85
2. The design of the application						
The application has an easy-to-use format.	4.41	0.72	4.45	0.65	0.20	0.84
The application uses appropriate design colors.	4.28	0.72	4.46	0.65	1.22	0.23
The application uses suitable designed texts.	4.44	0.68	4.55	0.61	0.77	0.44
Graphic design and animation in the application are suitable.	4.28	0.76	4.45	0.67	1.09	0.28
3. Satisfaction with the usability of the information system inside the museum						
It can help to reduce confusion in searching for information within the museum.	4.36	0.78	4.46	0.55	0.66	0.51
It can provide complete information within the museum.	4.41	0.79	4.44	0.59	0.11	0.91
It can help to reduce time spent searching for various points within the museum by yourself.	4.51	0.79	4.51	0.61	-0.13	0.89
It can help to create interest and encourage motivation to visit the museum.	4.38	0.88	4.58	0.52	1.23	0.22

Note: p-value <0.05

Table 5

The results of satisfaction assessment with the performance of the information system and mobile application design among different age ranges

Satisfaction assessment	Age Ranges						f	P (Sig.)
	18 - 29 years		30 - 39 years		40 and over			
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.		
1. Content and information provided inside the museum								
There is information provision within the museum covering all important areas.	4.40	0.71	4.17	0.70	4.31	0.70	1.12	0.33
There is information available to explain the details of the contents within the museum.	4.46	0.65	4.17	0.76	4.31	0.60	1.19	0.15
There is the provision of early warning information at an interesting point or at an area that cannot be easily noticed inside the museum.	4.24	0.95	4.29	0.75	4.38	0.62	0.04	0.97
Step-by-step information is provided, and there is a systematic pattern.	4.38	0.69	4.33	0.70	4.44	0.63	0.07	0.94
Useful information is provided, and it is easy to access the museum.	4.59	0.61	4.52	0.59	4.60	0.63	0.13	0.88
2. The design of the application								
The application has an easy-to-use format.	4.49	0.69	4.46	0.51	4.19	0.83	0.11	0.89
The application uses appropriate design colors.	4.45	0.65	4.42	0.65	4.19	0.83	0.96	0.91
The application uses suitable designed texts.	4.57	0.63	4.50	0.51	4.25	0.77	0.20	0.82
Graphic design and animation in the application are suitable.	4.40	0.70	4.38	0.65	4.44	0.81	0.02	0.98
3. Satisfaction with the usability of the information system inside the museum								
It can help to reduce confusion in searching for information within the museum.	4.44	0.61	4.42	0.72	4.44	0.63	0.02	0.98
It can provide complete information within the museum.	4.44	0.63	4.46	0.78	4.38	0.62	0.02	0.98
It can help to reduce time spent searching for various points within the museum by yourself.	4.49	0.69	4.57	0.73	4.56	0.51	0.12	0.89
It can help to create interest and encourage motivation to visit the museum.	4.57	0.63	4.42	0.83	4.44	0.51	0.55	0.58

Note: p-value <0.05

different speeds as well. Therefore, the museum should provide the museum's own internet connection service and spread the signal that covers the whole area so that there would not be dead spots in the distribution of wireless fidelity (Wi-Fi) signals. Interestingly, there was a suggestion in that if the museum had a specific device for information provision, this would be more convenient. Besides, there should be a sign showing that it is the area where the signal is transmitted so that visitors would be able to find the transmission point more accurately and stop or slow down their walking speed to wait for information provision.

- For the use of MUCON application, it should add contents in the application to look more interesting, include more Thai identity to the design, and add functionality that has a voice narration at each point so that visitors do not have to read on the screen or hold the phone to watch all the time.
- Signal transmission points should be increased in order to provide more information in the museum. Moreover, various precaution notifications should be added.
- MUCON applications should support all systems, especially IOS systems.

Conclusion and future work

We studied the information and information system of the museum and successfully designed and created a system for providing information within the museum via mobile applications, including the application called MUCON. Moreover, the satisfaction with the perfor-

mance of the information system and mobile application design in the local museum in this present study was also assessed and proved that they were suitable for use.

Interestingly, based on the results of this study, each different mobile device affects the quality of receiving information, either slowly or quickly. Besides, the Bluetooth signal and the speed of the internet signal of each visitor's mobile device also has an effect on receiving information. Therefore, this could be solved by spreading more Wi-Fi signal of the museum and covers every area where the Beacon signal is distributed.

The design of an application that puts all information into the application only, not using a server to store all data, will consume too many resources of the visitor's mobile device. Thus, the museum may have to prepare mobile devices (e.g., smart phone or tablet) for visitors since the form of signal transmission will be through a Bluetooth signal from the Beacon technology only. This leads to effective and stable information provision. It can be said that the key factor of using MUCON application in this present study draws mainly on the internet since all information is stored on a server. When the Internet networks used by visitors are different, or the systems of mobile phones (i.e., Android or iPhone Operating System (IOS)) are different, this exactly affects the signal transmission from the server to the device and can be problematic. This makes it possible that the user will receive information slower than it should be.

For future research, the design of information provision through voice narration in various points/areas in the local museum should be conducted. This will definitely improve the quality of information provision in the museum since visitors do not need to read information through their mobile devices all the time while visiting the museum. Additionally, MUCON application in this present study supports only Android system. Thus, the future study on iPhone Operating System (IOS) system should be investigated.

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Impact of the colour perception of graphic design on promoting tourist destinations of Southeast Europe

ABSTRACT

Graphic design plays a crucial role in branding and marketing in the current digital era. Digital marketing impacts the promotion of tourist destinations. Tourism has become an important and growing sector that has influenced the development of a country's economy. Colour as an element of graphic design evokes emotions and sets a certain mood for an image or graphic. The purpose of this study is to determine the role of colour perception in graphic design in promoting tourist destinations of Southeast Europe (SEE). We aim to explore the relationship between graphic design and the tourism industry in SEE countries, focusing on their tourism logos and slogans for advertising their tourist destinations. The analysis of the main characteristics of logos and slogans shows that they can be effective tools for promoting and supporting tourism in countries in the SEE region. It was observed that there is compatibility between the colours used in the logo and the country flag in 64% of the tourism logos of SEE countries. The colour green is the most commonly used colour in logo design.

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Colour perception, graphic design, tourism logo and slogan

Introduction

Graphic design is a creative field that has become increasingly relevant and popular over the past few decades. Graphic design has a significant impact on our daily lives and ourselves. Graphic design can be defined as the art or profession of visual communication that combines images, words and ideas to convey information to an audience. A graphic designer can use his professional skills in typography, visual art, page and text layout, computer software, etc. to achieve the goal of his assigned creative project (Han, 2020). The basic elements of graphic design are shape, colour, space, form, line, value, and texture. In order to create a creative and unique design, the graphic designer should combine these elements. Colour has a pivotal role in graphic design. Colour as an element of graphic design evokes emotions and sets certain mood for an image or graphic.

Additionally, colour perception is a complex phenomenon (Singh, 2006; Labrecque, Patrick & Milne 2013) and is related more to human emotions than to rational thinking (Ivanova, 2011). On the other hand, graphic design plays a crucial role in branding and marketing in the current digital era. Moreover, it is not only about creating visually appealing and memorable designs, but also about effectively and correctly conveying certain message to its target audience. In addition, there are new ways to achieve these goals in the Industry 4.0.

Digital marketing plays an important role in the advertising and promotion of any successful business, and the tourism industry is no exception. Digital marketing involves marketing to consumers through digital channels, including websites, mobile devices, and social media platforms. Graphic design is one of the most powerful arts that breathe new life into digital marketing.

The tourism industry can be considered an important sector for accelerating economic growth, increasing efficiency, and economic recovery (Stoykova & Paskaleva, 2021). In 2022, the Travel & Tourism sector contributed 7.6% to global GDP; an increase of 22% from 2021 levels (World Travel & Tourism Council, 2022).

Graphic design and creative branding in the tourism industry can attract tourists to visit one particular country or even a whole geographic region, attend an event, and sightsee some tourist attractions. The countries can promote themselves as an attractive tourist destination by designing a tourism logo, tourism slogans, and official websites for tourism and travel. These elements can support the success of the tourism industry. Logos are the most concise graphical vehicle for communicating a message. Tourism logos of countries should convey the country's identity. Slogan writing is perceived as the art and science of the concise use of words (Foster, 2012). According to Kotler, Haider & Rein (1993), image creators should develop a slogan that links a specific campaign and theme. Normally a slogan should be short and easy to remember. The logo and slogan design are produced in various digital formats that are appropriate and used in the website, web, and mobile applications.

The purpose of this study is to determine the role of colour perception in graphic design in promoting tourist destinations of Southeast Europe (SEE). We aim to explore the relationship between graphic design and the tourism industry in SEE countries, focusing on their tourism logos and slogans for advertising their tourist destinations.

Literature Review

The development of information and communication technologies has offered many challenges in tourism and this whole process has led to changes in the dynamics of the design and marketing of consumer experiences (Mossberg, 2007; Buhalis & Law, 2008; Neuhofer, Buhalis & Ladkin, 2012).

Ljajić & Bektović (2021) claim that Macedonia, Serbia, Kosovo*, and Bosnia and Hercegovina are excellent examples of countries where design is believed to be an effective methodology and tool for socio-cultural improvement. They prove that graphic design has a positive effect on the economy of Macedonia, Serbia, Kosovo*, and Bosnia and Hercegovina (Ljajić & Bektović, 2021). Sebbeh (2022) analyses the graphic design elements that can be used to accelerate the development of the tourism industry in Ghana. The results show that graphic design has a pivotal role in the development of tourism in Ghana (Sebbeh, 2022).

Sonnleitner (2011) gives an overview of destination image theory and its interrelationships with destination marketing and branding. The obtained results suggest that most tourist destinations spend a considerable amount of money and time creating and boosting a positive image (Sonnleitner, 2011). Dionyssopoulou, Pridezi & Mylonakis (2013) investigate the role of visual communication in promoting tourist destinations in Greece. The authors come to the conclusion that the destination's pre-visit image assumed by visitors of a tourist destination is essential for the competitiveness and promotion of the tourism product in Greece (Dionyssopoulou, Pridezi & Mylonakis, 2013). Agapito & Lacerda (2014) explore the role of Information and Communication Technologies (ICT) in the marketing and brand design of destination experiences. The authors present some practical applications of ICT at different moments of tourism trips, considering the impact on the marketing of destination experiences (Agapito & Lacerda, 2014). Situmorang, Wibowo & Fauzi (2019) argue that graphic design is the main determinant of digital marketing in the tourism industry. They prove that graphic design in digital marketing affects the sales of products and services of a travel company (Situmorang, Wibowo & Fauzi, 2019). Mohamed (2023) makes a conclusion that graphic design can help to promote more successful tourism services achieving tourist satisfaction at all touch points of their tourism experience. Wu (2021) explores the design of tourism cultural and creative products, using field research, questionnaire survey, analytic hierarchy, and other methods, based on regional historical and cultural elements. Marshalls (2007) analyses the role of a country's image in promoting a tourism destination. The author finds out that county image develops partially from natural elements that cannot be altered or easily manipulated as history, natural, geographical, people, etc. (Marshalls, 2007). Zhang & Wang (2020) claim that regional brand is the main core in the design process of tourism destination. The results reveal that visual design plays an important role in shaping the brand image of tourist destinations (Zhang & Wang, 2020). Jha & Biswal (2020) generate creative graphics using mathematical equations such as number theory, position vectors and trigonometry functions. The mathematical approaches, such as the kinematics of pendulum and recursive number theory, can also be used in various fields, including website design, magazine covers, bags, toys, etc. (Jha & Biswal, 2020).

Many researchers analyse the main characteristics that effective and successful slogans should have (Pike, 2004; Balmer & Grayser, 2006; Donaire & Galí, 2012; Semone & Kozak, 2012; Kohli, Thomas, & Suri, 2013).

Rivera & Gutierrez (2018) prove that tourism slogans are effective marketing initiatives that may influence young travellers to stay longer in a destination. Zeybek & Ünlü (2016) argue that a country's identity and image are achieved primarily through designing a good logo and also that each country has to design a promotional tourism logo, which reflects its visual image. The authors find out that half of the European Council member countries emphasize their geographical and cultural characteristics in their tourism logo designs. The results show that certain

countries aimed to develop behaviours by addressing emotions through the use of slogans (Zeybek & Ünlü, 2016).

Huang & Lin (2017) examine the awareness effects of tourism slogans of ten prominent destinations in Asia. The obtained results reveal that the slogans of China, Hong Kong, and Taiwan were the most effective in terms of destination recognition (Huang & Lin, 2017). Galí, Camprubí & Donaire (2017) prove that slogans tend to be very simple and have an exclusive appeal, which comes from emphasizing the affective component of the message. Abdia & Abdollah (2013) argue that the slogan has a substantial role in calling the audience's attention to one or more aspects of a product or service and that slogans claim that the advertised product or service is of the highest quality.

Materials and Methods

The materials for this study are the official tourism logos and slogans of the Southeast Europe (SEE) countries. The SEE countries included in the sample are Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Montenegro, North Macedonia, Romania, Serbia, Slovenia, and Turkey.

We removed Kosovo* from the list above because there is no available information about the official tourism logo and slogan of this country. Each of the analysed SEE countries has an official logo and slogan to promote tourism destinations, events, and attractions. The information regarding the official tourism logos and slogans of SEE countries is collected from either the official website of the National Tourism Organization or the official website of the Ministry of Tourism. The data was collected and processed as of August 8, 2023.

In this study, we employ various methods of data collection, colour analysis, descriptive statistics, and comparative analysis. Data analysis is conducted using descriptive statistics in EViews 12. We examine the main characteristics of the official tourism logo and slogan of SEE countries.

Results and Discussion

The objective of this study is to analyse the impact of colour perception of graphic design on promoting tourist destinations of Southeast Europe (SEE) considering their official tourism logo and slogan.

Colours are connected with certain associations and qualities due to their natural occurrence, specific usage, and cultural context (MacDonald, 1999). Colours generally affect both physical and psychological levels, and colour perception is a matter of personal taste and preference. Individual differences may vary by gender, age, and culture. Colour perception is very often accompanied by a strong emotional impact and has the ability to influence a person's physical condition. Table 1 presents the main colour psychology and associations.

Table 2 presents the official tourism slogans of the examined SEE countries, the number of words, the number of characters (no spaces), and number of characters (with spaces) used in each slogan. All of the slogans were collected from the official tourism websites of the country. Each of the slogans is short and consists of two, three, or four words. Additionally, 36% of the slogans contain four words, while 27% of the slogans contain three words. And the same percent (27%) of the slogans contain two words. Also, each one of the slogans is unique, credible, and entertaining. All of the analysed SEE countries use slogans to promote their tourist destinations.

Figure 1a and Figure 1b show the graphical representation of the results of descriptive statistics based on the number of words. The results reveal that the slogan of Romania contains the greatest number of characters without spaces, with a total of 26 characters. On the other hand, the slogans of Montenegro, Croatia, and North Macedonia contain the lowest number of characters without spaces (10 characters). The mean of the number of words in each slogan is 2.9, and the median is 3. The maximum number of words in each slogan is 4 and the minimum is 1. The standard division of the number of words is 1. The mean of the number of characters with space for each slogan is 17.7, while the median is 15. The maximum number of characters with space is 29 and the minimum is 11. The standard division of the number of characters with space is 7.0. The mean of number of characters (no space) for each slogan is 15.8 and the median is 13. The maximum number of characters without space in each slogan is 26, while the minimum is 10. The standard division of number of characters without space is 6.4. The values of skewness are positive for number of characters with spaces and the number of characters without spaces, indicating that the distribution is right-skewed with a long right tail. All kurtoses are positive, suggesting heavier tails and a more peaked distribution. To summarize, the SEE slogans effectively and successfully convey specific messages to their target audience and address emotions.

Table 3 summarizes the official tourism logos of the examined SEE countries. Each of the logos is collected from the official tourism websites of SEE countries. Analysing the individual logos, it can be concluded that they are highly diverse and the main elements of their graphic design (colour, typography, shape, composition) are successfully combined and interact. It is necessary to clarify here that more than one colour is used for the text and individual visual images in the design of each individual logo. Colours can evoke different ideas, feelings, emotions, and associations, but the choice of colour definition is always based on intuition (Gorn et al., 1997). On the other hand, the colours used in logo design need to convey a strong message, tell a story, and create a mood.

Table 1

Colour Psychology and Associations (Author's systematization)

Colour	Positive Associations	Negative Associations
Red	Passion, Power, Fearlessness, Energy, Strength, Excitement	Anger, Warning, Defiance, Danger, Aggression, Pain
Green	Spring, Nature, Environment, Health, Fertility, Safety, Freshness, Prosperity, Hope, Growth	Envy, Stagnation, Inexperience, Decay, Misfortune, Boredom, Sickness, Blandness, Enervation
Yellow	Summer, Sun, Gold, Happiness, Optimism, Creativity, Warmth, Intellect, Extraversion	Illness, Hazard Irrationality, Cowardice, Caution, Folly, Anxiety, Frustration, Treason
Blue	Sky, Sea, Unity, Peace, Stability, Depth, Trust, Dependability, Logic, Loyalty, Security, Serenity	Depression, Passivity, Obscenity, Conservatism, Emotionless, Unfriendliness, Coldness, Aloofness, Uncaring, Unappetizing
White	Snow, Peace, Purity, Innocence, Cleanliness, Simplicity, Clarity, Sophistication, Freshness	Cold, Surrender, Clinical, Banality, Sterility, Death, Unfriendliness, Sterility, Isolation, Emptiness, Elitism
Grey	Intelligence, Restraint, Dignity, Maturity, Intelligence, Reliability, Timelessness, Neutrality, Balance, Strength	Shadow, Concrete, Drabness, Boredom, Lack of confidence, Hibernation, Depression, Lack of energy, Dampness, Blandness
Black	Coal, Power, Formality, Depth, Solidity, Style, Power, Security, Authority, Sophistication, Elegance, Substance	Fear, Night, Void, Evil, Secrecy, Anonymity, Coldness, Menace, Oppression, Heaviness, Mourning
Orange	Confidence, Courage, Innovation, Energy, Warmth, Friendliness	Frustration, Deprivation, Immaturity, Frivolity, Ignorance, Sluggishness

Table 2

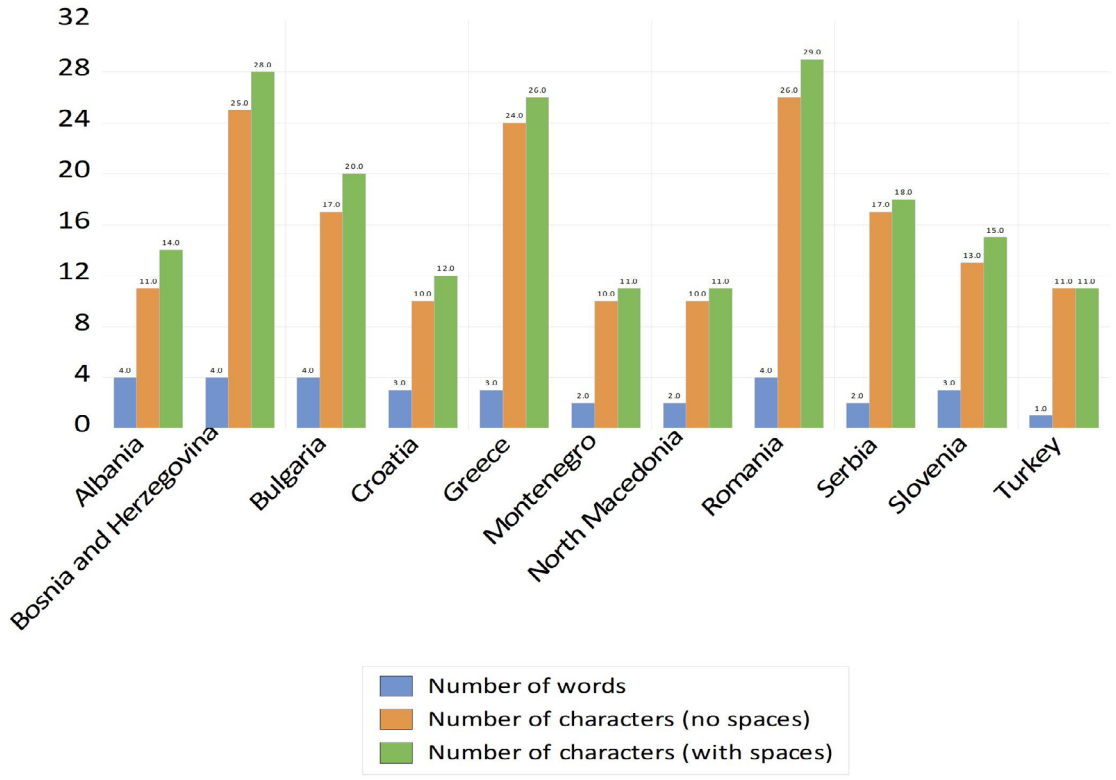
Official tourism slogans of the SEE countries
(Author's systematization and calculation)

Country (Tourist destination)	Tourism slogan
Albania	Go your own way
Bosnia and Herzegovina	where everything is possible
Bulgaria	A Discovery to Share
Croatia	Full of life
Greece	A life-changing experience
Montenegro	Wild Beauty
North Macedonia	Taste life!
Romania	explore the Carpathian garden
Serbia	Experience! SERBIA
Slovenia	I feel SLOVEnia
Turkey	Sustainable

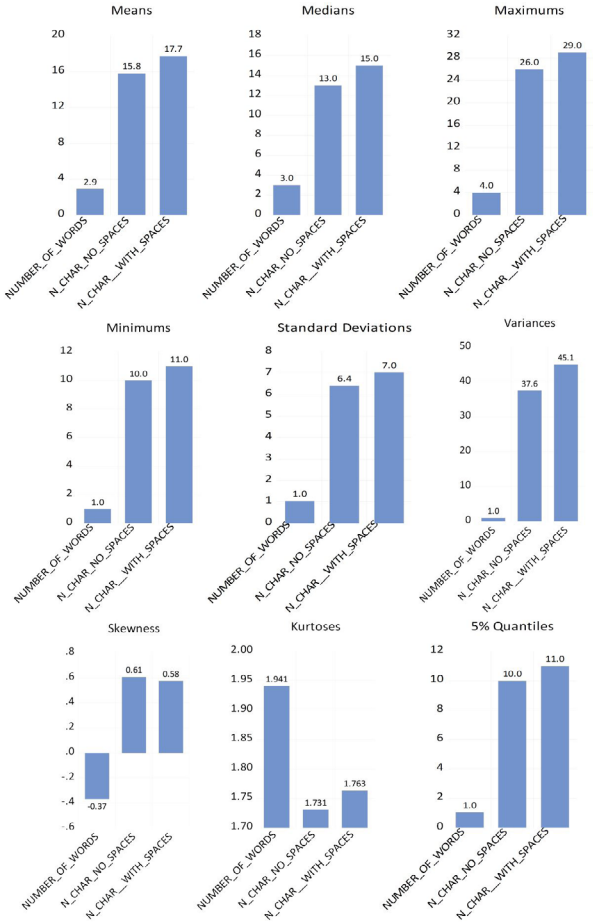
Figure 2a, Figure 2b, and Figure 2c display information regarding colour, typography, and emblem as elements in the tourism logos of SEE countries. The results obtained reveal that there is compatibility between colours used in the logo and the country flag in 64% of the tourism logos of SEE countries (Figure 2a). 73% of logos contain the colour green, which is associated with spring, nature, environment, safety, and freshness. This colour is found in logos from Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Montenegro, Romania, Slovenia, and Turkey. What's more, it is the most commonly used colour in logo design.

The colour blue is used in 64% of the examined logos (Albania, Bosnia and Herzegovina, Croatia, Greece, Montenegro, Romania and Turkey). In some of the logos, the colour blue is compatible with the country's flag, while in others, it can be associated with the sea, unity, peace, stability, trust, and security. On the other hand, the colour yellow is used in 36% of tourism logos, such as those of Albania, Croatia, Montenegro, and North Macedonia.

The colour yellow is positively associated with summer, sun, happiness, optimism, and warmth. In summary, we can conclude that the colours blue, green, and yellow are suitable choices as elements in the design of the tourism logo.



» **Figure 1a:** *Graphical representation of the summary of descriptive statistics by number of words (Author's calculation)*



» **Figure 1b:** *Graphical representation of the results of descriptive statistics by number of words (Author's calculation)*

Table 3

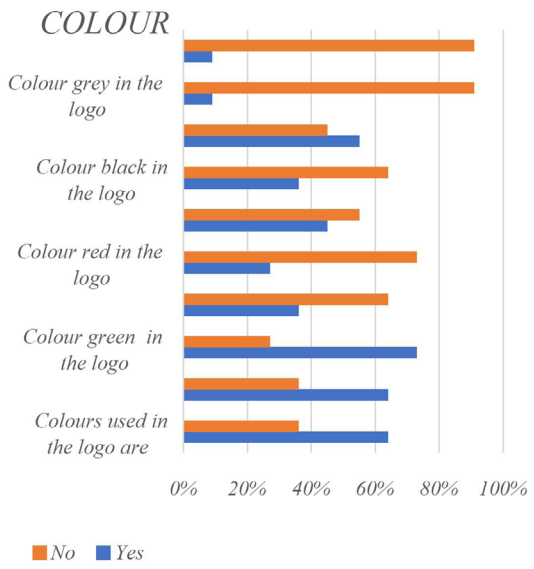
Official tourism logos of SEE countries (Author's systematization)

Country (Tourist destination)	Tourism logo
Albania	ALBANIA GO YOUR OWN WAY
Bosnia and Herzegovina	Bosna Hercegovina where everything is possible
Bulgaria	БЪЛГАРИЯ
Croatia	CROATIA Full of life
Greece	GREECE
Montenegro	MONTE NEGRO
North Macedonia	Taste life! NORTH MACEDONIA
Romania	România explore the Carpathian garden
Serbia	Experience! SERBIA
Slovenia	I FEEL SLOVENIA
Turkey	Türkiye Sustainable

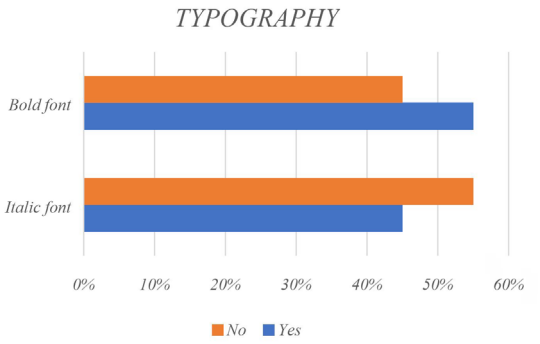
27% of logos contain the colour red (North Macedonia, Serbia, and Turkey) and this colour is connected with passion, power, energy, strength, and excitement. The colour orange is used in the design of five tourism logos (45%, namely Bosnia and Herzegovina, Bulgaria, Croatia, Montenegro, and Romania). The orange colour is positively associated with confidence, courage, warmth, and friendliness. The colour black is used for the text in four logo designs (Albania, Croatia, North Macedonia, and Turkey).

Figure 2b shows the typography as an element of the tourism logos of SEE countries. Italic font is applied in 45% of the tourism logos of SEE countries, while bold font is used in a total of six logos (55%).

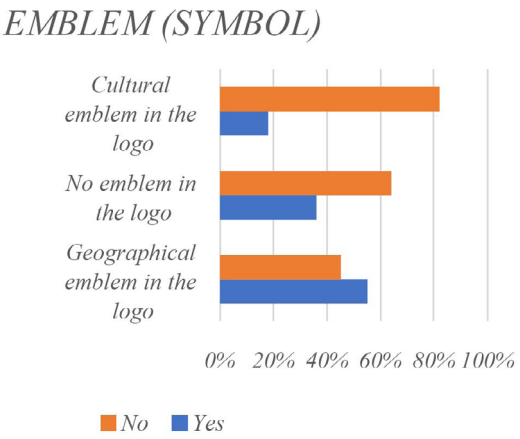
Figure 2c displays the symbol as an element of the tourism logos of SEE countries. There is a geographical emblem in 55% of the logos. Respectively, a cultural emblem is used in 18% of the logo designs, specifically in Bulgaria and Turkey. Additionally, four of the tourism logos (36%) do not feature any emblem.



» **Figure 2a:** *Colour as an element of the tourism logos of SEE countries (Author's calculation)*



» **Figure 2b:** *Typography as an element of the tourism logos of SEE countries (Author's calculation)*



» **Figure 2c:** *Symbol as an element of the tourism logos of SEE countries (Author's calculation)*

Conclusion

The countries can promote themselves as attractive tourist destinations by designing tourism logos, tourism slogans, and official tourism and travel websites. Graphic design and digital marketing play a crucial role in advertising tourist destinations in every country. The countries of Southeastern Europe are no exception either. It can be assumed that the development of the tourism sector in each individual country would have a positive impact on the prosperity and growth of the tourism industry in the entire geographical region. We established that one of the most crucial elements of logo design is colour, which must be effectively and skilfully integrated with the other elements of the logo. These results confirm the findings of previous researchers (Alexander, 2019; Sementina, 2019; Kronberg, 2020).

The objective of this study is to analyse the impact of colour perception of graphic design on promoting tourist destinations in Southeast Europe (SEE), taking into consideration their official tourism logo and slogan. The analysis of the main characteristics of logos and slogans shows that they can be effective tools for promoting and supporting tourism in countries in the SEE region. We have established that all of the analysed SEE countries use slogans to promote their tourist destinations. The results reveal that 36% of the slogans contain four words, while 27% of the slogans contain three words. And the same percent (27%) of slogans contain two words. The maximum number of words in each slogan is 4, and the minimum is 1. The maximum number of words in each slogan is 4 and 1 is the minimum. The maximum number of characters with space is 29, while the minimum is 11. Each of the slogans is unique, credible, and entertaining. The SEE slogans effectively and successfully convey specific messages to their target audience and evoke emotions. It was observed that

there is compatibility between colours used in the logo and the country flag in 64% of the tourism logos of SEE countries. The colour green is the most commonly used colour in logo design. Italic and bold fonts are commonly used in tourism logos. Additionally, it was found that 36% of the examined logos do not feature an emblem. It can be suggested that all elements of the logo design have been successfully combined. We found that tourism slogans and logos are effective marketing initiatives that can attract more visitors to tourist destinations in SEE countries and make them more appealing to travellers.

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Study of quality indicators of gravure imprints obtained with fluorescent ink

ABSTRACT

The peculiarities of the decoration of gravure imprints on cardboard using fluorescent inks are considered. The influence of the number of fluorescent impurities added to gravure printing ink on the optical indicators of printed image quality, particularly optical density, and gloss, is investigated. Increasing the number of fluorescent impurities added to the ink from 10 to 30% helps to increase the gloss on imprints from 2 to 15 units. Conducted thermogravimetric studies show the resistance of fluorescent imprints to the influence of temperatures during drying in the printing process. The topography of the surface of the substrates and its influence on the quality of imprints is studied. Conducted electron microscopic studies of imprints obtained with inks with different amounts of fluorescent impurities show their uniform distribution on the surface of the substrate. Studies of the fluorescence spectra of the ink and the imprints formed by it confirm the phenomenon of an increase in the intensity of the glow of printed images. The studies confirm the well-known influence of substrate roughness on the smoothness of gravure imprints. It is established that the absence of significant macro irregularities on the surface of Koppargloss FBB cardboard is due to the presence of two coating layers. Analysis of the surface profiles of FBB cardboard shows that its roughness parameter (R_a = 0.424 µm) is three times smaller compared to Incada Silk C GC1 cardboard (the roughness parameter R_a = 1.28 µm), with a single-layer coating. Such a pattern is also preserved on the imprints, which is reflected in their quality accordingly. Studies show that for imprints on GC1 cardboard, the average ΔE value is 2.23, for imprints on FBB cardboard, the average ΔE value is 3.71, which is due to the presence of double coating. The factors that can influence the process of fluorescence of printed images are outlined. The technological characteristics of inks for gravure printing on packaging are described.

KEY WORDS
Imprint, gravure printing, cardboard, fluorescent ink, optical density, gloss, colour reproduction, surface topography, quality

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Introduction

Analysis of marketing research shows increased consumer attention to packaging decoration. Therefore, the choice of the technological process of finishing packaging products is a responsible stage of production, which is influenced by several factors, in particular, the purpose of the packaging, the type of its design, the physical and mechanical characteristics of the materials, and their barrier properties. Gravure printing is widely used for packaging printing, which is in continuous development and provides high-quality imprints of various formats.

Gravure printing stands out from all the classic printing techniques primarily by the quality of the final product, excellent visual effect, high contrast, and the most accurate reproduction of single-colour and multi-colour originals in terms of the range and number of tones that can be reproduced. Particularly popular in gravure printing is the use of sheet-fed machines, which provide:

- Better surface quality of imprints;
- Lack of duplication when printing;
- Good ink coverage of the printed base;
- Easy printing with special inks, for example, gold, silver, metallic and glossy, flavoured, fluorescent, etc.;
- The possibility of covering with a thick layer of varnish;
- The possibility of printing on various surfaces: plastic, foil, paper, and cardboard with a grammage of 50 - 500 g/m^2.

The greatest attention in printing technologies of product protection is paid to the use of materials with special properties. This is, in particular, the use of inks visible or invisible in daylight, with fluorescent impurities, inks that manifest themselves under the influence of heat, cold, etc. Inks with fluorescent impurities are popular. The image printed with such ink begins to give off the energy accumulated during daylight (or artificial lighting). As is known, for the occurrence of fluorescence, it is necessary to transfer the particles of the investigated substance from the normal to the excited state and ensure its preservation during the time required for the electronic transition when the luminescence centres return to the excited state. The brightness and duration of the glow are subjective and depend on the properties of the human eye. Researchers identify several factors that can influence this process:

- Type of fluorescent impurities;
- Environmental temperature;
- The presence of impurities in the composition;
- Individual vision capabilities;
- The degree of darkness and the presence of "distracting" light sources;
- Brightness and duration of previous "charging" with light.

The ideal conditions for fluorescence are charging with bright light for 1-2 hours, immediately after that – additional afterglow without additional light sources. The afterglow is uneven: the first 15-20 minutes are the brightest, then within 40-60 minutes there is a gradual fading (60-70% of the initial, after 40-60 minutes – 30-40% of the initial), and after an hour-and-a-half – 20-25% The duration of the glow visible to the human eye can reach 12 hours (Elastoform, 2023).

The mechanism of ink transfer, the method of its drying or fixation on the printed material is determined by the structure of the substrate and the constituent components of the ink for gravure printing. As is known, liquid ink is used in gravure printing, which can fill the cells of forms well at high printing speed. The range of inks for gravure printing is very large: for example, there are inks with the help of which a layer of more than 2 μm is applied, as well as inks with special metallic pigments, etc. The chemical formulation of inks in connection with the direct transfer to the printed surface allows fundamentally great possibilities for composition variation. Toluene inks for gravure printing (with solvent regeneration) will have a limited release in the future due to the impact on the environment, in particular the possibility of its contamination with an excess of toluene. They can be replaced by water-based inks, they dry more slowly, but interact well with the paper base, but are more expensive.

The pigment content of gravure printing inks is lower than that of letterpress, offset, or flexographic printing inks because the thickness of the ink layer in gravure printing is greater. This thick layer of ink in the shadows of the image helps to provide that special gloss that characterizes "gravure printing quality".

Water-based gravure inks are widely used in packaging production, almost all gift packages are printed with these inks. Water does not require investments and does not create problems for the environment. Inks for gravure printing contain volatile (low-boiling) solvents, which easily evaporate when imprints are dried. They should not contain coarse particles that have an abrasive effect. Ink solvents are especially important in gravure printing. They provide low viscosity, and with their help, it is possible to change the concentration of pigments or the optical density of ink.

The most important solvents for gravure printing on packaging: are ethyl alcohol, ethyl acetate (acetic ether), and water (also together with organic solvents such as alcohols). To fulfil special, and differentiated requirements for packaging (for example, unacceptable reactions with the packaged product or absorption of smell), printing inks containing various organic solvents are used. However, their use is much less than that of inorganic solvents.

As is known, the ink system of the gravure printing machine consists of a thermostatic container with ink, an ink pan, an ink roller, and a scraper knife system - a doctor's blade. The ink roller is made of steel with a stretched coating of material, the lower part of which rotates in the ink pan, and the upper part of which is in contact with the printing form. The amount of pressure in the printing area (up to ~ 500 N/m^2) depends on:

- The type of used coating of the impression roller;
- Properties of the substrate for printing;
- The type of image being printed.

The thicker and more flexible the impression roller liner, the lower the pressure required. As the thickness of the substrate decreases, the required printing pressure increases. After each printing section, drying devices are installed, which cause consolidation of the printing ink with the substrate. The power and length of the installed drying chamber are determined by the required printing speed and the type of used inks. The type and parameters of the installed drying devices affect the possible printing speed and the

quality of imprints. The next stage of the technological process is the final drying of the imprint in the final drying tunnel, which is equipped with a system of compressed air nozzles. Heated air (gas/electric) is supplied to the nozzles and blown onto the printed surface from one or both sides to evaporate the solvent. Very strong turbulence is created between the rows of nozzles, which significantly speeds up the entire process of ink fixing on the substrate. It also allows the use of a lower drying temperature, which has a positive effect on the stability of the paper dimensions. Effective dryers allow to reduce the time of fixing the ink on the substrate. Temperature distribution during the drying of imprints is very important. The high temperature of the drying chamber also accelerates the drying process itself, but there is a limit beyond which the substrate curls, causing problems with printability and the printing process (Bohan, Claypole & Gethin, 2000). That is why thermogravimetric studies of gravure imprints were conducted.

The process of ink transfer to a gravure imprint depends on the viscosity of the ink, which varies between 50- 250 mPa•s (Pilc, 2007).

A special device is installed on some machines after the first air drying device, where the surface of the imprint is exposed to microwave radiation. Such microwave pre-drying makes it possible to generate thermal energy directly in the printing section, thanks to which the temperature rises in it and thus the solvent and water evaporate.

During the drying of water-based gravure printing inks with an admixture of solvent, in addition to the solvent, water also evaporates, which creates additional problems with the combination (matching) of the colors of the imprint on the paper base. As the water content decreases, the width of the paper sheet may also change, that is, it may shrink after successive passage through the printing sections. To prevent paper shrinkage, additional devices are used in the machine to moisten the sheet with dry steam, or the technological parameters of printing are changed.

Analysis of literature and problem statement

There are well-known works (Gravure Association of America & Gravire Education Foundation, 1991; Wessendorf, 2012; Szentgyörgyvölgyi, 2016), in which authors investigate the technological features of gravure printing, the influence of electrochemical and laser technology for the production of form cylinders on the quality of imprints, the choice of inks depending on the structure of the form surface and its engraved elements.

In the dissertation work (Wu, 2008) studies of the influence of the surface structure of substrates on the quality of gravure imprints are given, the influence of the chemical composition of the coating on the optical, physical, and mechanical properties of papers is analysed and experimentally determined, models of the interaction of ink with substrates are developed. Based on studies of densitometric indicators of optical density, color reproduction, and mottling, the author offers solutions to problems that may arise during printing and deteriorate the quality of imprints, and which are associated with different compositions of latex paper coatings.

The work (Goyat, Singh & Sharma, 2018) describes the features of the gravure printing technique, focuses attention on the technology of manufacturing gravure printing forms, the process of filling the printing elements on the form with ink, and the role of the blade in removing excess ink. The authors emphasize the process of direct transfer of ink to the substrate during its passage between the form and the printing cylinder.

The work (Ceyhan, 2016) describes research on the features of gravure printing on flexible electronics. The problem of obtaining a high-quality imprint when reproducing images smaller than 50 μm, which cannot be recognized by the human eye, is indicated. In printed electronics, micron-sized defects degrade the printed characteristics, i.e., the reproduction accuracy deteriorates. The influence of surface energy and the chemical composition of the surface of the substrate on the mechanism of imprint formation is investigated, and the role of the contact of the blade with the form in ensuring the quality of the imprint is emphasized. The work carried out by several researchers focuses on the multifaceted problems of ensuring the quality of gravure imprints. However, taking into account the intensive use of gravure printing for packaging decoration, research aimed at an in-depth study of the influence of the surface topography of substrates on the quality of printed images, the possibility of using fluorescent inks to protect products from counterfeiting to meet the requirements of manufacturers and consumers of packaging are relevant.

The purpose and objects of the research

The object of the study was gravure imprints, images fragments of which were printed with ink with fluorescent impurities. A red fluorescent pigment with a particle size of 0.1- 0.5 microns of the Flamingo IX-ASJ type was used, which was added to the gravure ink in an amount from 10 to 30%. Inks with a solvent based on ethyl methyl ketone were used. The brightness of the fluorescent pigment is manifested due to the absorption and reflection of ultraviolet light with an imitation of pink colour. According to the manufacturer's recommendation, the fluorescent pigment must be stored away from light, as the colour saturation

may weaken with constant exposure to direct sunlight. Therefore, the task of the study was to determine its effect on the optical and colorimetric indicators of imprints on cardboard. According to its technical characteristics, the pigment is stable in a wide pH range, withstands temperature changes, and is stable in various environments. The purpose of the research was also to check the heat resistance of imprints obtained with fluorescent ink since in gravure printing imprints are subjected to drying after each printing section and at the end of printing pass through a tunnel dryer.

As a substrate, FBB coated cardboard, Koppargloss brand with a weight of 200 g/m^2, was used (which consists of two layers of bleached cellulose and an intermediate layer of mechanical pulp. The double coating provides high levels of whiteness and gloss. The reverse side is uncoated. And also, GC1 cardboard of the Incada Silk brand with a weight of 220 g/m^2 (Holmen, 2023) was used, which is made of 100% primary fibres, the outer upper matte layer of bleached cellulose, and the lower one of chemical cellulose and the inner layer of mechanical cellulose, without wood mass, with high smoothness. Technical characteristics of these cardboard brands are presented in Table 1.

Materials and methods

Imprints obtained in laboratory conditions on the IGT F1 proof printing machine and dried in a thermal unit after successive application of CMYK colours and in a developed microwave dryer at the final stage were used for research (Figure 1). This made it possible to reproduce the real process of creating an imprint in a printing press with the help of simulation modeling.

The printing process on the proof printing machine was ensured by the following parameters: linear printing speed: 0.2÷1.5 m/s (12÷90 m/min); clamping force: 10÷500 N (0.25÷12.5 kN/m); printing width: 40 mm; printing length: 200 mm; diameter of the form cylinder: 167 mm; diameter of raster cylinder: 66-67 mm; mounting tape with a thickness of 5.2 mm; raster ruler of raster cylinder – 90 lines/cm and ink transfer – 18 ml/m^2; blade characteristics – blade width: 52 mm, blade angle: 60°, blade pressure: 67 N, blade type: MDC60.

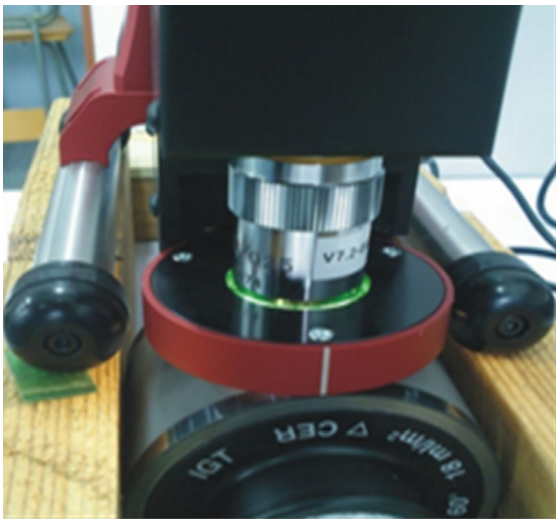
» **Figure 1:** *The proof printing machine of the IGT F1 model*

The topography of the surface of the cardboards and imprints was studied on the AniCam device of the company TROIKA Systems Limited (Figure 2), equipped with a 24-bit colour camera with a resolution of 640×480 pixels and a field of view from 1.25×0.92 mm. A three-dimensional image of the surface structure was obtained from the analysis of digital photographs of the surface of the substrate and imprint (measurement accuracy is ±1%).

Table 1

Technical characteristics of cardboard

Parameters	Units of measurement	Standard	Indicator	
			Cardboard FBB Koppargloss	Cardboard GC1 Incada Silk
Optical brightness	%	ISO 2470	82	91,5
Glossiness, 75˚	%	TAPPI 480 ISO 8254-1	> 40	50 ± 1
Roughness	µm	ISO 8791-4	< 1,3	0,9 1.2
Moisture absorption Cobb 60	g/m^2	ISO 535	55	30
Density	g/m^2	ISO 536:1996	200 ± 2,5%	220 ± 2,5%
Thickness	µm	ISO 534	340 ± 4%	325
Rigidity	mN/m	ISO 2493 TABER(15˚)	MD-8,2; CD-4,1	MD-18,5; CD-7,7



» **Figure 2:** *General view of the AniCam device for measuring the structure and profile of the surface of cardboard and imprints*

The densitometric indicators of imprints were studied on the GRETAG SPM 50 spectrodensitometer, which works in reflected light, determines the optical density of the background and printed areas, the squeezing (relative area) of the raster elements, trapping, grey balance, uniformity and contrast of printing. Standardized viewing angles of 20 and 100 are used for colorimetric measurements of images observed from different distances. To determine the value of colour distinguishing (ΔE), the colour coordinates in the CIE L*a*b system were measured. The gloss of the imprint was determined as a surface property expressed by the coefficient of direct light reflection measured on the print plane using a Zehntner ZGM 1020 gloss meter. Gloss measurements were performed at the same angle of 75° to avoid differences in reflectance from different measurement angles. Roughness was determined by the Bensen method.

The spectra of the fluorescent ink were measured on the FS5 spectrofluorometer (Edinburgh Instruments, 2023). All spectra were measured with the same slit configuration:

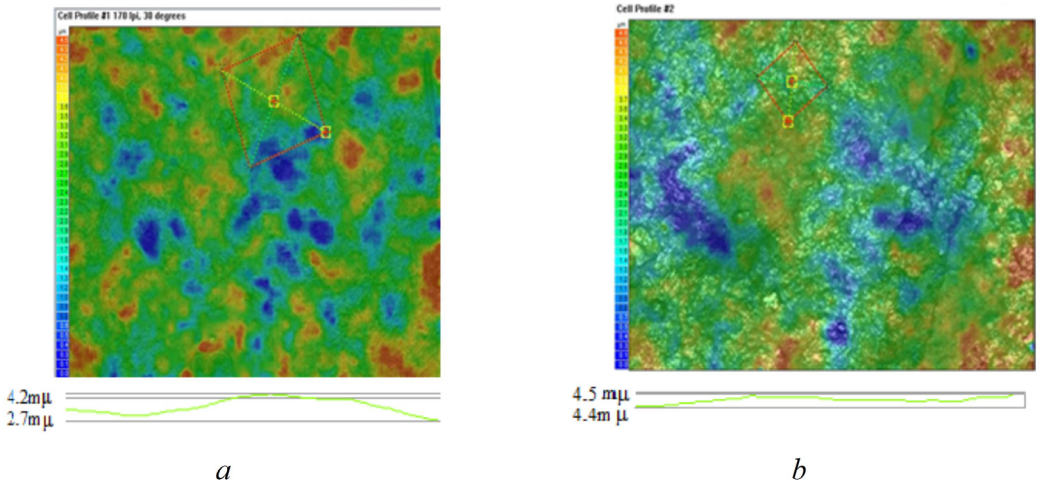
- For fluorescence excitation spectra – ExBW = 1 nm and EmBW = 3 nm
- For fluorescence spectra – ExBW = 3 nm and EmBW = 1 nm.

Using a Delta Optical Smart 2 MPix digital microscope, fluorescent images on imprints were recorded. This microscope provides a clear and richly coloured image. Magnification adjustment range from 10× to 250×. The maximum resolution is 2 MP (1600x1200).

To identify the effect of drying temperature on the quality of imprints, thermogravimetric studies were carried out on a Q-1500D derivatograph of the "Paulik-Paulik-Erdey" system, with computer registration of the analytical signal of mass loss and thermal effects. The samples were analysed in dynamic mode with a heating rate of 5°/min in air. The weight of the samples was 200 mg, and the reference substance was aluminium oxide Al_2O_3 (Menczel & Prime, 2008).

Results

It is known that smoothness (roughness) characterizes the microstructure of the substrate surface and uniformity, which determines their secondary structure, that is, volumetric macro homogeneity, and affects the efficiency of interaction with ink (El-Sherbiny, 2003). The limits of the values of micro-uniformities for different types of cardboard are determined by the numerical values of the irregularities Ra, Rz, the area of micro peaks, and micro valleys. The morphology of the surface of the investigated cardboard is presented in Figure 3.



a *b*

» **Figure 3:** *Topography of the cardboard surface: a – FBB Koppargloss, b – GC1 Incada Silk C*

A uniform distribution of structure elements is observed in the investigated Koppargloss cardboard. The absence of large macro irregularities is due to the presence of two coating layers on the surface of the cardboard. Analysis of cardboard surface profiles and microphotographs of the structure shows that the presence of double coating reduces the roughness parameter three times. The smooth surface of coated cardboard contributes to the formation of a strong bond between the ink and cellulose fibres, ensuring its uniform distribution on the imprint and the high quality of the printed image. Microphotographs of imprints on Incada Silk C cardboard clearly show indentations, micro valleys that remain unsmoothed even after the ink layer is applied. As a result of studies of the morphology of the surfaces of imprints on two-layer coated cardboard FBB and GC1, the numerical values of the irregularities Ra, Rz were obtained, which are presented in Table 2.

Table 2

Results of studies of the morphology of cardboard surfaces

Cardboard brand	Weight, g/m²	Coating	R_a, µm	R_z, µm	Peak area, µm²	Valley's area, µm²
Koppargloss FBB	200	two-layer	0,424	4,5	854	871
Incada Silk C GC1	220	one-layer	1,28	5,34	1084	1998

The analysis of tabular data shows that GC1 cardboard is characterized by a large degree of surface irregularities from -4.27 to +4.76 µm, which indicates an uneven distribution of surface structure elements. This is also confirmed by the roughness parameter R_a = 1.28 µm. The studied FBB cardboard has an average degree of surface irregularities from-2.71 to +4.23 microns, which indicates a more uniform distribution of the structure elements of bleached and chemical-thermomechanical cellulose fibres, the absence of large macro-irregularities. However, there are partially thin deep gaps in the surface of the cardboard. Two coating layers are applied to the surface of the cardboard, and the roughness parameter R_a = 0.424 µm, which indicates a highly developed micro- and sub-microstructure of the surface.

When applying an ink layer* on GC1 cardboard, the parameter R_a (arithmetic average deviation of the profile) decreases by 0.08 µm and is 1.2 µm, while the average roughness depth R_z increases from 8.34 to 8.79 µm. The peak area of the surface increases from 1084 to 1410 µm², and the valleys area decreases from 1998 to 1685 µm². The printed surface has become more uniform (there are no macro irregularities), but at the same time the R_z and peak area parameters have changed, which is explained by the fact that the ink is applied not a completely uneven layer, it has a raster structure, where each raster point has its microrelief, which affects the magnitude of peaks and valleys (Table 3). A similar pattern is observed for cardboard FBB with a two-layer coating: the roughness parameter R_a decreases and amounts to 0.419 µm, while the area of peaks increases to 892 µm², and the area of valleys decreases to 802 µm². Therefore, the conducted studies confirm that such a parameter as coating has a significant effect on the micro geometry of the surface.

The presence of a coating layer changes the roughness parameters and the area of peaks and valleys on the cardboard. It is known from scientific sources that the roughness of the substrate affects the smoothness of imprints of contact printing methods. Our research has confirmed that gravure imprints obtained with ink with introduced fluorescent impurities (30%) are characterized by a similar trend. The mechanism of influence of changing the number of fluorescent impurities in the ink on the smoothness of gravure imprints is insufficiently studied and requires further in-depth research. It was established that fluorescent impurities applied to the printed substrate affect the change in gloss value. Analysis of the diagrams (Figure 4) shows that the gloss of imprints varies depending on the colour of the image.

Table 3

Results of studies of the morphology of printed surfaces

Cardboard brand	Weight, g/m²	Coating	R_a, µm	R_z, µm	Peak area, µm²	Valley's area, µm²
Koppargloss FBB	200	two-layer	0,419	5,72	892	802
Incada Silk C GC1	220	one-layer	1,2	8,79	1410	1685

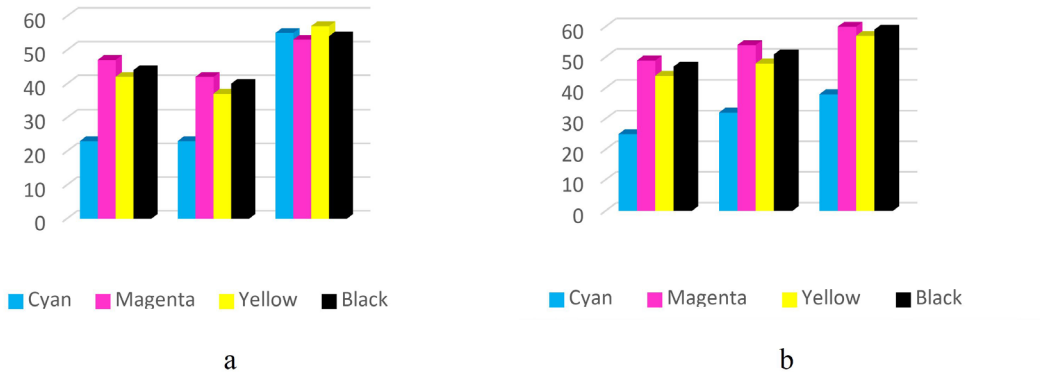
** content of fluorescent impurities 30%*

Thus, the gloss of the imprint of blue ink on GC1 cardboard remains unchanged (23.6 relative units) at 10 and 20% fluorescent impurities and increases more than twice (55.1 relative units) when adding fluorescent impurities to 30%. In the case of the magenta colour, when fluorescent impurities are increased to 20%, the gloss of the imprint decreases slightly (from 47 to 42 relative units) and when fluorescent impurities are 30%, it increases to 53 relative units. The results of studies of the gloss of imprints on FBB cardboard in printed areas with fluorescent impurities (from 10 to 30%) showed that fluorescent ink increases it from 2 to 15 units.

impurities), and Figure 7 shows the spectra of the obtained imprints.

In the course of the research, a CIE chromatic diagram was obtained with the determined emission of fluorescent impurities on the imprint. Under the influence of excitation, the emission of fluorescent impurities was obtained, which caused the material into which it was introduced to glow with color.

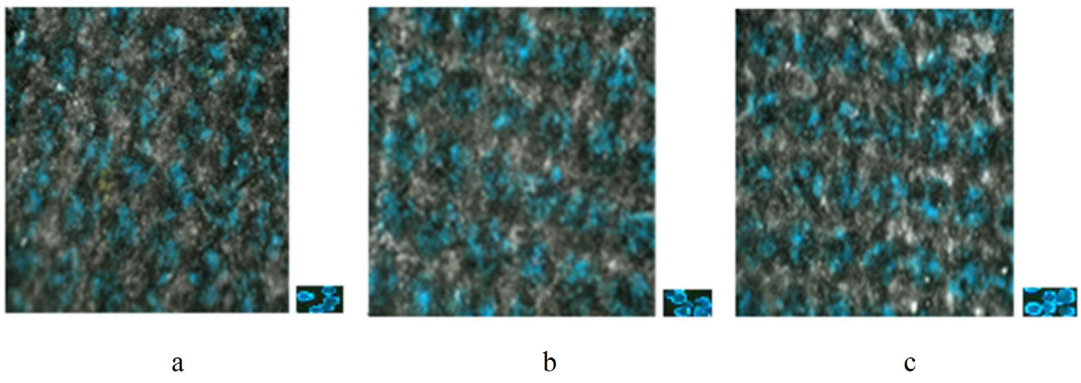
The glow effect was noticeable for CMY colors on imprints (Figure 8.).



» **Figure 4:** *Diagrams of the gloss of imprints formed by fluorescent ink on cardboard: a – GC1 Incada Silk C, b – FBB Koppargloss*

Conducted electron microscopic studies of imprints with different content of pigment (fluorescent impurities) proved that the impurities are evenly distributed on the surface of the image structure (Figure 5), therefore, they do not reduce the quality.

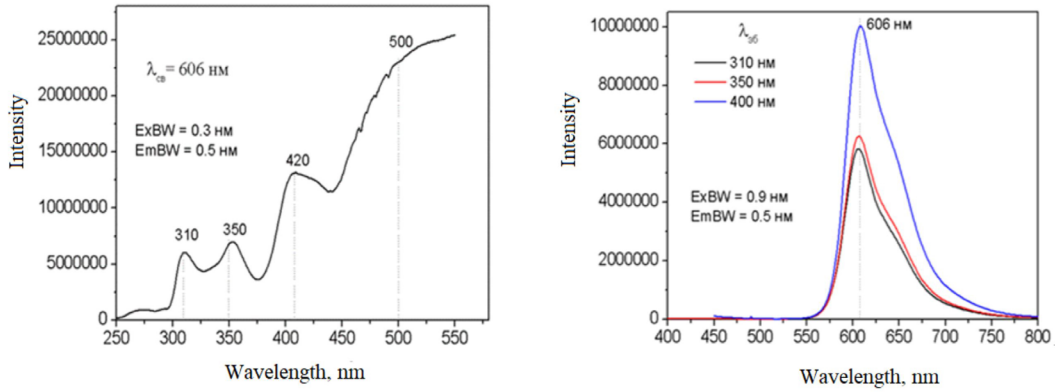
Studies of the optical density of imprints for each CMYK colour showed that yellow is characterized by the lowest values. The black imprint has the highest optical density. Moreover, the value of the optical density increases according to the increase in fluorescent impurities



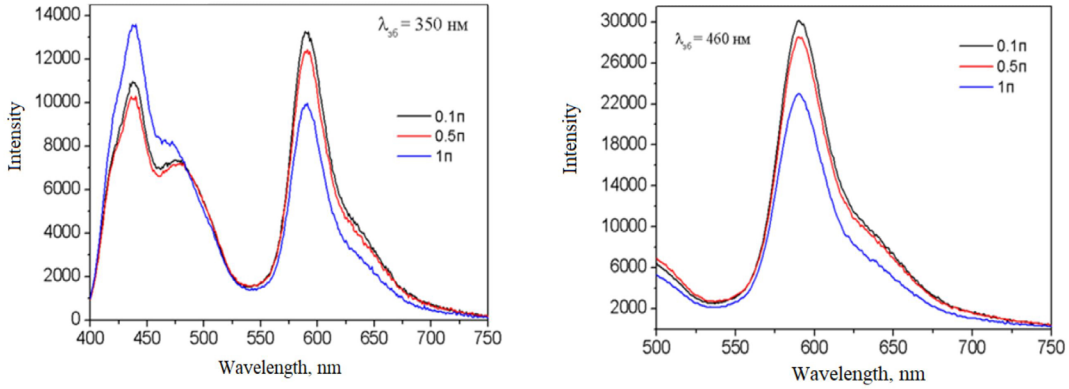
» **Figure 5:** *The surface structure of imprints formed by ink with different percentages of fluorescent impurities (magnification ×150): a – 10 %; b – 20 %; c – 30 %*

Analysis of the imprints showed that 30% of fluorescent impurities provide the maximum glow. Figure 6 shows the excitation and fluorescence spectra of ink (30%

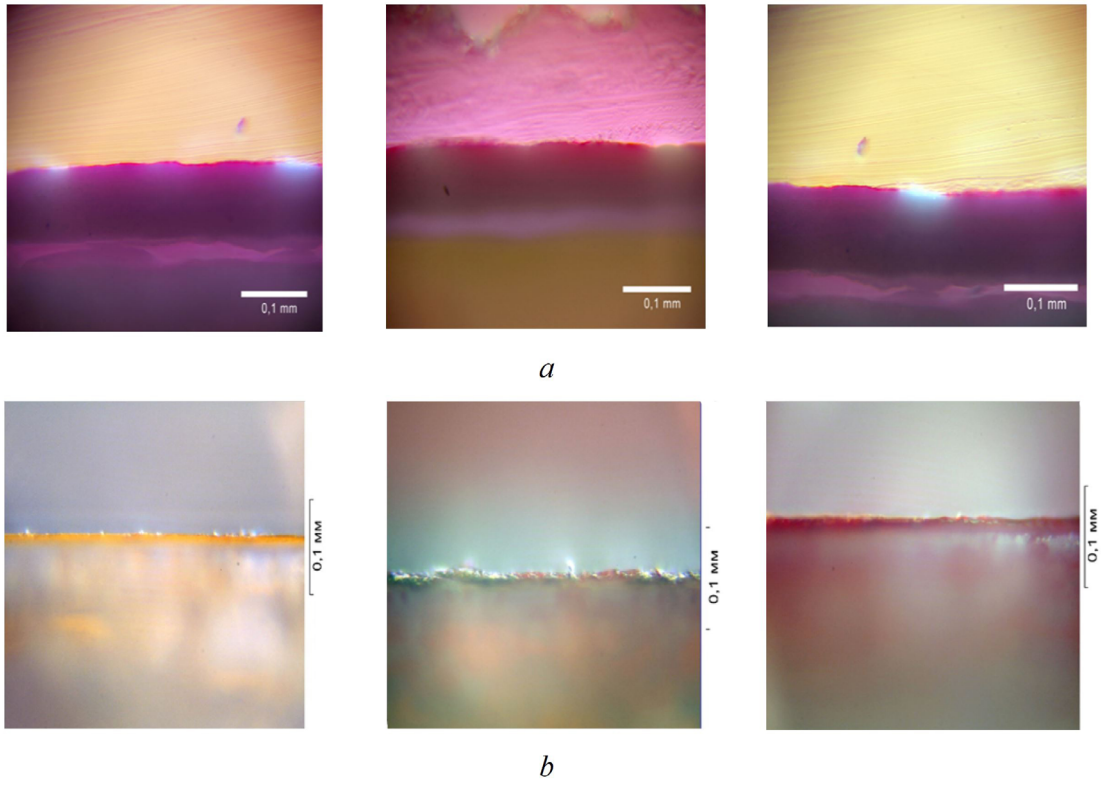
content (Table 4). For each CMYK colour, the optical density values obtained on imprints are different.



» **Figure 6:** *Excitation and fluorescence spectra of ink*
(where ExBW and EmBW are the sizes of the slits on the lamp and the detector, respectively)



» **Figure 7:** *Glow spectra of imprints formed by fluorescent ink*



» **Figure 8:** *Microphotographs of imprints obtained with fluorescent ink*
(the content of impurities is 30%) on cardboard: a – FBB Koppargloss, b – GC1 Incada Silk C

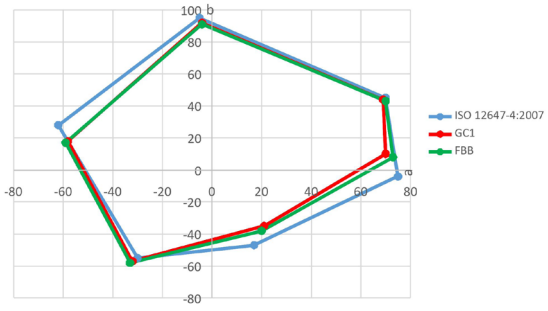
Table 4

The value of the optical density of imprints with different content of fluorescent impurities

Content of fluorescent impurities, %	Imprints on FBB cardboard				Imprints on GC1 cardboard			
	C	M	Y	K	C	M	Y	K
10	1,53	1,51	1,22	1,69	1,76	1,68	1,43	1,81
20	1,64	1,58	1,35	1,77	1,80	1,71	1,56	1,83
30	1,71	1,69	1,43	1,89	1,86	1,78	1,61	1,89

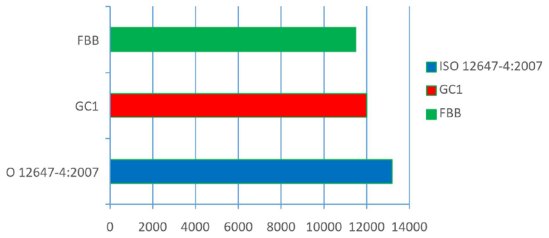
The addition of fluorescent nanoparticles to ink causes visible changes in colour perception. The differences in the colour characteristics of imprints show (Figure 9) that the imprint with 30% of fluorescent impurities has the largest colour coverage and the smallest – with 10% of fluorescent impurities. The constructed diagram shows the deviation from the standard of the determined colour coordinates on the imprint. Statistical processing of research results showed, that the largest measured colour difference was recorded for cyan and magenta ink, which is related to the more intensive interaction of fluorescent nanoparticles with these inks. This effect requires further research. The smallest measured colour difference was observed for black ink. An increase in fluorescent nanoparticles leads to an increase in the area of colour coverage on the imprint (International Organization for Standardization, 2007).

Studies have shown that for imprints on FBB cardboard, the average ΔE values were 3.71 (4.14 for light tones, 3.49 for medium, and 3.27 for dark areas of the image). For the imprint on GC1 cardboard, the highest ΔE value was 2.23 on average (1.41 for light tones, 2.69 for medium, and 2.59 for dark areas of the image), which indicates better printing stability.



» **Figure 9:** *A diagram of the color coverage of imprints*

Figure 10 shows the diagram of the surface area of the circle of color coverage.



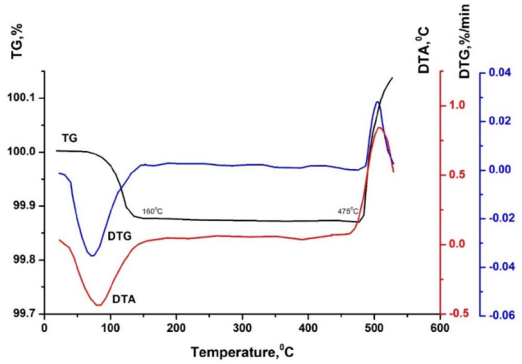
» **Figure 10:** *Area of the surface (hexagon) of the circle of color coverage*

Thus, one of the main reasons for the brightness of fluorescent inks is that these inks return a large percentage of the energy received by them to the surrounding space. The brightness of inks is determined both by the radiation of the absorbed part of the incident light and by the reflection of its unabsorbed part. Therefore, the more complete the reflection by the coating of the unabsorbed part of the incident light and the more complete the radiation of the of its absorbed part, the greater the brightness of the coating. Therefore, fluorescent inks have better reflectivity when applied to a smooth white surface with high reflectivity.

The thermal stability of the fluorescent ink sample was determined based on the data of the complex thermal analysis. The results of the thermal analysis of the ink sample are presented in the form of a thermogram (Figure 11). The thermogravimetric curve (TG) corresponds to the loss of mass of the sample when it is heated, the differential thermogravimetric curve (DTG) shows the rate of mass loss of the sample, the curve of differential thermal analysis (DTA) illustrates the thermal effects of the processes that occur in the sample when it is heated.

According to thermal analysis, a sample of fluorescent ink is thermally stable in the temperature range of 20-475°C. A slight loss of mass (0.125%) in the temperature range of 20- 160°C corresponds to the release of volatile impurities present in the sample.

This process is accompanied by a shallow endothermic effect on the DTA curve, with a maximum at a temperature of 70˚C. At temperatures higher than 475˚C, thermo-oxidative processes begin to occur in the fluorescent ink sample, which is accompanied by a clear exothermic effect on the DTA curve and an increase in the mass of the sample.



» **Figure 11:** *Thermogram of a sample of fluorescent ink*

Conclusions

Based on the conducted theoretical and practical studies, it can be stated that:

The use of fluorescent inks provides the desired decorative glow effect of printed images, which is observed when the light of a certain wavelength hits the imprint;

The amount of fluorescent particles in the ink is important for the fluorescence effect. It is noted that the glow of fluorescent impurities creates a better effect on the light areas of the imprint than on the dark areas of the image, which is apparently due to greater absorption of light in dark areas and less reflection;

Since the formation of imprints in the gravure printing machine occurs when the printed surface passes through the drying sections with high temperatures, a thermogravimetric analysis was conducted, which showed that the high temperatures of the drying devices do not hurt the quality of images formed by fluorescent inks and do not affect the effect of fluorescence;

The addition of fluorescent nanoparticles does not hurt the quality of the imprint by indicators of average values of optical density, ΔE, and color reproduction, and does not create problems in the printing process;

Studies have confirmed the existence of a connection between the parameters of the surface topography of the substrates and gravure imprints formed on them.

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1, 3, 6, 8-pyrene sulfonic acid tetrasodium fluorescent pigment synthesis and security ink production

ABSTRACT

Colorants used in security inks are special pigments that radiate in the UV region or IR region. Obtained pigments can be from valuable rare earth elements or they can be organic based. Organic-based pigments are generally insoluble in water, which limits their use. For this purpose, an organic-based UV-radiating pigment was synthesized and made water-soluble by forming its salt. With the obtained salt-formed pigment, inkjet ink that can be used in counterfeiting was applied and its printability and resistance properties were determined. In this study, 1, 3, 6, 8-pyrene sulfonic acid tetrasodium salt was synthesized and water-based inkjet inks with hydroxy ethyl cellulose binder were produced. The prepared inks were printed on the paper surface. The color and gloss of the prints obtained were measured both in the visible region and in the UV region. Its optical properties were detected by UV spectroscopy. Strength properties such as light fastness, nitro resistance, alkali resistance, acid resistance, rub resistance, drying time, adhesion and dry film weight of the prints were determined. As a result; Inkjet ink with 1, 3, 6, 8-pyrene sulfonic acid tetrasodium salt was produced and it was concluded that it has good resistance properties.

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Introduction

Security inks are used on important documents, labels and cards. security inks can be printed as a top varnish or added to the lamination to protect them from counterfeiting. these inks absorb light in one area and emit it in another, but for such inks to work properly, there must be no UV brightener in the substrate. Although anti-counterfeiting is mostly seen in money and passports in daily life, it is actually used in many fields from military to pharmacy. The use of secure information transfer is one of the techniques that reduces counterfeiting. Among the stimulus-sensing materials, there are photoluminescent materials. While these materials are not visible in visible light, their optical outputs can change under a different stimulus light. Thus, the image appears only under the desired light, which enables the product to be read only by those who will access the data. Security inks are frequently used for these applications (Song et al., 2016).

Organic fluorescent dyes are the most commonly used types in security inks as photoluminescent material. however, such colorants have low photostability (Pham et al., 2004). Apart from these, Conjugated polymers dots (Chang et al., 2014) and inorganic quantum dots are used with narrow and adjustable working bandwidths. Recently, photoluminescent materials radiating in the near infrared region have been used in areas where high security requirements are required (Sun et al., 2012).

Although organic fluorescent safety pigments are frequently encountered, one of the problems in use is that they do not dissolve in water and choose solvents. The use of colorant in ready-made ink varnish in ink production both facilitates production and reduces investment costs. For this reason, it is desired that the safety pigment produced is compatible with the ready-made varnish used in production. Organic fluorescent materials that have dissolution and dispersion problems are being improved in this regard.

Thanks to pyrene π-bonds, it has a rigid structure with good fluorescence properties and fast response stability better than some other organic fluorescent materials (Sonar et al., 2010). It attracts attention with these features (Chakraborty, Chakraborty & Das, 2018). There are studies in the literature to increase the water solubility of pyrene (Miskolczy et al., 2018; Khan, Ramu & Pitchumani, 2018).

As in printing with conventional inks, security inks are required to be compatible with the substrate, to have maximum resolution, to remain on the substrate for a long time without any problems, to be unaffected by sunlight and environmental conditions, or to have minimum color and effect changes. These printability properties can be listed as light fastness, nitro resistance, alkali resistance, acid resistance, rub resistance, drying time, adhesion and dry film weight of the prints etc (Leelajariyakul, Noguchi & Kiatkamjornwong, 2008). These features determine both the printing technique of the ink, the place of use and the life of the printed product, and also affect the cost.

In this study, 1, 3, 6, 8-pyrene sulfonic acid tetrasodium fluorescent safety pigment was synthesized and structurally and optically illuminated. Inkjet ink was produced using hydroxy ethyl cellulose with the obtained pigment and printed with a thermal inkjet printing machine. The printability properties of the produced prints were investigated. As a result, it has been determined that the fluorescent ink is invisible in daylight, but appears blue under UV light, has good printability properties and can be used in security inks.

Experimental

Materials

Pyrene, fumed sulphuric acid, nitrobenzene, calcium hydroxide, sodium carbonate, n-butanol and hydroxy ethyl cellulose were purchased from Sigma-Aldrich (Taufkirchen, Germany). Printed paper was purchased from UPM-Kymmene Corporation (Helsinki, Finland). The properties of the paper used are added to Table 1.

Methods

1,3, 6, 8-pyrene sulfonic acid tetrasodium salt has been synthesized to be used in ink. First of all, 8 mmol of pyrene and 30 mL of nitrobenzene were loaded into a single-necked reaction flask, and homogeneous distribution was achieved by mixing. Then, 5 mL of fumed sulfuric acid was added dropwise to the reaction flask. The mixture was stirred overnight keeping the temperature constant at 30 °C. then the temperature was raised to 60 °C. The mixture, which was stirred rapidly at 1000 rpm for one day at this temperature, was poured into ice-water and calcium hydroxide was added to the medium as a neutralizing agent. The obtained product was filtered and sodium carbonate was added at an equivalent rate to sulfuric acid. The product, washed with n-butanol to remove unreacted nitro benzene, was evaporated at 75 °C and dried in a vacuum oven at room temperature for 24 hours. The chemical structure of the synthesized substance was elucidated by ^{1}HNMR (Chen et al., 2019).

Table 1
Properties of the paper used in the printing

Features	Standard	Uncoated Paper
Grammage (g/m²)	ISO 536	120.0
Thickness (µm)	TAPPI T 411	107
Bulk (cm³/g)	ISO 534:1995	1.25
Whiteness (CIE D65/10) (%)	ISO 11475	146
Brightness (D65/10) (%)	ISO 2470-2	82.3
Opacity (D65/10) (%)	ISO 2471	96.5
Gloss (TAPPI 75) (%)	T480 om-92	6
Air permanence (Bendtsen) (µm/Pa·s)	ISO 5636/3	5.610

Inkjet ink was produced using the produced fluorescent pigment. For this, 0.5% (w/v) hydroxy ethyl cellulose water mixture was prepared and stirred at 250 rpm for 15 minutes at 90 °C until it became clear. The resulting mixture was cooled to 45 °C. 0.5 mg/ml of 1, 3, 6, 8-pyrene sulfonic acid tetrasodium salt was added to the mixture produced into the cooled mixture and stirred at room temperature for half an hour to obtain a homogeneous mixture. The viscosity of the ink is 4 mPa s. adjusted with water. The obtained ink was printed on the uncoated paper surface with the BENTSAI BTHH 6105 handheld thermal inkjet printing machine. Refillable cartridge with 42 mL ink capacity, 300 DPI printing resolution, printing speed 250 mm/s, printing delay 10 mm, cartridge voltage 10-12 V and the total nozzle number 54 are the parameters of thermal inkjet printing machine.

Characterization

^{1}H-NMR spectra were performed with using a Varian Unity Inova Spectrometer (CAL USA) operated at 400 MHz frequency. The color measurements of prints were made by CIE L *, a *, b * method using X-Rite eXact spectrophotometer according to ISO 12647-2: 2013 standard. The measurement conditions of the spectrophotometer are determined as polarization filter with 0° / 45° geometry with 2° observer angle with D50 light source in the range of 400-700 nm.

The difference between the colors of the different prints were calculated according to the CIE ΔE 2000 color-difference formula (1) ISO 11664-6:2014. Calculations were made by taking the average of five measurements. ΔL*, Δa*, Δb*: Difference in L*, a*, and b* values between specimen color and target color. Lightness is

represented by the L* axis which ranges from white to black. The red area is connected to the green by the a* axis, while the b* axis runs from yellow to blue.

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C}\frac{\Delta H'}{k_H S_H}} \quad (1)$$

where ΔL*, ΔC*, and ΔH* are the CIEL*a*b* metric lightness, chroma, and hue differences, respectively, calculated between the standard and sample in a pair, ΔR is an interactive term between chroma and hue differences. The S_L, S_C, and S_H are the weighting functions for the lightness, chroma, and hue components, respectively. The values calculated for these functions vary according to the positions of the sample pair being considered in CIEL*a*b* color space. The k_L, k_C, and k_H values are the parametric factors to be adjusted according to different viewing parameters such as textures, backgrounds, separations, etc., for the lightness, chroma, and hue components, respectively (Bates, Džimbeg-Malčić & Itrić, 2012).

The gloss was measured with BYK Gardner GmbH BYK Gardner GmbH micro Tri-gloss 60° geometry in accordance with ISO 2813:2014. The print was subjected to the light fastness test to determine how the color would change over time in the ground prints. In the light fastness test, all prints made with a blue wool scale were kept in a UV light cabinet for 192 hours, the initial and final CIEL*a*b* values were measured and how much the color changed according to BS4321 standard. Photographs of the printed products were taken with the Nikon D5300 camera using the UV-IR-cut filter.

Tesa-tape was used in the adhesion test, which is used to determine the interaction between the ink and the surface. In this method, the tape cut in a certain size is adhered to the printed surface and pulled quickly at an angle of 90°. After the tape separated from the surface was adhered to a white paper, visual examination was made under visible and UV light. The test was repeated 3 times. The rub resistance of the printed paper is made according to the ASTM D 5264 standard. After waiting for 2 days for the printed paper to dry completely, the test was carried out with a Sutherland Ink Rub Tester (San Antonia, Texas) at 920 g load, 30 oscillations measurement conditions. Rub resistance-treated specimens were visually inspected under UV and visible light.

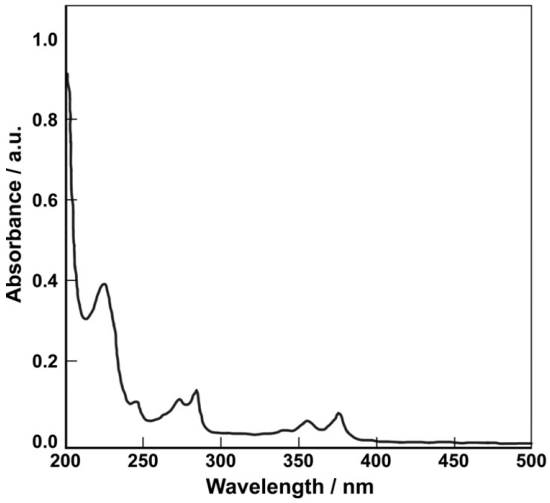
The method in the literature was used to measure the drying time (Carreira, Agbezuge & Gooray, 1995). After Solid tone printing is made with the produced ink, clean paper is covered and stretched between two cylinders with 350 N pressure. Ink on clean paper shows the remaining ink before it dries. Clean paper is visually inspected under both daylight and UV light. It is selected when there is no ink transfer to the clean paper during the full drying period. While determining the dry film weight of the printed ink, uncoated paper was first weighed (T1). 100 cm (A) solid tone was printed on this paper and weighed (T2). The dry ink weight was calculated with the following formula.

$$Dry\ Ink\ Film\ \ Weight = \frac{(T_2 - T_1)10000}{A} \quad (2)$$

The nitro, acid and alkali resistance of produced ink was performed as in the literature according to QB 568–1983 standard (Chen, Li & Chen, 2021).

Results and Discussion

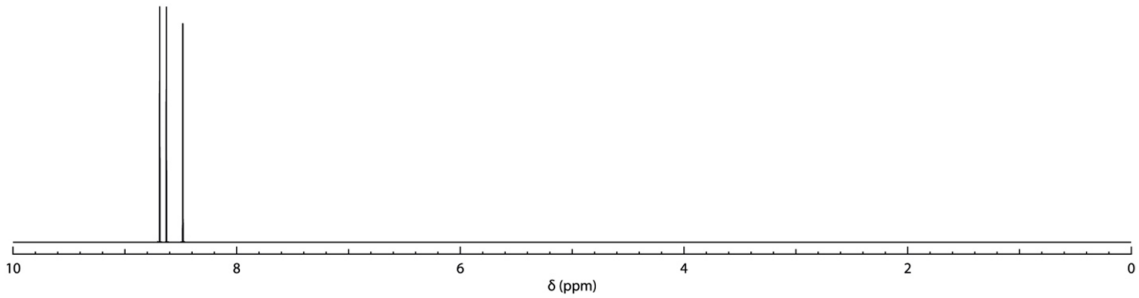
1, 3, 6, 8-pyrene sulfonic acid tetra sodium salt was examined by UV-vis spectroscopy of and is given in Figure 1. When Figure 1 is examined, two main absorption bands belonging to the p-p transition in pyrene are seen, as it is said in the literature (Costa et al., 2015). The first of these is the exciting state at 285 nm, and the other is the emission state at 400 nm.



» **Figure 1:** *UV-Vis spectrum of 1, 3, 6, 8-pyrene sulfonic acid tetra sodium in water.*

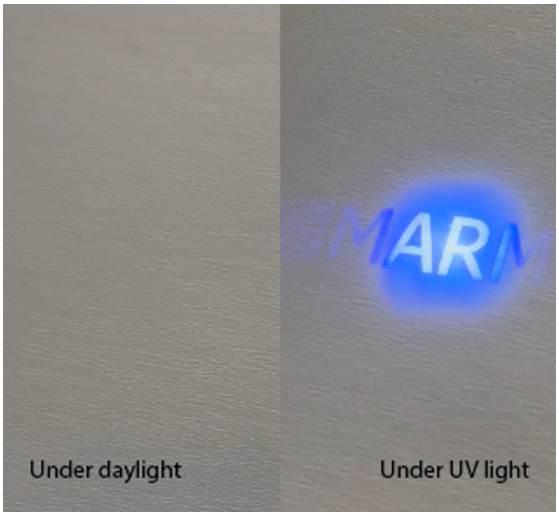
The chemical structure of the obtained 1, 3, 6, 8-pyrene sulfonic acid tetra sodium molecule was elucidated by ^{1}H NMR and given in Figure 2. When Figure 2 is examined, peaks belonging to two hydrogens are seen at 8.48 ppm and peaks belonging to 4 hydrogens at 8.66 ppm. This indicates that the molecule has been successfully synthesized. In addition, the results are in line with the literature (Rodenburg et al., 1988).

It has been determined that 1, 3, 6, 8-pyrene sulfonic acid tetrasodium can be easily dispersed both in water and in hydroxyethyl cellulose, and the resulting mixtures are transparent-white. The prepared inks were kept for sixty days and at the end it was determined that 1, 3, 6, 8-pyrene sulfonic acid tetrasodium was still homogeneously dispersed. The prepared ink has a homogeneous structure, and there is no settling problem up to a resolution of 1 mg/ml. No precipitation was observed depending on the temperature change in the



» **Figure 2:** *^{1}H NMR spectrum of 1, 3, 6, 8-pyrene sulfonic acid tetra sodium in water*

environment. The resulting inks were printed on a UV blocker-free paper surface and their images were examined in both visible and UV light. The results are given in Figure 3. When Figure 3 was examined, it was determined that there was no image on the printed paper in daylight, only the blue bright image was easily visible at 365 nm under UV light. This shows that the printed image keeps the information in daylight and makes it visible under a special light source, that is, the ink produced can be used in security prints. The results are in line with the literature (Yao et al., 2017; You et al., 2015).



» **Figure 3:** *Fluorescent ink printed surfaces photographs at under daylight and UV light*

Printability tests such as color, gloss, light fastness, adhesion, rub resistance, drying time, dry ink film weight, alkali, acid and nitro resistance were applied to the obtained security ink printed samples and the results are given in Table 2.

When Table 2 is examined; While printing under daylight shows that there is a white image in L*, a*, and b* values, there is no image, while the change in b* and a* values under UV light shows blue color. When examined in terms of gloss, a very glossy surface was obtained compared to the base paper. Because the spaces between the cellulose fibers are filled and a more gloss surface is obtained with less light scattering (Arman Kandirmaz et al., 2020). It has been concluded that the security ink, which has a light fastness of 7, can be used for two years without any problem on the exterior, where it is highly resistant to light.

Table 2

Printability test of security ink

Printability tests	Results			
Color (Daylight)	L*: 100	a*: 0	b*: 1	
Color (UV)	L*: 91	a*:-13	b*:-11	ΔE_{00}:16.37
Gloss	11.2			
Light fastness	7			
Adhesion	5 (excellent)			
Rub resistance	1 (excellent)			
Drying time	4 sec			
Dry ink film weight	2.5 g/m²			
Alkali resistance	✓			
Acid resistance	✓			
Nitro resistance	✓			

When the adhesion of the prints made with this ink is examined, it has been observed that no ink residues have passed onto the tape in all printed samples from 4 seconds after printing, both in visible light and UV light. In other words, it was determined that it had high adhesion. When examined in terms of rub resistance, it was determined that there was no scratch on the surface at the end of 30 oscillations, and the ink was resistant to friction. The drying time of the ink is 4 seconds and this is an expected time for inkjet inks (Selim et al., 1997), the dry film weight is the most important parameter that determines the price of the ink. It is used to determine the amount of ink to be used in 1 m² area. Although there is no written rule, using less than 3 g of ink for an average of 1 m² is both cost-effective and covers the amount of ink that the paper can carry in consecutive prints. When the ink produced in this sense was examined, it was concluded that this requirement was met with 2.5 g/m². In addition, it has been determined that the ink has acid, alkali and nitro resistance with the tests performed. Thus, it has been determined that the ink can be used in detergent packages, cleaning materials as well as suitable for inks in different formulations that can be produced. Nitro resistance also shows that it is suitable for post-press applications such as cellophane after printing.

Conclusions

In this study, 1, 3, 6, 8-pyrene sulfonic acid tetrasodium fluorescent salt was synthesized as an ink colorant. The synthesis has been proven by ^{1}HNMR, and its optical properties have been proven by UV spectroscopy. Using this synthesized colorant, ink jet ink with hydroxy ethyl cellulose binder was produced and printed. When the prints were examined, it was determined that the ink was invisible under daylight and blue under UV light. It is also supported by the spectrophotometer with the same feature. When its printability properties are examined, it has been determined that it can be used industrially in good quality, compatible with post-printing applications and has light fastness that can be used in the open area for two years. It is thought that the obtained ink in line with the above-mentioned visual and printable features will provide secure information transfer and can be used in counterfeiting.

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