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To meet the need for a high quality scientific publishing platform in its field, the International Association of Research Organizations for the Information, Media and Graphic Arts Industries is publishing a quarterly peer-reviewed research journal.

The journal is fostering multidisciplinary research and scholarly discussion on scientific and technical issues in the field of graphic arts and media communication, thereby advancing scientific research, knowledge creation, and industry development. Its aim is to be the leading international scientific journal in the field, offering publishing opportunities and serving as a forum for knowledge exchange between all those interested in contributing to or learning from research in this field.

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A letter from the Editor

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In the present June issue one original scientific and two research papers are published. The first article is dealing with print optical density, the well-known quantity used as a measure of the thickness and optical impact of the printing ink on the substrate; here, it is determined by using scanner and regression models instead of traditional measurement by densitometer.

The second paper shows the results of using multi-criteria methods for choosing the right option from different conventional and digital printing machines.

The third paper is based on the study of digital transformation adoption towards the broadcasting industry in Sri Lanka, however, the methods used and interesting findings are not geographically or nationally limited and can be taken into consideration more generally in any study of digitalization of media industry in modern society.

In the News&more section of Topicalities edited by Associate Editor Markéta Držková (marketa.drzkova@jpmtr.org), an interesting overview of the EU-funded projects confirms the role of contemporary printing technologies in research and development of new technologies in various areas. However, the role of printing in EU-funded research projects is a few steps beyond its "traditional" understanding as an activity bringing "added value" to paper or maybe as a declining kind of media, communication, or information technology. The modern keywords related to printing are: printed electronics, 3D printing, bioprinting, ... Complementary to the projects supported under the Horizon 2020 programs, the activities of SmartEEs association and the information on the newest report published by Intergraf are kind of confirmation of the current and future trends.

Also in the Bookshelf, an overview of new books is mainly based on new technologies, that maybe are not directly connected to traditional printing, however, the information on modern materials, technologies, and approaches in design is crucial for successful research work.

Traditionally, three academic dissertations are presented. A selection of doctoral dissertation topics also shows alteration from traditional topics and possible directions in the future development of our research fields.

The first one presented, on the use of printing methods for component fabrication for optics and electronic applications, was defended by Pauliina Vilmi at the University of Oulu, Finland. Tomislav Hudika defended his thesis on the use of nanocomposite coating on cardboard and its effect on packaging characteristics at the University of Zagreb, Croatia. The thesis on 3D printing and texture modification of cereal-based matrices was defended by Ahmed Raouf Fahmy at the Technical University of Munich, Germany.

An overview of the Events is a confirmation of the "normalizing" of our life after the pandemic. The list is a bit shorter, however, there are opportunities for attendance and cooperation at many well-known and recognized events worldwide. Among them is the September joint conference of iarigai and International Circle in Wuppertal, Germany. We are expecting a number of contributions from young as well as experienced researchers in print and media technology. All authors are also invited to submit their full papers, upgraded and extended, for publication in the Journal. On this occasion I would like to point out a small, but maybe significant difference between the conference contribution and a paper published in the Journal. The main role of the conference contribution (and paper or extended abstract published in the Proceedings) is to present the first promising results of the research, open questions, and discussion, and build a network of friends and partners for possible future cooperation. The paper published in the Journal is a confirmation of a successfully finished research project and a possible reference for future research in the same field. We need both and I hope we will come together to the Conference and receive many interesting manuscripts for publication in the Journal in the forthcoming months.

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An approach to predict print density using scanner and regression models

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Abstract

Optical density measurements are critical for process control and quality assurance during print production. Use of scanners and cameras for color correction and colorimetric measurements have been reported earlier in literature. This paper presents a procedure for using a scanner as a densitometer. Density of printed patches were calculated using the pixel intensity values obtained from scanning a test target. Optical density was measured simultaneously from a densitometer and also computed from the L^* measurements for the same patches. Four regression algorithms were used for modeling the behavior of the scanner using these two models. The models were tested and validated. The accuracy and performance of these models were compared. Results convey that the scanner can indeed be used for taking densitometric measurements obtained from the L^*, under the presented method.

Keywords: densitometer, process control, print quality, regression, machine learning

1. Introduction

Optical density is a measure of the share of light that gets reflected or transmitted from a surface. In the case of films, it is referred to as transmission density, while for opaque substrate, it is called reflection density. Process control plays a pivotal role in ensuring quality during print production. There exist multiple dimensions to the process control methodologies that are employed at press. Apart from colorimetric considerations, densitometric metrology and its control is required for achieving repeatable print results with other variables remaining the same. Many specifications and standards in print are based on achieving some pre-determined densitometric aims. Even when targeting the colorimetric aims, it is pertinent to achieve some standard print density. Density measurements provide a direct indication of the ink film deposition on the substrate. Offset printing is heavily reliant on the proportional quantities in which process inks are deposited. Optimal ink film deposition ensures good gray balance and printing without any color cast. Density can also give an insight into the quality of tonal reproduction during printing. In case of failure to attain densitometric targets or control thereof, problems that include hue shift during multi-color wet-on-wet printing are likely to occur. Densitometric measurements are also used for quantifying other parameters like dot gain, trap, contrast and hue error. Further, it is worthwhile to note that calibration of tonal values, which is a prerequisite to press characterization, also involves densitometric metrology.

The standard methodology for measurement of optical reflection density involves the use of a densitometer. Based on geometric construction and spectral behaviors of the instruments, there exists regional and international standards that define such measurement conditions. A densitometer typically employs a light source that is placed at an angle of 45° with respect to the sample where the light is focused using optical apparatus. The reflected light is recorded at an angle of 90°. This is done to capture the diffused light and ignore the gloss effects of the printed substrate. For traditional densitometers used in the printing industry, the reflected light would be made to pass through the color filters based on the ink whose density is being measured. For process colors, complimentary filters are used, while separate readings from each filter are required for non-process colors with the highest reading being the one corresponding to the density of such colors. However, present-day densitometers employ

spectral reflectance values at an optimum wavelength for the measurement of the densities of prints. This is especially important when measuring the densities of spot colors, as selecting any one of the fixed color filters would not yield optimal results. These instruments have built-in filter functions, each of which matches specific print condition (Eckhard, et al., 2014). The reflected light is then made to pass through a logarithmic amplifier and digitizer. The use of logarithmic scale is to ensure parity between densitometric measurements and logarithmic response nature of the human eyes. Further, to eliminate the differences in measurements owing to wet and dry ink films, polarization filters are provided both along the incident and reflected light path. The resulting reflected light is used to calculate the optical reflection density of the patch. Mathematically, optical density is given as the logarithm of the inverse of percentage reflectance.

Some of the earlier works (Derr, 1959) in constructing reflection densitometers have elaborated methods to develop the instrument to regulate the specular component of reflected light obtained from the printed surface. Kendall (1932) developed a reflection densitometer for the purpose of analysing the density of silver deposits on photographic papers. Watt (1956) developed a densitometer with similar geometry as referred to earlier, which was able to employ dense filters including interference filters to be used. McFarlane (1934) described a method for the construction of a versatile reflection densitometer with similar geometry that could be used for measurements on photographic papers as well as halftone printed substrate.

During print process control, faster densitometric measurements are required to implement any changes at press, if required. Densitometric measurements taken from patches printed on color bars are usually done from one patch to the other sequentially. This paper aims to implement a faster method in density measurements using an image scanner. Image scanners have been used in prior work in extracting densitometric measurements from plates (Lim and Mani, 1998; 1999), where the quality on solid prints referred to as mottle were evaluated from the lightness variation obtained from scanned image of a print. It is noteworthy that in the said work, the scanner was calibrated using calibration software and profiles were made for conversion of device dependent to independent data. In Wu (2001), investigation was conducted on the sources of error during measurements of print quality using a color scanner and proposed a method of linearizing followed by color scanner calibration to convert scanned colors from device space to independent space. In Rasmussen, Mishra, and Mongeon (2000), authors approached the problem of analysing print defects and quality using flatbed and drum scanners. They used multiple scanners for sample collection and converted the scanned color patches from RGB to CIELAB space using color transformation matrices. Metrics relating to lightness values of cyan, magenta, yellow and black patches printed on a test target were then utilized for print quality assessment. Scanners were also used for measuring print quality in Streckel, et al. (2003), where single color patches were scanned for analysing density followed by calibration of the scanner by means of converting the scanner responses to density using conversion tables.

Scanners have also been used in fields other than the graphic communication like in the medical technology field. Alva, et al. (2002), described a method wherein a flatbed image scanner was used to work like a densitometer for measuring the film response of radiochromic films. The films were irradiated in incremental manner leading to the formation of step wedges which were scanned and the film responses were evaluated and compared to optical density. An almost linear relationship was observed leading for the conclusion that film responses obtained from scanned films could be a substitute for optical density measurements. Xuong (1969) developed a system for measuring the density on x-ray diffraction films. The system used a drum type scanner for obtaining the measurements and the resultant light intensity were used for converting the film response to optical density. Hertel and Hultgren (2003) studied the granularity, which is a function of density differences, by measuring the densities from a scanned grayscale step-wedge on a flatbed scanner. Hertel, Töpfer and Böttcher (1994) used photodetector arrays to capture images of color films and as such calculated density from this setup. The results showed that the granularity density measured from the device and that obtained from a densitometer were comparable. In their study, Hertel and Brogan (2003) used a flat-bed scanner to analyze the image quality of prints. They processed the RGB signals to visual density measurements using visual weighing coefficients. A method for using a stepless wedge with varying density and a flatbed scanner to measure granularity versus density changes was developed by Hertel and Hultgren (2002). Brydges, et al. (1998), described a method of using a CCD color camera for measuring raw RGB values of printed patches to obtain densitometric measurements from the readings. Seymour (1995) has used a CCD camera for on-line detection of quality in printed output. The work proposes to use the measured grayscale values for R, G, B components of a patch obtained from the camera and their corresponding densities obtained from a densitometer to develop a look-up table and use the same for further calculation of densities of unknown patches. Other authors (Simomaa, 1987; Nemeth and Wang, 1993; Malmqvist, et al., 1993; Busk, et al., 1993) have also used CCD cameras for measuring optical densities of print.

In this paper, a method is presented of using a flatbed scanner for measuring the density of printed substrate using machine learning. There have been wide applications of machine learning techniques in identifying and analysing print quality. Verikas and Bacauskiene (2008) have demonstrated the use of a CCD-based color camera to obtain the spectral reflectance of color patches and converted these measurements to ink film density using a local kernel ridge regression method. Lundström, et al. (2013), have used a CCD-based camera for scanning printed patches on a web offset machine and implemented a random forest based algorithm to estimate ink density among other quality parameters. Al-Mutawa and Moon (1993) have used a connectionist expert system that learns the relationship between changes made by the press operator in ink key settings based on changes in the ink film density and automates the process. In Yang, Chou and Yang (2013), the authors used support vector regression (SVR) to calibrate non-linear systems like camera or computer for correct color reproduction. Kuo, Ng and Wang (2002) used SVM to compute differential gloss on printed substrate from a mapping function obtained from the density/gloss measurements. Verikas, Bacauskiene and Nilsson (2006) used SVR among other soft computing techniques to evaluate values of various print quality attributes to ensure print quality during production. Funt and Xiong presented a method of using SVR in determining the chromaticity of the light that has been used in illuminating a scene from the histogram of the image (Funt and Xiong, 2004; Xiong and Funt, 2006). Evans and Fisher (1994) used decision-tree modelling that resulted in reduction of banding during gravure print production. Das, et al. (2022), have presented a method of using various machine learning including decision tree to solve the delays in print production of gravure printing that involves cylinder banding. Rabiha, et al. (2018), used decision tree based data-mining methods to develop a set of rules and segment of customers that helped a printing company to push marketing strategies.

There have been multiple implementations of regression methods to solve problems pertaining to print and print quality. Various methodologies towards scanner and other optical devices characterization have reportedly used these techniques. Izadan and Nobbs (2006) have used regression techniques for modelling the scanner behaviour in converting the RGB values to XYZ space. Lundström and Verikas (2013) used regression techniques among other methods to quantify and assess quality of print based on various parameters. Multiple linear regression methods were used for characterizing the colorimetric behaviour of desktop scanners while developing a color management module for desktop-based printing system in Iino and Berns (1998). In their work, Gebejes, et al. (2013), showed methods for recovering reflectance data from multi-angular camera RGB data using regression methods. Kucuk, et al. (2022), have studied and compared the results of camera color correction for converting camera RGB data to XYZ data based on regression method and that obtained from neural network based method. Bangyong, Han and Shisheng (2014) applied polynomial regression methods to model the relationship between the measured and printed colors of patches in a test target to ultimately obtain the gray values of the patches. Hirn, et al. (2009), have reported the relationship between print density differences and the local properties of the paper and modelled this using linear regression method. A method of calibrating scanner for converting recorded device-dependent color data to independent one using polynomial regression has been proposed by Hardeberg, et al. (1996). Another method of using polynomial regression for characterizing digital color camera by converting native space color data to independent data was proposed by Hong, Luo and Rhodes (2001) and Han (1998). Shaw, et al. (2003), and Yang, et al. (2010), have used principal component regression in characterizing printers and modelling their output behaviour. Jetsu, et al. (2006), and Lo, et al. (2006) presented methods for characterizing printers and converting device-dependent color to their corresponding reflectance spectra using polynomial regression, among others.

The contribution of this paper includes a machine learning based framework for prediction of densitometric measurement from the scanned color patches and a comparative analysis between performances of some of the popular conventional prediction techniques on the same. The success of the presented method can result in development of much less expensive and easy to operate system for density measurement since the commercially used densitometers are considerably expensive and often not available in small presses, while scanner is available in most of the presses.

2. Methods

Prior to the experimentation, a test target was developed. Since the work involved characterizing the behaviour of a scanner, the test target was made in line with IT 8.7/2. The patches were designed with CIE $L^*a^*b^*$ values from a reference file obtained online. Since this target is a standard that is used worldwide, it was seen fit to use it for the work. The target contains 264 color patches and 24 gray patches. Once the target was developed, it was printed using a CMYK inkjet desktop printer on an optical brightening agent (OBA) free photopaper. The target was then scanned using an Epson Perfection V19 Photo scanning device.

Since any changes that might be done to the image during scanning or processing might lead to alteration of pixel intensity values of the image, and it might lose its fidelity to the original, the scan was done in RAW mode, without any further processing like color correction, sharpening and exposure control. The image was scanned with linear Gamma at 8-bit RGB color and 1200 dpi resolution. The scanned image was stored in uncompressed TIFF format.

The image was analyzed using ImageJ (Pérez and Pascau, 2013). The mean pixel intensity values for individual patches were extracted using the software from the scanned image of the target. Since optical density is a measure of the logarithmic ratio of incident and reflected light (Merton, 1924), the incident light (I_0) has been considered here as the highest possible pixel intensity value for an 8-bit RGB image, i.e., 255, while the reflected light (I) is mean pixel intensity obtained for a patch, as given in Equation [1].

$$\mathrm{OD} = \log_{10}\left(\frac{I_0}{I}\right) \qquad [1]$$

The mean pixel intensity was extracted from the individual patches, and the optical density (OD) was derived for the patches using Equation [1].

For characterizing the behaviour of the scanner, two models were developed. The first was comparing the densities obtained from mean pixel intensities (OD) of the patches to their corresponding actual optical densities (MD) obtained from a densitometer. Hence, for this model, OD was the independent variable and MD was the dependent variable. This will be further referred to as the MD model. The second model involved extracting the L^* values of the said patches using a spectrophotometer. The L^* refers to the lightness of luminance component (León, et al., 2006) of a color and is chroma-independent. The CIE $L^*a^*b^*$ color space is perceptually uniform and as such it is a metric that can define the darkness or lightness of a patch. A Techkon SpectroDens spectrophotometer was used for measuring the L^* values for the patches in the test target. The M1 measurement conditions were used with D50/10° illuminant/observer. Equations [2] and [3] describe the method to compute L^* values.

$$L^* = 116\left(\frac{Y}{Y_n}\right)^{\frac{1}{3}} - 16, \text{ if } \left(\frac{Y}{Y_n}\right) \geq 0.008856 \qquad [2]$$

$$L^* = 903.3\left(\frac{Y}{Y_n}\right), \text{ if } \left(\frac{Y}{Y_n}\right) < 0.008856 \qquad [3]$$

where L^* is the CIE lightness value (Ebner, 2007), and Y_n is the Y tristimulus value for the reference white used for measurement. The Y tristimulus value represents the percentage luminance factor. The ratio Y/Y_n when raised to the one third cube represents a perceptual attribute of lightness (Sharma, 2018). The value of Y is 100 for perfect white patches and 0 for patches that absorb no light (Hunt and Pointer, 2011). Thus, this metric can be used for converting the L^* values to optical density, as the ratio (Y/Y_n) correlates to the ratio (I/I_0) as given in Equation [1]. This results in the following equations:

$$\mathrm{LD} = \log_{10}\left(\frac{116}{L^* + 16}\right)^3, \text{ if } \frac{Y}{Y_n} \geq 0.008856 \qquad [4]$$

$$\mathrm{LD} = \log_{10}\left(\frac{903.3}{L^*}\right), \text{ if } \frac{Y}{Y_n} < 0.008856 \qquad [5]$$

Equations [4] or [5], depending on satisfying the given condition, were used for converting the L^* values to optical density (LD) for the measured patches. These are the actual density values for the patches (dependent variable) that were used along with OD (independent variable) for modelling the behaviour of the scanner. This will be further referred to as the LD model. An example of scanned patches and corresponding mean intensity and L^* values is shown in Figure 1.

Along with the density-based model (MD), the L^* based model (LD) was also considered owing to two reasons: L^* is an indicator of darkness or lightness of a patch and having two distinct models for prediction would allow scope of cross-validation of results. For both the models, i.e., MD and LD, four regression techniques were applied to find the best prediction model; namely LR: linear regression, PR-2: second-order polynomial regression, SVR: support vector regression, and DT: decision trees. A brief of these algorithms has been provided below for ready reference. In this work, for

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Mean pixel intensity	35.00	38.81	42.67	45.19	66.33	72.56	76.76	77.29	127.88	133.36	139.45	137.02	203.55	206.46	203.73	200.42	198.97	201.52	202.76	25.22	41.62	58.91
L^* value	17.17	18.23	19.91	20.97	32.15	33.57	34.58	33.95	58.33	59.76	60.63	58.63	79.49	79.52	79.46	79.57	79.71	80.18	80.02	10.89	18.58	24.84

Figure 1: Example of scanned printed patches and corresponding mean intensity and L values*

Table 1: Pseudocodes of used regression algorithms

Linear and polynomial regression	Support vector regression	Decision trees
General form of representation: $y = a_0 + a_1x + a_2x^2 \ldots + a_nx^n$ For linear regression $n = 1$ Run the algorithm to find the coefficients (a_0, a_1, a_2, …, a_n) following the least square method where the sum of squared residuals (S) is calculated as below and minimized. $S = \sum_{i=1}^{n} r_i^2$ where $r_i = y_i - f(x_i, a_i)$	Unlike linear and polynomial regression the goal is to minimize the L2 norm of the coefficients represented as: $\min \frac{1}{2}\|a\|^2$ where the error term is included in terms of a constrained presented as $\|y_i - a_i x_i\| \leq \varepsilon$ where ε is the maximum acceptable error.	This algorithm learns the decision rules from the training data. It starts with a root node and then keep on splitting into child node in order to reduce entropy (E) and increase information gain (IG) that are calculated as follows: $E = \sum_{i=1}^{N} - p_i \log_2(p_i)$ $\mathrm{IG} = E_l - \sum_{j=1}^{K} E_{j,l+1}$ where l is the iteration and j is the index of subject in total number of subset K in that split.

all the models, 60 % of the total number of patches were used for training, 20 % for model validation and remaining 20 % for testing.

The stated regression algorithms were subjected to 10-fold cross-validation to arrive into the model parameters to be used for testing. Among these algorithms DT needs to have two important user specified parameters, i.e., maximum depth of tree, which regulates the maximum number of splits a tree can make, and minimum number of sample leaf, which conveys the minimum number of samples or observations needed to make a leaf under a parent node. From the literature review (Doğru, Buyrukoğlu and Arı, 2023; Hou, et al., 2023; Yazu, et al., 2022) and trial- and-error runs with different combinations of values, it has been found that 40 for depth of tree and 10 for minimum sample leaf may be optimal for this work. Nevertheless, scope of optimizing the DT parameters is still open and has not been considered under the focus of this work. The LD and MD based models were then assessed based on their accuracy and error metrics.

2.1 Regression algorithms

Regression algorithms are commonly used for prediction of continuous real values. Regression analysis corresponds to the mathematical process of identifying the relationship between a dependent variable and one or more independent variable. Among different algorithms, linear and polynomial regression (Weisberg, 2005; Seber, 2012; Ostertagová, 2012), support vector regression, (Vapnik, Golowich and Smola, 1997; Vapnik, 1999; Drucker, et al., 1996), and decision trees (Kingsford and Salzberg, 2008; Kotsiantis, 2013; Breiman, et al., 1984) are the popular algorithms that have been explored in this work. The pseudocodes of these algorithms are shown in Table 1.

3. Results

The results of 10-fold cross validation runs have been provided in Table 2, where the best folds have been highlighted in bold.

Table 2 shows that LR, SVR and DT perform equivalently while PR-2 shows better performance in comparison to other algorithms under consideration. The betterment is reflected in the average and standard deviation values as well. In case of PR-2, the average value is higher than others and standard deviation value is lower. Table 2 also shows that LD model provides visibly better prediction performance than the MD model for all the regression models under consideration.

Figures 2 and 3 show the prediction plots of the MD model and LD model, respectively, for the regression models under consideration. In these plots the diagonal line presents ideal line where predicted values exactly match the actual values. Hence, the deviation of the scattered points from the diagonal line shows the goodness of the prediction.

The accuracy of prediction can further be visualized using residual plots shown in Figure 4 and Figure 5 for the MD based and LD based models, respectively. In these plots the differences in percentage between actual and predicted values have been plotted. The differences between predicted and actual values were

Table 2: Results of 10-fold cross-validation for different regression algorithms for both MD and LD models

	LR		**PR-2**		**SVR**		**DT**	
	MD	LD	MD	LD	MD	LD	MD	LD
Fold 1	**0.8781**	0.9555	0.8721	0.9855	0.8683	0.9855	0.7610	**0.9855**
Fold 2	0.6435	0.9805	0.6835	0.9555	0.6541	0.9555	0.7090	0.9555
Fold 3	0.7600	0.9627	0.7900	0.9805	0.7550	0.9805	0.7742	0.9505
Fold 4	0.6302	0.9792	0.8172	0.9627	0.6494	0.9627	0.5840	0.9627
Fold 5	0.7562	0.9642	0.8232	0.9792	0.7506	0.9792	0.6978	0.9592
Fold 6	0.8476	0.9743	0.8500	**0.9912**	**0.8832**	0.9642	**0.8149**	0.9642
Fold 7	0.7229	**0.9866**	0.8120	0.9743	0.6978	0.9743	0.7474	0.9743
Fold 8	0.7238	0.9715	0.7842	0.9866	0.7038	**0.9866**	0.6779	0.9766
Fold 9	0.8137	0.9521	**0.8847**	0.9715	0.7894	0.9715	0.7882	0.9515
Fold 10	0.6358	0.9555	0.7829	0.9521	0.6309	0.9521	0.7386	0.9521
Average	0.7411	0.9682	0.8099	0.9739	0.7382	0.9712	0.7293	0.9632
Standard deviation	0.0878	0.0113	0.0568	0.0126	0.0883	0.0115	0.0661	0.0113

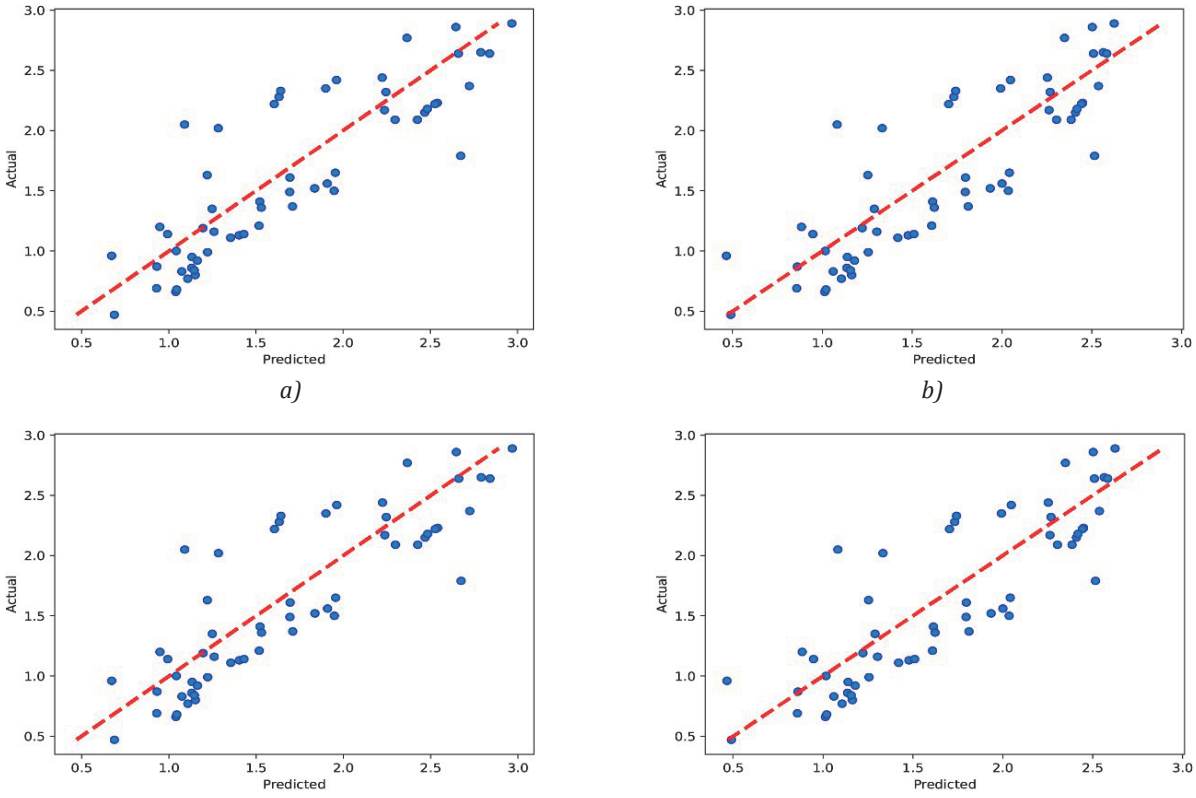

Figure 2: Prediction results with the MD model for different regression algorithms; (a) LR, (b) PR-2, (c) SVR and (d) DT

interpreted in percentage values using Equation [6]. The straight line at '0' is the reference line that would result if the predicted values were exactly same as the actual values.

$$\text{Residual value (\%)} = \frac{|x_i - y_i|}{x_i} \times 100 \qquad [6]$$

where x_i and y_i are individual actual and predicted values, respectively.

Apart from the visual presentations, the results of predictions were further evaluated against some of the popular metrics (Naser, 2020; Ostertagová, 2012), namely, mean squared error (MSE), mean absolute error (MAE) and *R*-squared (R^2) values. The first two metrics represent goodness of the prediction model by small values, while higher the R^2 values the better prediction performance. The results of evaluation for the MD and LD models are presented in Table 3.

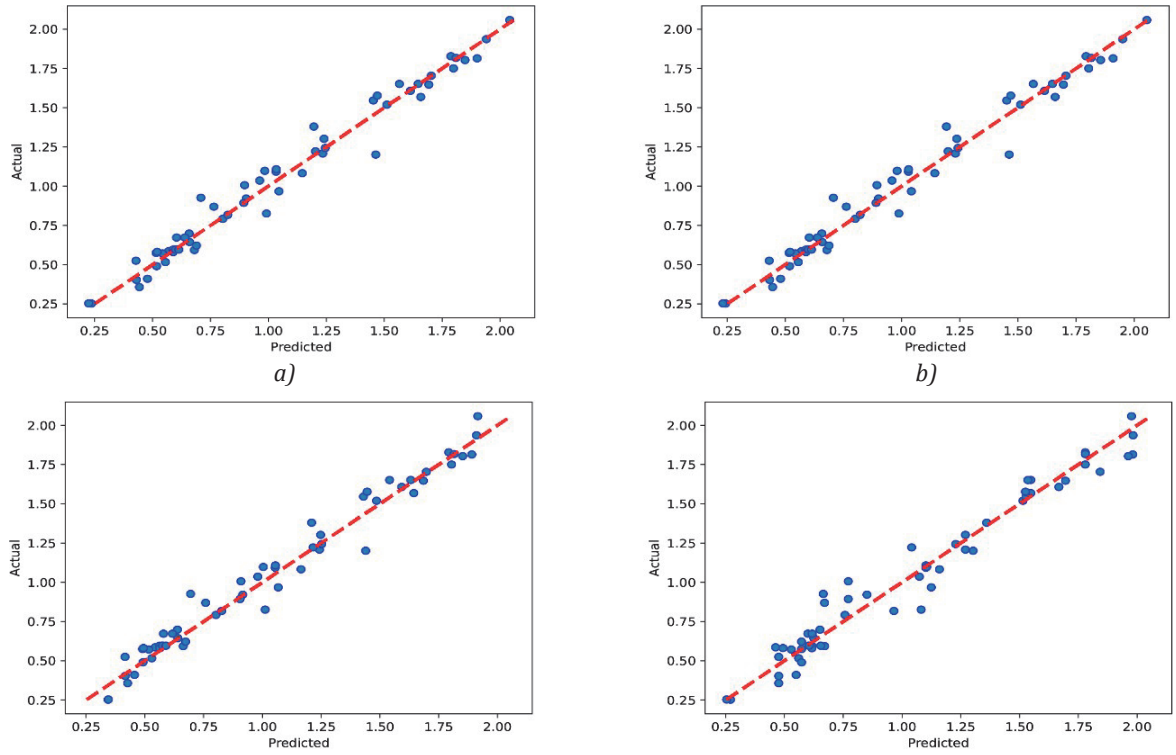

Figure 3: Prediction results with the LD model for different regression algorithms; (a) LR, (b) PR-2, (c) SVR and (d) DT

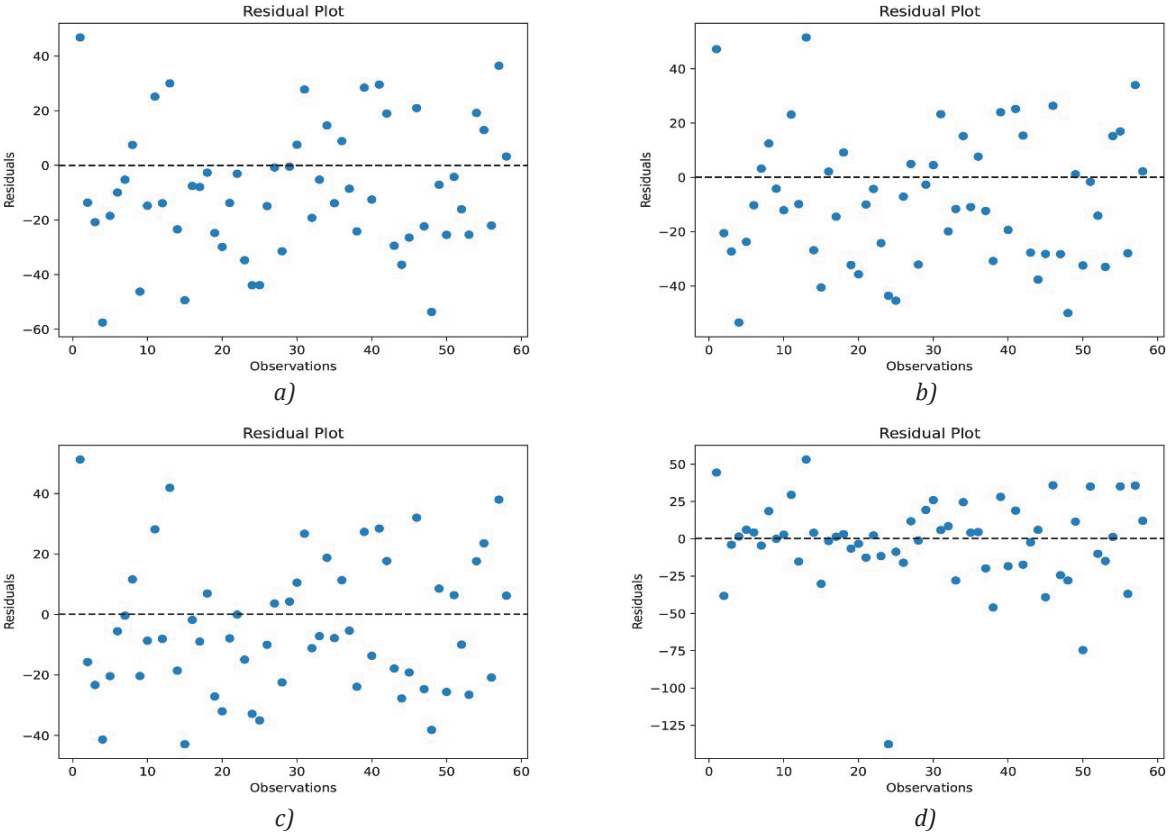

Figure 4: The residual plots with the MD model for different regression algorithms; (a) LR, (b) PR-2, (c) SVR and (d) DT

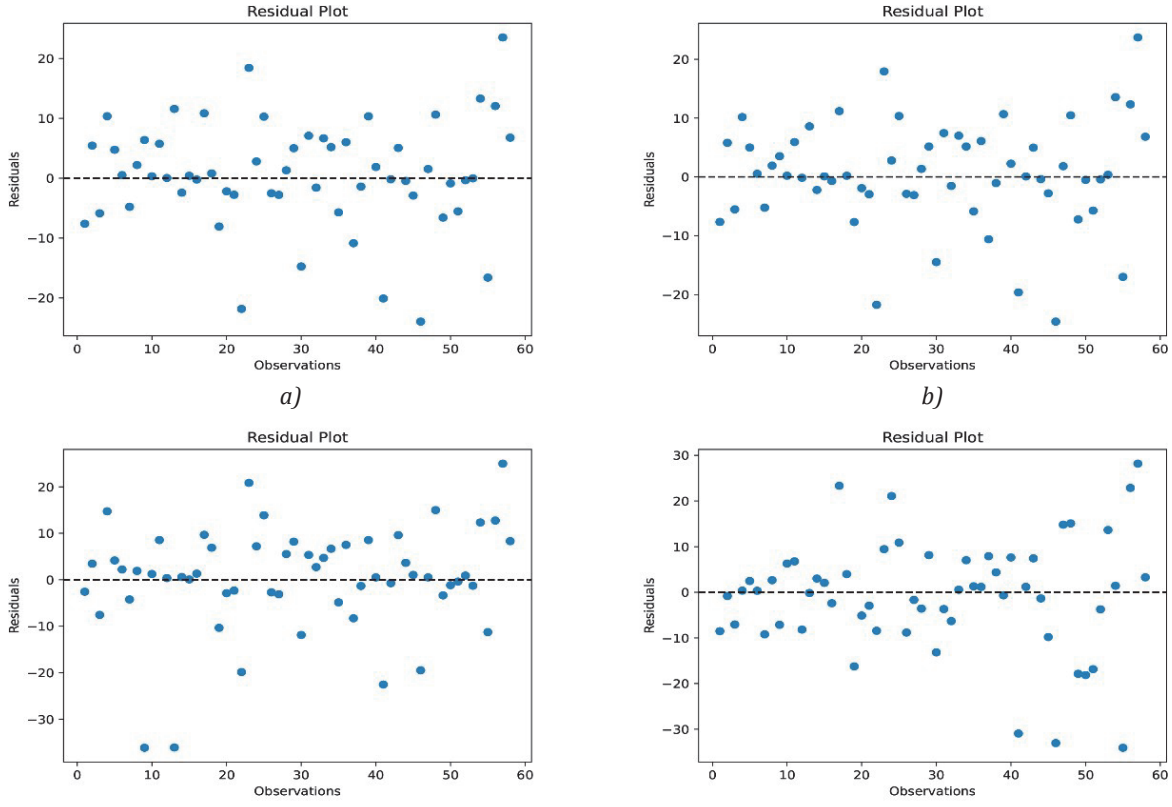

Figure 5: The residual plots with the LD model for different regression algorithms; (a) LR, (b) PR-2, (c) SVR and (d) DT

Table 3: Performance evaluation of the models with various regression algorithms

Regression algorithm	**MSE**		**MAE**		**R^2**	
	MD	LD	MD	LD	MD	LD
LR	0.1261	0.0060	0.2967	0.0559	0.7204	0.9753
PR-2	0.1235	0.0013	0.2998	0.0256	0.7262	0.9932
SVR	0.1188	0.0069	0.2779	0.0627	0.7366	0.9718
DT	0.1423	0.0098	0.2839	0.0756	0.6845	0.9597

4. Discussions

From the MD model prediction results that can be seen in Figure 2, it is clearly evident that the predicted points are widely spread out away from the diagonal line, indicating poorer goodness of fit. From the prediction results of all four regression algorithms, it is further evident that the dependent (MD) and independent (OD) variables most likely do not share a linear relationship.

The prediction results shown in Figure 3 for the LD model show that in all the cases the predicted points are in close proximity to the diagonal line, which reflects the goodness of fit. The figure also conveys the low degree of relational non-linearity between OD and LD. Due to such relation, simple regression models like LR and PR-2 have also shown good prediction results.

Figure 4 describes the residual plots for the MD model. The residues are again more widely spread out for all the regression algorithms as compared to the LD model. The overall spread for the residues has increased as can be seen from the increased limits for the axes that vary within ±45 for LR, PR-2 and SVR algorithms and from +55 to –150 for the DT algorithm, indicating poor predictors.

Residual plots in Figure 5 for the LD model show that residues are denser near the origin, scarce away from it and have no apparent patterns when moved along the *x*-axis, which are characteristics of good plots. The residual plots validate the model performance and increase the confidence in its accuracy. The plots for PR-2, LR and SVR suggest that most of the data resides within ±10 % from the origin. There is no obvious patterns observable in the residuals. The plot for DT model contained more residuals away from the origin in comparison to other models. And it is quite noticeable that the residuals for PR-2 are concentrated along the origin line more than for any other model. This is in line with the observations from the earlier findings. From the results discussed, it may be understood that the PR-2 model performed better than other models for this experiment.

Table 3 shows that in terms of the accuracy of the four regression algorithms, the PR-2 model with the R^2 error at 0.9932 performs the best among all. The results for MSE and MAE also are the lowest for the PR-2 model. This can be verified with the fact that the independent variable is one-dimensional and is highly correlated with the dependent variable. The R^2 error for PR-2 and LR are similar, yet MSE and MAE values for PR-2 are significantly higher than for LR. It is interesting to note that performance of models LR and SVR is almost comparable. It may be due to the fact that SVR performs well for multidimensional input variables. It seems that DT has performed relatively poorer in modeling the scanner behavior. The reason might be attributed to the fact that DT results in over-fitting frequently, hence there are comparatively more cases where DT could not perform well in predicting unknown observations. However, if their variables had higher degree of non-linearity, DT could have performed well compared to LR and PR-2. Although the R^2 values are indicative of the accuracy of the model, other metrics are required to validate the models. Residual plot might be useful in visualizing and validating the performance of the regression algorithms and MAE and MSE values may act as the validator for R^2 results.

Table 3 also presents the error metrics for MD model. As evident, the error metrics for all the regression algorithms have poorer values when compared to those obtained from the LD model. Of the four regression algorithms used for the MD model, PR-2 performed better than the rest. When compared to their LD counterparts, the MD regression algorithms fell short by more than 24 % in R^2 error, by more than 73 % in MAE, and by more than 93 % in MSE. This finding is in line with the prediction and residual data discussed earlier.

When compared to the MD model, the LD model certainly not only outperformed it but also predicted results with substantial accuracy. Overall, the results are encouraging and lead to the inference that using the PR-2 regression algorithm of the LD model, the scanner behavior can be characterized and the scanner as such can be used for the purpose of densitometric measurements.

5. Conclusion

This work provides an insight into a new regression-based investigation that may be used for characterizing a scanner for using it as a densitometer. Two models were tested, one based on actual density measurements and the other based on density measurements obtained from L^* values. Multiple regression algorithms were implemented for both these models in data analysis and the results suggested that PR-2 algorithm of the LD model outperformed other machine learning algorithms. One reason behind this might be the fact that the independent input variables were one-dimensional and machine learning algorithms with higher computational complexity deal well with complex multidimensional data. The scope of this work included estimation of density of patches printed using inkjet technology on a single type of paper. While working with photopapers, the measurement condition is important. It might be prudent to use the polarizing filter along with M2 measurement condition for substrates that are glossy and fluorescent. Further work may include measuring density on a wide variety of substrates printed with multiple technologies and collecting other data along with pixel intensities. In such cases, machine learning algorithms might prove efficient in handling larger multi-variate data. Instead of measuring the density of individual patches, a single scan can provide the density of hundreds of patches, resulting in increased efficiency of process control during print production. The reported work thus can be a promising step towards mapping scanned print patches into possible densitometric measurements.

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Multi-criteria choosing the method to print a job

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Abstract

The choice of printing method for this or other print product depends on many factors and, in particular, on the type and characteristics of a publication such as its volume, and the urgency of an order. The optimal selection from the available methods variety strives to get the best "price–quality–time" ratio. The issues with finding the best solutions to achieve the set goals with limited resources have always been faced by people. The concept of decision-making considers a decision a conscious choice of one of many options. At present, in connection with the growing needs of practice, an interdisciplinary scientific direction is actively developing. One of its sectors is the mathematical theory of decision-making under many criteria. With the exemplary choice of a particular print job (publication), the multi-criteria task of printing technology choice and the effect of a job volume on the cost and time of its manufacture are considered in the light of Edgeworth–Pareto principle.

Keywords: print run, printing time, print sheet, cost, Edgeworth–Pareto set

1. Introduction and background

For various tasks, starting with the products advertising and ending with vendor image performance, almost all the companies widely use printing industry services. Unfortunately, customers are not always aware of the wide print production ways variety. The choice of printing method depends on many factors and, in particular, on the type and technical characteristics of the publication, its volume, and the urgency of the order.

The most commonly used technologies are offset lithography, flexography, screen printing, inkjet printing, and electrophotography as well as some others. With the right choice of method, one can get the optimal "price–quality" ratio. It can also significantly affect both the cost and time of the order fulfilment.

Such factors as cost, time of manufacture, print run volume, print substrate, number of inks used, and of course, the quality requirements are taken into account for making the decision when choosing the printing method for a particular publication. Quality requirements are in general understood as a set of properties that reflect the level of novelty, reliability and durability, economic, ergonomic, aesthetic, environmental, and other consumer demands to the product, reflecting its ability to meet the conditioned or intended needs in the producer–customer relations (Shishkina and Khvalenya, 2021; Put, 2010; Pedersen, 2011).

Besides assessing the quality of printed products and practical advices for both printing professionals and customers, Khvalenya (2020) considers not only theoretical issues but also gives recommendations for the measurement accuracy, use of standards, quality assessment of consumables and finished products, use of the measuring instruments and objective measurement methods. There is underlined that the scientific approach to the introduction of a quality assessment system in the printing industry should be based on the recommendations of ISO standards.

The need for a systematic approach to determining the quality of print products was considered by Ivashko and Piguz (2018) with the accent on its estimation by taking into account the psychophysiological issues of hardcopy data visual perception, as well as the technology specifics directly affecting a certain feature of

product quality. There were also attempts to reveal the print quality dependence on the job size for various technologies such as electrophotography, inkjet, screen printing, and offset lithography (SOOPAK, 2021).

When applying to a printing company, almost any customer has a logical question: is it possible to reduce the cost of an order without losing quality? Along with the other issues, this greatly depends on the choice of equipment. Analysis of the cost of manufacturing orders in various print houses shows that digital printing fits in general the urgent small jobs, while the traditional offset lithographic processes is preferable for large print runs and both kinds of technology complement each other very effectively (cgsadmin, 2019; Kingsley, 2022).

On the contrary, the cost of each copy greatly depends on the volume of the prepress work in traditional, for example, offset lithographic printing and the run increase leads to a reduction of each copy cost. Graphically these dependencies comprise a direct horizontal line for digital and hyperbole for offset lithographic processes. Their intersection point separates the areas of application of the two technologies. In this light, the comparison of purposeful production speeds for two particular presses: the Canon copier and Heidelberg QM 46 DI, shows that the latter prints faster just starting from the volume of 300 copies (Bendyugovsky, 2001).

It follows from above that due to the number of various factors to be taken into account, an individual approach to the choice of manufacturing technology for each specific publication is necessary.

2. Search for the best solutions

The problems associated with the search for the best solution to achieve the goals set with limited opportunities (resources) have always been posed. The concept of decision-making as a primary element of activity considers the decision as a conscious choice of one of a number of options (alternatives, plans, strategies, etc.). This choice is made by the "decision maker" who strives to achieve certain goals, i.e., by a person or a group of people who have decision-making rights, the possibilities of implementation, and are responsible for the consequences, for example, the head of the organization, an individual customer – it all depends on the specific decision-making situation (Podinovski, 1999).

Problems of multi-criteria selection, which contains not one, but several criteria at once, are of both theoretical and practical interest since a large number of applied technological and economic problems are formalized in a multi-criteria form. Positive solution is of great interest to practice, since in specific applied problems, the choice, as a rule, should be limited to one or a relatively narrow number of selected options. According to the well-known Edgeworth–Pareto principle, each option chosen must be Pareto-optimal. The criterion of optimality of the Italian economist Pareto is used in solving problems with optimization means improving some indicators without worsening others (Pareto, 1919). The Pareto region is associated with the choice of a particular Pareto-optimal option as the "best".

As an example, this paper discusses the task of choosing the method of printing a job in a particular print house. To make a decision, goals are formulated, which are technical and economic indicators of production. Particular attention is paid to identifying and describing the "decision maker" preferences. His goals are most often strived by the desire to increase or decrease special functions called criteria (indicators of efficiency or quality, target functions…). In relatively simple cases, it is possible to deal with one criterion. And then the best or optimal option is the one that maximizes or minimizes it.

Edgeworth–Pareto principle allows to solve multi-criteria problems. In this case, the problem of choosing the optimal solution is solved according to three criteria (cost, production time, print quality), while the choice of printing method was earlier carried out only according to one criterion – the print product quality.

The principles set forth in the work of Pareto were used by many authors, primarily to assess social phenomena, in particular, the well-known rule "80 : 20" is a universal principle, according to the general assessment, of an event (Podinovski, 1999; Bogoyavlensky, 2014). The Pareto set can be defined as a set in which the value of any of the particular optimality criteria can be improved only by worsening other particular criteria – any of the solutions belonging to the Pareto set cannot be improved simultaneously according to all the particular criteria. In the works of Podinovski (1999), and Lotov, Bushenkov and Kamenev (2004) such problem solution is specified under conditions of uncertainty and risk. So, the analysis and construction of the histogram (Pareto diagrams) is not relevant, since the work considers the field of compromises and creates a space of variable criteria, and solutions belonging to the Pareto set are called effective (optimal).

The mathematical model of the decision-making situation consists in the choice of this optimal criterion. Denote through the vector X variable data on the cost of publication manufacture S_{cpm}, and the optimality criterion Z_i (i = 1, ..., m). Let Q be the set of valid values of the model variable.

In other words, for the set Q there is given an ordered set of Z_i (Z_1, Z_2, ..., Z_m), which consists of m functions Z_i, each of them corresponding to the vector X at the value of a certain criterion Z_i (X), in this case the time to print T_{time}.

Formulation of the multi-criteria Pareto optimality looks like

$$\forall X \in Q,\ 0 \le x \le x_i = 1,\ i = 1, n$$

$$X_{xx}\,(S_{cpm}) = X_{min}\,(S_{cpm}) \text{ at } X_{xx} = 0 \qquad [1]$$

if for valid solutions X_1, ..., X_i the conditions of the task are met

$$Z_i(X_1) \ge Z_i(X_2).\ i = 1, 2, 3, \cdots, m \qquad [2]$$

and there is such a criterion Z_j ($1 \le j \le m$) that the strict inequality is satisfied

$$Z_j(X_1) > Z_j(X_2), \qquad [3]$$

then solution $X_1 \in Q$ is said to dominate solution $X_2 \in Q$.

In accordance with the introduced definition the solution X_i of a set of permissible ones within the multi-criteria optimization problem [1] will be optimal according to Pareto.

To assess the impact of various parameters at some standard quality level on a process of printing, the calculations were carried out with building the graphs for conditional print sheet cost and printing time dependence on the print run size.

To choose the best method, there is taken a standard edition possible to be printed both digitally and by offset lithography: a brochure printed on a sheet of 60 cm × 84 cm / 16 format, with a volume of 2 physical print sheets and inking schemes 1+1 and 4+4, respectively. A coefficient that indicates the inking of the face and turnover K_{lo} = 2. Since different paper formats are used for different presses, a brief description of the publication parameters as applied for printing on each of the selected machines is given in Table 1.

To compare the digital and offset lithographic processes printing methods (as alternatives), including the comparison of 1+1 and 4+4 inking schemes, the printing presses listed in Table 2 were selected.

To determine the optimal version of printing for this publication, it is necessary to solve a multi-criteria task by building a matrix of initial parameters for finding a solution as the optimal way to perform a job.

In order to objectively assess the quality of print products, materials of the same price class were selected for

Table 1: Publication parameters

Model	Paper sheet size $H \times W / P$	K_{br}	O_{pps}	$K_{sh\text{-}run}$	d
Printing scheme 1+1					
Xerox Nuvera 314 EA	21 × 29.7 / 2	1	32	1	1
Konica Minolta bizhub PRO 1250	21 × 29.7 / 2	0	32	2	1
KBA Rapida 66-2	42 × 60 / 8	1	8	1	1
KBA Rapida 105-2	60 × 84 / 16	1	4	1	1
Heidelberg QM 46-2 DI	31 × 42 / 4	1	32	1	1
Printing scheme 4+4					
Xerox Colour C75	21 × 29.7 / 2	0			1
ComColor 9150 Rice	21 × 29.7 / 2	0			1
Konica Minolta C1100	21 × 29.7 / 2	0			1
KBA Performa 66-4	42 × 60 / 8	2			1
Heidelberg SM 74-8	42 × 60 / 8	4			1

Where H and W are height and width in and P denotes the number of pages taht fit the format of the printed sheet (forming a signature); if 4 pages fit on a printed sheet, the edition is 4 share (1/4 of the full printed sheet).
K_{br} is a coefficient of bringing the paper sheet format to 60 cm × 90 cm;
O_{pps} is a volume of publication in physical print sheets (pps);
$K_{sh\text{-}run}$ is a coefficient that takes into account the number of sheet-runs per 1 physical printed sheet;
d is a number of duplicates on the printed sheet, pieces.

Table 2: Machines used in comparison

Model	Inking Face	Turnover	Printing method
Printing scheme 1+1			
Xerox Nuvera 314 EA	1	1	Digital
Konica Minolta bizhub PRO 1250	1	0	Digital
KBA Rapida 66-2	1	1	Offset lithography
KBA Rapida 105-2	1	1	Offset lithography
Heidelberg QM 46-2 DI	1	1	Offset lithography
Printing scheme 4+4			
Xerox Colour C75	4	0	Digital
ComColor 9150 Rice	4	0	Digital
Konica Minolta C1100	4	0	Digital
KBA Performa 66-4	2	2	Offset lithography
Heidelberg SM 74-8	4	4	Offset lithography

calculations. The required amount of consumables and the labor needed to manufacture the products were calculated.

Based on these calculations, the cost of printing one conditional printed sheet at 1+1 and 4+4 inking, as well as the time of printing were obtained. It seemed expedient to take as a basis the interval of job volumes from 200 to 500 copies and compare the technical and economic efficiency of their production with various printing methods.

3. Results of calculations

The results of calculating the cost of one conditional print sheet and the duration of production are presented in Table 3.

To select the preferred way of printing there is used the model which consists of two parts. The first one describes the cost per copy (S_{cpm}) dependence on job volume while the other shows how the latter affects the duration (T_{time}) of manufacture. Both parts objectively reflect the printing process, as they are built on the basis of actual data. Alternative values and criteria are shown in Table 3 for 200 and 500 copies. Currently, the considered job volume is most often encountered in practice when deciding on the choice of digital or offset lithography technologies. The practice of choosing one of them shows that for runs of less than 200 copies at 4+4 inking scheme the digital one is more cost-effective while for the runs of more than 1 000 copies at the same inking scheme the traditional offset lithography is more preferable. However, for 1+1 inking scheme runs from 500 to 2 000 copies the worldwide practice tends to more widely use digital printing.

Table 3: Results for alternative printing technologies

No.	Alternative	Cost S_{cpm} (rub.)		Duration T_{time} (hour)	
	Printing scheme 1+1				
	Job volume (copies)	**200**	**500**	**200**	**500**
1	Xerox Nuvera 314 EA	17.17	11.58	1.04	1.81
2	Konica Minolta bizhub PRO 1250	27.54	23.03	3.28	6.60
3	KBA Rapida 66-2	26.87	13.84	2.92	3.31
4	KBA Rapida 105-2	39.72	18.73	2.10	2.24
5	Heidelberg QM 46-2 DI	51.27	26.90	8.90	10.26
	Printing scheme 4+4				
	Job volume (copies)	**200**	**500**	**200**	**500**
1	Xerox Colour C75	44.27	37.88	2.09	3.62
2	ComColor 9150 Rice	33.67	29.50	3.28	6.60
3	Konica Minolta C1100	34.46	27.51	3.12	6.20
4	KBA Performa 66-4	110.66	41.72	8.39	8.97
5	Heidelberg SM 74-8	126.79	47.12	5.56	5.90

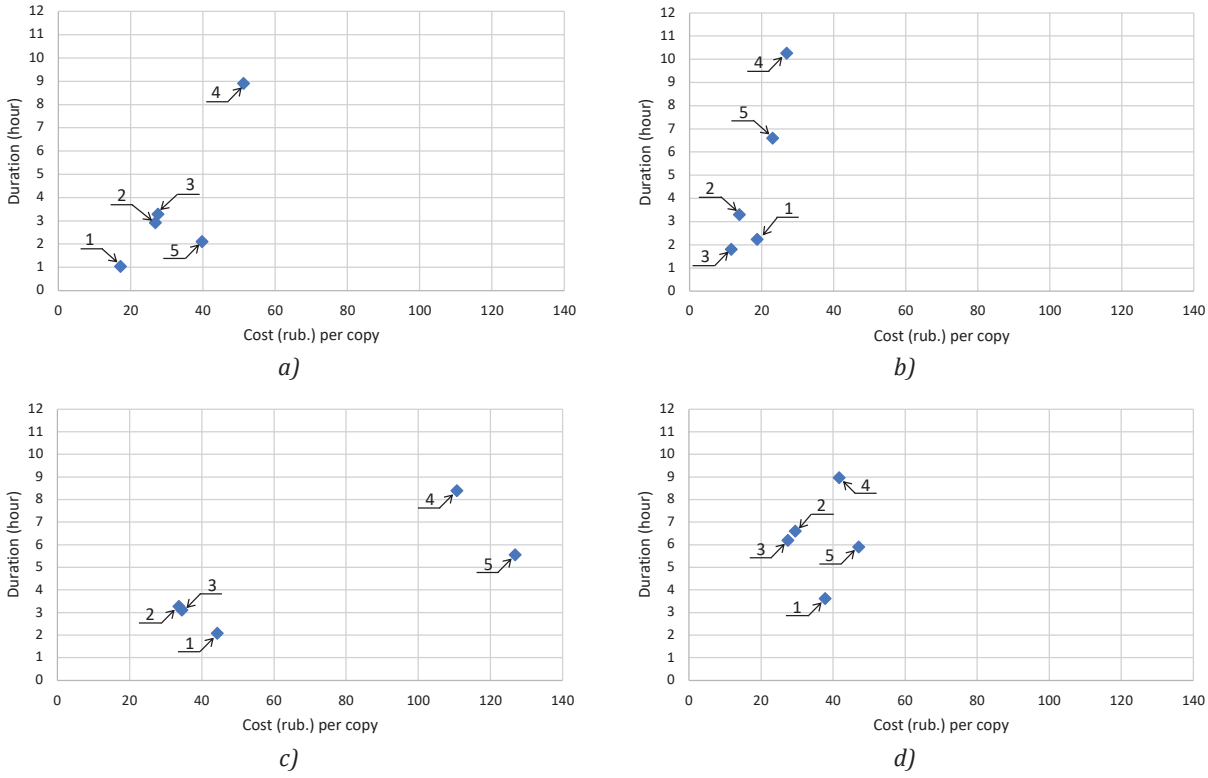

Figure 1: Two-dimensional criteria space and a Pareto set for 1+1 inking for 200 copies (a), and 500 copies (b); and for 4+4 inking for 200 copies (c), and 500 copies (d), respectively

So, the research and calculations to compare the economic feasibility of the printing technologies under consideration for larger print runs with 1+1 inking scheme are carried here using the proposed method as an example of exploring the existing scientific principles for solving complex problems where multiple parameters need to be considered. The proposed method can be also used for the effectiveness comparing of the other printing technologies, for example, flexography vs. gravure printing.

Evaluation of alternative printing methods (alternatives in general) is carried out according to the so-called "risk matrix". To consider the choice of the best alternative on the base of Savage's criterion (Nogin, 2005) we build a table of values (Table 3) and find acceptable solutions, as well as determine the values that are optimal according to Pareto (Lotov, Bushenkov and Kamenev, 2004). Two-dimensional criteria space in size according to the number of criteria and individual alternatives is presented in Figure 1.

4. Discussion

Let's choose the Pareto set by a pairwise comparison of alternatives according to all criteria.

According to criteria of "cost" and "time" the alternative 1 is optimal from alternatives 1 and 2 (Figure 1a, Figure 1b) at 1+1 inking scheme. Then alternative 2 is excluded from consideration due to the higher costs and time. Comparison of alternatives 2 and 3 shows, in turn, that the latter one is more preferable according to the same set of criteria, which excludes the alternative 2 from consideration.

Further comparison of alternatives 3 and 4 reveals that the first of them is more preferable according to the "cost" criterion, while the other (4) prevails in relation of spent "time".

Therefore, none of these alternatives is excluded from consideration. At the same time, the preference of alternative 4 over 5 is vivid according to the both criteria.

So, only the options 1, 3, and 4 comprise the Pareto set for the "decision maker" choice.

The Pareto set of alternatives shown in Figures 1a, 1b, and in Figures 1c, 1d includes the most optimal alternatives for choosing the way of printing among the concerned typical nomenclature of "digital / offset lithographic processes" presses.

As a result, the following options are included in the Pareto set:

- the alternatives 1, 2, 3 for 200 copies and 1, 3, 4 for 500 copies at 1+1 inking scheme;
- the alternatives 1, 2, 3 for the both job volumes of 200 and 500 copies at 4+4 inking scheme.

The choice of the best option from the proposed ones remains with the "decision maker".

5. Conclusions

Task of choosing the optimal way to print a publication according to the "cost – time" criteria at a standard quality level is solved with taking into account the results of comparative calculations based on parameters of 10 digital and offset lithographic processes presses.

Diagrams characterizing the two-dimensional criteria spaces and the Pareto set for printing at 1+1 and 4+4 inking of 200 copies and 500 copies have been built on the basis of calculated data. Among all possible options, the one that was optimal according to Pareto was chosen. The best alternatives were chosen, also guided by Savage's criterion.

The proposed solution of the multi-criteria optimization problem can be used by print house managers to develop the optimal version for the way of production with taking into account the customer demands.

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The impact of digital transformation adoption towards broadcasting industry in Sri Lanka

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Abstract

Sri Lanka's media landscape follows the global broadcasting industry's popularity. Digitalization has had the greatest impact on the sector and all its usage scenarios. Therefore, the primary goal of this study is to ascertain how Sri Lanka's broadcast business would be impacted by the digital revolution. This study seeks to uncover the factors that influence the media industry's transition to a digital model and determine how much viewers, broadcasters, content providers, and infrastructure in Sri Lanka depend on public digital media use. A standardized questionnaire has been administered to reach the goal. From a sample of 1174 respondents in the Western Province, information about the nine research constructs was gathered using previously validated instruments SmartPLS 3 and the SPSS 26 that were used to systematically assure the empirical validation of the theoretical model. The conceptual framework did not match the research's real-world reality. Digital broadcasts and digital literacy affect broadcasters' digital uptake. User device availability, price, and perceived ease of use mediate the intention to use a digital device. Perceived usefulness partially mediates broadcast user digital adoption. Age and gender moderating variables, produced from solid empirical findings and fully excluded from the study, established a new field of study for the literature. The findings also omit the independent policy on digitalization variable. Hence, the study showed that its survey results had a considerable impact on the conceptual model compared to past empirical investigations, and most importantly, it opened up a new field of knowledge for future research. Lastly, the study's findings were discussed and recommendations are provided. Sri Lanka's media industry's digital transformation will benefit from applying the research's findings. The proper application of the research's conclusions will improve the sector by bringing about several advantages for Sri Lanka's media industry's digital transformation.

Keywords: broadcast, digital adoption, digitalization, digital literacy, digital transformation

1. Introduction and background

The landscape of the audio-visual market has been drastically changing over the last thirty years (Medina, Herrero and Etayo, 2015). Digitalization has far reached impact to broadcasting industry and it has been tending to cease the common experience and shared the activity as an individual experience (Chalaby and Segell, 1999).

Dominick (2009) says "*Hoping to capitalize and utilize the public's increasing awareness of high-definition television (HDTV) the radio industry is introducing high-definition (HD) radio, a digital service that generally improves the signal quality of terrestrial radio stations broadcast.*"

It is observed that digital media consumption has exponentially increased in the world and digital video viewer count has doubled during the last five years to 1.3 million and 66 % use the smartphone as connecting device (Tiwary and Shloma, 2019). Even though digital has gained a share of consumer time spent, it hasn't substituted traditional media but total media exposure time has increased substantially over the period (Ganesh, 2018). Oliver Botti, as summarized by Davies (2019), pointed out two areas where linear TV is currently and will continue to thrive, that is live sports and reality TV programming. Some of the traditional broadcaster experiences cannot replicate in an on-demand environment and thus will continue to be relevant for traditional broadcasters and liner programming (Davies, 2019).

The Deloitte Report (Boehm, et al., 2018) about the future of the TV and video landscape by 2030 has mentioned a few key parameters that are impacting digital transformation, as an influence of ageing viewership, the number of content producers, the digital capability of the general public, diversification of players in TV / video market, and transmission / frequency. Further, Clara (2022) predicted the coexistence of traditional TV with non-linear content offerings in the year 2030 as well.

1.1 The current situation of the study

Odun and Utulu (2016) claim that despite the widespread use of digital media, there are still several barriers preventing its usage by all segments of society. These barriers include poor internet connectivity, power outages, the inability to maintain digital equipment, and low money.

In 1923, radio service was launched in Sri Lanka, while television service followed in 1979 (Ransirilal, 2016). Sri Lanka was the first country in south Asia to begin broadcasting. In Sri Lanka, 80 % of people who watch television and 75.4 % of people who listen to the radio do so (Ransirilal, 2016). People began utilizing the internet when it was introduced to Sri Lanka in 1992 (Induruwa, 2017), and by January 2020, 10.10 million people were using it (Kemp, 2020) on both mobile and fixed devices. In addition to being heavily used, the internet has emerged as one of the primary media used for information sharing among other things.

As the internet expands, a technology known as "Media Convergence" is developed to enable the joining of many communication platforms from disparate groups into a single entity. This technology serves as a "tool" to support the operation of technological progress (Chalaby, 2016; Chinmi and Marta, 2020).

Nearly all Sri Lankan broadcast stations have at least one social media platform to engage with their viewers, according to Statcounter (2023). Nonetheless, radio and television still account for the majority of analog transmission reception in Sri Lanka, with 100 % and 76 %, respectively (Statista, 2014). There are 53 analog FM radio channels and 21 analog television broadcast channels included. However, just 50 % of television broadcasters and 65 % of radio broadcasters use at least one digital medium to connect with their audience. As a result, it shows that, in contrast to the rest of the world, Sri Lanka still does not place a high priority on using digital platforms to connect with its audience.

The goal of this research is to examine how audiences perceive the digital revolution of the broadcasting business and to pinpoint the factors that influence how people utilize digital media.

This type of study has not been done in Sri Lanka when refereeing the public archive of the government document repository and internet enabled journals. Hence, this study will carry a considerable amount of heavy weightage to the academia to start a similar kind of study for future researchers. This study will be used in academia to assess the elements that have an impact on the broadcast business and to provide broadcast government authorities with supporting data and facts to set up a plan for digital transformation.

1.2 Problem statement

According to Datareportal (2023), 5.18 billion people were active internet users encompassing 64.6 % of the global population. Hence, more than half of the population has the connectivity to use digital media.

Even though Asia is listed as having the highest number of online users with 2.3 billion on count population it has the lowest percentage of online media use at 29 % (Kameke, 2023). This derives the requirement of existence of the traditional media to cater the gap of 71 % who do not have access to digital media. Gunawardene (2015) states that about 30 % of Sri Lankan television households now subscribed to foreign pay television content on digital platforms but there are 70 % of the population still using traditional media as their main source of information. Hence, almost two third of the population still use traditional media, which prevents them to have the features of digital media including on-demand features, high-quality video and audio, interactivity, and the ability to use multiple devices (Serrano-Puche, 2017).

Despite having many advantages of the use of digital media, and a high level of internet penetration in Sri Lanka of 52.6 % (Kemp, 2022), the adaptation of digital media is not as per expectation.

In Sri Lankan radio bouquet, all the radio channels and 84 % of television channels are analog, which depicts the problem of not having sufficient broadcast to receive by public. Sri Lanka does not have free view digital television service and digital pay TV is having 30 USD initial connection fee and a 5 USD minimum monthly fee (Dialog TV, 2020). Thus, it is difficult to afford the digital service by the majority of the audience, which is derived from high switching costs and the monthly recurrent fee.

According to Kemp (2022), Sri Lanka has a 35.9 % flat TV penetration in the market, which depicts that 64.1 % do not have digital reception enable device.

Hence, unavailability of the sufficient device for reception of digital TV also makes barriers to digital transformation.

According to LIRNEasia (2020), Sri Lanka has poor digital awareness and 61 % of non-internet users do not know what the internet is. Hence, lack of awareness of digital broadcasting and its service could impact to slow down the digital transformation in Sri Lanka's broadcasting industry.

According to ITU (2012), Sri Lanka had started to define the policy to migrate analog TV using DVB-T technology. But in 2014, local authorities signed an agreement with Japan International Cooperation Agency (JICA) to start digital transmission using ISDB-T technology by aiming to complete the digital transition and analog switch-off by 2018 (JICA, 2014).

Even though Sri Lanka has launched the national digital policy for 2020–2025 by the media and information ministry (MDIIT, 2019) it does not mention a plan for broadcast digital transformation. Hence, there are neither roadmap nor guidelines in Sri Lanka, which have been imposed by local authorities to be followed by the broadcasting industry. This has led to arising uncertainty in the broadcasting industry in digital transformation.

Thus, there is a requirement to study the people's perception of traditional vs digital media, factors affecting the use of digital media and identify the drivers and barriers to consuming digital media in the Sri Lankan context.

1.3 Research objective

The main objective of this research is to determine the impact of digital transformation on the broadcast industry in Sri Lanka.

Specific objectives are:

1. To examine whether Sri Lanka has adequate digital broadcast services to cater to audience demand.
2. To analyze the switching cost and operational cost for the audience and whether they can be accommodated by the public.
3. To analyze the audience's awareness of digital usage.
4. To analyze the market readiness for user terminals to consume digital services.
5. To study the available digitalization policies in Sri Lanka and impact on the industry.

2. Methods

The study is focused on analyzing the audience's behavior and intention using the quantitative analysis of the public. Since Sri Lanka had 5.1 million households in 2020 (von Kameke, 2017), it is required to have 384 samples (Krejcie and Morgan, 1970) using a simple random method to conduct the survey. The general response rate of the field questionnaire is 84.4 % (Campisi, et al., 2020), from which is derived that the total questionnaire shall be 455. Since the research was going to be carried out in three districts including Colombo, Gampaha, and Kandy the corresponding total sample was 1365.

It was hypothesized that digital broadcast availability (DBA), digital literacy (DL), and policy on digitalization (PoD) have a direct relationship with user digital adoption (UDigAd). Further, user device availability (UDA), affordability (AFO), perceived usefulness (USE), and perceived ease of use (EOU) mediate the intention to use the digital device (ItU). Age and gender moderate the independent and mediating variables.

This study has been limited to the television broadcast reception audience in Sri Lanka. Those who do not have a television reception unit were exempted.

The target population was the people who live in Sri Lanka and research has been carried out within the Western Province, which is the 28.2 % total population of the country (Brinkhoff, 2022). This makes possible to extrapolate the result to the whole country as the Western Province is the most populated province, equally urbanized and ethnicity-diversified area.

Since the research has been conducted to gather information mainly using a self-administered questionnaire depicted in Annex 2, it is expected to have basic knowledge of the reading and writing skills of the selected population.

2.1 Theoretical framework

According to Cubukcuoglu (2013), use of technology depends on the wide availability of the technological system. Hence, it is important to have digital broadcast, video, or audio services in Sri Lanka for users to adopt digital service usage.

Affordability is the one of key elements when considering user adaptation to the technology. Usually, there is a rule of thumb explaining that if a particular product price exceeds 5 % of disposable income it will substantially reduce the demand (Galperin, 2012). Digital reception device availability in the market is also one of the key factors that impact the growing digital con-

sumer audience (Stafford Global, 2022). If the customer is equipped with the digital reception enabling device, his switching cost would be minimal when transforming as a digital user.

One of the key barriers to digital transformation is the lack of a clear and coherent digital transformation strategy for the industry (van Dyk and Van Belle, 2019).

Technology acceptance explains the causal relationship between USE and EOU impact to use the technology by the public (Davis, 1989). The perceived usefulness depicts to which extent particular technology is helping to enhance the performance of the job. The EOU indicates to which extent the system is helping to use the technology free from effort. According to Davis (1989), USE and EOU have a direct relationship with the tendency of using the technology and continue to use it.

Unified theory of acceptance and use of technology 2 (UTAUT2) model has indicated social influence has the impact on users of new technologies by consumers (Venkatesh, et al., 2003). This reflects the importance of others' beliefs in society and perceived social status and pressure to use the technological system.

The theoretical model explained in Figure 1 has been derived based on the compilation of facts of the findings in previous studies.

According to UTAUT 2 model age, gender, and experience are impacting the behavioral intention of technology use, which can be considered to act as moderating variables for USE, EOU, social influence, and hedonic motivation.

It requires having at least some level of awareness and/or technology literacy to use the technical system (Obot and Inwang, 2012); without having any literacy customers will not tend to use it.

2.2 Hypotheses

According to Wolverton (2009), the hypothesis is a testable prediction that is expected to occur in different circumstances and having relationship with two or more variables in the study. As per the theoretical framework in Figure 1, there are seven independent variables, one mediating variable, and two moderating variables with dependent variables considered in the study.

There are eight key hypotheses that were developed to achieve the objectives of the research by testing the variables.

H1 There is a relationship between digital broadcast availability in Sri Lanka and broadcast user digital adoption.

H2 There is a relationship between digital literacy and broadcast user digital adoption.

H3 There is a relationship between govern policy on digitalization and broadcast user digital adoption.

H4 There is a relationship between end-user terminal availability in the market and the intention to use the digital device.

H5 There is a relationship between the affordability of the device and the intention to use the digital devices.

H6 There is a relationship between perceived usefulness and intention to use the digital devices.

H7 There is a relationship between perceived ease of use and intention to use of the digital devices.

H8 Age moderates the relationship between perceived usefulness and intention to use the digital devices.

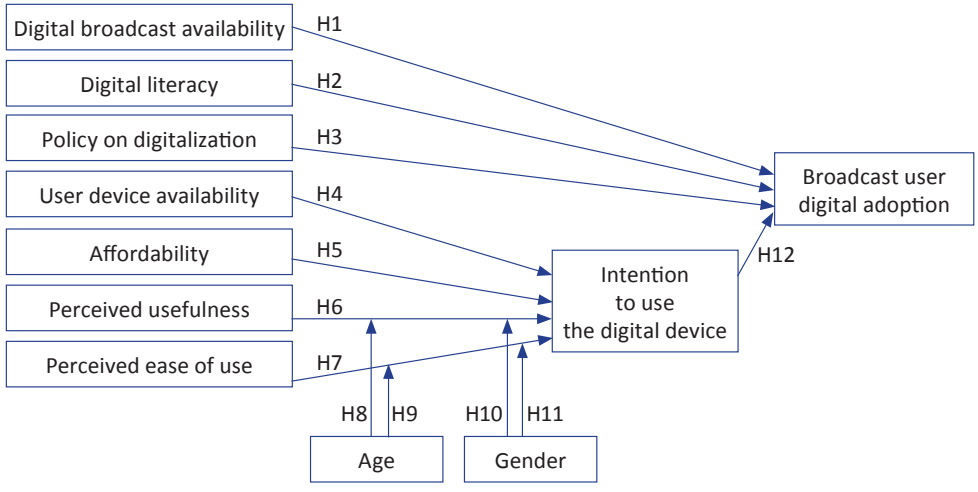

Figure 1: Theoretical model for analyzing impact of digital transformation in broadcast industry

H9 Age moderates the relationship between perceived ease of use and intention to use the digital devices.

H10 Gender moderates the relationship between perceived usefulness and intention to use the digital device.

H11 Gender moderates the relationship between perceived ease of use and intention to use the digital devices.

H12 There is a relationship between intention to use the digital device and broadcast user digital adoption.

2.3 Sampling and sampling procedures

Table 1: Registered voters of the Western Province in Sri Lanka in 2021 (Election Commission of Sri Lanka, 2023)

District	Population
Colombo	1 709 209
Gampaha	1 785 964
Kaluthara	972 319

As per Table 1 there were 4 467 492 people considered as the population of the research. According to Krejcie and Morgan (1970), and Anon (1960), the sample size of 384 was selected to carry out the research with a confidence level of 95 % and a margin of error of 5 %.

The field study included questionnaire method to obtain data from a selected sample of the population and use a numerical questionnaire with nominal, ordinal, and ratio scales including the Likert scale as well to obtain the answers. The questionnaire has been designed such a way that expected analysis could be gathered using responded data fields. The questionnaire for the study has been divided into three parts described below.

Section 1: Participant's demography factors.

Section 2: TV, radio and social media usage behavior of the participant.

Section 3: Participant's expectation related to broadcast digitalization and its use cases.

2.4 Data analysis

Primary and secondary data have been used for the analysis. Primary data were collected from the main survey using sample selection from the districts of Colombo, Gampaha, and Kaluthara. The researcher distributed hard copies of questionnaires in English, Sinhala, and Tamil language from simple random sampling selection according to the proportionate ethnicity. Secondary data was collected from telecommunication regulation commission (TRC) research data and publications, broadcaster publications, magazines, journals, books, and previous research.

All collected data from primary research have been coded before proceeding with the analysis. Non-scaling variables such as gender and education were coded using numerical values. The remaining Likert scale variables have been mapped from 1 to 5 levels for analysis. All the data taht have been coded were fed to the statistical package for social science – SPSS version 26 for analysis. Once data have been filtered for multivariate outliers, it has been tested for normality. The normality check can be done on the 1174 responses on the questionnaire (degree of freedom) using Kolmogorov-Smirnov test (Kirkman, 1996).

Table 2: Test of normality for degree of freedom of 1174

Variable	Kolmogorov-Smirnov Statistic	Shapiro-Wilk Statistic
DBA	0.137	0.923
DL	0.146	0.909
PoD	0.175	0.931
UDA	0.135	0.930
AFO	0.123	0.949
USE	0.155	0.932
EOU	0.177	0.906
ItU	0.097	0.956
UDigAd	0.122	0.926

The significance value of Kolmogorov-Simirnov was 0.000, less than 0.05, which means the null hypothesis is rejected and the data are not normally distributed. Further Shapiro-Wilk test also accrued out to test the normality of response. According to Dahiru (2008), since the *p*-value of the test is less than 0.05, then the null hypothesis is rejected at 5 % significance and the conclusion is non-normality of the data.

According to Hair Jr, et al. (2014), since the data are non-normal based on the analysis, it is decided to use the PLS-SEM analysis technique. Thus SmartPLS 3 statistical software was used to do the measurement model and structural model assessments.

2.5 Data screening

The research was conducted purely using physical interaction with a hardcopy questionnaire. Hence, all the answered questions were observed to check whether all the questions have been accessed by the responder. Those questions have been manually entered by the researcher and double-checked by a third party to maintain the highest level of accuracy. All the entries were verified item by item and descriptive statistics have been run to check the normality.

3. Results

3.1 Sample characteristics

The questionnaire has been distributed to 1365 samples among the population in the Western Province. Out of the circulated hard copies of the questionnaire sheets, 1225 have been responded to. After the data cleansing process, 1174 responses have been considered for the data analysis (Table 3).

Table 3: Demographic characteristics of the respondents

Characteristic	Variable	Number	%
Gender	Male	704	59.97
	Female	470	40.03
Age	18–30	347	29.56
	31–40	451	38.42
	41–60	318	27.09
	Above 60	58	4.94
Language	Sinhala	850	72.40
	Tamil	267	22.74
	English	57	4.86
Education	GCE O/L	258	21.98
	GCE A/L	592	50.43
	Diploma	144	12.27
	Graduate	154	13.12
	Postgraduate	26	2.21
Employment	Business	121	10.31
	Professionals	73	6.22
	Government employee	295	25.13
	Private employee	407	34.67
	Student	160	13.63
	Other	118	10.05
Family income (Sri Lankan Rupees)	less than 50 000	305	25.98
	50 001 to 100 000	552	47.02
	100 001 to 300 000	202	17.21
	300 001 above	115	9.80
District	Colombo	391	33.30
	Kaluthara	395	33.65
	Gampaha	388	33.05

The sample responses were received mainly from the males, which are about 59 % of the responses, hence, answers could be considered slightly to bias to the male response. The highest age category mentioned as over 60 and received a 5 % response from that group. However, the majority of responses came from the age group between years 31 to 40 stated as 38.4 %.

With regards to the language, 72.2 % responded in Sinhala, 22.7 % in Tamil, and 5 % in English. Sri Lanka consists of 74.9 % Sinhalese, 24.6 % Tamil, Muslims, and 0.5 % others, which reflects the sample shows approximately the same results (Nortwestern University, 2018).

Regarding the education level, most of the responses are from advanced-level qualified persons comprising 50.4 %, and the lowest response is from post-graduate qualifications at 2.2 %. Regarding the employment level of the sample, the majority is 34.7 % from the private sector, 25.1 % from the government and 13 % from students. However, all the respondents have good language literacy since the entire sample could fill out the questionnaire without external guidance.

The questionnaire has included the geographic area the respondent lives in and it has been observed approximately 33 % of responses from each area, which will help to have an unbiased response.

3.2 Dimensions of the variables

The quality of the latent variables in the study was assessed based on the evaluation of results of the measurement model. The assessment of the quality of the criteria starts from the factor loading test and thereafter constructs reliability and validity. According to Hair Jr, et al. (2017), measurement models need to be tested for item reliability, composite reliability, discriminant, and convergence validity. Further, reflective and formative constructs require different procedures; they were analyzed separately.

3.3 Exploratory factor analysis

Indicator reliability of reflective factors construct can be tested using factor loading in SmartPLS (Hair Jr, et al., 2017). The convergence validity of the model construct was assessed using three criteria. According to the Fornell and Larcker (1981), construct and items factor value should be greater than 0.7. Second, the composite reliability of each latent variable should be equal or above 0.70. Thirdly, according to Fornell and Larcker (1981), the average variance extracted (AVE) for each construct should be greater than 0.50.

According to Hair Jr, et al. (2017), items scoring between 0.4 and 0.7 should be removed from the list if they negatively affect the AVE of their construct. In the initial stage with all the factor loadings, three items had factor loading less than 0.7, which are from constructs of UDA, ItU, and UDigAd. Those constructs negatively impacted their AVE and after removing single items that were less than 0.7 in each construct, AVE values have been improved to greater than 0.5.

The convergent validity of the scale items was assessed using three criteria. Cronbach's alpha of each construct should be more than 0.7 (Nunnally and Bernstein, 1994; Hair, 2010). All the constructs must exceed the composite reliability (CR) value of 0.7. Furthermore, Dijkstra and Henseler (2015) have introduced the Rho_A coef-

Table 4: Fornell-Larcker Criterion

	AFO	DBA	DL	ItU	EOU	USE	PoD	UDA	UDigAd
AFO	0.713								
DBA	0.528	0.708							
DL	0.470	0.685	0.763						
ItU	0.628	0.596	0.561	0.724					
EOU	0.518	0.546	0.572	0.724	0.811				
USE	0.602	0.570	0.576	0.748	0.737	0.807			
PoD	0.349	0.344	0.483	0.416	0.431	0.424	0.751		
UDA	0.475	0.467	0.523	0.519	0.533	0.498	0.482	0.719	
UDigAd	0.587	0.668	0.656	0.750	0.694	0.722	0.433	0.552	0.714

ficient, which is related to the quality of the construct. It is necessary to maintain a Rho_A value greater than 0.7. The Cronbach's alpha value of all the constructs are greater than 0.7 and also composite reliability values exceed 0.7. Further, Rho_A value of all the constructs has exceeded 0.7. Therefore, it has been exhibited that the internal consistency of the analytical data set is at an acceptable level.

According to Fornell and Larcker (1981), it has been stated that AVE and CR require to check on convergent validity. The AVE represents the extent to which a construct can explain the variance of its items and how much of the variance can be attributed to the measurement error (Esposito Vinzi, et al., 2010). To have high convergent validity, the average variance extracted value shall be greater than 0.5 and composite reliability shall be greater than 0.7. According to Table 4, it has been implied that AVE and CR value is in expected range, which was the case for all the constructs, and overall results will portrait the high convergent validity of the constructs.

The discriminant validity specifies to which extent a given construct is different from the other constructs in the model. Discriminant validity assessment has been performed by comparing the correlations among the construct with the square root of AVE (Fornell and Larcker, 1981), cross loading and heterotrait–monotrait (HTMT) ratio of correlations. According to Hair, et al. (2019), indicator cross loading shall be greater than 0.7 or should be the highest value among all other non-related constructs. As per Annex 1, all the related constructs have the highest cross-loading factors in each indicator. To satisfy the Fornell-Larcker criterion, the correlation of the square root of each construct, AVE needs to be lower than the related constructs. According to Table 4, this was the case for all constructs except ItU, thus their discriminant validity according to the Fornell-Larcker criterion can be claimed (Hair Jr, et al., 2017).

However, Henseler, Ringle and Sarstedt (2015), have claimed that neither the Fornell-Larcker criterion nor the evaluation of the cross-loadings completely explained the discriminant validity problems. Hence, HTMT was used as an alternative measurement for discriminant validity (Henseler, Ringle and Sarstedt, 2015).

Since the ItU had some issue in Fornell-Larker creations, heterotrait-monotrait ratio has been considered to the analysis.

3.4 Structural equation modelling

The structural model evaluates the relationship among all the variables. Multicollinearity is the main factor, which uses checking the correlation between constructs (Hair, 2010). The structural model can be checked for multicollinearity problems by examining the variance inflation factor (VIF) values of all predictor variables. According to Hair, Ringle and Sarstedt (2011), a maximum threshold 5 or lower is required to avoid the issue of collinearity.

Table 5: The variance inflation factor values

Variable	**USE**	**UDigAd**
AFO	1.734	
EOU	2.422	
USE	2.738	
UDA	1.525	
PoD	0.546	1.363
DBA	0.570	2.154
DL	0.344	2.239
ItU	0.668	1.738

As depicted in Table 5 all values of the VIF are below the restrictive cut-off value of 3.3 (Petter, Straub and Rai, 2007). Hence, above statement concludes that each exogenous variable is independent of each other and every exogenous variable have a unique piece of information about an endogenous variable.

To test hypothesis for significance, bootstrapping procedure is performed using two-tailed *t*-distribution (Hair, 2010). The bootstrapping was run using 5 000 subsample iterations. According to 95 % confidence interval testing, value shall not pass the zero (Richter,

et al., 2015). According to the analysis results, neither of 95 % confidence intervals includes zero as zero does not fall in any of the path confidence interval. A two-tailed test was computed for *t*- and *p*-values to test the significance of the path coefficient at a significance level of 1 %. The *t*-value shall be above 1.96 and the *p*-value shall be less than 0.05. Results yield *t*-value above 2.22 and *p*-value below 0.026, which indicates that there exists a significant relationship between all paths of the connected constructs.

The structural model was tested for the significance of the direct relationships between independent and dependent variables (Dürrbaum and Sattler, 2019; Wamba, et al., 2017). This has been done by examining the path coefficients between the constructs and the values for the path coefficients are usually between –1 and +1, indicating a strongly negative and strongly positive relationship between the variables. Values close to 0 present a weak relationship. In the analysis, all the relationship between construct displays the positive significant relationship. Further, ItU (0.478) was indicated as the most influencing factor followed by USE (0.344) and EOU (0.316).

As per Cohen (1988), effect size *f*-square (f^2) indicates how much exogenous latent variable contributes to the endogenous latent variable R^2 value. The effective size will assess the overall magnitude and strength of the relationship between the latent variables, which helps to gauge on overall contribution to research study (Table 6).

Table 6: The f-square values

Variable	ItU	UDigAd
AFO	0.074	
DBA		0.067
DL		0.060
ItU		0.395
EOU	0.116	
USE	0.146	
PoD		0.007
UDA	0.010	

The rule of thumb of f^2 value is that between 0.02 to 0.15 it is small, 0.15 to 0.35 is medium and 0.35 and above shows a large effect (Cohen, 1988; Hair Jr, et al., 2017). According to Table 6, independent constructs such as AFO, EOU, USE have weak relationship with ItU and DBA and DL with UDigAd. However, ItU has strong relationship with UDigAd. Furthermore, PoD and UDA almost do not have relationship with exogenous latent variables as both values are less than 0.05.

The assessment of the goodness of fit *R*-square (R^2) indicates the strength of the structural model is fitted based on derived factors. This R^2 coefficient represents the collective effect of all exogenous latent variables on the endogenous latent variable. Hair, Ringle and Sarstedt (2011) explained the values of 0.75, 0.50, and 0.25 for endogenous latent variables, which are referred to as substantial, moderate, and weak prediction power, respectively.

Table 7: The R-square values

Variable	R^2	R^2 adjusted
UDigAd	0.668	0.667
ItU	0.666	0.665

The results in Table 7 show R^2 value of 0.668 for UDigAd and 0.666 for ItU.

Predictive relevance of a model can be measured by the *Q*-square (Q^2) value (Stone, 1974; Geisser, 1974). The effect size Q^2 allows assessing an exogenous construct's contribution to the endogenous latent variable's Q^2. As a relative measure of predictive relevance, Q^2 value of 0.02 to 0.15 indicates small, 0.15 to 0.35 medium and above 0.35 large predictive relevance for endogenous construct (Hair, et al., 2018).

Table 8: The Q-square values

Variable	SSO	SSE	$Q^2 = 1 - SSE/SSO$
Broadcast user digital adoption	16436	10925	0.335
ItU	8218	5413	0.341

According to Table 8, the values depict that the research model has medium prediction power for the endogenous constructs. Hence, the path model can be considered as goodness of prediction value has medium strength.

3.4.1 Mediating relationships

The mediation effect was analysed by following the guidelines provided by Hair Jr, et al. (2017), and few of the research studies conducted using SmartPLS (Berghman, et al., 2013; Wamba, et al., 2017). The mediation analysis is done based on the path coefficients and standard errors of the direct path relationships between the independent and the mediating variable, and the mediating and the dependent variable (Wamba, et al., 2017).

Table 9 depict the figures derived from SmartPLS for mediating analysis. These show that AFO, EOU and UDA do not have direct relationship with dependent variable UDigAd as *p*-value is greater than 0.05 (Hair, 2010). However, USE has a direct relationship with dependent variable UDigAd.

According to Table 10, all four indirect construct variables are significant since neither 95 % confidence interval includes zero. Further, *t*-values and *p*-values are consecutively above 1.96 and below 0.05, which emphasizes the significance further. When considering direct effect, it has been observed that AFO → UDigAd, EOU → UDigAd and UDA → UDigAd relationships *p*-value greater than 0.05, which deprives the significance of the paths. However, AFO → ItU, EOU → UDigAd and UDA → ItU path *p*-values, *t*-values and 95 % confidence intervals did not cross the zero, which indicates their significance in mediating. Hence, AFO, EOU and UDA constructs relationships are fully mediated by ItU.

Further, USE → UDigAd path maintains *p*-value less than 0.05, *t*-value greater than 1.96 and standard coefficient of 95 % confidence interval without crossing the zero. Therefor, USE → UDigAd relationship is partially mediated by the ItU construct. Since both direct and indirect effects are in the same direction, respective relationships can be considered complementary for mediation situation (Hair, et al., 2018).

3.4.2 Moderating effects

According to Hair Jr, et al. (2017), moderation analysis can be done using SmartPls. Since the proposed moderating variables are categorical variables, initially had to be created dummy variables for gender and age categories. In order to test for the significance of the moderation, the bootstrapping procedure with 5 000 iterations and no sign changes was applied (Hair Jr, et al., 2017).

Table 9: Mediation analysis

	Without direct path to IV to DV avoiding MV						**With direct path to IV to DV**					
Relationship	Orig.	2.50 %	97.50 %	*t*-value	*p*-value	Sig.	Orig.	2.50 %	97.50 %	*t*-value	*p*-value	Sig.
AFO → UDigAd							0.049	−0.011	0.107	1.604	0.1090	Yes
AFO → ItU	0.222	0.167	0.275	7.986	0.000	Yes	0.222	0.169	0.277	7.959	0.0000	Yes
DBA → UDigAd	0.219	0.155	0.285	6.658	0.000	Yes	0.175	0.109	0.240	5.248	0.0000	Yes
DL → UDA	0.211	0.148	0.273	6.535	0.000	Yes	0.148	0.083	0.213	4.440	0.0000	Yes
ItU → UDA	0.478	0.406	0.544	13.578	0.000	Yes	0.272	0.196	0.347	6.966	0.0000	Yes
EOU → UDigAd							0.119	0.039	0.207	2.793	0.0500	No
EOU → ItU	0.316	0.247	0.390	8.691	0.000	Yes	0.315	0.242	0.385	8.568	0.0000	Yes
USE → UDA							0.177	0.092	0.255	4.188	0.0000	Yes
USE → ItU	0.344	0.276	0.417	9.560	0.000	Yes	0.344	0.273	0.418	9.178	0.0000	Yes
PoD → UDigAd	0.057	0.006	0.105	2.222	0.026	Yes	0.011	0.037	0.061	0.423	0.6730	No
UDA → UDigAd							0.072	0.003	0.147	1.942	0.0520	No
UDA → ItU	0.074	0.017	0.129	2.640	0.008	Yes	0.074	0.022	0.130	2.649	0.0080	Yes

Table 10: Direct and indirect effect analysis of the mediating construct

	Direct effect					**Indirect effect**					
Relationship	Orig.	2.50 %	97.50 %	*t*-value	*p*-value	Orig.	2.50 %	97.50 %	*t*-value	*p*-value	Type of mediation
AFO → UDigAd	0.049	−0.011	0.107	1.604	0.1090	0.222	0.169	0.277	7.959	0.0000	Fully
EOU → UDigAd	0.119	0.039	0.207	2.793	0.0500	0.315	0.242	0.385	8.568	0.0000	Fully
USE → UDigAd	0.177	0.092	0.255	4.188	0.0000	0.344	0.273	0.418	9.178	0.0000	Partially
UDA → UDigAd	0.072	0.003	0.147	1.942	0.0520	0.074	0.022	0.130	2.649	0.0080	Fully

Table 11: Moderating effect of gender construct

	Original	Sample mean	Standard deviation	2.50 %	97.50 %	*T*-stat.	*p*-value
Gender (M) → ItU	0.009	0.008	0.017	−0.025	0.040	0.508	0.611
Moderating effect of gender to EOU → ItU	−0.011	−0.001	0.035	−0.069	0.066	0.020	0.984
Moderating effect of gender to USE → ItU	−0.010	−0.009	0.034	−0.076	0.058	0.289	0.773

Table 12: Moderating effect of age construct

	Original	Sample mean	Standard deviation	2.50 %	97.50 %	*T*-stat.	*p*-value
Age → ItU	0.023	0.025	0.019	−0.012	0.063	1.184	0.236
Moderating effect of age to EOU → ItU	0.034	0.032	0.045	−0.056	0.119	0.759	0.448
Moderating effect of age to USE → ItU	−0.037	−0.034	0.042	−0.114	0.049	0.889	0.374

Table 13: Summary of the hypotheses testing

#	Hypothesis	Significance	Relationship	Coclusion
H1	There is a relationship between digital broadcast availability in Sri Lanka and broadcast user digital adaption.	Significant	Weak positive	Supported
H2	There is a relationship between digital literacy and broadcast user digital adaption.	Significant	Weak positive	Supported
H3	There is a relationship between govern policy on digitalization and broadcast user digital adaption.	Not significant	Extremely weak positive	Not Supported
H4	There is a relationship between end user terminal availability in the market and intention to use of digital device.	Significant	Extremely weak positive	Supported
H5	There is a relationship between affordability of the user and intention to use of digital device.	Significant	Weak – fully mediating positive	Supported
H6	There is a relationship between perceived usefulness and intention to use of digital device.	Significant	Weak – partially mediating positive	Supported
H7	There is a relationship between perceived ease of use and intention to use of digital device.	Significant	Weak – fully mediating positive	Supported
H8	Age moderate the relationship between perceived usefulness and intention to use of digital device.	Not significant	Moderating	Not Supported
H9	Age moderates the relationship between perceived ease of use and intention to use of digital device.	Not significant	Moderating	Not Supported
H10	Gender moderates the relationship between perceived usefulness and intention to use of digital device.	Not significant	Moderating	Not Supported
H11	Gender moderates the relationship between perceived ease of use and intention to use of digital device.	Not significant	Moderating	Not Supported
H12	There is a relationship between intention to use of digital device and broadcast user digital adoption.	Significant	Strong positive	Supported

The SmartPLS algorithm was used to test the moderating effect of age between EOU → ItU and USE → ItU relationship.

According to Table 11, confidence intervals of all the moderating structural variable paths cross the zero value. Thus, gender to ItU, EOU to ItU and USE to ItU do not satisfy the significance requirement. Further, *p*-values are also greater than 0.05, which confirms the non-significance of the gender variable in the proposed structural model.

The second moderating variable of age has been considered in the SmartPLS 3 algorithm to check the moderating effect including path coefficient.

As per Table 12, all the moderating structural variable paths confidence intervals cross the zero value. Thus, age to ItU, EOU to ItU and USE to ItU does not satisfy the significance requirement. Furthermore, *p*-values of each path also greater than 0.05, which depict the non-significance of the age variable in the structural model.

According to the analysis carried out in the chapter, the initial structural model has been changed based on the results derived from SPSS and SmartPLS software.

The UDigAd and DL against BCA relationship in Sri Lanka has been tested and verified using the results from Table 9. Further, UDA, AFO, EOU and USE have mediating relationship with the ItU as per Table 10. The above variables have significant relationship according to assigned hypothesis. However, according to Table 9, the relationship between PoD and UDigAd was insignificant, which tends to remove the exogenous variable from the model. The moderating variables of gender and age have been tested in the structural model and the summarized results in Table 13 depict that none of the relationships are moderated by the latent variables. Hence, seven of the relationships have been accepted according to the derived results and discussions.

3.5 Comparison of the revised model with the initial model

According to De Souzabido and Da Silva (2019), initial structural model can be redrawn considering the facts used based on the accepted and rejected hypotheses. Hence, revised structural model has been included in Figure 2. According to Figure 2, the revised model does not contain the moderating variables and it includes partially mediating variable of ItU, which mediates the relationship of USE and UDigAd. Further, the independent variable of PoD has been removed from the model based on the significance analysis. Moreover, UDA, EOU and AFO fully mediate the relationship to dependent variable of UDigAd via ItU. Final derived model has been depicted in Figure 3.

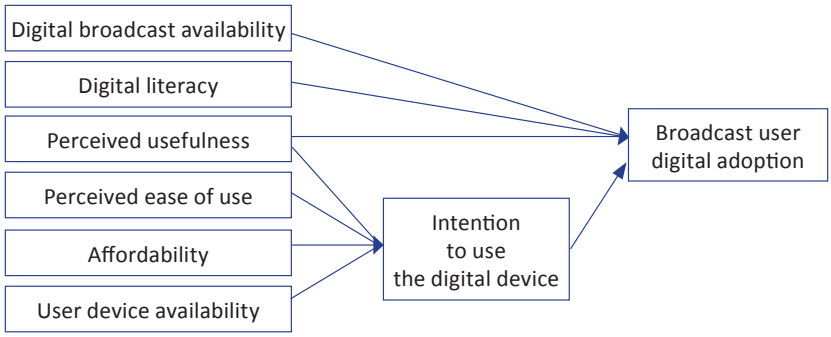

Figure 2: Revised structural model based on the results

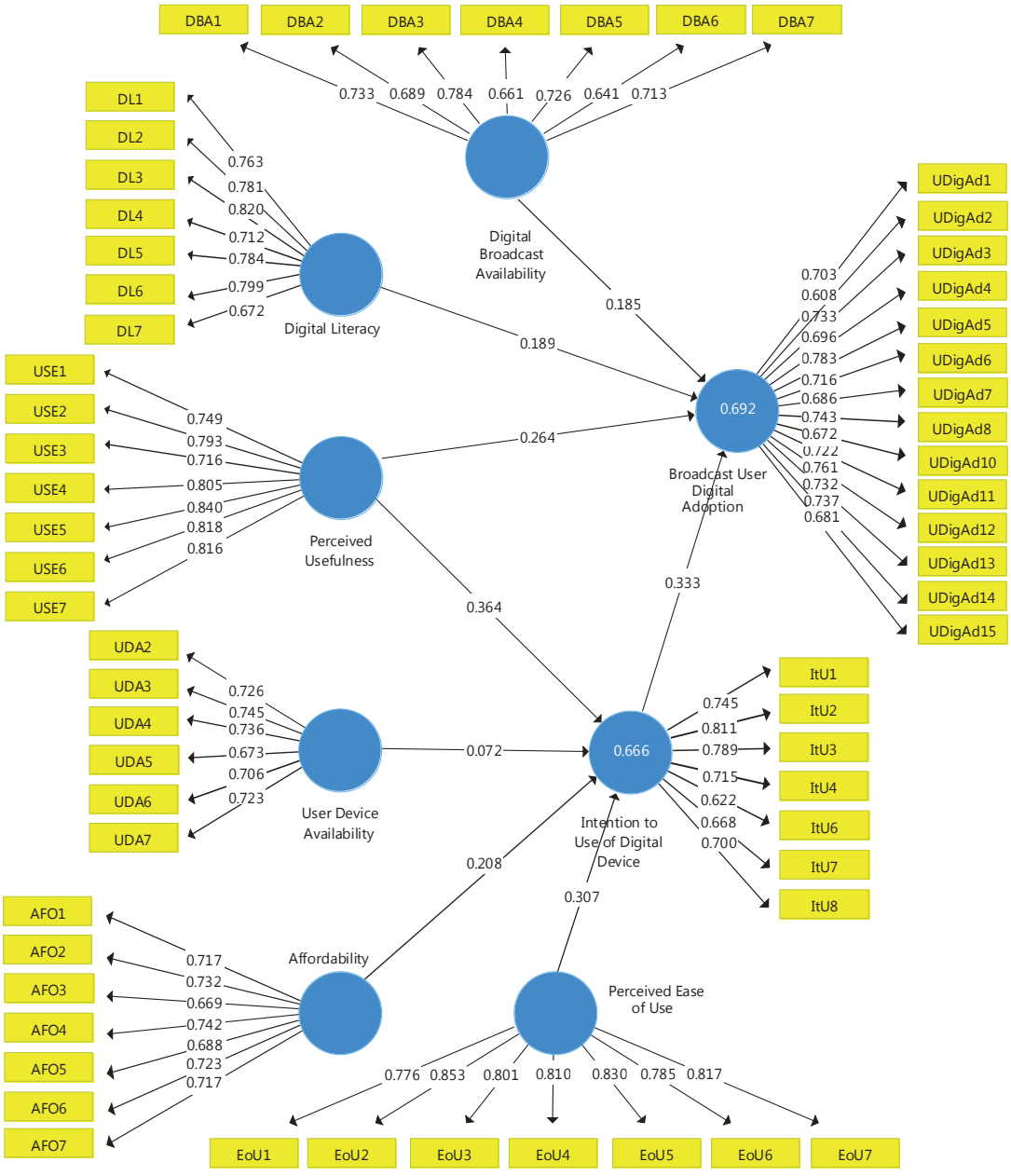

Figure 3: Final model derived from SmartPLS 3

4. Discussion

This research has been carried out with the main objective of determining the impact of digital transformation towards broadcast industry in Sri Lanka. Therefore, research has been conceptualized based on theoretical framework with the facts extracted from literature survey and have derived four specific objectives.

4.1 Objective 1: To examine whether Sri Lanka has adequate digital broadcast services to cater audience demand

The results indicate DBA positively related to UDigAd. Specifically, this study hypothesized that there exists a positive relationship between DBA and UDigAd (H1). The empirical findings support this hypothesis. The relationship between DBA and UdigAd is statistically significant (B = 0.219, p = 0.000). However, f^2 value of the relationship has been considered as weak relationship (0.067). Further, in the importance performance matrix DBA is in below the mean performance level (30.679) and importance (0.219) in above the mean, thus it can be considered an important factor that can increase UdigAd and need attention with highest priority.

4.2 Objective 2: To analyze the switching cost and operational cost for audience and whether they can be accommodated by public

The analysis has been done under the hypothesis of AFO and UdigAd mediated by the ItU (H5). The relationship has been identified as significant (B = 0.222, p-value = 0.000) and positive relationship. Since f^2 value is 0.074, the relationship is weak. Moreover, importance performance matrix has indicated the AFO importance level (0.099) is below the mean and performance level (37.538) is above the mean value. Hence, it is in the category requiring less attention, which indicates that even improvement can be done, the impact to UDigAd will be very low.

4.3 Objective 3: To analyze the audience awareness about digital usage

The audience awareness about digital usage have been evaluated by hypotheses H2, H6, H8, H10, and H12. DL and UDigAd has significant and positive weak relationship. This indicates that DL has impact on UDigAd. Hypothesis 6 results indicate that USE and ItU have significant and partially mediating effect for UDigAd. However, the hypotheses H8 and H10 have been rejected with the indication of age and gender do not have any moderating effect to the relationship between USE and UDigAd. Further, ItU and UdigAd have significant and strong positive relationship.

4.4 Objective 4: To analyze the market readiness for user terminals to consume digital services

The market readiness for digital user terminals to consume digital device have been analyzed by the hypotheses H4, H7, H9 and H11. Hypothesis 4 evaluates the relationship between UDigAd and UDA. Since the results indicate B = 0.074 and p-value = 0.008 it can be concluded that user terminal availability has weak but positive significant relationship. Further, user device availability is below the mean level of importance (0.034) and below the performance (27.17) mean average, which indicates that even though UDA get improved its impact to UdigAd will be very low. The results of H7 evaluation indicate that perceived EOU and ItU have weak but significant positive relationship. However, according to the H9 and H11 results, it has been depicted that age and gender do not moderate the relationship between EOU and UDigAd. According to the results discussed above it has been implied that market readiness of user devices has impact on UDigAd.

4.5 Objective 5: To study the available digitalization policies in Sri Lanka and impact to the industry

According to hypothesis H3, the UDigAd shall be related to PoD. However, it has been tested for significance and it indicates that a higher p-value (0.673) in the relationship depicts the non-significance of the relationship. Hence, it can be concluded that even though the literature showed the relationship between PoD and UDigAd (Dialog TV, 2020), it has not been confirmed in the case of this study, which shows a non-significant relationship. Hence, any policy-making decision will not have high impact to broadcast user digital adoption.

5. Conclusion

Digital broadcast adoption in Sri Lanka is being a topic for the last decade and a process yet to be implemented officially. However, when considering the technological advancement that happened during the last period it has been observed that people have adapted to use of digital broadcast to some extent. But as discussed in chapter 1, the research gap showed that compared to the connectivity device penetration in Sri Lanka taht is about 47 %, still very low margin of about 30 % has been adopted to receive the digital broadcast. Ten factors have been identified as impacting variables to digital broadcast adoption via analysis of the literature review using theoretical models. Among those factors digital broadcast availability, digital literacy, user device availability, affordability, perceived usefulness, perceived ease of use and intention to use of the digital

device have been identified as the influencing attributes. However, policy on digitalization, age, and gender have been identified as non-significant factors according to the analysis results. Thus, it can be concluded that user digital adaptation will not much be impacted policy on digitalization. Hence, users will tend to adopt the digital broadcast regardless of the policy makers decision but based on the incremental advancement of remaining factors. Based on the results, it is of utmost importance to have a clear roadmap in digitalization policy as otherwise user will adopt to get used to different digital broadcast technologies regardless of the intended technology, which is planed by the policy makers.

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Annex 1: Cross loading analysis – Part 1

	AFO	DBA	DL	ItU	EoU	USE	PoD	UDA	UDigAd
AFO1	**0.717**	0.385	0.285	0.447	0.391	0.427	0.156	0.291	0.399
AFO2	**0.732**	0.334	0.264	0.372	0.332	0.342	0.184	0.287	0.358
AFO3	**0.669**	0.281	0.240	0.309	0.251	0.315	0.152	0.239	0.297
AFO4	**0.742**	0.312	0.255	0.400	0.305	0.361	0.212	0.270	0.360
AFO5	**0.688**	0.385	0.369	0.458	0.353	0.438	0.318	0.353	0.456
AFO6	**0.723**	0.435	0.445	0.549	0.485	0.569	0.350	0.440	0.527
AFO7	**0.717**	0.439	0.406	0.508	0.392	0.462	0.293	0.413	0.452
DBA1	0.428	**0.733**	0.462	0.466	0.413	0.427	0.196	0.332	0.462
DBA2	0.402	**0.689**	0.449	0.466	0.358	0.410	0.206	0.331	0.488
DBA3	0.415	**0.784**	0.505	0.470	0.399	0.440	0.225	0.336	0.513
DBA4	0.398	**0.661**	0.415	0.418	0.338	0.342	0.250	0.324	0.435
DBA5	0.361	**0.726**	0.501	0.421	0.392	0.434	0.283	0.323	0.493
DBA6	0.267	**0.641**	0.503	0.300	0.370	0.334	0.249	0.306	0.416
DBA7	0.337	**0.712**	0.557	0.398	0.433	0.424	0.297	0.364	0.492
DL1	0.374	0.600	**0.763**	0.426	0.449	0.462	0.329	0.394	0.531
DL2	0.370	0.587	**0.781**	0.443	0.442	0.437	0.344	0.372	0.540
DL3	0.379	0.553	**0.820**	0.440	0.504	0.473	0.395	0.396	0.546
DL4	0.359	0.456	**0.712**	0.426	0.350	0.430	0.372	0.350	0.445
DL5	0.350	0.488	**0.784**	0.463	0.437	0.452	0.392	0.439	0.469
DL6	0.354	0.492	**0.798**	0.446	0.454	0.466	0.422	0.448	0.498
DL7	0.320	0.458	**0.672**	0.348	0.404	0.350	0.331	0.397	0.461
ItU1	0.493	0.456	0.460	**0.745**	0.606	0.601	0.345	0.392	0.572
ItU2	0.460	0.490	0.425	**0.811**	0.570	0.608	0.300	0.384	0.587
ItU3	0.525	0.504	0.457	**0.789**	0.663	0.646	0.334	0.444	0.615
ItU4	0.418	0.451	0.442	**0.715**	0.596	0.560	0.374	0.456	0.573
ItU6	0.459	0.306	0.247	**0.621**	0.310	0.372	0.180	0.224	0.391
ItU7	0.407	0.367	0.363	**0.668**	0.410	0.454	0.237	0.345	0.503
ItU8	0.422	0.402	0.403	**0.700**	0.419	0.483	0.298	0.338	0.521
EoU1	0.475	0.443	0.449	0.623	**0.776**	0.621	0.339	0.435	0.549
EoU2	0.454	0.439	0.463	0.592	**0.853**	0.640	0.361	0.424	0.586
EoU3	0.370	0.436	0.484	0.538	**0.801**	0.559	0.364	0.430	0.531
EoU4	0.429	0.455	0.438	0.606	**0.810**	0.616	0.353	0.401	0.571
EoU5	0.386	0.415	0.473	0.580	**0.830**	0.612	0.364	0.434	0.538
EoU6	0.401	0.443	0.452	0.561	**0.785**	0.539	0.345	0.452	0.565
EoU7	0.411	0.465	0.489	0.599	**0.817**	0.587	0.320	0.450	0.593
USE2	0.495	0.490	0.483	0.626	0.629	**0.773**	0.348	0.416	0.622
USE3	0.438	0.418	0.460	0.572	0.493	**0.726**	0.366	0.355	0.498
USE4	0.502	0.492	0.458	0.606	0.588	**0.814**	0.272	0.397	0.590
USE5	0.529	0.469	0.438	0.635	0.600	**0.852**	0.332	0.408	0.607
USE6	0.464	0.461	0.484	0.583	0.615	**0.834**	0.364	0.435	0.581
USE7	0.477	0.421	0.466	0.588	0.637	**0.834**	0.372	0.396	0.586

Cross loading analysis – Part 2

	AFO	DBA	DL	ItU	EoU	USE	PoD	UDA	UDigAd
PoD1	0.234	0.215	0.353	0.324	0.359	0.343	**0.633**	0.330	0.317
PoD2	0.241	0.265	0.390	0.271	0.276	0.280	**0.783**	0.375	0.305
PoD3	0.280	0.245	0.330	0.340	0.276	0.305	**0.741**	0.376	0.316
PoD4	0.269	0.265	0.359	0.346	0.355	0.364	**0.802**	0.370	0.338
PoD5	0.248	0.254	0.347	0.286	0.317	0.294	**0.790**	0.327	0.323
PoD6	0.242	0.252	0.317	0.260	0.299	0.271	**0.757**	0.368	0.293
PoD7	0.303	0.300	0.427	0.342	0.365	0.354	**0.738**	0.377	0.368
UDA2	0.302	0.300	0.321	0.357	0.404	0.368	0.367	**0.726**	0.381
UDA3	0.314	0.305	0.352	0.341	0.420	0.353	0.372	**0.745**	0.380
UDA4	0.361	0.319	0.355	0.347	0.352	0.328	0.343	**0.736**	0.362
UDA5	0.293	0.331	0.379	0.338	0.323	0.315	0.309	**0.673**	0.357
UDA6	0.318	0.355	0.378	0.380	0.360	0.320	0.272	**0.706**	0.401
UDA7	0.433	0.388	0.448	0.450	0.426	0.440	0.403	**0.723**	0.476
UDigAd1	0.498	0.481	0.453	0.635	0.558	0.597	0.290	0.403	**0.701**
UDigAd2	0.388	0.450	0.419	0.486	0.410	0.412	0.216	0.417	**0.610**
UDigAd3	0.479	0.483	0.495	0.546	0.508	0.527	0.372	0.441	**0.733**
UDigAd4	0.395	0.444	0.486	0.495	0.483	0.507	0.372	0.409	**0.696**
UDigAd5	0.457	0.525	0.524	0.610	0.577	0.572	0.327	0.425	**0.783**
UDigAd6	0.393	0.465	0.462	0.534	0.437	0.471	0.273	0.394	**0.717**
UDigAd7	0.417	0.468	0.436	0.545	0.403	0.472	0.265	0.355	**0.687**
UDigAd8	0.414	0.461	0.453	0.526	0.488	0.553	0.291	0.379	**0.741**
UDigAd10	0.410	0.454	0.471	0.505	0.472	0.460	0.323	0.367	**0.673**
UDigAd11	0.419	0.529	0.467	0.537	0.490	0.516	0.298	0.366	**0.723**
UDigAd12	0.382	0.482	0.489	0.522	0.584	0.554	0.328	0.405	**0.760**
UDigAd13	0.396	0.485	0.467	0.522	0.552	0.551	0.306	0.370	**0.730**
UDigAd14	0.397	0.503	0.467	0.523	0.468	0.497	0.314	0.395	**0.738**
UDigAd15	0.403	0.429	0.460	0.483	0.475	0.495	0.348	0.389	**0.681**

Annex 2: Survey form

Survey on digital broadcast establishment in Sri Lanka
Questionnaire for potential users

Date ……..

Dear Sir/Madam,

It would be highly appreciating that you have decided to take part on the research survey. Following questionnaire is defined as to study on Digital conversion of Sri Lanka Broadcasting services with special reference to Televisions. The questionnaire will not consist of personal identifiable information and it will make sure not to disclose any information you are sharing here to any third-party personals and this will use for academic purpose only.

Further I will make sure to secure your confidentiality and all the response forms will discard after completion of the research.

If you have any facts to clarify regarding this questionnaire, please don't hesitate to contact principal investigator on email: darshitha@hotmail.com; phone: 0777337050; WhatsApp: +94777337050.

Section 1

This section consists of the participant information which will corelated on evaluation of the TV and radio usage.

1 Gender

Male ☐ Female ☐

2 Age (Years)

18-30 ☐ 30-40 ☐ 40-60 ☐ over 60 ☐

3 Highest level of education

O/L or less ☐ A/L ☐ Diploma ☐ Bachelor ☐ Master ☐

PhD ☐

4 Civil Status

Married ☐ Unmarried ☐ Separated ☐

5 Members in the house

2 or less ☐ 3-5 ☐ 6-9 ☐ Above 10 ☐

6 Type of occupation

Business ☐ Professional ☐ Government ☐ Student ☐

Others (Specify)……..

7 Monthly individual income of your' s

Less than 50,000 ☐ 50,000 − 100,000 ☐ 100,000 − 300,000 ☐

More than 300,000 ☐

8 Monthly household income (All family members living in house)

Lass than 50,000 ☐ 50,000 − 100,000 ☐ 100,000 − 300,000 ☐

More than 300,000 ☐

9 District (your house is located at)

Colombo ☐ Katluthara ☐ Gampaha ☐

10 Your preferred language

English ☐ Sinhala ☐ Tamil ☐

Section 2

This section consists of yours TV and Social media usage behavior which will help to determine the TV and radio usage confined on the research.

1 Do you have a TV/ TVs in your home?

Yes ☐ No ☐

2 If "No" for Q1, what is the reason for not having a TV?

…….

3 If "No" for Q1, are you intended to have a TV in near future (within 2 years' time)?

Yes ☐ No ☐

4 If "Yes" for Q1, how many TVs do you have at home?

1 ☐ 2 ☐ 3 ☐ 4 or more ☐

5 If "Yes" for Q1, what are the types of TVs you have at home?

CRT ☐ LCD/LED/Flat Screen ☐ Smart TV/WEB TV ☐

6 How many hours do you spend to watch TV in a week?

Less than 5 Hrs ☐ 5-10 Hrs ☐ 11-20 Hrs ☐ More than 20 hours ☐

7 Are you using a smart phone/ phones?

Yes ☐ No ☐

8 Are you using paid video service in mobile? (Like Netflix, Iflix, ALTBalagi etc)?

Yes ☐ No ☐

9 Are you using any pay TV connection in house?

Yes ☐ No ☐

10 Who are the services providers?

Dialog TV ☐ Peo TV ☐ Dish TV ☐ Cable TV ☐

11 What is the reason that you tend to have a Pay TV connection. (There could be more than one selection)?

Better Video Quality ☐ Better Audio Quality ☐ Easy for reception ☐

Easy to use ☐ Maintain Social Status ☐ Rewind TV ☐

12 What is the monthly rental you pay for the TV?

……

13 Do you see the value for money of paying monthly amount for a TV connection?

Yes ☐ No ☐

14 If “No” for Q15, what is the monthly fee that you are willing to pay for "Pay TV" connection?

…….

15 Do you have internet connection at home?

Yes ☐ No ☐

16 Are you usually watching video from internet?

Yes ☐ No ☐

17 Are you using social media?

Yes ☐ No ☐

18 How many hours do you spend in social media per week?

Don’t Use ☐ Less than 5 Hrs ☐ 5-10 Hrs ☐ 11-20 Hrs ☐

More than 20 Hrs ☐

Section 3

This section consists of your believe and expectation related to TV, Radio and internet connectivity benefits, expectations and behavior which will help on developing the roadmap for digital broadcasting adaptation in Sri Lanka.

Questions from 19−32 related to digital broadcast availability and literacy in Sri Lanka and please place X mark in the suitable box.

		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
19	I expect to use Digital TV					
20	I expect to access my TV program in any location from my mobile or any screen device					
21	I expect to use digital TV when I need it					
22	I expect more TV channels in Sri Lanka					
23	I expect higher quality video in TV channels					
24	I expect to watch my favorite programs continually without interrupting advertisements					
25	I expect to watch my favorite TV program in later day as recorded content whenever I required					
26	I know how to use Digital TV					
27	I know about digital Receiver Box connected to TV					
28	I know about Video On Demand					
29	I know about time shift TV					
30	I know about Cathup TV					
31	I know about electronic program guide (EPG)					
32	In terms of your Internet skills, do you consider yourself to be a knowledgeable person is to use internet.					

Questions from 33−39 related to policy on digitalization in Sri Lanka and please place “X” mark in the appropriate box.

		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
33	Have you heard about " Telecommunication Regulation Commission" ?					
34	Do you believe that Government policy making institutes want to intervene to digitalize the television					
35	Do you think that government policy making institutes is currently sufficiently involving for make policy for media					
36	Do you think that government institutes want to encourage TV stations to upgrade to digital					
37	Do you think that government want to standardize the media digitalization in Sri Lanka					
38	Do you think that government want to educate consumers about broadcast digitalization in Sri Lanka					
39	Do you think that government want to act as network operator and rent out space/tower for all private and public TV channels.					

Questions from 40−46 related to user device availability and please place "X" mark in the appropriate box.

		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
40	I have access to digital TV devices in my home or workplace					
41	I have seen digital TV available to sell in the market					
42	I have seen there are advertisement related to digital TV in the media					
43	I have seen digital service providers (Dialog TV, PeoTV) advertisement/promotions					
44	I believe there are sufficient collection of devices available in Sri Lanka to receive digital TV					
45	I have access to watch video from my mobile phone					
46	Probably I will consider digital TV reception availability if I purchase a new TV					

Questions from 47−53 related to affordability of using the digital TV and please place "X" mark in the appropriate box.

		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
47	I am willing to pay some money to have digital TV connection to my home					
48	I am willing to pay 2000 LKR for initial connection fee for Digital TV reception					
49	I am willing to pay 800 LKR in monthly basis to receive 30+ local channels in digital reception					
50	I am willing to pay 1500 LKR to receive international news, sports, film, drama, education channels in monthly connection					
51	I believe my friends and families also willing to pay some monthly rental to receive good quality TV content					
52	I might consider having digital TV connection, If I purchase a new TV in coming months.					
53	I might consider to purchase more digital connections to have personalize viewing (private)					

Questions from 54–60 related to usefulness of using the digital TV and please place "X" mark in the appropriate box.

		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
54	Digital TV services will make my life easier					
55	Digital TV services will help me to watch my favorite program whenever I required					
56	Digital TV services will help me to arrange reminder for the favorite program					
57	Digital TV services will be beneficial in my life					
58	Digital TV services will increase my efficiency and effectiveness of TV usage					
59	Digital TV connection will enable opportunities to learn new things than analog TV					
60	Overall, I find the Digital TV service to be useful in my life					

Questions from 61–67 related to ease of use the digital TV and please place "X" mark in the appropriate box.

		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
61	Learning to operate the Digital TV services will be easy for me					
62	Digital TV service usage will be clear and understandable					
63	It will be easy to me to watch what I need from Digital TV services more than traditional TV					
64	I will be easily become skillful for using the Digital TV services					
65	I found it is easy to use "Digital TV" to view the program what I want					
66	I think that I can use Digital TV without obtaining the help from others					
67	Overall, the Digital TV services are easy to use					

Questions from 68–75 related to intention of use the digital TV and please place "X" mark in the appropriate box.

		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
68	I intend to use Digital TV service					
69	I convince and promote others to use Digital TV service					
70	I Plan to use Digital TV service					
71	I think most of my family members would like to use the Digital TV					
72	I am expecting to increase my TV size within next two years' time					
73	I am expecting to view TV channels continuously using my TV and mobile in same time					
74	I want to use my mobile screen as a TV whenever required					
75	I want to use my single TV subscription in multiple devices whenever required					

Questions from 76–90 related to broadcast users digital adoption and please place "X" mark in the appropriate box.

		Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
76	Digital TV usage will be pleasant experience					
77	I am currently using internet to view video					
78	I am/will use digital TV service whenever required					
79	I believe my family members like to use Digital TV service					
80	I believe I can use digital TV effectively					
81	I require to use TV in mobile environment (using mobile phone or portable screen)					
82	I want to continue the viewing program while I move					
83	I want to watch my favorite program whenever I want it (when I'm ready)					
84	I want to purchase TV which is recommended by TRC (Telecommunication Regulation Commission)					
85	I want to use the Digital TV by learning all the features by myself (without ohers help)					
86	I want to use digital TV using my existing TV setup.					
87	I want to use digital TV as its easy to use					
88	I want to use Digital TV because it seems useful for me.					
89	I expect channels dedicated to different services (like Sports, education, drama, film, cartoon)					
90	I believe the analog TV will shut down and Digital TV will replace within next 5-10 years' time in Sri Lanka.					

TOPICALITIES

Edited by Markéta Držková

CONTENTS

News & more

A yearly update on recently completed EU-funded projects

The selected projects that were supported under Horizon 2020 programmes and are based on or related to printing and media are introduced in more detail in the following sections. A few more examples are briefly mentioned here. The project Graphene 3D received funding for research and innovation staff exchange to facilitate the development of multifunctional graphene-based nanocomposites with robust electromagnetic and thermal properties intended for the 3D printing of multifunctional cellular structures for electronics. The innovation in the ceramics industry making use of dedicated inkjet printing machines was supported within the European Training Networks funding scheme in the scope of the DOC-3D-PRINTING project. Several projects dealt with biomedicine, such as the two supporting business innovations: Bone3Dmatch, developing patient-specific biomimetic materials for bone regeneration, and InnovationOrigin, assessing products based on cultivated medical-grade marine coral as biomaterials for 3D printing in health care. Another direction is represented by the ERC project D3, which developed methods for the automatic interpretation of drawings to create 3D models.

CapTherPV – Integration of capacitor, thermoelectric and photovoltaic thin films for efficient energy conversion and storage

The outcomes of this seven-year project that received the ERC Consolidator Grant include, among others, new transparent photothermal devices, organic solar cells integrated with transparent capacitors on both rigid and flexible substrates, and graphene-based capacitors applied directly to solar cells. The research work is described in more than 30 master theses and articles.

APOLO – Smart designed full printed flexible robust efficient organic halide perovskite solar cells

The publications resulting from this research and innovation action mostly deal with materials and design improvements of perovskite solar cells; one paper presents the interlaboratory study on the stability of carbon-based perovskite solar cells prepared by screen printing and provides insight into the suitability of different methods used for stability assessment.

SHERO – Self-healing soft robotics

The soft robotics demonstrators developed in the scope of this research and innovation action include, for example, the robotic gripper that could heal and resume its original tasks after being damaged under controlled conditions. The research described in about 50 papers involved the synthesis and characterisation of different types of reversible polymer networks and combining several processing techniques.

FUTURE-PRINT – Tuneable 2D nanosheet networks for printed electronics

The research within this long-term project that was funded by the ERC Advanced Grant is presented in 30 articles, which, besides the development

The European network in the field of flexible and wearable electronics

The EU-wide SmartEEs Association builds on the two innovation actions of the same name, which received funding from the Horizon 2020 programme for industrial leadership (SmartEEs for the period of 2017–2020 and SmartEEs2 for 2020–2023).

The projects supported selected European companies, from small enterprises to mid-cap ones, in their innovation efforts, which enabled testing of the implementation of flexible and wearable electronics technologies in various areas. The proposed applications include smart textiles in the vehicle interiors to improve thermal perception and comfort, a backpack illuminated with organic light-emitting diodes to provide additional safety and increase attractiveness of the sustainable activities it is intended for, a reusable, real-time monitoring device ensuring traceability of blood bags and the maintenance of adequate cold-chain conditions, a sensor composed solely of organic optoelectronics and measuring human pulse and arterial blood oxygenation, a small-scale datalogger integrated into boots, and an energy autonomous and flexible temperature logger using organic photovoltaic technology as an energy-harvester power source, to name a few.

The services to association members include the offer of courses on different levels and in various areas of interest, full access to a virtual marketplace, which provides information on technical solutions and helps business development, as well as other resources, such as white papers and reports, the organisation of different kinds of events to facilitate networking, and the support in finding funding, public or private.

New Intergraf publications

The 2023 edition of the annual Intergraf Economic Report presents statistical information for the 27 member countries of the European Union, complemented by the data for the United Kingdom, Norway, Switzerland and Iceland. The official consolidated statistics from Eurostat cover the years up to 2020, 2021 or 2022, depending on their type. The key indicators for the European printing industry show that the number of companies and employees remained rather stable during the last years with approx. 2 % decline, but the turnover decreased by more than 10 %. Packaging and labels represented 55 % of the production value, while periodicals and books were 9 % each. Among EU27, Poland, followed by Italy, Netherlands and Germany, are the main net exporters of printed products, whereas the top net importer is France. The import of printed products from China almost doubled when comparing 2020 and 2022, where books and colouring books make up 63 %. Within the historical review, interesting insight is provided by comparing the 2022 electricity prices to 2020 and 2008. Traditionally, the report includes the European print market review and forecast by Smithers.

This spring, Intergraf with FEP, the Federation of European Publishers, and Cepi, the Confederation of European Paper Industries, published a joint statement entitled 'Books as a driver of Europe's knowledge economy'. Building on the PISA report 21st-Century Readers: Developing Literacy Skills in a Digital World (OECD, 2021), the EC Digital Economy and Society Index (DESI) 2020, the COST E-READ Stavanger Declaration Concerning the Future of Reading (2019) and the European Paper Recycling Council Monitoring Report 2021, it claims that books build culture, printed books promote fairness across the digital divide and are a healthy alternative to screen time, the best tools for long-form reading, sustainable and essential for Europe's economy as well as to the development of communities.

and characterisation of nanosheet networks, describe their use in all-printed thin-film transistors and dielectric capacitors, discuss the effect of the gate volume on the performance of printed transistors based on nanosheet networks, and more.

3D2DPrint – 3D Printing of novel 2D nanomaterials: adding advanced 2D functionalities to revolutionary tailored 3D manufacturing

Among over 30 articles resulting from this long-term project that received the ERC Consolidator Grant, the most recent deal, for example, with functionalising single-walled carbon nanotubes in printed supercapacitor devices, confining silicon microparticles with nanoporous structure in the carbon nanotube segregated network, which enables the fabrication of high-performance electrodes, the mechanism of the oxygen reduction reaction in $BaMnO_3$ and the source of inherent instability in electrocatalysts for the oxygen evolution reaction based on NiFe layered double hydroxides.

DROP-IT – Drop-on demand flexible optoelectronics & photovoltaics by means of lead-free halide perovskites

Three of about 20 articles resulting from this research and innovation action describe heterojunction diodes for photodetection applications, halide perovskite light-emitting diodes on rigid and flexible substrates and high-quality emissive nanocrystalline perovskite layers for colour conversion and light-emitting diodes applications, all printed by inkjet. Others mainly deal with studies on perovskite materials, including their crystallographic data.

MADRAS – Advanced materials and processing in organic electronics

The technology developed during this innovation action, which includes nanocellulose-based substrates, conductive and semiconducting inks and in-mould electronic devices, was implemented into two different demonstrators: the geotracking smart tag comprising a flexible self-adhesive label with a rigid electronic unit and the fingerprint reader with a biometric sensor.

LEE-BED – Innovation test bed for development and production of nanomaterials for lightweight embedded electronics

The test bed developed within this innovation action offers consulting services concerning the technical, economic, pre-safety, hazard and life-cycle assessment, standardisation, intellectual property rights and patenting, funding and investment capital search on the one hand, together with pilot lines for developing and scaling-up nanomaterials and formulations, printing and assembling of components, characterising print and selecting the appropriate printing technology for production on the other hand.

EMoBookTrade – The early modern book trade: an evidence-based reconstruction of the economic and juridical framework of the European book market

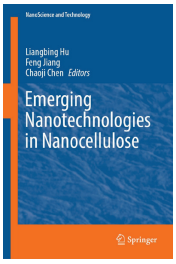
This research, funded by the ERC Advanced Grant, used unexplored evidence revealing connections between book history and economic history. The data were processed and collected in two online research databases, one containing about 33 000 book prices derived from 73 sources from major European firms in 10 different currencies, and the other 5 300 Venetian book privileges. The findings were shared during conferences, seminars and workshops and published in several books, book chapters and articles.

Bookshelf

Emerging Nanotechnologies in Nanocellulose

This book from the NanoScience and Technology series was written to provide a comprehensive overview of design principles, fundamental knowledge and up-to-date research in the field of nanocellulose and the related emerging nanotechnologies. The present attention paid to this material reflects the environmental concerns as well as the substantial advances in nanotechnologies. The potential application areas of high-performance materials based on cellulose include optics, electronics, energy, environment and health. The printing technologies are used mainly for producing batteries or other energy-storage devices and in various biomedical applications.

The content comprises twelve chapters. The first introduces cellulose nanomaterials, methods of their production and characterisation and the current technical and economic challenges. The second is focused on the top-down processing of nanocellulose materials. It describes their intrinsic structure and fabrication strategies, different forms from 3D porous foam or dense bulk structure to 2D film up to 1D fibre. The applications of top-down nanocellulose materials also are mentioned, including electronics. The third chapter presents the recent development of multifunctional nanocomposites based on bacterial nanocellulose, the corresponding design principles and recent applications. The fourth one is dedicated to nanocellulose aerogels, namely the methods for constructing and controlling their structures, properties and functions and the applications of these materials. The fifth presents the design principles of strong and tough materials based on nanocellulose, their superb mechanical performance and modelling approaches explaining the multi-scale mechanics, while the sixth one focuses on light management of nanocellulose films and the corresponding design principles, theories and current strategies, including structural colour, as well as potential applications in optoelectronics and smart photonics. Chapter 7 discusses the advantages and limitations of nanocellulose paper as a flexible electronic substrate and describes the electrodes and flexible electronic devices, including the electromechanical transducer, energy storage device, solar cell, thin film transistor, organic light-emitting diode and touch screen. Two chapters deal with energy storage and nanocellulose-based printed power sources, printing techniques, preparation and characterisation of inks and printed devices – supercapacitors, lithium-ion batteries and others. Chapter 10 presents the application of nanocellulose for water treatment, namely its use in membranes or filters, adsorbents/absorbents and solar conversion devices for water generation. Chapter 11 is focused on mechanical energy harvesting and engineering nanocellulose thin films to develop triboelectric nanogenerators, e.g., a flexible and compact film with nanoscale surface roughness for harvesting energy from footsteps. Finally, the last chapter deals with biomedical applications of nanocellulose, the synthesis of different types of nanocellulose for functional biomaterials and the example applications, including 3D/4D printed scaffolds and hydrogels.

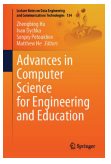


Editors: Liangbing Hu, Feng Jiang, Chaoji Chen

Publisher: Springer
1st ed., November 2022
ISBN: 978-3-031-14042-6
432 pages, 179 images
Hardcover
Available also as an eBook

Advances in Computer Science for Engineering and Education

Editors: Zhengbing Hu, Ivan Dychka, Sergey Petoukhov, Matthew He



Publisher: Springer
1st ed., April 2022
ISBN: 978-3031048111
554 pages, 233 images
Softcover
Also as an eBook

This volume presents a selection of 46 papers from the Fifth International Conference on Computer Science, Engineering, and Education Applications, ICCSEEA 2022, held in Kyiv, Ukraine. The wide range of topics includes, among others, modelling and simulating modulated ink flows in a short printing system of parallel structure and modelling of tone reproduction with round raster elements in the same system, mulsemedia, i.e. multiple sensorial media, namely the mulsemedia data processing language based on the algebraic system of aggregates (ASAMPL 2.0), which is designed to facilitate the development of mulsemedia applications, and the study of effects of students' interaction patterns on cognitive processes in blended learning.

Human-Computer Interaction Technological Innovation

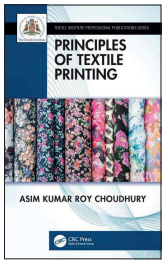
Editor: Masaaki Kurosu

Publisher: Springer
1st ed., May 2022
ISBN: 978-3031054082
700 pages, 359 images
Softcover
Also as an eBook

The 24th International Conference on Human-Computer Interaction, HCII 2022, which took place virtualy, comprised 21 thematic areas and affiliated conferences. This book, with 47 papers focused on technological innovation, is a part of the three-volume set, which includes the refereed proceedings of the thematic area that gave the conference its name, i.e. the human–computer interaction. The contributions

Principles of Textile Printing

Complementing the author's previous books on different aspects of textile chemistry, this one deals with the topic of textile printing from a technical perspective. The book aims to be of interest to all textile printers, from large printing houses to small ones. It begins with a history of textile colouration by dyeing and printing, providing the fundamental background on the preparation of materials and the printing devices, methods and styles. Then, the pre-processing of both natural and synthetic textile materials is presented, such as scouring and different types of bleaching. The following chapter is dedicated to dyes and auxiliary agents for thickening, wetting, oxidation and reduction, swelling, etc. The text presents the classification of colourants according to their chemical constitution and the application method. Also, it discusses the colour-fastness properties, toxicity and environmental aspects. The remaining five chapters deal with printing. First, an overview of various types of textile printing is presented. One chapter details direct printing with pigmented inks, reactive dyes, vat dyes, acid dyes and other dye types; it also briefly covers the discharge and resist printing styles. Then, one chapter is dedicated to manual printing methods, and the following describes the roller and screen printing machines. The last chapter deals with digital printing, including its comparison with screen printing. It outlines the basic concepts and principles, describes inkjet printers and inks, and discusses specific aspects of digital printing. Finally, it mentions 3D printing on textiles and innovative applications for technical textiles.



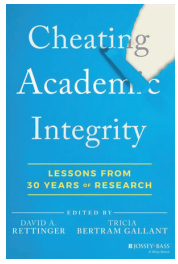
Author: Asim K. R. Choudhury

Publisher: CRC Press
1st ed., August 2022
ISBN: 978-1-138-47874-9
374 pages
Hardcover
Available also as an eBook

Cheating Academic Integrity Lessons from 30 Years of Research

Nine chapters of this book deal with the important topic of academic integrity, the reasons and ways of cheating by students, the role of the faculty and staff, and the methods helping to prevent or at least recognise academic cheating and plagiarism. The key point is communicated already in the first chapter, arguing that the last 30 years of research have shown that cheating is evitable – it can be mitigated and minimised. Two chapters provide an overview of trends in plagiarism and cheating prevalence from the 1990s to the present and a closer look at contract cheating. It seems that the trend

Editors: David A. Rettinger, Tricia Bertram Gallant

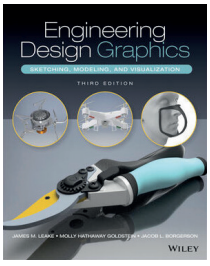


Publisher: Jossey-Bass
1st ed., March 2022
ISBN: 978-1-119-86817-0
256 pages
Softcover
Available also as an eBook

is positive, probably thanks to the efforts put in increased awareness and improved skills; however, the disruption due to COVID-19 and the recent enormous development of technologies can lead to an opposite shift. The same factors are substantial also in the case of contract cheating. Then, the book offers a psychological perspective on the causes of cheating, including practical suggestions on enhancing academic integrity, as well as insights into the perception of cheating and the consequent decisions to cheat or not. The following text stresses the importance of implementing high-impact pedagogical practices, which also applies to online teaching. The last two chapters review the most influential pieces from 30 years of research on academic integrity and provide an outlook for the next 30 years.

Engineering Design Graphics
Sketching, Modeling, and Visualization

This popular textbook was first published in 2008. The current edition was revised to reflect the development since the second one from 2012, such as the trends toward cloud-based solutions, freeform modelling, 3D printing and scanning, generative design, and also human-centred design. The text covers the steps of the engineering design process, design thinking and communicating, hand drawing, 2D and 3D graphics terms, formats and software, different views and projections, including isometric drawing, design for additive manufacturing, file formats of 3D printers, and more. The accompanying website provides the image gallery and solutions manual for each chapter; in addition, videos are available for the two chapters dealing with planar and perspective projections.



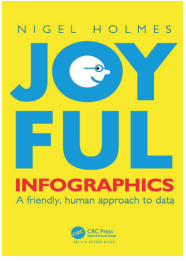
Authors: James M. Leake, Molly Hathaway Goldstein, Jacob L. Borgerson

Publisher: Wiley
3rd ed., March 2022
ISBN: 978-1-119-68842-6
464 pages
Softcover
Available also as an eBook

Joyful Infographics
A Friendly, Human Approach to Data

Thanks to the author's experience, this new book on infographics brings what its title promises. Nigel Holmes shares his influences, a personal timeline of infographic landmarks, approaches to make graphics joyful, as well as examples illustrating what to avoid. Further, he deals with icons, presentations, comprehensible scientific infographics and illustrated charts.

Author: Nigel Holmes



Publisher: CRC Press
1st ed., December 2022
ISBN: 978-1-03-211965-6
215 pages, 259 images
Hardcover
Available also as an eBook

present, for example, the method for high-speed thermochromism control, which integrates water cooling circuits and electric heating circuits printed with conductive silver nanoparticle ink, or the paper-based numeric keyboard using ArUco markers, intended as a low-cost disposable keyboard for VR systems and mobile devices. The focus of the other two parts is on the theoretical approaches and design methods and the user experience and behaviour, respectively.

Advances in Design, Music and Arts II

Editors: Daniel Raposo, João Neves, Ricardo Silva, Luísa Correia Castilho, Rui Dias

Publisher: Springer
1st ed., June 2022
ISBN: 978-3031096587
909 pages, 352 images
Hardcover
Also as an eBook

This book comprises the proceedings of the 8th International Meeting of Research in Music, Arts and Design, EIMAD 2022, held in Castelo Branco, Portugal. Almost 60 contributions are organised into five parts, including the first one presenting 14 papers on Communication Design, Design Education and Thinking.

Bauhaus Effects in Art, Architecture, and Design

Editors: Kathleen James-Chakraborty, Sabine T. Kriebel

Publisher: Routledge
1st ed., April 2022
ISBN: 978-1032205397
212 pages, 63 images
Hardcover
Also as an eBook

This part of the Routledge Research in Art History series focuses on the impact of the Bauhaus in a wide range of fields, including the relationship with New Typography and its effects on graphic design discussed in the second chapter.

Flexible OLEDs
Fundamental and Novel Practical Technologies

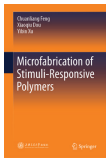
Author: Mitsuhiro Koden

Publisher: Springer
1st ed., July 2022
ISBN: 978-9811935435
112 pages, 128 images
Softcover
Also as an eBook

This concise book published in the SpringerBriefs in Applied Sciences and Technology series provides the basics and history of flexible organic light-emitting diodes and an overview of suitable substrates, gas barrier technologies, encapsulation and novel electrode technologies. The last chapter describes diodes with on-demand patterns by ink-jet printing.

Microfabrication of Stimuli-Responsive Polymers

Authors: Chuanliang Feng, Xiaoqiu Dou, Yibin Xu



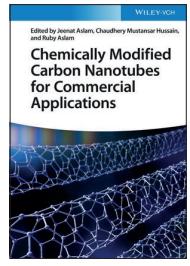
Publisher: Springer
1st ed., March 2021
ISBN: 978-9813368682
197 pages, 124 images
Hardcover
Also as an eBook

This book focuses on interfacial reactions, the immobilisation of (bio)molecules and the fabrication of biomolecular patterns by reactive microcontact printing. In nine chapters, it covers reactive platforms for controllable fabrication of functional interfaces, surface reactions of organic and polymeric films and the methods for their patterning, confinement effects on the reactivity in ultrathin polymer films, platforms for the immobilisation of biomolecules, tailored biointerfaces via derivatisation of polystyrene-*b*-poly(*tert*-butyl acrylate) thin films, reactive microcontact printing, submicron molecular patterning, nanofabrication on reactive block copolymer film platforms, and bioinspired hierarchically structured polymer interfaces for promising biomedical applications.

Chemically Modified Carbon Nanotubes for Commercial Applications

The aim of this book was to summarise the recent advancements in the chemical modification of carbon nanotubes, facilitating their use in various applications on a commercial scale. The first part provides the background on the properties, synthesis, characterisation and surface modification of carbon nanotubes, together with an overview of their commercialisation and the related economic aspects. The remaining five parts deal with applications of chemically modified carbon nanotubes, presenting current approaches, case studies and future perspectives; four parts cover the areas of energy and environment, electronics and related devices, biomedicine and construction, and the fifth one is dedicated to the emerging applications. In particular, individual chapters describe the use in energy production and storage, adsorption of pollutants, removal of textiles effluents, membrane separation, water purification, electronics and photonics, electrochemical sensors, lab-on-chip devices, cancer therapy, drug delivery, tissue engineering, cement-based materials, 3D and 4D printing with the example applications including liquid sensors and stretchable supercapacitors, tribology applications for controlling friction and wear properties, and corrosion protection. The last chapter discusses the commercial-scale developments for the fabrication of chemically modified carbon nanotubes, covering several methods of both covalent and non-covalent functionalisation.

Editors: Jeenat Aslam, Chaudhery M. Hussain, Ruby Aslam

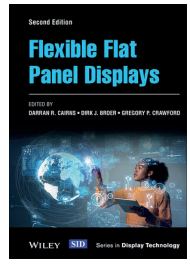


Publisher: Wiley-VCH
1st ed., February 2023
ISBN: 978-3-527-35072-8
544 pages
Hardcover
Available also as an eBook

Flexible Flat Panel Displays

The original edition of this book was published in 2005. This revised edition brings a completely restructured content that was contributed by 45 experts active in the field worldwide and reflects the substantial progress achieved, especially in the areas of foldable organic light-emitting diode displays and flexible liquid-crystal displays, as well as the state-of-the-art solutions to technical challenges. The chapters deal with liquid crystal optical coatings, metallic nanowires, optically clear adhesives, self-healing polymer and flexible glass substrates, encapsulation, organic field-effect transistors, reflective display, electronic paper, flexible batteries, x-ray detectors, roll-to-roll production challenges, direct ink writing, and more.

Editors: Darran R. Cairns, Dirk J. Broer, Gregory P. Crawford



Publisher: Wiley
2nd ed., February 2023
ISBN: 978-1-118-75111-4
416 pages
Hardcover
Available also as an eBook

Bookshelf

Academic dissertations

Component Fabrication by Printing Methods for Optics and Electronics Applications

Doctoral thesis – Summary

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Speciality field:
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Supervisor:
Tapio Fabritius

Defended:
26 February 2021, University of Oulu, Faculty of Information Technology and Electrical Engineering Oulu, Finland

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Further reading:
ISBN: 978-952-62-2854-9

The research within this thesis explored the capabilities of printing as a beneficial fabrication method for three types of components: the high-quality, low-cost microlens array, the fully printed functional memristor, and the double-sided capacitive sensor element. The main focus was on the design and fabrication processes. Inkjet printing was used for microlenses and memristors, whereas for the sensor, it was screen printing. These two methods complement each other in terms of the resolution and size of printed features while both enabling roll-to-roll processing. In addition, the functionality of the fabricated components in specific applications was also verified. Thanks to the chosen printing techniques and components applicable in different fields, the work demonstrates the versatility of printed intelligence.

The dissertation reviews the relevant characteristics of inkjet and screen printing technologies, the inks, substrates and methods used for the fabrication of components, as well as the methods used for their characterisation, which included profilometry, optical and scanning electron microscopy and measurements of current–voltage characteristics and capacitance. Then it presents and discusses the results achieved for individual components. For microlenses, a transparent UV-curable photoresist was inkjet-printed on flexible polyethylene terephthalate and rigid glass substrates pre-patterned by the photolithography. Based on the direct microscopy imaging results, the imaging quality of the microlens array printed on glass is comparable to that of the commercial glass reference and outperforms the hot-embossed lenses. For the memristive structure, all materials, i.e. silver nanoparticle ink, TiO_x and photoresist, were printed by inkjet. Its characterisation confirmed the device's functionality and revealed the limitations due to the ununiform thickness of the active layer and the short lifetime. Capacitive sensors were screen-printed with a silver paste onto a high-efficient particulate air filter to detect its dirtiness level and successfully integrated into a vacuum cleaner.

Influence of the Nanocomposite Coating Composition on the Cardboard Packaging Characteristics

Doctoral thesis – Summary

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This thesis investigated the possibility of improving the protective function of printed packaging through special coating. The approach is based on adding nanoparticles into commercial varnish so that its application will reduce the degradation of the packaging material caused by electromagnetic radiation, improve its barrier properties and, with the assistance of UV radiation, also antimicrobial properties while not significantly changing its colorimetric characteristics.

The first chapter of the dissertation presents the results of preliminary research on consumers' attitudes towards packaging. The responses of over 150 survey participants indicated the impact of its properties on the perceived quality of goods, especially due to colour degradation and mechanical damage of the packaging. In addition, about a third of respondents would value protection from potentially dangerous microbes. The text then defines the

objectives and provides the background on the packaging industry, materials, branding and design, paperboard, printing and coatings. The theoretical part also presents the basic characteristics of nanoparticles used for coating modification, namely zinc oxide, titanium dioxide and silicon dioxide. The study included four types of modified coatings; nanocomposites were formulated with ZnO, TiO_2, ZnO/SiO_2 and TiO_2/SiO_2. Two chapters explain the structure of the experiment, specify materials, i.e. woodfree coated paperboard, offset process inks based on vegetable oil, water-based varnish and the three types of nanoparticles, describe sample preparation, which comprised printing by offset lithography, preparation and application of nanocomposite coating with 0.25–1 % of nanoparticles by flexography and subsequently the accelerated ageing, and provide details on characterisation methods. Another two chapters present and compare the results achieved. For individual process colours, the modification with nanoparticles induced the change up to approx. 2.5 ΔE^*_{ab} when compared to the coating with commercial varnish. Mostly, the coatings with TiO_2 provided higher protection against accelerated ageing and water vapour. Regarding antimicrobial properties, the best results were obtained for the coatings with ZnO in the case of aerobic mesophilic bacteria contamination and *Listeria monocytogenes* growth after artificial inoculation.

Further reading:
http://eprints.grf.unizg.hr/id/eprint/3359

Doctoral thesis – Summary

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3D Printing and Texture Modulation of Cereal-Based Matrices

This thesis advanced the existing knowledge in the area of 3D-printed starch-based materials and their tailoring in different aspects. To accomplish the aims concerning the relationship between texture and taste and creating the appropriate textures, the work comprised the development of methods for assessing printing quality and material structure to elucidate its behaviour, the sensory design of food textures, their thermal stabilisation, and texture modulation with respect to hardness and deformation.

The first part of the dissertation provides a concise overview of the relevant concepts from 3D printing of food material systems, available printing techniques, material and process parameters, their effects on printing behaviour and quality with its assessment, to modulation of cellular starch-based foams using 3D printing, describing the formation and stabilisation of the porous structure, the relation between structure and texture, mechanical behaviour of starch-based foams important for handling and mastication, up to reviewing state of the art in 3D printing and fabrication of starch-based textures. Further, it deals with the methods for post-processing and thermal stabilisation after 3D printing. Finally, it presents the thesis objectives defined on this basis along with the approach and methods used for the characterisation of raw materials, 3D printing, image processing, finite element modelling and simulations, rheological measurement and texture profile analysis. The main part presents the four studies and discusses the overall outcomes. The first study investigated the printability of gluten-containing and gluten-free starch-based material systems at various hydration levels and proposed the in-line camera-based method to characterise the morphology and the resulting behaviour and quality. The second was focused on sensory design in food 3D printing. In particular, it dealt with precise structuring, texture modulation, taste localisation by the inhomogeneous spatial distribution of sodium chloride, and thermal stabilisation using an in-line NIR heating system. The last two studies investigated texture modulation in and beyond the elastic regime, developing and verifying the design formula relating hardness to the chosen Young's modulus, porosity and geometry and analysing the large-deformation stress–strain profiles, the strain rate and viscoelastic response to extend the textural modulation in the non-linear regime.

Further reading:
https://nbn-resolving.de/urn/resolver.pl?urn:nbn:de:bvb:91-diss-20230426-1687067-1-9

Events

NANOTEXNOLOGY 2023

Thessaloniki, Greece
1–8 July 2023

Traditionally, this large international event combines multiple conferences presenting the advances in the fields of nanosciences and nanotechnologies (NN23), flexible organic electronics (ISFOE23), digital and additive manufacturing and 3D (bio)printing (I3D23), accompanied by the related summer schools (ISSON23) and exhibition, as well as the three-day business forum and matchmaking event. The first conference is already in its 20th edition. The speakers invited for this year's plenary session are Magnus Berggren presenting 'Thiophene-based trimers for evolvable and in-vivo-manufactured electrodes and electronics', Peer Fischer on 'Nanostructures in motion: chemical motors and nanorobotic systems' and David King with the lecture 'The climate crisis: the state of climate science, and what must be done now'. Overall, the rich programme features almost a hundred keynotes and invited talks by experts representing research organisations from across the globe, numerous conference papers and also over 50 posters in the dedicated ISSON23 session. The ISSON participants interested in organic electronics can learn about the design of nanoscale structures in optimising organic solar cells, design and synthetic aspects of organic and polymer materials, hybrid interfaces between nanosensors and living cells, brain-inspired next-generation optoelectronics, advanced characterisation and simulation of photovoltaics and organic light-emitting diodes performance, microelectronics, intelligent nanomanufacturing and in-line metrology for quality control, and more.

FLEPS 2023
5th IEEE International Conference on Flexible, Printable Sensors and Systems

Boston, Massachusetts, USA
9–12 July 2023

In 2023, this event offers five tutorials on the first day; their topics cover scalable and self-healing hybrid electronic materials, bioinspired in-sensor computing, flexible and stretchable inorganic solar cells, materials, design, manufacturing, functionalities and applications of e-tattoos, and fabrication strategies for wearable and implantable biochemical sensors. The conference technical programme is scheduled for three days, each opened by a plenary lecture. The announced topics are 'Flexible electronics: challenges and opportunities – a materials science view' by Natalie Stingelin, 'Electrophoretic display technology for ultra-low power smart and green switching surfaces' by Edzer Huitema, and 'Soft bioelectronics: design concepts for engineered elasticity' by Stephanie Lacour. Also, the programme offers 20 invited lectures and seven focused sessions that reflect selected emerging areas not covered by regular tracks. To facilitate networking between the academic community and industry in the field, the programme includes talks by six industry experts in a dedicated session and lab tours.

FuturePrint 2023

São Paulo, Brazil
12–15 July 2023

After the two years impacted by the pandemic, the 2022 edition of this Latin American fair, a successor of the Serigrafia SIGN FutureTEXTIL show, attracted over 40 000 visitors. This year's edition again offers a wide range of brands and products for screen printing, digital printing, 3D printing, cutting and recording, finishing and other accessories, as well as software solutions, for the sectors of sign and signage, textile digital printing, packaging, promotional materials, and digital signage.

XVIII Color Conference

Lecco, Italy
15–16 September 2023

The speakers invited to the current edition of this established event are the light artist Christopher Bauder, Raimondo Schettini on colour in data visualisation, and Andrew Stockman, presenting cone fundamentals and the research towards predicting the colour matching functions of individual observers, e.g. those with colour-vision deficiency.

CIE 2023
30th Quadrennial Session of the CIE

Ljubljana, Slovenia
15–23 September 2023

Besides the CIE division and technical meetings, this event includes the conference themed 'Innovative Lighting Technologies' (18–20 September) and offers five workshops on photometry, lighting design and education.

SGI Dubai 2023
Sign & Graphic Imaging Middle East

Dubai, UAE
18–20 September 2023

This exhibition for the Middle East and Africa, now in its 26th edition, covers a wide range of both proven and innovative solutions and materials for applications in the printing, signage, graphic and imaging industries.

C!print

Madrid, Spain
19–21 September 2023

The Madrid edition of this show offers, among others, the Plug&Play workshop to demonstrate the current options for the customisation and personalisation of products, including a dedicated online application.

Pack Print International 2023

Bangkok, Thailand
20–23 September 2023

The 9th International Packaging and Printing Exhibition for Asia highlights the current trends – sustainability, artificial intelligence, safety and security, digital economy, premium design and 3D printing.

Digital Textile Congress 2023

Ghent, Belgium
28–29 September 2023

The lectures scheduled for this year deal with process parameters determining the resulting quality and, thus, the optimal applications, different types of inks and their properties, new solutions to increase sustainability, the use of extended reality, and more.

FLEX 2023

San Francisco, California, USA
11–13 July 2023

This event for flexible hybrid and printed electronics, held with the SEMICON West show, is this year also co-located with the 60th DAC – Design Automation Conference. The Flex keynote speakers are Richard Price, emphasising the importance of simplification when developing flexible integrated circuits, Michelle Foss, highlighting the need for flexibility also in materials supply chains, and Kris Erickson, discussing the advances in additively manufactured electronics.

SIGGRAPH 2023
The 50th International Conference & Exhibition on Computer Graphics & Interactive Techniques

Los Angeles, California, USA
6–10 August 2023

The extensive programme of this year's edition celebrates 50 years of the SIGGRAPH event, offering five days of conference sessions, a three-day exhibition, and more. It can be joined in person or online.

SPIE Optics & Photonics 2023

San Diego, California, USA
20–24 August 2023

Again, the contributions of this large multidisciplinary event include those presenting various advances related to printing. Several papers deal with 3D printing of lighting components and systems, such as 3D-printed refractive secondary optics for light-emitting diodes or advanced luminaire using 3D-printed electronics, and components printed by inkjet, e.g. metal-halide perovskite large-area optoelectronic devices, large-area dichroic mirrors and ternary logic circuits based on carbon nanotube homojunctions. Others present the in-situ reactive inkjet synthesis of ZnO nanostructures, dry transfer printing of nanomaterials for advanced wearable displays, photobleaching of transparent photopolymer resins, integrating printed organic electronics with plant tissues for environmental monitoring, etc., or further topics, e.g. the segmentation of Ottoman and early Turkish Republic printed documents and advanced correlation filters for printed character recognition.

49th iarigai and 54th International Circle Conferences

Wuppertal, Germany
18–20 September 2023

The annual conferences of the International Association of Research Organizations for the Information, Media and Graphic Arts Industries and the International Circle of Educational Institutes of Graphic-Media Technology and Management are again held as joint event. The scientific programme is complemented by the ESMA Networking Day on 20 September.

Journal of Print and Media Technology Research
A PEER-REVIEWED QUARTERLY

ISSN 2414-6250 (Online)
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UDC 665

Call for papers

The Journal of Print and Media Technology Research is a peer-reviewed periodical, published quarterly by iarigai, the International Association of Research Organizations for the Information, Media and Graphic Arts Industries.

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Authors are invited to prepare and submit complete, previously unpublished and original works, which are not under review in any other journals and/or conferences.

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Journal of Print and Media Technology Research
A PEER-REVIEWED QUARTERLY

Vol. 12, 2023
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2-2023

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- Printing technology and related processes
- Premedia technology and processes
- Emerging media and future trends
- Social impacts

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