IJISEM
INTERNATIONAL JOURNAL OF INNOVATIONS IN SCIENCE ENGINEERING AND MANAGEMENT

International Journal of Innovations In Science Engineering And Management

OPEN ACCESS

Volume: 5

Issue: 2

Month: June

Year: 2026

ISSN: 2583-7117

Published: 22.06.2026

Citation:

Aman Tyagi, Sonam Verma "A Critical Comparative Investigation into the Role of Paper Substrate Physicochemical Characteristics in Determining Image Reproduction Accuracy and Print Quality Outcomes in Sheet-Fed Offset Lithographic Printing" International Journal of Innovations in Science Engineering and Management, vol. 5, no. 2, 2026, pp. 538-543

DOI:

10.69968/ijisem.2026v5i2538-543

A Critical Comparative Investigation into the Role of Paper Substrate Physicochemical Characteristics in Determining Image Reproduction Accuracy and Print Quality Outcomes in Sheet-Fed Offset Lithographic Printing

Mrs. Sonam Verma[1], **Aman Tyagi**[2]

[1]*Assistant Professor, Department of Printing Technology, Somany Institute of Technology & Management, Rewari, Haryana.*

[2]*Research Scholar, Department of Printing Technology, Somany Institute of Technology & Management, Rewari, Haryana.*

Abstract

The quality of printed products in sheet-fed offset lithographic printing is significantly influenced by the physicochemical characteristics of the paper substrate. Properties such as grammage, thickness, brightness, opacity, surface roughness, tensile strength, tear resistance, and absorbency play a crucial role in determining ink transfer, image reproduction accuracy, and overall print quality. This study presents a critical comparative investigation of different paper substrates used in sheet-fed offset printing to evaluate their impact on key print quality parameters, including dot gain, print density, color reproduction, trapping efficiency, print contrast, and image sharpness.

Standardized printing conditions were maintained throughout the experimentation to ensure that variations in print performance could be attributed primarily to substrate characteristics. The physicochemical properties of selected paper grades were measured using standardized testing methods, and the resulting print samples were analyzed using appropriate print quality assessment techniques. The findings reveal significant correlations between substrate properties and print quality outcomes, demonstrating that coated papers generally provide superior image reproduction accuracy, colour fidelity, and surface finish compared to uncoated substrates. The study contributes to a better understanding of substrate–print interactions and offers valuable insights for printers, publishers, and packaging manufacturers in selecting suitable paper grades for achieving optimum print quality and production efficiency.

Keywords; Sheet-fed Offset Printing, Paper Substrate, Physicochemical Properties, Image Reproduction, Print Quality, Dot Gain, Colour Reproduction, Lithographic Printing

INTRODUCTION

Printing is one of the most influential technologies for the communication and reproduction of information, images, and graphical content. Among the various printing techniques, sheet-fed offset lithographic printing remains one of the most widely used processes due to its ability to produce high-quality prints with excellent image sharpness, colour consistency, and production efficiency. The quality of the final printed product is determined by several factors, including printing equipment, ink formulation, press settings, environmental conditions, and, most importantly, the characteristics of the paper substrate. Since paper serves as the primary medium for image transfer and ink reception, its properties significantly influence the visual and functional quality of printed materials.

Paper substrates possess a wide range of physicochemical characteristics, such as grammage, thickness, density, brightness, opacity, surface roughness, porosity, moisture content, tensile strength, and absorbency. These properties affect the interaction between ink and paper during the printing process, thereby influencing print quality parameters such as dot gain, print density, trapping efficiency, colour reproduction accuracy, image sharpness, and gloss. Variations in these characteristics can lead to differences in ink absorption, dot formation, and colour appearance, resulting in noticeable changes in the overall print performance.

Consequently, understanding the relationship between paper properties and print quality has become an important area of research for printers, publishers, and packaging manufacturers.

This study presents a critical comparative investigation into the role of paper substrate physicochemical characteristics in determining image reproduction accuracy and print quality outcomes in sheet-fed offset lithographic printing. The research evaluates and compares selected paper grades under standardized printing conditions to examine how their physical and chemical properties influence key print quality attributes. By establishing correlations between substrate characteristics and printing performance, the study aims to provide valuable insights for substrate selection, process optimization, and quality enhancement in commercial printing applications. The findings are expected to contribute to improved decision-making in the printing industry and support the production of high-quality printed products.

RESEARCH OBJECTIVE

The physicochemical characteristics of paper substrates play a crucial role in determining the quality of printed products in sheet-fed offset lithographic printing. Properties such as grammage, thickness, brightness, opacity, surface roughness, tensile strength, and absorbency directly influence ink transfer, dot formation, color reproduction, and image sharpness. Variations in these properties can lead to significant differences in print performance, affecting both visual appearance and production efficiency. Therefore, a systematic investigation of the relationship between paper substrate characteristics and print quality parameters is essential for optimizing printing processes and selecting appropriate substrates for high-quality image reproduction.

- To evaluate and compare the physicochemical characteristics of selected paper substrates and determine their influence on image reproduction accuracy in sheet-fed offset lithographic printing.
- To analyze the relationship between paper substrate properties and key print quality parameters, including dot gain, print density, color reproduction, trapping efficiency, and image sharpness.

RESEARCH METHODOLOGY

This study was conducted in the Printing Technology Laboratory of Somany Institute of Technology and Management to investigate the influence of paper substrate physicochemical characteristics on image reproduction accuracy and print quality in sheet-fed offset lithographic printing. Three commercially used paper grades, namely Matte Art, Gloss Art, and Map-litho papers with grammage ranging from 70 to 120 GSM, were selected for comparative evaluation. Prior to testing, all paper samples were conditioned at a temperature of 23 ± 1°C and a relative humidity of 65% in accordance with TAPPI T 402 om-88 standards to ensure uniform environmental conditions.

The physicochemical properties of the selected papers were determined using standardized testing procedures. Grammage was measured according to TAPPI T 410 om-88, tensile strength according to TAPPI T 494 om-01, tear index and tearing strength according to TAPPI T 414 om-88, and caliper (thickness) according to TAPPI T 411 om-89. These properties were selected because of their direct influence on ink transfer, printability, and image reproduction performance during the offset printing process.

After characterization of the substrates, printing trials were carried out using a Heidelberg Speedmaster CD 102 sheet-fed offset printing machine under standardized operating conditions. For each paper type, 500 impressions were produced using identical printing parameters, ink formulations, and press settings to minimize process-related variations. Three representative sheets were randomly selected from the 100th, 300th, and 500th impressions for detailed print quality evaluation.

The printed samples were analyzed using an Exact Spectro-Densitometer in accordance with ISO 12647-2 guidelines. Key print quality parameters, including solid ink density, print contrast, dot gain, and trapping efficiency, were measured and recorded. The average values obtained from the selected samples were calculated and used for comparative analysis. The collected data were subsequently evaluated to establish relationships between the physicochemical properties of the paper substrates and their corresponding print quality outcomes, thereby identifying the substrate characteristics that contribute most significantly to accurate image reproduction in sheet-fed offset lithographic printing.

DATA COLLECTION & ANALYSIS

Data for this study were collected through both laboratory testing and print quality evaluation of the selected paper substrates. The physicochemical properties of Matte Art, Gloss Art, and Map-litho papers, including grammage, thickness, tensile strength, and tearing strength, were measured using standardized TAPPI testing methods. Following substrate characterization, printing trials were conducted on a Heidelberg Speedmaster CD 102 sheet-fed

offset printing machine under controlled operating conditions. For each paper type, 500 impressions were produced, and representative samples were selected from the 100th, 300th, and 500th impressions. Print quality data, including solid ink density, print contrast, dot gain, and trapping efficiency, were collected using an Exact Spectro-Densitometer in accordance with ISO 12647-2 standards. The recorded measurements were compiled and averaged to ensure reliability and consistency of the results. The collected data served as the basis for evaluating the relationship between paper substrate characteristics and image reproduction accuracy in sheet-fed offset lithographic printing.

Table 1, Average SID of offset printed papers

S. No.	Features	Matte	Gloss	High Grade Map-Litho
1.	Cyan-C	1.27	1.05	0.81
2.	Magenta-M	1.26	1.04	0.78
3.	Yellow-Y	1.25	1.05	0.82
4.	Key-K	1.29	1.05	0.82

The table 1, presents a comparison of solid ink density (SID) values for four printing colour features i.e., Cyan, Magenta, Yellow, and Key/Black—across three types of paper: Matte, Gloss, and High-Grade Map-Litho. The results show that Matte paper consistently records the highest SID values, ranging from 1.25 to 1.29, which indicates stronger ink absorption and richer colour reproduction. Gloss paper demonstrates moderate SID values, around 1.04 to 1.05, reflecting smoother ink laydown but comparatively lighter density. In contrast, High Grade Map-Litho paper exhibits the lowest SID values, between 0.78 and 0.82, suggesting reduced ink hold and weaker tonal strength. Overall, the data highlights that paper finish significantly influences print quality, with Matte paper providing the densest colour output, Gloss paper offering balanced but lighter density, and Map-Litho paper showing the least ink density among the three.

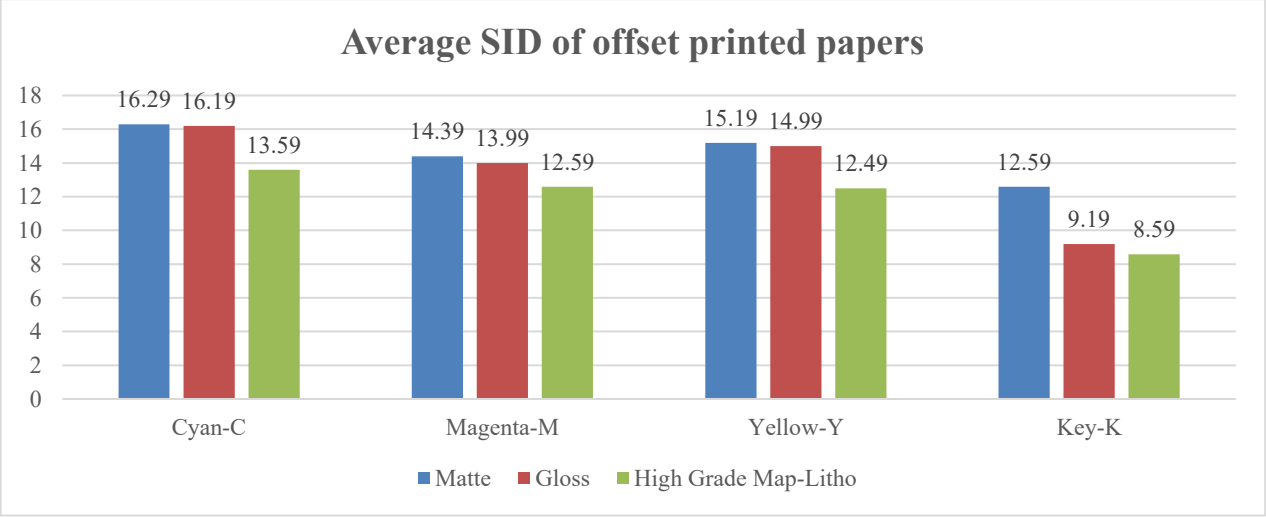


Table 2, Average Dot Gain of offset printed papers

S. No.	Features	Matte	Gloss	High Grade Map-Litho
1.	Cyan-C	16.29	16.19	13.59
2.	Magenta-M	14.39	13.99	12.59
3.	Yellow-Y	15.19	14.99	12.49
4.	Key-K	12.59	9.19	8.59

The table-2, provides a comparison of dot gain values for Cyan, Magenta, Yellow, and Key/Black across three paper types: Matte, Gloss, and High-Grade Map-Litho. The results indicate that Matte paper generally shows the highest dot gain, with values ranging from 12.59 to 16.29, suggesting greater ink spread and stronger tonal buildup. Gloss paper records slightly lower dot gain values, between 9.19 and 16.19, reflecting smoother ink control and reduced spread compared to Matte. High Grade Map-Litho paper consistently exhibits the lowest dot gain values, ranging from 8.59 to 13.59, which points to tighter ink hold and more accurate reproduction of halftone dots. Overall, the data highlights that paper finish significantly influences dot gain behaviour in offset printing, with Matte paper showing the greatest ink expansion, Gloss paper offering moderate control, and Map-Litho paper delivering the most precise dot retention.

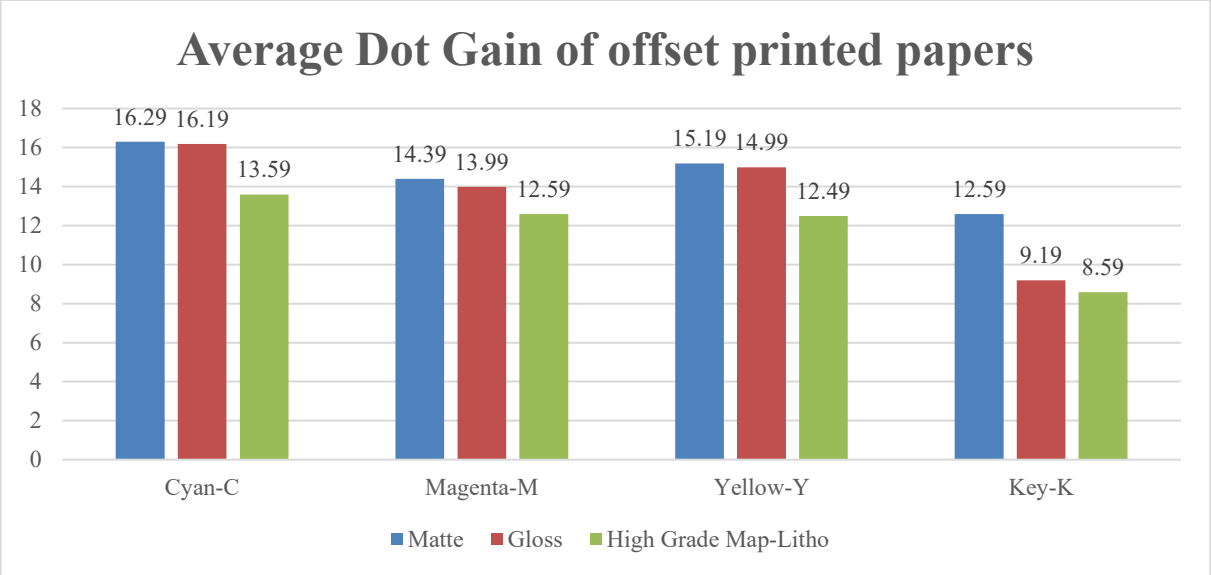


Table 3, Average Print Density and Print Contrast of offset printed papers

S. No.	Features	Matte		Gloss		High Grade Map-Litho	
		PD	PC	PD	PC	PD	PC
1.	Cyan-C	1.65	31.19	1.65	30.79	1.3	24.59
2.	Magenta-M	1.3	31.69	1.33	30.89	1.11	23.49
3.	Yellow-Y	1.2	27.29	1.29	25.29	1.18	22.99
4.	Key-K	1.49	50.89	1.51	49.89	1.46	39.59

The table-3, compares Cyan, Magenta, Yellow, and Key/Black across three paper types i.e., Matte, Gloss, and High-Grade Map-Litho using two parameters: Print Density (PD) and Print Contrast (PC). The results show that Matte and Gloss papers generally maintain higher print density values, with Cyan reaching 1.65 on both, while Map-Litho records lower densities, such as 1.3 for Cyan and 1.11 for Magenta. Print contrast follows a similar trend: Matte and Gloss papers achieve stronger contrasts, with Key/Black showing the highest values (50.89 for Matte and 49.89 for Gloss), whereas Map-Litho consistently delivers lower contrasts, such as 39.59 for Key/Black. Overall, the data highlights that Matte and Gloss papers provide richer tonal strength and sharper contrasts, while High Grade Map-Litho paper yields comparatively weaker density and contrast, underscoring the influence of paper finish on print quality.

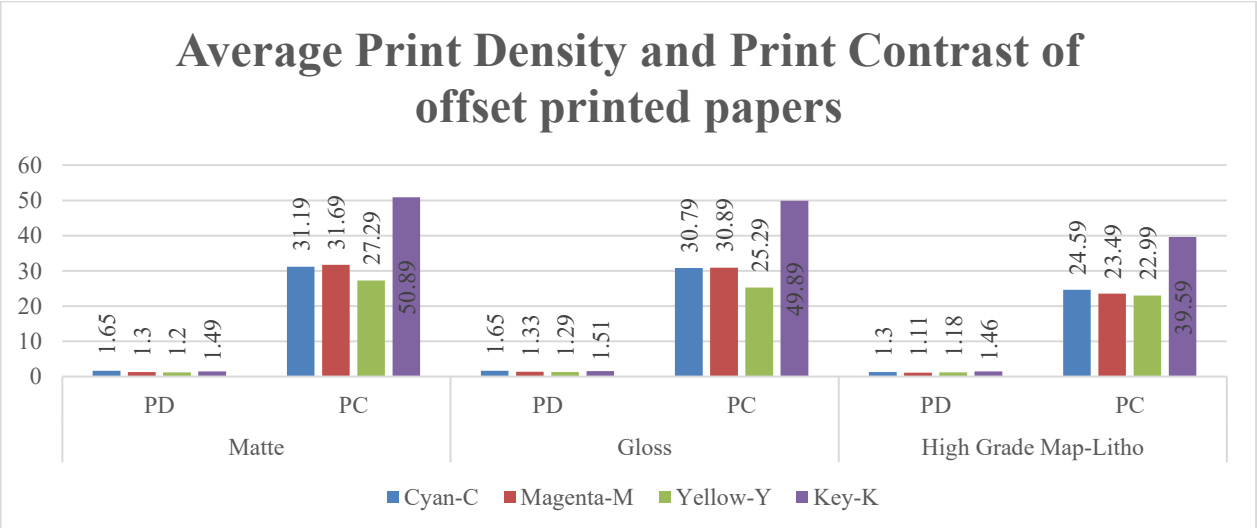
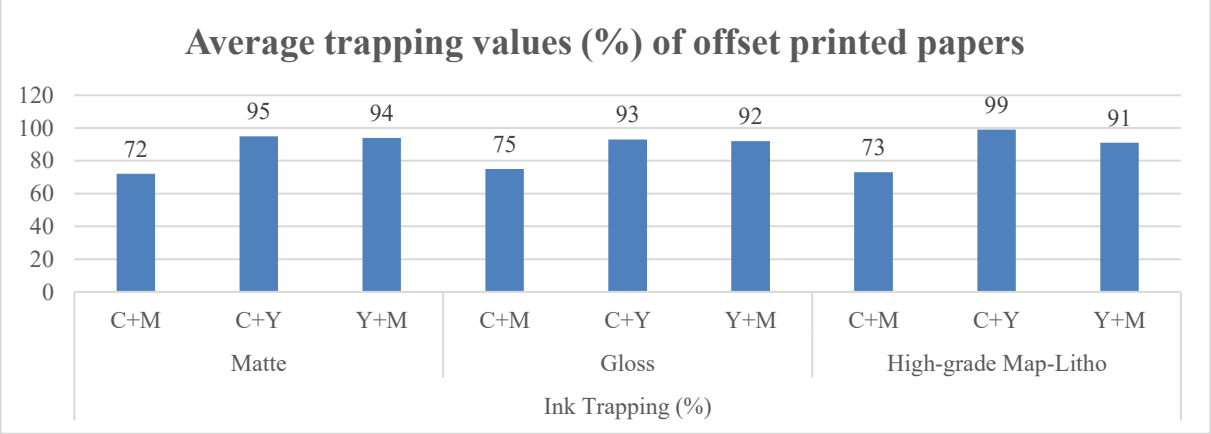


Table 4, Average trapping values (%) of offset printed papers

Matte			Gloss			High-grade Map-Litho		
C+M	C+Y	Y+M	C+M	C+Y	Y+M	C+M	C+Y	Y+M
72	95	94	75	93	92	73	99	91

The table-4, compares how well inks trap on three paper types i.e., Matte, Gloss, and High Grade Map-Litho using three colour combinations: Cyan + Magenta (C+M), Cyan + Yellow (C+Y), and Yellow + Magenta (Y+M). The results show that Gloss paper achieves the highest trapping for C+M at 75%, while Map-Litho records the strongest trapping for C+Y at 99%. Matte paper demonstrates consistently high values across all combinations, with 72% for C+M, 95% for C+Y, and 94% for Y+M. Gloss paper follows closely, with slightly lower values for C+Y (93%) and Y+M (92%). Map-Litho paper, while showing exceptional trapping for C+Y, records slightly lower values for Y+M (91%) compared to Matte. Overall, the data highlights that all three paper types provide strong ink trapping performance, with Matte offering balanced consistency, Gloss excelling in C+M trapping, and Map-Litho showing superior trapping in C+Y combinations.



RESULTS & DISCUSSION

The results of the study clearly demonstrate that paper finish strongly influences offset printing performance across all measured parameters. Matte paper consistently produced the highest solid ink density and dot gain values, which translated into richer colour reproduction and stronger tonal strength. However, this came with greater ink spread, which may affect fine detail reproduction. Gloss paper showed moderate values, balancing density and contrast with smoother ink laydown, while High Grade Map-Litho paper recorded the lowest density and contrast but offered tighter dot retention and more controlled ink behaviour.

In terms of print density and contrast, Matte and Gloss papers performed similarly, with both achieving higher values compared to Map-Litho. The Key/Black feature showed particularly strong contrast on Matte (50.89) and Gloss (49.89), whereas Map-Litho lagged behind at 39.59. Trapping values further highlighted the differences: Gloss excelled in Cyan + Magenta combinations, Map-Litho achieved superior trapping in Cyan + Yellow, and Matte provided consistently high values across all combinations. These variations underline how substrate choice directly impacts ink interaction and overall print quality.

CONCLUSION

The comparative evaluation of offset printed papers demonstrates that substrate choice directly influences print quality outcomes. Matte paper consistently provided the highest solid ink density, dot gain, and strong print contrast, making it most suitable for applications requiring vibrant colours and rich tonal strength. Gloss paper offered a balanced performance, combining moderate density and contrast with smoother ink laydown and controlled dot gain, which makes it ideal for achieving both visual appeal and precision. High Grade Map-Litho paper, although showing lower density and contrast, excelled in dot retention and trapping efficiency, making it valuable for jobs where accuracy and ink control are prioritized over colour intensity.

Overall, the findings confirm that each paper type has distinct advantages: Matte for maximum colour strength, Gloss for balanced reproduction, and Map-Litho for precision printing. This highlights the importance of carefully selecting paper finishes in offset printing to align with specific production goals and quality requirements.

REFERENCES

[1] Adamcewicz, J.E., (1994). A Study on the effects of dot gain, print contrast and tone reproduction as it relates to increased solid ink density on stochastically screened images versus conventionally screened images. Master‘s thesis, School of Printing Management [Accessed on 5 January 2021]

[2] Anonim, (1998). Tappi Test Methods. Tappi Pres. Atlanta.

[3] Aydemir, (2014). The effect of paper roughness on print color deviation, lightfastness and print gloss. Marmara Journal of Pure and Applied Sciences, 26(3), pp. 81-88. [Accessed on 5 January 2021]

[4] Baral, A.K. and Sharma, K., 2014. Effect of Paper Properties in Machine Direction & Cross Direction. International Journal of Science, Engineering and Computer Technology, 4(3/4), pp.74-77.

[5] Caulfield, D.F. and Gunderson, D.E., 1988, October. Paper testing and strength characteristics. In 1988 Paper Preservation Symposium: Capital Hilton, Washington, DC, October 19-21 (pp. 31-40). [Accessed on 5 January 2021]

[6] Chung, R. and Rees, M., 2007. A survey of digital and offset print quality issues.

[7] Cigula, T., Tomašegović, T., Hudika, T. and Donevski, D., INFLUENCE OF THE INK AND SUBSTRATE PROPERTIES ON THE INK TRANSFER IN LITHOGRAPHY.

[8] Haenen, J.P., Resch, P. and Scholte, B., Sappi Netherlands Services BV, 2012. Coated paper for sheet-fed offset printing. U.S. Patent 8,101,250. [Accessed on 5 January 2021]

[9] Hsieh, Y.C., 1997. Factors affecting dot gain on sheetfed offset presses. Journal of Visual Communications. University of Houston, Houston, TX, pp.39-52.

[10] https://www.tappi.org/Get-Involved/Develop-Standards-Methods/#:~:text=TAPPI%20Test%20Methods%20are%20testing,and%20Useful%20Method%20(UM) [Accessed on 4 January 2021]

[11] Hu, Y., Li, X., Geng, D., Cai, M., Li, R., Sun, X., (2013). Influence of paper thickness on the electrochemical performances of graphene papers as an anode for lithium ion batteries. Electrochimica Acta, Vol: 91, pp. 227-233. [Accessed on 5 January 2021]

[12] ISO, (2011). International Standard ISO 534: Paper and board-Determination of thickness, 007Ad+ensity and specific volume. International Organization for Standardization, Geneva. [Accessed on 5 January 2021]

[13] Koppelkamm, G., Schädlich, R. and Behmel, J., Manroland Druckmaschinen AG, 2002. Offset printing unit. U.S. Patent 6,408,747. [Accessed on 5 January 2021]

[14] Milošević, R., Stančić, N.K.D.N.M. And Adamović, S., 2013. Investigation of the printing pressure level application influence on sheet-fed offset print quality. reproduction, 10, p.13. [Accessed on 6 January 2021]

[15] Sahin, C., (2012). Evaluation of the effect of the efficiency of operators on print quality in offset printing. Doktoral thesis, Gazi Üniversity, Ankara, Turkey. [Accessed on 5 January 2021]

[16] Tutu, A., Yilmaz, U. And Çġçekler, M., 2017. Effects of Physical Properties of Some Papers on Offset Printing Quality. In IV. International Multidisciplinary Eurasian Congress.

[17] Tutu, A., Yilmaz, U. And Çġçekler, M., Effects of Physical Properties of Some Papers on Offset Printing Quality. [Accessed on 5 January 2021]

[18] Verikas, A., Lundström, J., Bacauskiene, M. and Gelzinis, A., 2011. Advances in computational intelligence-based print quality assessment and control in offset colour printing. Expert Systems with Applications, 38(10), pp.13441-13447.