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Optimizing a selection of printing method for label production

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1. Introduction

Current selection of printing method (technology), i.e. digital or analogue press, for label production, is based on the quantity required, with some other considerations regarding customer requirements [3, pp. 973–974]. Traditionally, it is assumed that above certain quantity the unit cost of traditionally printed labels is lower than labels digitally printed [3, pp. 975–978]. Some requirements (e.g. substrate type, additional finishing processes, variable data) may force the selection of appropriate press as well. In most cases however, a supplied label design can be printed in either way. For such cases, it might be interesting to select the press to minimize the cost of printing process.

It is assumed that direct costs of printing for each press have been properly ascertained and can be divided into fixed and variable costs. Since fixed costs are independent from the printed quantity, and variable cost are dependent mainly on the printed quantity, we may assume that for each press:

$$C_i = C_{fi} + f(n) \tag{1}$$

where i is the index of the press used, f indicates fixed press costs and n is the required product quantity.

For conventional printing, the variable costs can be considered the product of unit label cost and the required quantity, while the unit label costs are generally the sum of substrate cost per label and machine variable costs per label. Thus for conventional press we have:

$$C_{conc} = C_{fconv} + n \cdot (c_s + c_p) \tag{2}$$

where c_s are the unit substrate cost (per label), and c_p – unit printing costs (per label). One must also add the cost of errors (technological allowances) that result in waste print, which is usually a function of required quantity. This is true for all conventional printing methods, either using offset (sheetfed) presses, or using flexographic/hybrid narrow web presses.

For digital printing, there are several costing models [2], which are based either on:

– click charges, i.e. total costs of printing for single page/web unit length,

– lease/purchase, i.e. similar to the conventional press, where variable costs are based on ink/toner and substrate usage.

The click charge method has been used extensively for Xerox [2], but expands to other vendors in the digital printing market. It is widely used with electrographic presses [2]. Similar sales methods are used by other vendors, especially for the inkjet presses widely employed for the label printing [4].

For the click charge costing model, the direct cost of digital label printing may be simply written as:

$$C_{\mathrm{dig}} = n \cdot (c_{\mathrm{cc}} + c_{\mathrm{ds}}) \tag{3}$$

where c_{cc} is the click charge per label, and c_{ds} – digital substrate costs per label.

For lease/purchase costing model, the costs may be written as:

$$C_{\mathrm{dig}} = C_{\mathrm{fdig}} + n \cdot (c_{\mathrm{ds}} + c_{\mathrm{dp}}) \tag{4}$$

where c_{dp} is the unit digital press cost (per label). For the digital printing it is usually assumed that technological allowances are not necessary, i.e. all printed labels can be sold. However, in some cases such assumption is invalid.

Typically, the cost of digital substrate and ink/toner per label printed is higher than the unit label printing costs in conventional printing (which include the costs of prepress and press, as well as costs of inks and substrate). However, the fixed costs of digital printing are generally much lower, and in some cases even nil (for click charge costing model). This makes digital label printing an attractive proposal for short runs. For longer runs, it is possible that lower unit printing costs make conventional printing more economical [3]. Therefore, for each job, one may compare costs of printing in either of these methods and use it as a guideline for selecting the appropriate printing system.

2. Optimizing the printing method

Assuming that the technological allowances for conventional printing are known function of required quantity [1] (and possibly other factors), we may consider thatthe print run will be longer than required to satisfy the customer order only, and the cost of conventional printing must be increased proportionally, thus being:

$$C_{\mathrm{conv}} = C_{\mathrm{fconv}} + n \cdot (1 + \delta)(c_{\mathrm{s}} + c_{\mathrm{p}}) \tag{5}$$

where $\delta = n_a/n$ is the coefficient of technological allowances for a given job, and n_a is the actual quantity of technological allowances for a given print run. For offline finishing, the quantity required for printing should also take into account the allowances required for the postpress processes.

Based on the cost criteria, the job can be digitally printed, if $C_{\mathrm{conv}} > C_{\mathrm{dig}}$, and should be conventionally printed otherwise. If both costs are considered equal within the arbitrarily chosen tolerance, either technology can be used. The job quantity where the costs of digital and conventional printing are equal is a threshold quantity.

By further assuming that δ can be approximated by an exponential equation [1], i.e. that:

$$\delta = An^b \tag{6}$$

where both A and b are constant and known, we may finally obtain that for the click charge costing model the threshold quantity n_t must satisfy the following equation:

$$C_{\text{fconv}} + n_t \cdot (1 + An_t^b)(c_x + c_p) - n_t \cdot (c_{cc} + c_{ds}) = 0 \tag{7}$$

which may be rewritten as:

$$An_t^{b+1}(c_s + c_p) + n_t(c_s + c_p - c_{cc} - c_{ds}) + C_{\text{fconv}} = 0 \tag{8}$$

By solving this equation we obtain the threshold quantity, above which the conventional press should be the optimum choice. However, solving this equation for any value of b (in general, a real value) may be difficult and possible with numerical methods only. Some special cases are, however, typically observed.

If $b = 0$, then the coefficient of technological allowances is fixed and independent of job quantity. The actual allowances are linear function of quantity printed: $n_a = An$. This is a common way of estimating the technological allowances in conventional printing. In such a case we have:

$$n_t(1 + A)(c_s + c_p) - n_t(c_{cc} + c_{ds}) + C_{\text{fconv}} = 0 \tag{9}$$

which gives us the value of threshold quantity in such case as:

$$n_t = \frac{C_{\text{fconv}}}{c_{cc} + c_{ds} - (1 + A)(c_s + c_p)} \tag{10}$$

This dependence is widely used to calculate the threshold quantity for commercial digital printing, traditionally disregarding the increased conventional unit printing costs because of technological allowances. By including this factor we may observe that the digital label printing may be an optimum choice for higher quantities than traditionally assumed, since the coefficient of technological allowances acts as a decrement in difference between unit costs of digital and conventional printing.

It is also interesting to note that should the technological allowances coefficient rise to a value of:

$$A_t = \frac{c_{cc} + c_{ds}}{c_s + c_p} - 1 \tag{11}$$

then the threshold quantity will rise infinitely, and all jobs should be digitally printed. However to achieve that, the coefficient of technological allowances should be significantly larger than 1, i.e. the number of waste labels is greater than the labels meeting the quality criteria. It also means that there may be a reason to digitally print jobs in cases where quality control can reject a large number of printed labels.

In many cases the technological allowances quantity is constant, i.e. $b = -1$ and $n_a = A$. This happens primarily when no allowances are provided for waste during the print run. With this in mind we have:

$$A(c_s + c_c) + n_t(c_s + c_p - c_{cc} - c_{ds}) + C_{\text{fconv}} = 0 \tag{12}$$

Then the threshold quantity may be found as:

$$n_{\mathrm{t}} = \frac{C_{\mathrm{fconv}} + A(c_{\mathrm{s}} + c_{\mathrm{p}})}{c_{\mathrm{cc}} + c_{\mathrm{ds}} - c_{\mathrm{s}} - c_{\mathrm{p}}} \tag{13}$$

Thus the threshold quantity will be also higher than traditionally assumed, if the costs of technological allowances are taken into account.

For the lease/purchase costing model the similar equations may be provided.

It must be noted that this model considers only direct printing costs. However, as other (indirect) costs are generally accounted as a proportion of direct costs, and salaries may also be generalized in such way, such formulae are still valid while the actual costs may be increased by an appropriate indirect cost coefficients. Furthermore, it must also be noted that the amount of technological allowances may be a function of other job parametres as well [1] (e.g. the number of colours printed, substrate type, ink tack etc.) By using such information it is possible to make the cost comparison tied to more job data than quantity only and thus dynamically assign the most appropriate printing technology for each single job.

Finally, it is also possible to use this model with the unit costs per substrate length or substrate area and not per single label, provided that all quantities (including the run length and threshold quantity) are expressed accordingly.

3. Case study

A Polish label printer is using a conventional 6-unit Nilpeter F2400 flexographic web press with maximum web width of 230 mm, for which the fixed hourly costs are accounted at 250 PLN/hr. For standard self-adhesive label printing, the press runs at 2800 m/hr (46,67 m/min) and the printing (variable) costs are accounted at 0,115 PLN/m. The substrate used for printing such labels is bought for the price of 1,9415 PLN per square metre, which gives substrate costs at 0,447 PLN/m. The printer assumes that 60 metres of substrate is required to pass the web through the press and 140 metres are wasted during the setup of the the 6-colour print run. The printer also assumes that there is no waste during the printing stage, however the actual quality is further checked during the inspection while rewinding the rolls. The fixed prepress costs are averaged at 80,5 PLN for each printing plate (colour printed). At the moment of writing 1 PLN equals 0,2373 EUR or 0,3169 USD correspondingly.

The printer is considering the purchase of EFI Jetrion 4900 digital label printing system with 5-colour double side printing capability and a maximum web width of 229 mm, i.e. almost identical to that of conventional press. The system is sold in an “ink-only” model [4] which replaces the “click charge”, with the ink price approx. 100 USD per litre. According to [4] it shall give 0,013 USD (i.e. 0,041 PLN) per average printed label unit cost. Using UV-curable inks, the digital press does not require a special substrate, thus saving the need to add a primer cost for digitally printed label. Both the conventional and (planned) digital press are equipped with inline die-cutting unit, therefore completing the required functionalities for label printing.

For printing the company standard 76 x 101 mm self-adhesive label it is possible to fit the 25 labels on the 1 linear metre of substrate, which gives unit digital printing cost per linear metre at 1,025 PLN. As the same substrate will be used for both conventional and digital printing, the difference in substrate cost is nil. The conventional printing fixed costs will now depend on the print run length and may be expressed as:

$$C_{\mathrm{fconv}} = C_{\mathrm{hr}} \frac{n}{v_{\mathrm{p}}} + C_{\mathrm{fp}} \qquad (14)$$

where C_{hr} is the fixed hourly cost, C_{fp} is the fixed prepress cost, and v_{p} is the press speed in units (metres or labels) per hour.

Then the equation (12) which is valid in this case will become:

$$A(c_{\mathrm{s}} + c_{\mathrm{c}}) + n_{\mathrm{t}}(c_{\mathrm{s}} + c_{\mathrm{p}} - c_{\mathrm{cc}} - c_{\mathrm{ds}}) + C_{\mathrm{fconv}} = 0 \qquad (15)$$

which, considering that $c_{\mathrm{s}} = c_{\mathrm{ds}}$, gives:

$$n_{\mathrm{t}} = \frac{C_{\mathrm{fp}} + A(c_{\mathrm{s}} + c_{\mathrm{p}})}{c_{\mathrm{cc}} - \frac{C_{\mathrm{hr}}}{v_{\mathrm{p}}} - c_{\mathrm{p}}} \qquad (16)$$

In the given case the threshold quantity (in metres) for printing such labels conventionally over digitally may be given as:

$$n_{\mathrm{t}} = \frac{6 \cdot 80.5 + 200 \cdot (0.115 + 0.447)}{1.025 - \frac{250}{2800} - 0.115} = 725 \text{ m} \qquad (17)$$

which corresponds to 18125 individual labels. Thus, the digital printing system should be the preferred option for all orders below that quantity, and the conventional Nilpeter press is more economic for quantities above that threshold. However, the conventional press would then be able to print 6 colours including 2 spots, while the digital press would have to simulate the spot colours with their CMYK equivalent which may not be desirable for certain jobs.

The threshold will change when only 4-colour conventional printing is required, as the substrate waste for setting up the print will be lowered to 110 metres (and only four plates will be required). Therefore the threshold quantity will be 508,4 m or 12709 labels, and with no spot colours there should be no quality-dependent factor in deciding which press to use.

It is important to stress that the threshold quantity will be dependent on the label size. A precise calculation shall take into account the different cylinders (cut-off lengths) which may be used for conventional printing of identically sized labels, changing the unit substrate cost per label (or conversely number of labels printed for linear metre of substrate). This factor is not present in the digital printing system, where the layout may be changed at the printer's convenience.

Of note is also the maximum conventional waste quantity coefficient as expressed by the equation (11), which in the specific case amounts to 1,62. This means that if the conventional printing waste quantity shall exceed 162 per cent of the print run length, the above mentioned labels should be printed digitally.

To show the influence of the label size, another standard label size of 50 x 100 mm (which allows to print 38 labels per linear metre of substrate and results in average digital printing unit cost of 1,558 PLN per metre) printed if four colours gives the threshold quantity of 308,2 m or 7705 labels respectively. Increased ink consumption for digital printing, as well as the larger number of labels produced for each conventional press cycle, shift the threshold quantity towards smaller figures. Conversely, for yet another standard label size of 71,315 x 207 mm there will be 13 labels per linear metre and the average digital printing cost per metre will be 0,533 PLN. This gives the threshold quantity of 1269,1 m or 31727 labels.

It would be interesting to note that the Jetrion 4900 printing speed is roughly half of the Nilpeter 2400 (21,34 m/min versus 46,67 m/min). Thus the production run will take twice as long on the Jetrion. However, the prepress time and press setup time required for conventional printing process in case of Nilpeter 2400 will nullify the difference. Imaging the four flexographic plates required for printing may take up to 40 minutes, and the Jetrion may produce as much as 853 metres of printed substrate during that period. This factor stresses the suitability of digital printing for quick production changes, where the conventional press must wait for the prepress stage to finish.

4. Conclusions

The paper presents a possibility of selecting the printing method (if available) for label printing based on optimum costs criteria, which takes into account the amount of waste (technological allowances) required for conventional printing, and a costing model widely used for digital printing. In general, a threshold quantity can be calculated by dividing fixed costs of the conventional press run by a difference in unit printing costs (digital less conventional). However, the general equation presented here allows the threshold quantity to be dynamically calculated for each job, where different parametres can also be taken into account. It explains that digital label printing may be used for longer runs than traditionally assumed, as the cost of technological allowance will increase the threshold quantity. However, the digital printing costs (click charge) may widely differ between presses and printing houses, and for that reason the selection criteria must be individually computed for a given printing house.

It must also be stressed that there might be other factors that influence the printing method selection. A number of spot colours or varnishes used in conventional printing cannot be used for digital printing, and some inks used in label production will require a certain printing method. Also, some finishing methods are possible only for labels printed in a certain way. The difference of printing speeds (and thus fixed costs if accounted per hour of machine time) should also be noted. Availability of printing plates and dies (e.g. for the standard jobs) for any press may also change the conditions of printing method selection. Notwithstanding these limitations, for most common cases it is possible to optimize the printing method selection using the method shown above.

The solution can easily be extended to other digital printing costing models, like shown in the case study. It is also adaptable to management information systems which support the printing houses' production and business processes management [3, pp. 934–936]. By using appropriate Business Intelligence method on the database of actual printing jobs, it is possible to further automate the process of optimizing the printing methods for subsequent print runs, with dynamic changes of the costing data according to the current information.

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Streszczenie

Optymalizacja wyboru metody drukowania przy produkcji etykiet

W artykule przedstawiono sposób wyboru metody drukowania etykiet, który pozwala na optymalizacje kosztów produkcji z uwzględnieniem ilości makulatury, a zatem i normatywów technologicznych, dla danego nakładu. W typowych zastosowaniach wybór pomiędzy analogowymi i cyfrowymi technikami drukowania dokonywany jest na podstawie wielkości nakładu, przy czym przez porównanie kosztów stałych i zmiennych dla obu technik wyznaczany jest nakład minimalny, powyżej którego optymalnym wyborem jest drukowanie analogowe. Zakładając, że znana jest relacja pomiędzy wymaganym nakładem a ilością makulatury dla każdego z procesów, możliwe jest dokładniejsze prognozowanie kosztu drukowania, a zatem dokładniejsze wyznaczenie nakładu granicznego pomiędzy drukowaniem cyfrowym i analogowym. Przy tym podejściu określenie nakładu minimalnego, dla którego proces analogowy jest tańszy niż cyfrowy, polega na rozwiązaniu nieliniowego równania. Dla szczególnych przypadków tego równania przeprowadzono dyskusję wyników i zaprezentowano porównanie pomiędzy typowym podejściem a zaproponowanym modelem. Wyniki tego porównania częściowo wyjaśniają rosnącą popularność cyfrowego drukowania etykiet, a jednocześnie można je zastosować do doboru określonej maszyny drukującej dla procesu, jeśli dla każdej z analizowanych maszyn znany jest związek pomiędzy nakładem i ilością makulatury.