Monitoring Digital Package Printing Performance

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Abstract

This paper deals with performance monitoring and data management of digital package printing and fiber-based packaging production. The aim of this case specific study was to determine the characteristics of demand driven packaging production. In order to make equal and stable benchmarking long-term data gathering was performed. According to results ground for economically viable demand driven packaging production exists, but several technical as well as economical limitations were identified.

In this case printing was identified as a bottleneck and the majority of resource costs were associated with printing activity. According to results printing accounted easily 50% or more of all costs. Other significant cost factors were packaging activity, toner and carton usage. Attention should be paid for maintenance cycles, press control and incoming designs. The role of carton and especially the coating layer is critical and attention should be paid to the selection of the right carton for digitally printed packaging.

Introduction

This paper deals with performance monitoring and data management of digital package printing and packaging production. Equipment performance and reliability are major concerns when new businesses or processes are created, clearer map of economic profitability and losses are wanted, and benchmarking of current practices are being carried out. There is also continuous demand of better efficiency and optimal quality.

The aim of this case specific study was to determine the characteristics of demand driven packaging production. This way a platform for better customer satisfaction and basis for profitable production could be provided.

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The results and conclusions presented in this paper are based on long-term data and information gathering. This enabled continuous analysis of process data and financial evaluation of a start-up production line.

The study was divided into sections covering technical and economical aspects of the production line in question. The technical part was more focused on machine performance and key parameters. In the business section machine performance and resource consumption were quantified in monetary terms. Finally the key performance parameters were combined with financial data to show the effect of production line performance on product cost and profitability. This data is mainly indicative of the performance of the packaging production line where digital printing is used for fiber-based packaging.

Methods

The study was based on quantitative research in production environment. Data was gathered from the production line consisting of digital press, converter, and packaging machine. In addition to printing, converting and packaging activities also data from order handling, prepress, and logistics were collected and used for the analysis. The line is used for producing fiber-based non-food packaging on customer's premises thus eliminating the need for transportation of empty packaging. In this study electrophotography was used for printing activity.

Real production data was used for analyzing equipment performance and cost behavior. Standard PCs were used for collecting and storing production data. Cost analyses were carried out using commercially available activity-based costing software and data processing and also pre-calculation were done using Excel, Matlab Statistics Toolbox, and tools developed by VTT.

In addition to principles of activity-based costing (Cooper, 1990, Kaplan, 1998) and key financial measures production line performance was monitored using overall equipment effectiveness (OEE). This ratio is used to measure the ability of process to carry out value added activities (Hide, 2004). OEE incorporates three basic indicators of equipment or production line performance and reliability:

- uptime (or availability)
- efficiency
- output quality

OEE measure offers an easy and standard way of identifying areas where resource utilization is unsatisfactory. Workflow and activities covered in this case are presented in Figure 1.

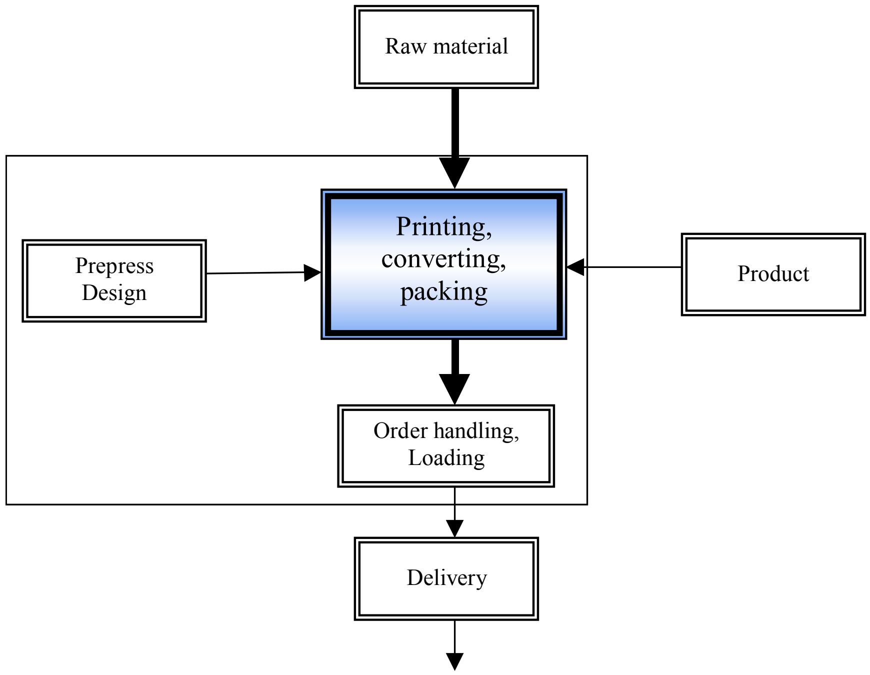

Figure 1. Schematic illustration of packaging production analyzed and modeled (outlined).

Results

The results of this research showed how different factors affected machine and production line performance as well as the total cost and profit level of packaging. Ground for economically viable demand driven packaging production exists, but several technical as well as economical limitations were identified. These limitations relate mainly to the press control, speed, and printing quality. These limitations should be taken into consideration when planning the production and pricing orders. In this study real variation between different products could be characterized because product-specific cost drivers were used instead of averages.

Digital printing performance

According to data gathered it seemed that disturbance was caused by variation in print quality especially during set-up activity and it was a major source of waste. Certain colors and color combinations were troublesome to print and the share of full color area in a packaging correlated negatively with printing speed

(Figure 2). However, the use of variable data did not affect printing efficiency, but it increased workload in prepress activity. Some 11% of all orders included variable data. Data analysis revealed also that there was some variation between weekdays regarding press speed (Figure 3). This indicated that the electrophotographic press was thoroughly cleaned and maintained at the beginning of the week and towards the end of the week problems increased and dirt was accumulating into the press. Also motivation after the weekend might have been better.

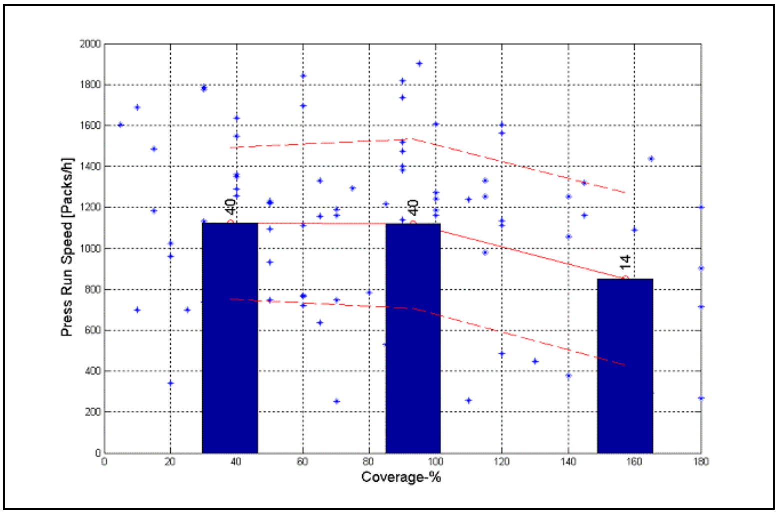

Figure 2. Press speed as a function of toner coverage. Number above the column denotes the sample size in the group.

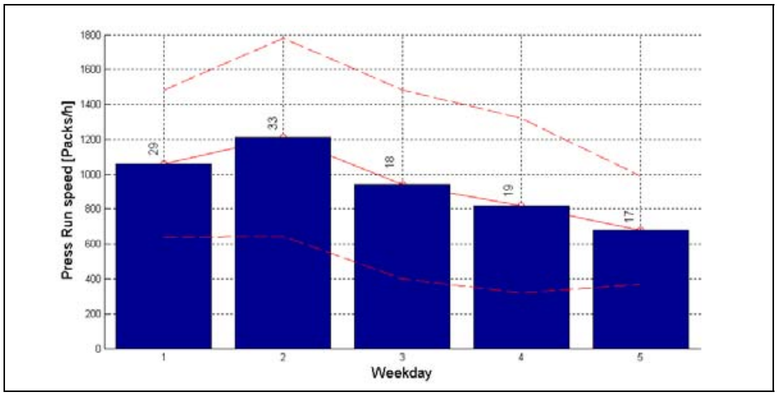

Figure 3. The effect of weekday on press speed. Weekdays are indexed from 1 to 5 denoting days from Monday (1) to Friday (5).

The development of press key performance ratios during the research period is presented in Figure 4. Both efficiency and prime had an improving trend, but run rate varied noticeably. Figure 4 shows how process improvements during month four affected printing and converting performance. The major cause of efficiency loss was located in the converting activity and the fixing of that problem increased run rate. However, at the end of the period run rate decreased again and pause time increased respectively. High utilization rate and some time consuming maintenance stops seemed to affect run rate negatively

The OEE ratio improved during the research period and the average OEE was around 35%. However, global studies indicate that the average OEE in manufacturing plants is around 60%. A world class organization is considered to be 85% or better (Hide, 2004). Defect rate could also support learning curve. It was recognized that the repetition of the activities resulted in less waste or effort expended on activities.

Utilization time distribution for different activities are presented in Figure 5. Some 10% of the utilization time were consumed in the set-up activities, but quite a lot of variation occurred. When the digital press was compared to the flexo press it was noticed that the share of pause, maintenance or no work time was significantly higher for digital. It is very usual that, although running at the higher level of practical capacity, the flexo press needs less care than the digital press and this study supported that finding.

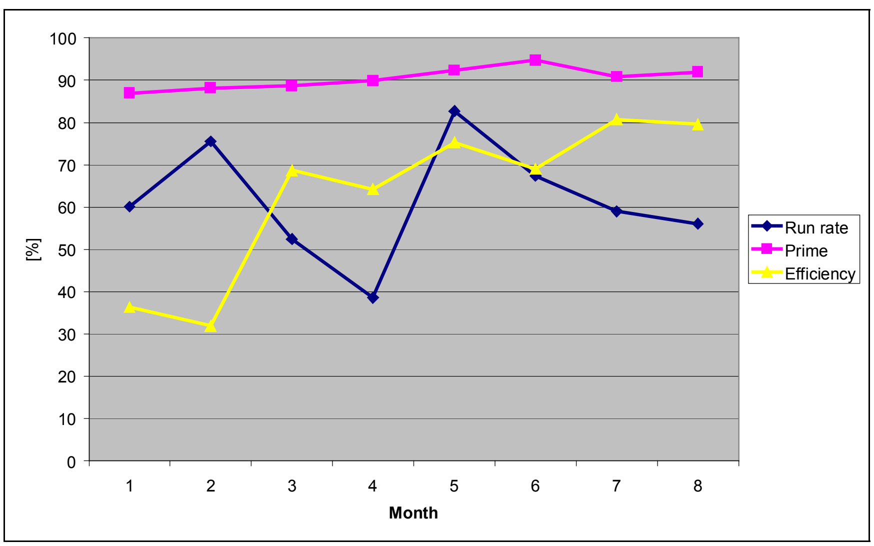

Figure 4. The development of press key ratios during the selected period.

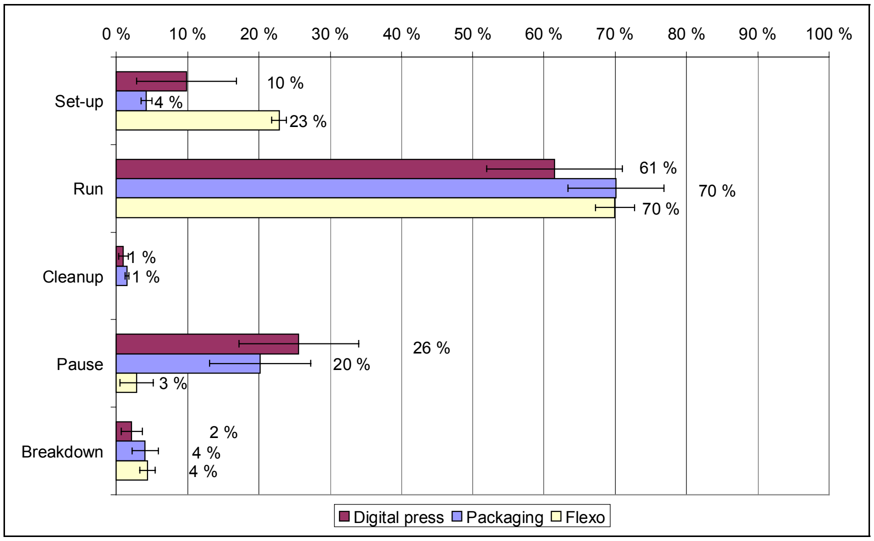

Figure 5. Utilization time distribution of digital and flexo printing, converting, and packaging activities.

Financial evaluation

Printing was identified as a bottleneck and the majority of resource costs were associated with printing activity. According to results printing accounted easily 50% or more of all costs (Figure 6). Other significant cost factors were packaging activity, toner, and carton usage. Attention should be paid for maintenance cycles, press control, and incoming designs. The role of carton and especially the coating layer is critical thus effort should be made for selecting the right carton for each application.

The correlation between key performance parameters and the unit cost of packaging can be noticed in Figure 7 (see also Appendices, Table 1). The unit cost of packaging decreased since the start-up reaching a stable level at the end of the period. When the average monthly unit cost was depicted against the monthly-calculated key performance parameters it can be seen that from the single key parameters press efficiency naturally had the highest correlation with the unit cost. Based on this data the change of the press OEE ratio from 40% to 50% drops the average unit cost approximately 15%. Because printing was dominating the total cost the packaging OEE ratio did not have that strong correlation with the unit cost of packaging.

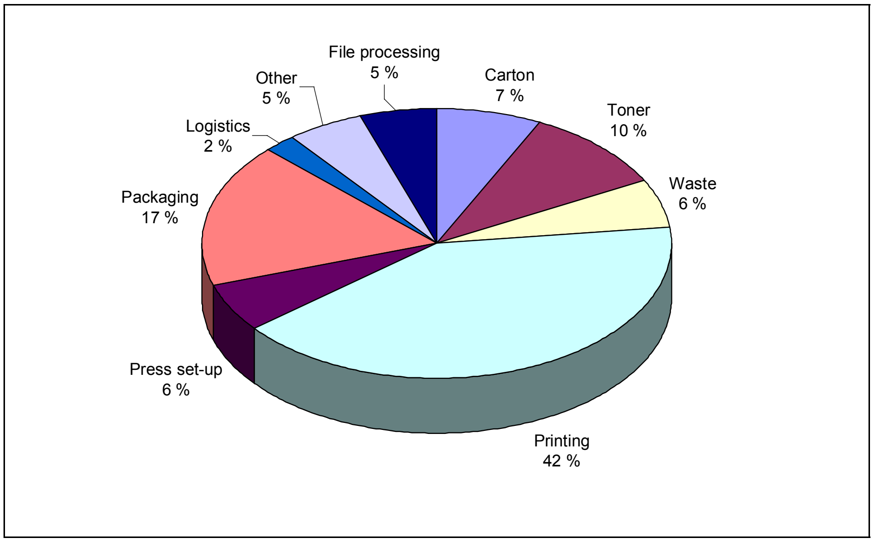

Figure 6. The cost structure of digitally printed packaging. Costs are divided to activity costs and direct resource costs.

An example of the value added analysis of packaging is presented in Figure 8. It was found out that significant potential exists for creating more value with digitally printed packaging than with conventional packaging that has become a commodity product. Customers are willing to pay even seven times more for the digitally printed packaging than for the conventional. This was the case when very small orders were produced. The overall economic viability depends on the total volume and market distribution of these orders.

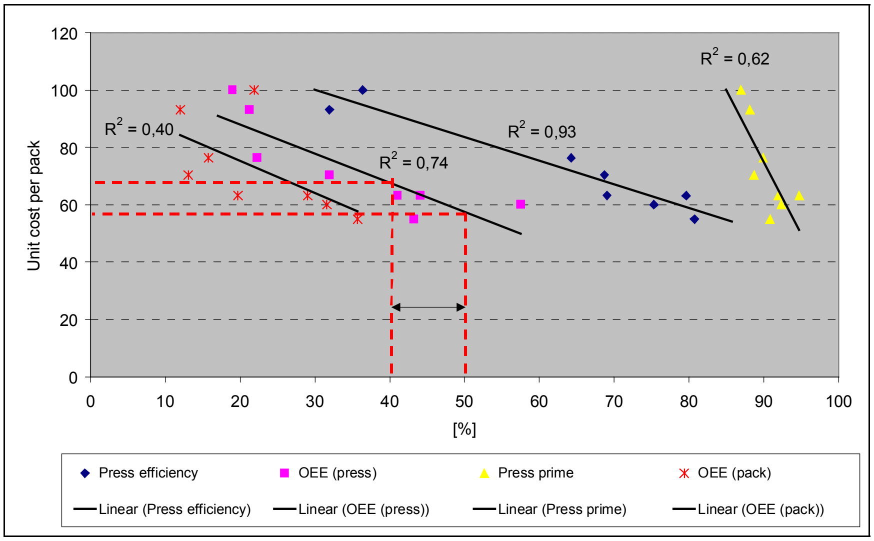

Figure 7. The unit cost of packaging as a function of selected key performance parameters.

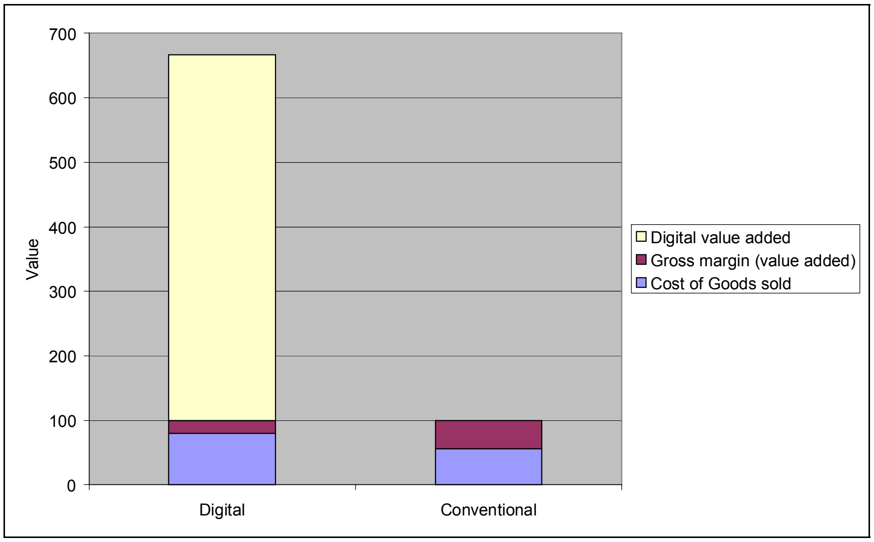

Figure 8. The value added of digitally printed and currently favored conventional packaging.

Cost model for packaging production

After the first phase when the cost structure and the most significant production parameters were identified a multivariable regression model was constructed. This way the number of different variables could be compressed into a reasonable level. The model could be used for estimating product cost and to support pricing. It covered production and material factors and was based on single runs recorded during the data-gathering period.

In the first phase stepwise regression was used to select the most significant factors affecting the total cost of order (Figure 9). Some filtering was needed before the analysis to improve the accuracy of the model. It was also found out that because of inconsistent initial data it was impossible to construct one model that would well depict a wide range of different orders. For a wide range of orders three or more different cost functions would have been required to get realistic responses. Because there was not enough data for large order sizes it was decided to focus on a cost model that would cover the range of small order sizes.

The most significant factors that were selected for the cost model in descending order were:

- y1: Press run speed [packs/h]
- y2: Press production [packs]
- y3: Press set-up time [h]
- y4: Order size [packs]
- y5: Toner coverage [%]
- y6: Total waste [packs]

The total waste level was included in the final model so that the effect of excess material could be quantified. The model can be presented in the following simplified form:

$$C_{total} = C_0 + \sum_{i=1}^{n} a_i * y_i \qquad (1)$$

Where

C_{tot} = Total cost of order,

C_0 = Committed (fixed) batch-level cost factor,

a_i = Coefficient,

y_i = Selected variable, i = 1,...,6 .

The model can also be extended by adding selected terms or resource costs from other activities. The effect of the selection of the most significant factors on the root mean square error is presented in Figure 9 (lower part). It can be seen that the three most significant factors, which related to printing (production size, press speed and set-up time) already give a very good model response, which emphasize the importance of printing and converting phases.

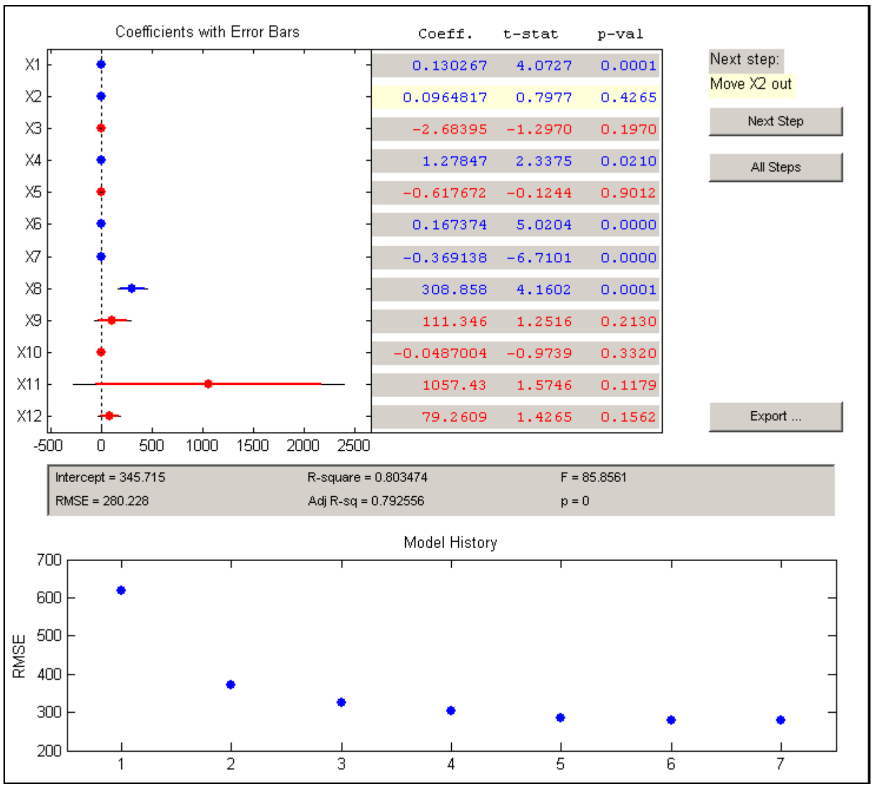

Figure 9. Stepwise regression was used for selecting the most significant factors affecting the total cost.

The accuracy of the model was tested by comparing the recorded values against the modeled values (Figure 10). In total 133 single orders were included in this phase. The model seemed to work well for the defined range and the R-squared value of the model in question was over 0.90. All in all, the model can be used for simulating the cost accumulation and profitability of different product repertoire or production scenarios.

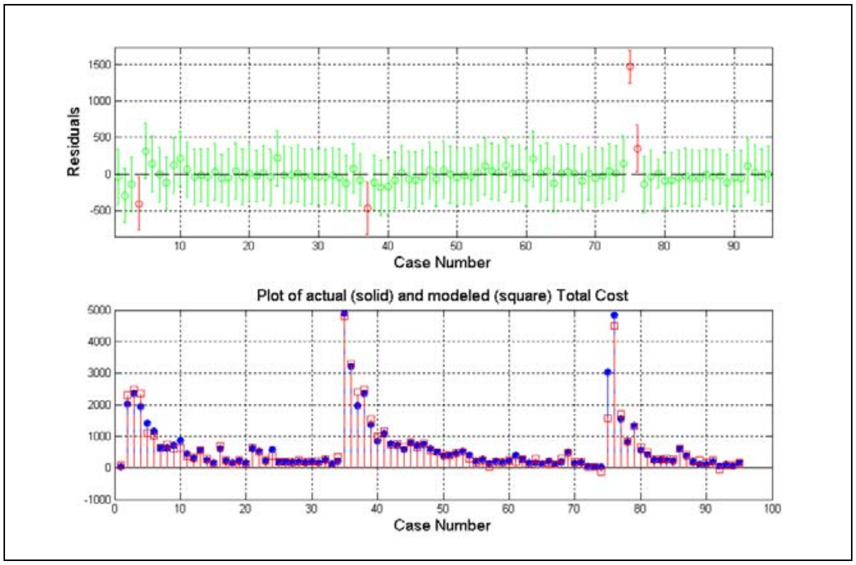

Figure 10. The plot of recorded and modeled total cost. The difference between recorded data and cost model data is presented in the upper figure describing the accuracy of the model.

Conclusions

Relatively slow printing speeds, in comparison with conventional printing methods, combined with color limitations and maintenance requirements in continuous production are the main constraints in the case of digital printing in the packaging sector. According to the results one of the most significant factors affecting printing performance is the share of compact, solid printed area. Especially certain colors and color combinations are troublesome to print when using electrophotography. This should be realized when designing packages. In this case printing accounted easily 50% or more of all costs. Other significant cost factors were packaging activity, toner, and carton usage.

Improvements in digital printing technology together with declining color and equipment costs could change the situation in many ways. Also long-term monitoring in real production environment is needed in order to develop new technology further.

In total this means that digital printing makes sense for certain tasks where packaging size or printed area and run length are small. Because current supply and demand chains are very streamlined and capable of doing JIT production with low inventory levels the opportunity to implement digital printing technology will offer advantages in the areas where distinct advantages are obvious. Special advantages of digital printing are design and production flexibility, customization, fast response time when near-line with the packaging process, and decreased inventory costs for slow-moving consumer goods packaging.

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Appendices

Table 1. Matrix of correlation for the unit cost of packaging and key performance parameters.

	Unit cost
Unit cost	1
OEE (press)	-0,86
Press run rate	-0,03
Press efficiency	-0,96
Press prime	-0,78
OEE (pack)	-0,62
Pack run rate	-0,32
Pack prime	-0,03
Pack efficiency	-0,53
Order size	-0,59