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REDESIGNING A BOOK PRODUCTION PROCESS USING DFE TOOLS

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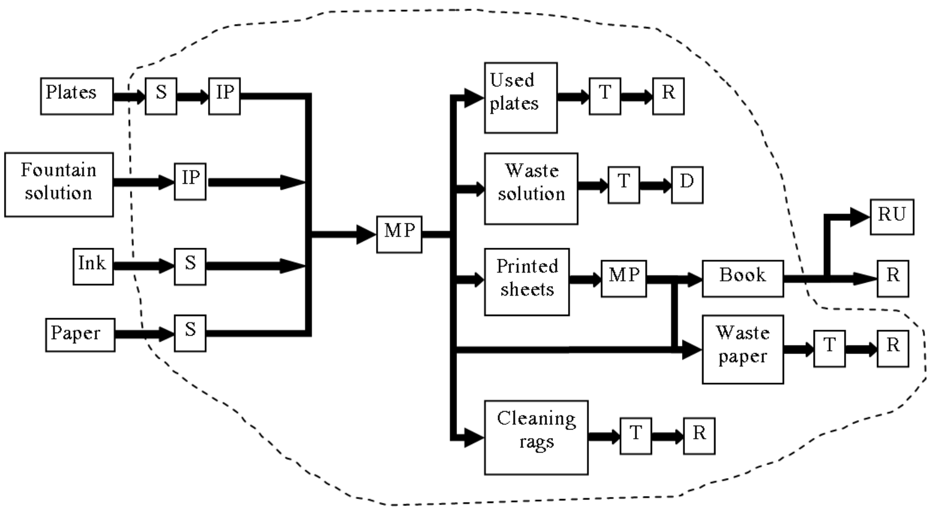
ABSTRACT
The design for the environment (DfE) tools are used to include the environmental objectives into all of the company's processes, and their suppliers and customers if possible. This paper investigates the benefits of applying DFE tools in the graphic arts industry, specifically the book production process. A present book production process in a print shop was redesigned taking into account the quality, cost and the environmental impact. The results suggest that with the proper use of the DFE tools, significant improvements can be made in all of the abovementioned aspects of the book production process, and other print production processes as the technology is generally similar.
Keywords: DFE, book production, industrial ecology

1. INTRODUCTION
Companies have been pressed since the 1960s to reduce their emissions and waste output from their plants.The traditional approach within a company is to regulate the output of harmful materials. However, in the late 1980s a new approach was introduced. Industrial ecology is the study of the flows of materials and energy in industrial and consumer activities, of the effects of these flows on the environment, and of the influences of economic, political, regulatory, and social factors on the flow, use, and transformation of resources.The objective of industrial ecology is to understand better how we can integrate environmental concerns into our economic activities. This integration, an ongoing process, is necessary if we are to address current and future environmental concerns. Industrial ecology takes the view of the company as an eco-system [1]. Ideally, the waste streams from one process should serve as materials for another process, thereby allowing the company to obtain as much monetary value from its raw materials and processed materials as possible.
In general, a company begins this process by introducing design for the environment (DFE) as a set of tools and methodologies that can help guide a company to include environmental objectives into their purchasing, design, and manufacturing processes [2]. The field of intervention of DFE is considered to cover the design of both products and processes. For this reason a distinction is made between 'environmentally concious product design' and 'environmentally conscious process design' [3]. In this paper it will be introduced a methodology that can be used in conjunction with the concurrent engineering methodology and that will allow a small company to incorporate DFE into the design of their products - books and processes.

2. MAPPING THE PRODUCT LIFE CYCLE

To estimate the impact of a product on the environment, a product's life cycle must be assessed. Only by taking into account all of the stages, from raw material acquisition, to the product end-of-life, can the environmental impact be estimated in its totality. The sphere of influence comprises those parts of the product life cycle that the company can influence. It is a DFE (design for the environment) tool used to mark out those parts as a first step of identifying the stages and processes which can be improved.

As shown in Figure 1, the book production process consists of acquiring raw materials (plates, fountain solution, ink and paper), storing and preprocessing those materials before the manufacturing process, output from which are the printed sheets and some solid and liquid waste. The printed sheets are the input to another manufacturing process, or to be more correct, a series of processes (postpress operations), resulting in the final product and waste paper. The area marked out with the dashed line in Figure 1 represents the sphere of influence. The case presented here did not take into account the production of raw materials and their choice, so most of the steps fall within the sphere of influence. The only stage that isn't under the company's direct control is the final product's end-of-life.



S – storage, **IP** - initial production, **MP** - manufacturing process, **T** – transportation

D – disposal, **RU** – reuse, R - recycling

Figure 1. Product life cycle with defined sphere of influence

3. APPLICATION OF INVENTORY TOOLS

The inventory tools, used to determine the materials and energy flow through the manufacturing process, are the flow chart and the energy balance. Figure 2 shows the flow chart of a book production process. It shows all the materials entering and exiting the manufacturing process. In addition to flow chart, the energy balance has to be made in order to assess the amount of energy going into the process, and the amount of waste energy going out of the process.

From the data collected using the inventory tools, a SLCA (streamlined life cycle analysis) matrix was derived. The matrix is shown in Table 1. The scores ranging from 0 to 4 were assigned to different categories in different life cycle stages. Zero corresponds to the least acceptable result, and 4 corresponds to the most acceptable result. Such notation was introduced in earlier work because the authors of the method believed that in the business environment it is better to set higher scores to represent better results. From the matrix presented in Table 1, it is obvious that the most critical stages are the incoming and outgoing transportation, and the chemicals used in the plate making and the printing process.

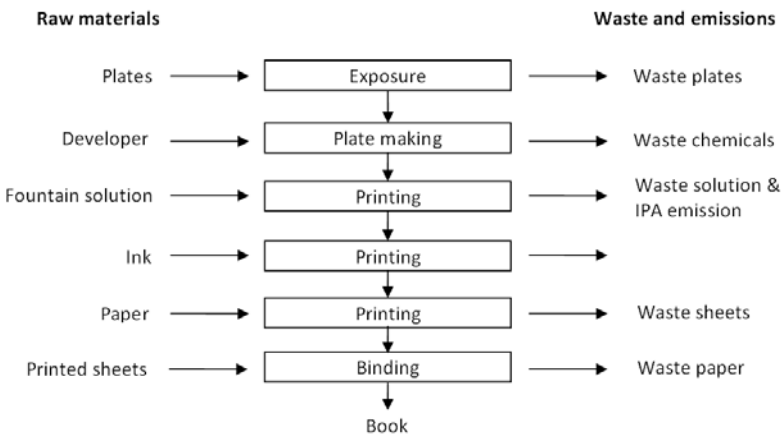


Figure 2. Flow diagram of a book production process

Table 1. SLCA matrix of a book production process

	Environmental Stressor			
Life Cycle Stage	**Health Hazards**	**Energy Use**	**Waste & Emission**	**Total**
Incoming transportation	3	2	1	6
Incoming Packaging	4	2	4	10
Plate making	3	3	0	6
Printing	3	2	1	6
Binding	3	2	2	7
Package	3	4	4	11
Transportation	3	3	1	7
Use	4	4	4	12
Totals	26	22	17	65

The process is therefore redesigned within the current sphere of influence. The incoming transportation is not under the company's direct control. The outgoing transportation currently has no alternatives, but is possible to improve in the future if the recycling companies become available locally. The plate making process can be improved can be improved by adopting the chemistry free technology, which requires an investment, but on the other hand reduces the costs of waste disposal. The waste fountain solution from the printing process, in addition to being the major environmental problem, causes significant costs of disposal. The adoption of some of the fountain solution purification systems can both extend its life and improve the product quality. By reducing the amount of waste fountain solution, the disposal costs are also reduced.

The concept comparison matrix shown in Table 2 was used to evaluate different concepts for quality, environmental impacts and cost. Each concept was evaluated on the scale from 1 to 10, and the scores were placed in the appropriate row (concept category) and column (selected evaluation criteria). Weights were assigned to each of the three categories, quality, environment and cost. Additional weights (importance factors) were assigned to each of the evaluation criteria. Those values were used to calculate the satisfaction scores for each concept, which are a measure of how each of the concepts compare in satisfying the three requirements of quality, environment and cost. The difference [%] is the measure of improvement between concepts and is calculated from their scores. The estimated improvements in the case presented in this paper, shown in Table 2, can be considered significant. Therefore, both process redesign concepts are considered to be worth adopting.

Table 2. Comparison matrix

	Quality	Environment			Cost				
Concept	Product	Waste mass	Waste hazard	Human health	Waste disposal	Raw material	Capital equipment	Satisfaction	Difference
Chemistry plate making	7	3	4	6	4	3	5	79,4	
Chemistry free plate making	7	10	10	10	10	7	8	139,4	76 %
No fountain solution purification	5	6	5	7	6	6	5	89	
Fountain solution purification	7	8	5	7	8	8	7	114,2	28 %
Weights	0,4	0,2			0,4				
Weight (1-10)	9	7	8	9	7	3	9		

4. CONCLUSIONS

This paper illustrates how the principles of industrial ecology can be integrated into the engineering methodology using DFE tools. Appropriate DFE tools were identified for design phases and shown how they integrate into those phases. Using a tool such as sphere of influence, boundaries within which the environmental performance of products-books can be affected are defined. However, it should be noted that environmental protection cannot be achieved through an approach addressing purely technical problems, localizing to a single actor – the 'producer'. Since it is interaction between government, manufacturers, recyclers and consumers [4] that finally determines the environmental performance of a product over its entire life cycle, the development of the issues raised must be accompanied by a complex study of the mechanisms of the entire system.

5. REFERENCES

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