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ASSESSING THE DEGREE TO WHICH A PULP AND PAPER ENTERPRISE MEETS THE REQUIREMENTS OF SUSTAINABLE DEVELOPMENT

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Abstract: The aim of the paper is to evaluate the degree of satisfaction of the requirements related to sustainable development for an enterprise. Starting from the requirements of a sustainable development and the impact of pulp and paper industry on the environment we have identified and formulated a series of criteria in order to do this assessment. We have proposed in this paper criteria referring to four different aspects related to sustainable development: pollution, manufacturing technology, materials, energy consumption. In the paper there is proposed an aggregation indicator, which we named Performance of the Technological Management Indicator (PTMI), in order to reflect an overall judgement about the degree of satisfaction of the chose objectives, built on enterprises responds to the considered criteria, and on the basis of multicriteria techniques. The proposed indicator can be an extremely useful tool for those involved in technological and environmental management, in all enterprises from this industrial sector and not only for these, because indicator's evaluation at different moments of time can reflect if the enterprise's activity satisfies the requirements of a sustainable development. The indicator can help the decision makers, or policy makers, to create a hierarchy for factories in the field, indicating those enterprises which can be considered an example of good practice for that industrial sector.

Keywords: pulp and paper industry, multi criteria decision methods, management, sustainable development, environment, hierarchy

1 INTRODUCTION

Sustainable development is a solution to the ecological crisis caused by the intensive industrial exploitation of resources and the continuous degradation of the environment. The development of enterprises is currently carried out on a lot of concepts and principles of sustainable development.

In an enterprise, production is based on modern, automated manufacturing technologies, whose technological performances must have as little negative impact on the environment as possible.

The technical and economic performance of a technological manufacturing system is highlighted by the implementation of a quality technological management system in enterprises (Gutterman, 2017).

The goals of sustainable development are many, those directly involved in the case analysis of this paper, are: clean and accessible energy, (sustainable energy / renewable energy), innovation in industry and infrastructure, consumption and responsible production, ("Sustainable Development", n.d.).

Research is needed on how to take decisions when spoke about efficient technology management that includes the realization of the conceptual provisions of real sustainable development.

With the help of the sustainable development strategy, in paper (Pererva, Kobielieva, Kuchinskyi, Garmash, Danko, 2021) it was made an attempt to find a way to make optimal decisions in a company in order to solve problems related to the environment, the economic medium or the social medium.

One of the most important industrial branches in our economy, but also one of the most polluting industries, is represented by the pulp and paper industry.

The pulp and paper industry plays an important role in the economy, in meeting social needs, and is an energy-consuming business that supports the implementation of low-carbon energy systems.

Paper is a major component of the industry, with many consumers in all its forms. The environmental effects of the paper are significant. Disposable paper has become a relatively cheap merchandise, which has led to a high level of consumption and waste.

The pulp and paper industry has substantial effects on the environment from the supply of raw materials, the production itself, to the end of the life of its products ("The State of the Global Paper Industry", 2018).

The problems of environmental degradation that arise due to pollution can be attenuate by adopting new solutions, innovation, technology transfer, and specific rules.

There are regulations in effect that transpose the directives of the European Parliament and the EU Council, for major industrial pollutants, rules that they must comply with in order to ensure the minimization of their activities negative impact on the environment.

Companies are practically, in some respects, obliged to comply with certain rules, or sometimes the rules are only recommended and their compliance is voluntary, but also generates long-term economic benefits.

However, it is important to be able to analyze how well these companies respond to the established rules, and also whether they take action to continuously improve, from this point of view, the activity they carry out.

So, it is important to find the best way to have a technological management so that the level of sustainable development of enterprises is increased.

The method proposed in this paper can help companies in doing such analyzes.

The aim of the paper is to present a tool that can assess the degree to which a pulp and paper business meets the requirements of sustainable development, and how it can be calculated, as well as the components on which it is based. In its assessment, the most important and critical aspects related to the activity of an enterprise in the pulp and paper industry are taken into account, because the criteria we have formulated reflect not only the main directions of action to be taken toward a sustainable development, but also the most problematic aspects of the pulp and paper industry.

The use of the tool proposed in the paper by managers responsible for environmental issues, by managers at the highest level, periodically, or at certain well-established stages, allows the evaluation of the results of steps taken to

improve the company's responses to sustainable development requirements.

2 PULP AND PAPER INDUSTRY AND SUSTAINABLE DEVELOPMENT

In the specialized literature in the field of Technology and Innovation Management, several concepts have been developed to understand the role of technology for sustainable development.

”Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”, as defined by the World Commission on Environment and Development (WCED) (”Brundtland Report”, 1987).

The specialized literature shows that technology plays a key role in ensuring sustainable development (Marcus Wagner et al. 2014).

An overview of the application of sustainable development practices in the pulp and paper industry is presented in the paper (Moraes, Silva, Rampasso, Anholon, Quelhas, Farias Filho, Toledo, 2021).

The production process shows that there is a consumption of resources at a higher rate than their regenerative capacity, thus appearing the tendency to deplete the natural resources of energy, raw materials due to intensive use or even waste which leads to the deterioration of environmental factors: water, air and soil.

Proper technology management - in a pulp and paper business - is important and requires the use of less water, raw materials, the use of green energy, innovation in the introduction of green technologies, all with the role to contribute to sustainable development, as stated above.

Major environmental problems created by this industry, such as air and water pollution, climate change, massive tree felling, have led to many regulations and the need for clean technologies.

Pulp and paper mills contribute to air, water and soil pollution.

There are many sources of pollutants in the pulp and paper industry such as: nutrients, dissolved organic materials, agents such as alcohol, inorganic materials and chlorides found in wastewater discharges; nitrogen oxides, sulfur oxides and carbon dioxide.

Paper consumption is increasing and in order to ensure a sustainable production in this field it is necessary to invest in recycling.

Improper practices in the recycling industry cause more harm than good, because of the secondary products and waste generated.

Paper waste, compared to other waste, faces the additional danger of toxic inks, dyes and polymers that could be potentially carcinogenic when are incinerated or mixed with groundwater by traditional burial methods. Paper recycling attenuates this impact.

The fact that pulp and paper mills influence a lot air pollution creating potential environmental challenges and human health impacts, is also mentioned in (Dionne**,** Walker**,** 2021). The study assesses air pollution and associated impacts from some connected pulp and paper facilities which operate in Canada and US, and have exceeded their approvals to operate and national air quality regulations multiple times between 2010 and 2017. The authors also mention that previous studies have linked many types of cancer as well as respiratory and cardio- vascular diseases to air pollution emitted by pulp and paper mills and recommendations for improvements to mill operations to improve environmental and human health are also presented.

There are studies, including (Johansson, Broberg, Ottosson, 2021), (Kupalova, Ignatyuk, Goncharenko, Andrusiv, Kopetska, 2021) dedicated to the problem of increasing the efficient use of energy resources in enterprises in the pulp and paper industry in Europe.

The pulp and paper industry uses more water to produce a ton of product than any other industry ("Pulp and Paper", n.d.).

The pulp and paper industry consumes huge quantities of cubic meters of water and the production process results in huge amounts of polluted wastewater that must be treated.

Conventional wastewater treatment methods are presented in the paper (Toczyłowska-Mamińska, 2017).

In the paper (Sharma, Tripathi, Purchase, Chandra, 2021) it is also presented the use of native plants, as a new ecological process for the treatment of hazardous industrial wastewater from polluted sites, for the removal of heavy metals from wastewater in the pulp and paper industry.

The study (Sharma, Iqbal, Chandra, 2021) showed that wastewater from the pulp and paper industry has pollution parameters and heavy metals above the allowable limit.

One of the most important method to reduce greenhouse gas emissions is to improve industrial energy efficiency.

High energy consumption and high CO_2 emissions from the pulp and paper industry are analyzed in several papers. Solutions for reducing CO_2 emissions, such as the use of energy obtained from biomass generated during paper manufacture, solar energy or wind energy, are presented in the paper (Sonsale, Purohit, Pohekar, 2021). Many of the surveyed factories use biomass energy but the use of solar energy and wind energy remains rather poorly represented due to their still high costs.

In paper (Man, Li, Hong, Han, 2020), there is mentioned that pulp and paper industry is one of the eight critical industries for controlling carbon emissions in China. The study uses life cycle assessment to evaluate the greenhouse gas emissions of China's papermaking industry chain in order to propose emission reduction targets.

In paper (Andersson, Thollander, 2019), where it is mentioned that pulp and paper industry is one of the five most energy intensive industry world-wide, the current level of implementation and operationalization of energy related KPIs (Key performance indicators) in the Swedish pulp and paper industry is studied. The study has shown a potential for improvement, even if the pulp and paper factories had been certified with standardized energy management systems since 2005.

In paper (Mandeep, Kumar Gupta, Shukla, 2020), there is mentioned that the large amount of waste generated from processes within this industry can be utilized in sustainable ways to generate useful resources through technological innovations and to reduce the health hazards associated with generated waste.

As shown above many studies have been carry out about the pulp and paper industry's impact on the environment, about the management and processes optimization within this industry, about increasing the efficiency of energy used, about improving the efficiency of raw materials, or reducing water consumption, or about air and soil pollution.

However, studies that assess the global activity of a factory in the pulp and paper industry, from the point of view of sustainable development, do not exist in the literature, and also no tool available to managers, police makers, or to all those involved in such activities, for evaluating these aspects, has not been proposed.

The observation mentioned in the previous paragraph is the one from which the idea of the present study started

3 METHODOLOGY

3.1 Important criteria for our approach and their types

Based on criteria closely related to the production process in a paper company, we have built a tool to assess the degree to which technology management meets the requirements of sustainable development.

From the analysis of the problems faced by a cellulose and paper-producing enterprise opposite the environment protection, we have detached several more important criteria which we have grouped into four major categories: pollution criteria including two important criteria such as water pollution and air pollution, manufacturing technologies in which we included both criteria related to manufacturing technology such as water consumption and yield as well as a criterion that takes into account the work environment in the enterprise - sound pollution, the material category in which we have introduced criteria related to the type of prime materials used in the production process - recyclable materials and short renewal cycle, as well as a criterion that highlights rational exploitation of raw materials. The last category but not the least important, is related to the energy consumption in which we considered a criterion that highlights the weight of green energy in the total energy used. A schematic representation is given in Figure 1.

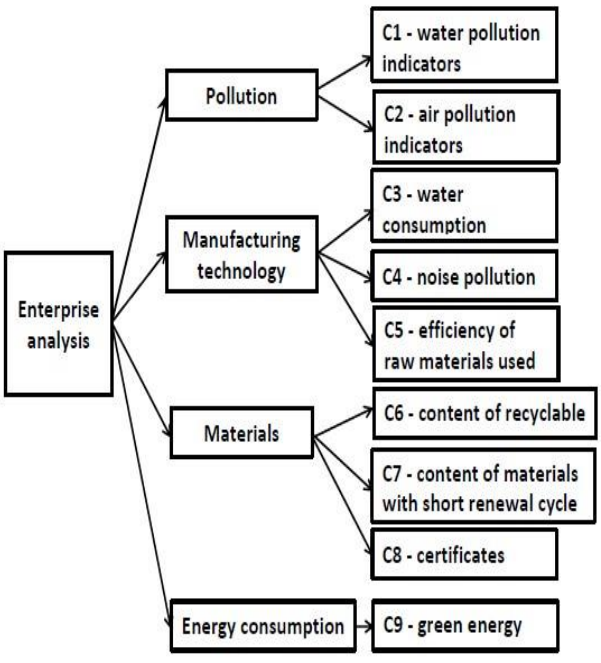

Figure 1. Proposed criteria

And as the application of multicriteria decision methods involves establishing whether the criteria used are minimum or maximum, we analyzed each criterion in turn obtaining 4 minimum criteria and 5 maximum criteria.

- minimum criteria
  - C1 - water pollution indicators (Minimum criterion)
  - C2 - air pollution indicators (Minimum criterion)
  - C3 - water consumption (Minimum criterion)
  - C4 - noise pollution (Minimum criterion)
- maximum criteria
  - C5 - efficiency of raw materials used (Maximum criterion)
  - C6 - recyclable material content (Maximum criterion)
  - C7 - the content of materials with a short renewal cycle (Maximum criterion)
  - C8 - maximum certificates (Maximum criterion)
  - C9 - green energy consumption (Maximum criterion)

Each criterion has a coefficient of importance. It is important for each criterion to see what the company's answers are, to evaluate these answers because decisions are made according to these criteria.

3.2 Multiple criteria Decision-Making Methods-Basic concepts

The efficiency of a managerial act is closely related to the decisions taken, to the results obtained, results that can be maximized only by optimal decisions.

Multiple Criteria Decision-Making Methods or simpler saying Multi-Criteria Decision Methods (MCDM) represents complex, but useful tools, for any kind of management. They support decision-makers in case of problems in which

many criteria appear and many solutions exist, and a solution which optimize all criteria is hard to be found or does not exist. They involve quantitative but also qualitative factors, and can deal with a large number of problems that arise in various fields, related to various aspects of economic and social life.

There are many multiple criteria decision-making methods that can be applied to find the optimal solution, all involving the use of same core concepts. The following are only some few examples from the very large set of MCDM methods: Weighted Sum Method or Simple Additive Weighting Method (WSM or SAW), Weighted Product Method (WPM), Analytical Hierarchy Process (AHP), ELECTRE, VIKOR, SMART, TOPSIS, PROMETHEE, their fuzzy variants: Fuzzy SAW, Fuzzy AHP, Fuzzy TOPSIS, and others. There are many papers which describe and apply these methods, as for example (Hwang, Yoon, 1981), (Figueira, Greco, Ehrgott, 2004), (Steuer, 1986), (Triantaphyllou, 2000). Their importance is not only given by the fact that they help decision makers to solve difficult problems, but also by the fact that they have a very large area of applications.

Multicriteria decision-making methods represent a valuable tool in the decision-making process on sustainable development issues too (Laurinkevičiūtė, Stasiškienė, 2010), (Radulescu, 2013).

Managerial decisions are an area of interest because in complex issues that arise in an enterprise, they can be approached by scientific methods.

In this paper we apply SAW (WSM) method because it is a simple method, easy to apply, and because the objective of this paper is first of all to propose a simple indicator for evaluating the degree of satisfaction of the objectives of a sustainable development by a pulp and paper industry factory, to formulate the criteria to be used to achieve this goal.

SAW method, as it name says, is based on the concept of weighted average, so on the formulation of a global judgment, which includes all the partial judgments made for each criterion, using an additive aggregation function. In fact, a score, an indicator, or, as mentioned by (Tzeng, Huang, 2011) "a synthesizing performance value", is evaluated for each alternative, based on its normalized values and the corresponding weights of the involved criteria. Based on this method the optimal alternative is associated with the highest value of the score.

When applying any multicriteria method we first need to establish the criteria which should be used, and the type of each of them. Consider a case with *m* criteria, noted $C_1, C_2, \dots, C_m$, and *n* alternatives: $v_1, v_2, \dots, v_n$. Criteria can be of "max" or "min" type.

Because some of them may be more important than others, we have to assign weights (coefficients of importance), $p_1, p_2, \dots, p_m$ for all criteria involved, and obvious, the more important the criterion, the greater its weight.

In this paper, for the evaluation of weights, we apply a classical procedure, in which we order the criteria in a descending hierarchy according to their importance, and then we build a matrix, noted *D*,

$$D = \left(d_{i,j}\right)_{1 \le i,j \le m}$$

where:

$$d_{ij} = \begin{cases} 2, if\ C_j > C_i \\ 1, if\ C_j = C_i \\ 0, if\ C_j < C_i \end{cases} \qquad (1)$$

We have used the following notations: $C_j > C_i$ for the case when criterion C_j is more important thanC_i, $C_j = C_i$ when both criteria have same importance, and $C_j < C_i$ for the case when C_j is less important thanC_i.

We associate to each criterion the following weight:

$$p_j = \frac{v(C_j)}{\sum_{i=1}^{m} v(C_i)}, \quad v\left(C_j\right) = \sum_{i=1}^{n} d_{ij} \quad (2)$$

Evaluating the consequences brought by each alternative to the considered criteria we

obtain a matrix, named the consequences matrix:

$$A = \left(a_{ij}\right)_{1\le i\le n, 1\le j\le m}$$

For bringing all values from the consequences matrix into the same range and to uniform all criteria we have to normalize the data. We so obtain utilities matrix, the matrix containing the normalized values:

$$U = \left(u_{ij}\right)_{1\le i\le n, 1\le j\le m}$$

For data normalization we use in this paper a linear interpolation scheme.

The next step is to select a method to be used to make the choice. Each of the multi criteria decision methods offers a tool and a way to make an overall judgment, which often leads to an indicator used to make the hierarchy of the alternatives, and so helping the decision makers to find the best alternative.

Evaluating the indicator, based on SAW method, means to associate to each alternative the following weighted mean:

$$u(v_i) = u_i = \sum_{j=1}^{m} u_{ij} p_j \ , i = \overline{1,n} \qquad (3)$$

We have named this indicator as it follows: Performance of the Technological Management Indicator (PTMI), because all the aspects it includes are closely related to the processes and technologies used.

Ranking the variants according to a descending order of the above indicator will put on the first position the best alternative, namely the best period of time or the enterprise which satisfies at the highest degree the requests for a sustainable development.

4 STEPS IN EVALUATING THE INDICATOR AND ITS ROLE

In order to show how this indicator can be used for evaluating the degree of satisfaction of the requirements related to sustainable development by an enterprise of pulp and paper industry, we have considered three enterprises form this industrial sector, and have applied the above considerations, in fact SAW method, based on the criteria formulated in the second paragraph of the herein paper. In our approach we have considered that the alternatives are the three pulp and paper factories.

Analyzing how strong is the connection between the nine criteria and the objectives of the sustainable development, we considered in this paper the following hierarchy in terms of the importance of the criteria: C5>C2=C9>C1>C3=C6>C7>C4>C8.

Based on it, and on formula (1), matrix D is built and with relation (2) we have obtained the following values for the criteria weights.

Table 1. Criteria Weights

Criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
Weights	0.135802	0.172840	0.098765	0.037037	0.209877	0.098765	0.061728	0.012346	0.172840

In order to show how the proposed indicator can be evaluated, but also to highlight its role, we considered the hypothetical situation of three companies in this industrial sector. The data used are hypothetical but still start from some real values, presented in the operation authorizations and annual environmental reports.

Such a study to highlight the real situation of the pulp and paper mills operating in Romania, so starting from concrete, real data, implies either the need for transparency of activity in this

sector, either the voluntary agreement of the factories to provide such data.

We have built the consequence matrix based on the enterprise responses to the nine mentioned criteria, so considering the following nine aspects in each enterprise: the water pollution indicator (built on the level of pollution in the wastewater), the air pollution indicator (built on the level of pollution induced by the pollutants generated in the atmosphere, considering here only the main pollutants generated, such as nitrogen oxides, sulfur oxides and carbon dioxide), the annual consumption of water used in the production process, the average annual level of decibels at the workplace, the efficiency of raw materials used is the production processes is considered as a ratio between the quantity of the final products and the quantity of the materials used for obtaining them, the percentage of recycled raw materials used in the production cycle, the percentage of raw materials with a short renewal cycle, the number of certificates held, certificates meant to attest an increased attention on the supply chain and on the judicious exploitation of natural resources, the percentage of renewable energy used in the enterprise. The consequence matrix is presented in Table 2.

Table 2. The consequence matrix

Criteria	C1	C2	C3 [10^3 m^3 /year]	C4 [dB]	C5	C6 [%]	C7 [%]	C8	C9 [%]
Enterprise 1	0.7	0.6	760	82	80	30	10	4	25
Enterprise 2	0.6	0.8	750	80	75	35	14	6	30
Enterprise 3	0.5	0.7	754	84	78	33	16	6	28

By applying the normalization technique based on the linear interpolation scheme we get the following normalized values, presented in Table 3.

Table 3. Normalized values (utility matrix)

Criteria	C1	C2	C3 [10^3 m^3 /year]	C4 [dB]	C5	C6 [%]	C7 [%]	C8	C9 [%]
Enterprise 1	0	1	0	0.5	1	0	0	0	0
Enterprise 2	0.5	0	1	1	0	1	0.666667	1	1
Enterprise 3	1	0.5	0.6	0	0.6	0.6	1	1	0.6

Using the aggregation formula given by (3) we evaluate for each enterprise a score, the proposed indicator. The results are presented in the following table, Table 4, together with the rank obtained based on the descending values of this indicator.

As one can observe the enterprise for which the indicator has the highest value is enterprise

number 3, so it can be said that in this enterprise the nine criteria are better satisfied overall, and so, in this enterprise, the compliance with the objectives of sustainable development is more advanced.

Table 4. Indicator values and the ranking

	Indicator (PTMI)	**Rank**
E1	0.401234568	3
E2	0.528806584	2
E3	0.644444444	1

It is observed that on the first position in the hierarchy it is situated the third enterprise. In a separate analysis, done for each criterion, it is on the first position only for three of the nine considered criteria, but, at the same time, it is only once on the last position. However, the weights of the criteria are not equal, and this fact is reflected in the final result, which places it in the first place, in front of the enterprise no.2, which leads to more than half of the criteria, but is in last place in two of them.

This example highlights the fact that the method allows the synthesis of the individual performances at each criterion, in a single result, the proposed indicator, namely PTMI.

We can mention that the above example can be adapted to be use for surveying the evolution of an enterprise during a period of time, in fact to see if it has improved its position on sustainable development, by considering that the three enterprises in Table 2 (Enterprise 1, Enterprise 2, Enterprise 3) represent in fact the same enterprise at three different moments of time.

5 CONCLUSIONS

The importance of technological management is all the more obvious as it is directly involved in coordinating processes of high profitability but also ecological, in finding innovative solutions that lead to added value, efficiency and quality in production processes, and should be reflected in the quality of final products delivered to customers.

The companies really involved in achieving the goals imposed by a sustainable development prove to be both the strongest on the market, and the most appreciated by customers, so in a world, the most profitable.

Based on these considerations, we approached in this paper the problematic generated by finding tools that can support decision makers in studying the efficiency of technological management in achieving the objectives related to sustainable development.

Technological management influences the directions of action of the enterprise and has an important role in their orientation towards a sustainable development.

In an extremely dynamic economy, multicriteria decision-making tools prove to be useful tools in management. As proved in this study by applying multiple criteria decision methods, we can observe if there is a strong connection between the decisions taken by the managers and the objectives of a sustainable development.

The nine criteria proposed in this paper are extremely valuable for studying this connection in case of enterprises from pulp and paper industry. Based on them and on SAW method the indicator, PMTI, was built.

The proposed indicator can be an extremely useful tool for those involved in technological and environmental management, in all enterprises from this industrial sector and not only for these, and can help the decision makers, or policy makers, to create a hierarchy for factories in the field, indicating which are those enterprises that can be considered an example of good practice for that industrial sector.

If concrete and actual data regarding the enterprise's responses to the nine criteria considered in this study should be available an

assessment of the real situation of the pulp and paper mills operating in any country can be realized. In a furthered work we will try to make such a study, based on the voluntary responses of enterprises.

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