AUTOMATED EVALUATION AND SELECTION OF A RATIONAL TECHNOLOGICAL PROCESS

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Abstract: *Informed and rational decision making in today's fast-paced manufacturing environment is essential to increase efficiency, optimize costs and maintain the competitiveness of manufacturing companies. Modern industry is often faced with the need to evaluate multiple criteria such as: performance, accuracy, roughness, etc. This makes traditional (manual methods) inefficient and error prone. Based on the mentioned requirements and in order to follow the principles of Industry 4.0. for automation of production processes, the paper presents a tool for evaluation and selection of a rational technological process, implemented in the MS Excel environment. The presented methodology, which is implemented in the evaluation tool, and the practical example demonstrate how the flexible adaptation of criteria and their weights can lead to informed decision-making that can benefit both manufacturing companies and other industrial sectors. The developed tool contributes to make informed decisions by providing fast and reliable analysis, in addition to providing information on the stability of the processes under consideration.*
Key words: *Process, Excel, Rational, Automated, MCDM, FUCOM.*

1. INTRODUCTION

In today's dynamic world of industrial processes and technology, making the right decisions is one of the major factors for achieving efficiency, reducing costs, and improving competitiveness. For companies faced with choosing between multiple technological processes on a daily basis, finding the rational variant can be a complex task [1]. This choice often requires evaluating a large number of criteria, such as cost, production time, resources, end product quality, and others. Associating weights to different criteria allows the evaluation to be customized to the specific needs of the user [2]. This is where the automated approach and the use of software programs to support the analysis and the selection comes in.

The development of a tool to automatically calculate the rational process flow from among multiple proposed ones offers a practical solution to this problem. Microsoft Excel is a familiar, accessible, and widely used software in all industries, making it the ideal platform to

create such a tool. On the other hand, manual calculation is slow and prone to errors. Often in complex analyses, even a small inaccuracy in the estimation of one parameter can lead to the selection of an inefficient technological process or one that does not meet the customer's requirements, which can lead to losses for the business. Automation not only reduces the risk of errors but also saves engineers valuable time that can be directed to other strategic tasks [3-4].

The aim of this paper is to present a developed tool for the evaluation and selection of a rational technological process (among several technological processes) in the MS Excel environment, to explain its functionality and methodology and to show its advantages through example. The created tool provides the opportunity to easily enter data for each technological process, evaluate it based on multiple criteria and generate a clear result for the rational technological process. This makes it suitable for a wide range of applications from manufacturing plants to planning operations and even scientific research.

2. DEVELOPMENT OF "TOOL FOR AUTOMATED EVALUATION AND SELECTION OF A RATIONAL TECHNOLOGICAL PROCESS"

For the creation of the "Tool for automatic evaluation and selection of a rational technological process" a previously developed methodology was used, which served as a backbone in an algorithm [5], which is, in itself, implemented in the MS Excel program.

The methodology applies the multi-criteria method FUCOM [6] to objectively assign weights to the criteria used allowing a reliable and systematic evaluation of the different technological processes:

- Input of criteria for evaluation of the technological processes, which may include: product cost, lead time, accuracy, roughness, etc.;
- Input of the criteria quantitative evaluations;
- Automatic calculation and comparison of different technological process alternatives through built-in formulas and algorithms;
- Presentation of results in a clear and understandable form (tables, graphs, etc.).

The selection of a suitable programming environment for the creation of the "Tool for automatic evaluation and selection of a rational technological process" is an important precondition for its successful application in practice. Among the variety of software solutions, it is necessary to choose one that is both functional and efficient, and easily accessible to users. Solving problems using multicriteria decision making methods (MCDM) using widely available software tools is becoming more important. In this regard, the authors [7-9] demonstrate the potential of MS Excel as an efficient and accessible platform for the application of MCDM methods, including through the development of specialized add-ins. Among other tools developed for MCDM methods, the one of the authors [10] stands out, which presents two additional modules - DEA Excel Solver.

In this context, MS Excel stands out as one of the most suitable choices, thanks to a number of its advantages that make it an optimal solution for both small and large enterprises. MS Excel was chosen as the platform to develop the tool due to several key advantages:

- Widespread accessibility and distribution: MS Excel is widely used in industries and is well-known to most professionals and engineers, making implementation easier and reducing the need for specialized training;
- Easy integration with other systems: MS Excel easily communicates with third-party databases, ERP-systems and engineering software, allowing convenient data exchange and data processing.
- Flexibility and adaptability: the tool can be quickly adapted to the specific requirements of each company, easily changing or adding new criteria and weights.
- Automation capabilities through built-in functions and VBA: MS Excel provides automated calculation capabilities, macros, and automatic report generation, which greatly speeds up analysis.
- Visualization of results: Built-in graphs and tables allow clear and visual presentation of results, making analysis and decision making easier.

3. STEPS IN THE DEVELOPMENT OF "TOOL FOR AUTOMATED EVALUATION AND SELECTION OF A RATIONAL TECHNOLOGICAL PROCESS"

The creation of a tool for automatic evaluation and selection of a rational technological process requires structured planning and sequential execution of a number of interconnected tasks.

In order to achieve the effectiveness and applicability of the tool in real production conditions, it is important to clearly define the requirements, methodology and objectives of the analysis in advance. The consistency in developing and implementing this type of tool facilitates the decision-making process and ensures objectivity and accuracy of the results. The specific steps in the development of the "Tool for evaluation and selection of a rational technological process" are presented in Fig. 1.
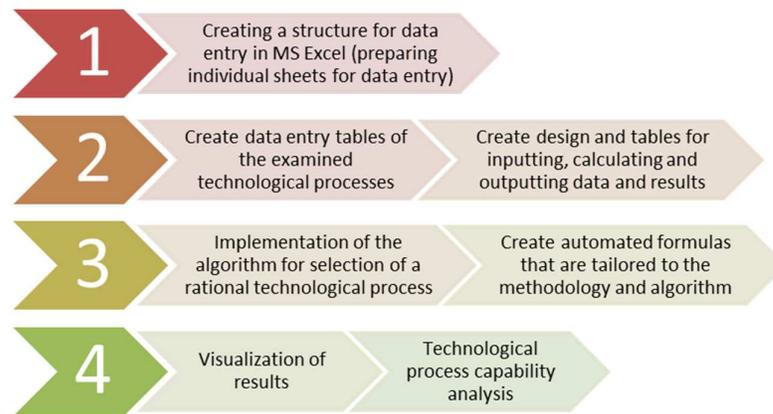
Fig. 1. Steps in the development of "Tool for Automated Evaluation and Selection of a Rational Technological Process".

This consistency ensures clarity, objectivity and efficiency in the evaluation and selection of technological processes, supporting rational and well-founded decision-making in the manufacturing sector.

Various sheets have been created which includes:

- Home: a navigation sheet through which users can navigate between the different sheets, includes buttons with hyperlinks for quick access to the parts of the tool, thus making it easier for the user to first start and navigate through the system;
- Manual: a guide to using the "Tool for evaluation and selection of a rational technological process";
- Calculations: the rational technological process selection algorithm is implemented on this sheet, together with the MCDM method - FUCOM. The user writes down the different technological processes and the importance of their criteria (according to the product quality parameters and customer requirements) in a pre-prepared table. Necessary macros are used to create also additional sheets for more process technologies (TP) and criteria. The calculations for selecting a rational process are performed on this sheet, and each process is given a quantitative score on the basis of which they are compared;
- TP 1; TP 2 … TP n: on these sheets the measurable data such as: dimensional accuracy, roughness, etc. are normalized. A

batch of parts (made in a test batch) is measured and the values are entered in the corresponding table for the criterion. The normalization is performed using Eq. 1, also the warning limits are entered to signal that the parameter is starting to approach its critical limits and may exceed the tolerances if corrective measures are not taken;

- Report: here can be entered the data of the company as well as the expert performing the analysis. Also, the capability of each technological process is evaluated using the static index CpK and its visualization by the Gaussian normal distribution curve.

$$P_N = \left(1 - \frac{N_w}{N}\right).100\% \qquad (1)$$

where,

N - Total number of measured values;

Nw - Number of measured values within warning limits $LWL \leq x \leq UWL$;

LWL - Lower Warning Limit;

UWL - Upper Warning Limit.

4. USED FEATURES AND TOOL DESIGN IN MS EXCEL

The functions that were used to create the "Tool for Automated Evaluation and Selection of a Rational Technological Process" are presented in Table 1.

Table 1

Used functions in MS Excel.

Category	Used functions

Statistical/Mathematical	AVERAGE, STDEV, MIN, MAX, NORM.DIST
Logical (conditional)	IF, COUNTIFS
Basic Functions	SORT, References between sheets and cells
Visual	Different styles for the cell function; Charts.
Other	VBA macros; Solver

The design of the tool is oriented towards intuitive and consistent use of the individual worksheets, providing a logical flow from data entry to final visualization of results. Within each page is a specific set of input fields, tables, and formulas that step-by-step guide the user through the key steps of the analysis. In addition to this, the presence of supporting elements, such as colour differentiation of cells, highlights which areas are provided for data entry and which generate automatic calculations.

Table 2

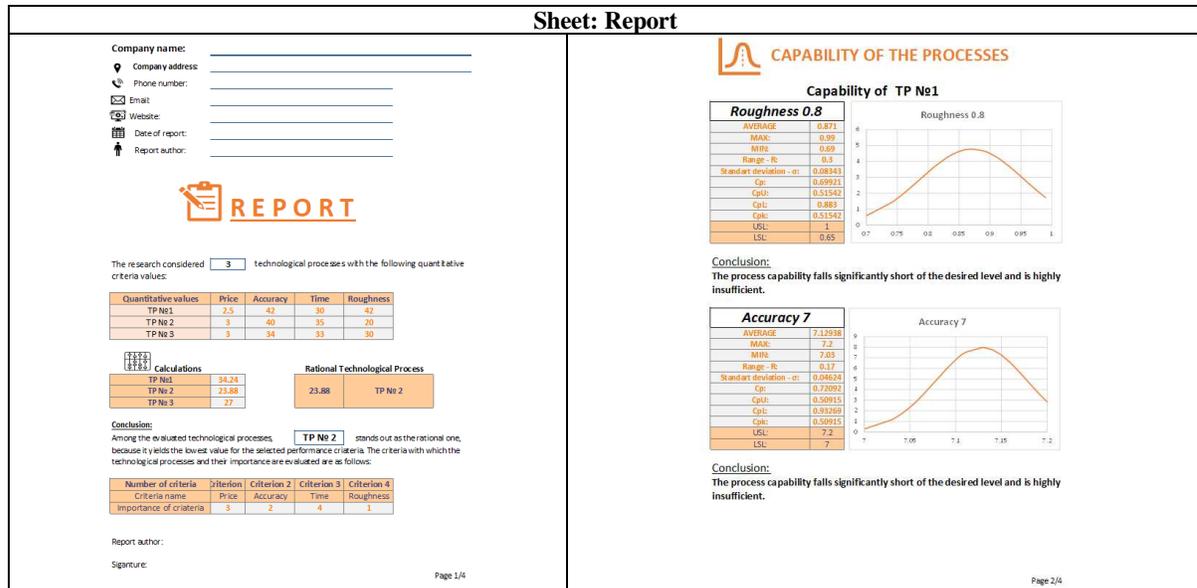**Design and layout of individual worksheets.**

A structure is also provided to separate the data associated with the different technological processes in order to prevent unintentional mixing of data from different sources. This approach ensures greater clarity and reduces the likelihood of errors during data entry and processing. Table 2 presents the organization and design of the main worksheets in the developed "Tool for Automated Evaluation and Selection of a Rational Technological Process" in MS Excel. Each worksheet has a clearly defined function and the Home, Manual, Calculations, TP 1 to TP n-1 and Report should be considered separately.

4. USING AND OPERATING OF THE EVALUATING TOOL FOR SELECTING RATIONAL TECHNOLOGICAL PROCESS

The developed tool in MS Excel provides an intuitive way to automate the selection of a rational technological process. For this purpose, it is necessary to follow the following steps:

4.1 Entering a number of technological processes under examination.

The first step in using the tool is to enter information about the different technological process alternatives for the manufacture of a part. This is done in a specially prepared table in Sheet - Calculations, where the user fills in: number of technological processes and new sheets are added to normalize the data - TP 1, TP 2 ... TP n (Fig. 2).

Fig. 2. Entering number of technological processes.

4.2 Establishing criteria and weights.

In order for the tool to select the most suitable technological process according to the given requirements, it is necessary to define the evaluation criteria. These can be related to the cost of the product, time for production, the quality of the machined surface (accuracy, surface roughness, deviation from shape and other measurable parameters responsible for the quality of the product), etc. Each criterion is assigned a weight depending on its importance Fig. 3. For example, if quality is more important than cost in a production, a higher weight can be assigned to accuracy and roughness. The tool offers flexibility by allowing the user to change the weights according to the specifics of the task and the requirements set by the customer.
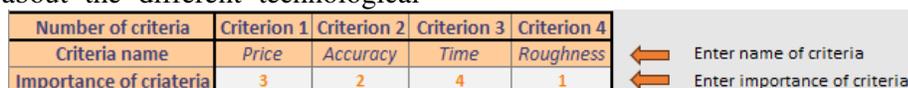

Fig. 3. Defining criteria and assigning weights.

4.3 Entry of criteria that do not need normalization.

In the working process with the tool there are also criteria whose values are not subject to normalization, as they are directly comparable and uniquely measurable. These values are entered directly into the corresponding MS Excel tables without further calculations. Such criteria may include absolute numerical parameters such as production time or price in monetary units Fig. 4.

Quantitative values	Price	Accuracy	Time	Roughness	
TP №1	2.5	42	30	42	Enter non normalizing data, by hand
TP № 2	3	40	35	20	
TP № 3	3	34	33	30	

Fig. 4. Entry of criteria that do not need normalization.

The user must enter this quantitative data accurately and correctly to ensure the reliability and accuracy of the automated calculations and analysis of the results that follow. Each value should be entered in clearly defined fields (criteria), which further simplifies the process and minimizes the likelihood of data processing errors.

4.4 Entry of data that needs normalization.

Data normalization is an important stage in the evaluation and selection of a rational technological process as it provides the opportunity for a fair comparison between different criteria that are expressed in different units and scales (e.g. size accuracy, roughness, etc.). Through this transformation, criteria of different nature become directly comparable, allowing an objective and reliable analysis. The application of normalization ensures that the choice of a rational technological process is not influenced by the different scales of measurement. Fig. 5-(a) shows part of the table in which the measurable data are entered, and Fig. 5-(b) shows the table in which the warning limits for each measurable criterion are entered.

DATA		
№	Roughness	Accuracy 7
1		
2		
3		
4		
5		
...		
n-1		

Roughness		Accuracy Ø7	
AVERAGE	0.871	AVERAGE	7.1282
Standart deviation - σ:	0.083427838	Standart deviation - σ:	0.04992607
UWL:	0.9	UWL:	7.15
LWL:	0.7	LWL:	7.05

a)　　　　　　　　　　　　　　　　b)

Fig. 5. Entry and normalization of measurable data: a) Table for entry of measured values; b) Table for warning limits.

4.5 Output of the final result.

Using automated formulas in MS Excel, Solver and VBA macros, the "Tool for evaluation and selection of rational technological process" combines the normalized values of the individual criteria and the resulting weights, using the MCDM method - FUCOM, generating a combined final score for each technological process Fig. 6. The tool also shows which of all the process options for the manufacture of a product is rational based on the set importance of the criteria (according to the quality, functionality and serviceability requirements of the product and the customer requirements) at the very beginning.

Results		Min.value	Rational TP
TP №1	34.24		
TP № 2	23.88	23.88	TP № 2
TP № 3	27		

Fig. 6. Output of the final result for each technological process and the rational between them.

As a final step of the analysis and selection of a rational technological process, a Report can be generated to bring out which is the selected technological process, as well as an analysis of the capability of the considered technological processes by the statistical index CpK. The capability of the technological processes is visualized by the Gaussian normal distribution curve. The tool also automatically derives a

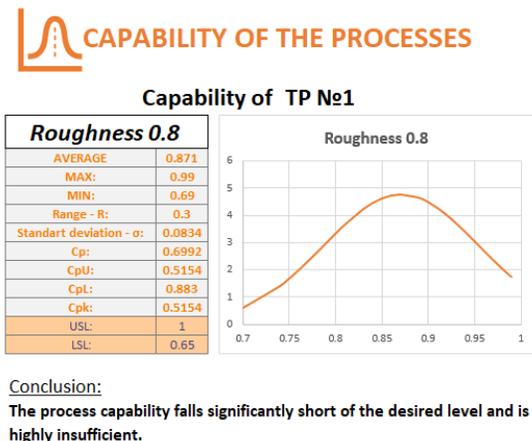conclusion about the stability of the technological process Fig. 7.

CAPABILITY OF THE PROCESSES

Capability of TP №1

Roughness 0.8	
AVERAGE	0.871
MAX:	0.99
MIN:	0.69
Range - R:	0.3
Standart deviation - σ:	0.0834
Cp:	0.6992
CpU:	0.5154
CpL:	0.883
Cpk:	0.5154
USL:	1
LSL:	0.65

Conclusion:
The process capability falls significantly short of the desired level and is highly insufficient.

Fig. 7. Generation of process capability analysis and report.

5. CONCLUSION

The developed tool in MS Excel for evaluation and selection of a rational technological process provides a quick solution for the complex and time-consuming process of selecting a rational technological process among various developed options for manufacturing a product and the associated mathematical calculations. By automating and using an established methodology and algorithm, it offers substantiated results that help the user make informed decisions.

The tool stands out for its flexibility, allowing to change the criteria for the selection of a rational technological process and their weight at any moment, depending on the change of the customer's requirements (different customers) to the manufactured product. The tabular visualizations further ease the analysis and understanding of the results and provide transparency in the selection process. The tool could be used both for mechanical engineering enterprises - small and large, as well as in industries in other production areas. The simplicity and accessibility of the tool in MS Excel make it suitable for a wide range of users (without the need for costly and time-consuming training), while increasing efficiency and improving quality in decision making.

Despite the automatic calculation of the methodology for selecting a rational technological process, if several processes are examined, the user must manually enter the necessary rows in the tables and the relationships between the individual sections. If more criteria are considered, calculations must also be made again for their weighting. In this case it must be considered that this may lead to errors or incorrect input of functions. Future developments of the scientific team will be directed precisely in this direction - to completely eliminate the likelihood of such errors and to fully automate the process by creating a software application for selecting a rational technological process.

6. ACKNOWLEDGEMENTS

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EVALUAREA ȘI SELECTAREA AUTOMATĂ A UNUI PROCES TEHNOLOGIC RAȚIONAL

Rezumat: Luarea deciziilor informate și raționale în mediul de producție rapid de astăzi este esențială pentru a crește eficiența, optimiza costurile și menține competitivitatea companiilor de producție. Industria modernă se confruntă adesea cu necesitatea de a evalua mai multe criterii precum: performanță, precizie, rugozitate etc. Acest lucru face ca metodele tradiționale (manuale) să fie ineficiente și predispuse la erori. Pe baza cerințelor menționate și pentru a respecta principiile Industriei 4.0. pentru automatizarea proceselor de producție, lucrarea prezintă un instrument de evaluare și selecție a unui proces tehnologic rațional, implementat în mediul MS Excel. Metodologia prezentată, care este implementată în instrumentul de evaluare, și exemplul practic demonstrează modul în care adaptarea flexibilă a criteriilor și a ponderilor acestora poate duce la un proces decizional în cunoștință de cauză care poate aduce beneficii atât întreprinderilor de producție, cât și altor sectoare industriale. Instrumentul dezvoltat contribuie la luarea deciziilor în cunoștință de cauză prin furnizarea de analize rapide și fiabile, pe lângă furnizarea de informații privind stabilitatea proceselor avute în vedere.
Cuvinte cheie: Proces, Excel, Rațional, Automatizat, MCDM, FUCOM.

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