Risk management, implementation of new technological solutions, selection of process flow options

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3 IMPROVING THE IMPLEMENTATION OF A NEW TECHNOLOGICAL SOLUTION IN A PRODUCTION COMPANY

Abstract

The implementation of new technological solutions involves many important strategic decisions. This publication focuses on the improvement of new solution implementation processes in a manufacturing company. The presented approach provides support for the evaluation and selection of the best option of a new technological solution and the improvement of the modified production system in the area of information flow, materials and ensuring production capacity.

3.1. INTRODUCTION

The most important role of production management is designing the production process in accordance with the company's aims and taking into account all the conditions and circumstances of real production processes. Nowadays, there is a significant increase in competition, shortening product life cycles, rapidly changing buyer requirements and an increase in non-price instruments [1]. Ability to change is crucial to remain competitive and to continue achieving success.

There is a noticeable lack of literature studies on the evaluation and implementation of new technological solutions for production processes in companies with small batch production. This publication responds to this situation by discussing the problems of selecting a new technological solution for implementation in a manufacturing company. The study includes the creation of a methodology to determine the effectiveness of the process of managing the implementation of a new solution in a small batch manufacturing company. The purpose of the article is to present a method for evaluating options and improving the implementation of the selected preferred one. Research is based on the development of a procedural model for processes related to the selection of the best technological solution and a proposal for the improvement of the production system under conditions of variable demand and small batch production.

In order to evaluate and select the most appropriate solution, there was developed an approach using the classical method of evaluating solution options based on technical,

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economic and ergonomic criteria, complemented by a risk assessment using fuzzy logic. Subsequently, this involved the design of a production system structure, the project of improving the organisation of material flow in the modified production system, and the refinement of the production process through the implementation of multi-station working.

3.2. DETERMINANTS OF THE EVALUATION AND SELECTION OF A NEW TECHNOLOGICAL SOLUTION IN A MANUFACTURING COMPANY

The implementation processes of new solutions are characterised by a high degree of risk due to the unpredictability of results or difficulties in forecasting. The level of risk can vary at each implementation stage and depend on the particular situation [2].

The purpose of multi-criteria decision-making is to determine the best solution, considering more than one criterion in the selection process [3, 4]. It enables decision-makers to evaluate complicated problems that involve a range of criteria and uncertainties. This method is particularly beneficial when applied in areas, where decision-making requires a balance from a lot of considerations [5, 6]. These methods make it possible to identify best solutions by performing both quantitative and qualitative assessments, including the preferences and priorities of different stakeholders [7].

Creating successful projects involves constantly trying to minimise risk, so the most risky elements of the plan should be reviewed [8]. Fuzzy logic is widely used for risk assessment [9]. The fuzzy logic was developed by Dr Lotfi Zadeh in the 1960s. Rather than focusing only on the extreme cases of truth (0 or 1), the fuzzy logic includes various states of truth in between [10]. A fuzzy set (A) in a certain space (X), labelled A ⊆ X, is called a set of pairs [11]:

$$A = \{(x, \mu_A(x));\ x \in X\} \tag{3.1}$$

$\mu_A\colon X \to [0,1]$ is the membership function of a given fuzzy set A.
This function attributes to each element x ∈ X the degree of membership of this fuzzy set A. Three cases can be identified:

- $\mu A (x) = 1$ is full membership of the fuzzy set A, i.e. x ∈ A,
- $\mu A (x) = 0$ is no membership of an element x in the fuzzy set A, i.e. x ∉ A,
- $0 < \mu A (x) < 1$ means partial membership of the element x to the fuzzy set A.

3.3. THE ASPECTS OF PROCESS IMPROVEMENT FOR ENSURING THE SUSTAINABILITY OF PRODUCTION SYSTEMS

Research shows that the stages of design and technical preparation of production have a huge impact on costs associated with the entire production process (70-80%) and technological preparation between 20 and 70% depending on the type of production [12, 13]. The efficiency of production depends on a set of factors that change over time and are varying for each production system. Its performance relates on very narrow range of criteria, meaning the most important parameters [14].

The main problem areas in which modelling and simulation of the production process is applied include the design of production systems, the analysis and comparison of different manufacturing strategies, or the forecasting and planning of material requirements [15]. The literature mentions various models of the production process [16]. Simulation models represent symbolic interpretations of the relation in real processes and these are expressed through mathematical symbols and relations [17]. Among the most used models are schematic models. These represent the production process, its structure, relationships between elements and the way in which the production system works, but do not provide an opportunity to determine the effects of the decisions. To achieve this aim, computer simulation models are used [18]. These belong to the group of symbolic models, which use symbols and mathematical relationships to represent reality.

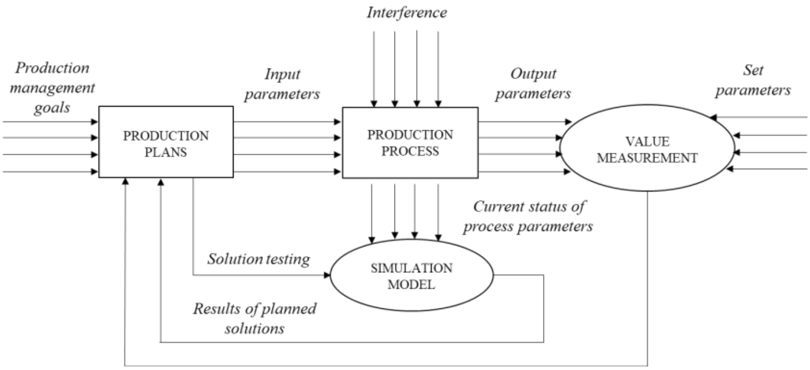

Fig. 3.1. Production process management using a simulation model [own elaboration]

The simulation reports which are generated provide important information about the analyzed system. These allow evaluation of system parameters without conducting experiments on the real object [19].

3.4. THE PROJECT OF IMPROVING THE COMPANY'S PRODUCTION SYSTEM

3.4.1. Object of research

The analyzed company is a well-known manufacturer of cutting tools. There are several main groups of band knives offered by the company. The production process, depending on the type of band knife, involves various processes, among which are measuring and cutting to size, welding, toothing, sharpening and setting.

3.4.2. Course of research

The processes of implementing new projects require organized operation at many levels simultaneously. However, these are an important step in the development of the company and can generate significant results. The specifics of small batch production require efficient creation of new customer value already at the innovation concept stage, when resources are limited in subsequent project stages.

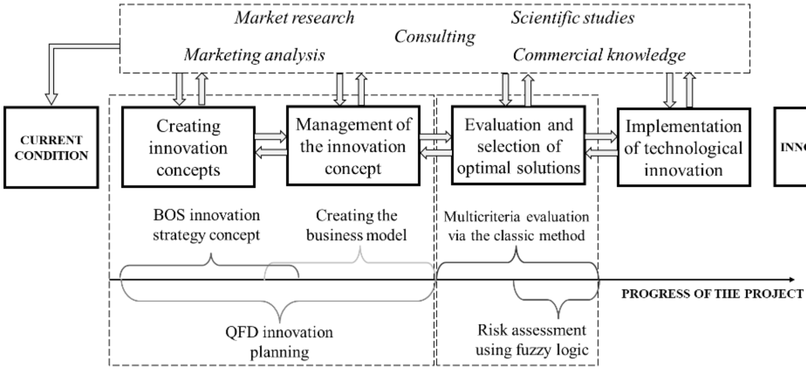

Fig. 3.2. Proposed process flow for the implementation of a technological solution [own elaboration]

The project to improve the implementation of a new technological solution grew out of the need to develop a methodology for solving problems related to the implementation of new solutions in small-batch production. The first step in the proposed approach to developing a concept for a new solution is to apply the schemes described in the Blue Ocean Strategy concept [20, 21, 22]. The second approach integrated in the proposed model is the way in which the value proposition is created [23, 24]. The Quality Function Deployment (QFD) methodology makes it possible to transfer designed customer requirements into the parameters of the designed product [25, 26].

The research began with a competitive analysis after which Blue Ocean Strategy techniques were applied to develop a strategy for a new solution:

- Four Actions Framework,
- Six Paths Framework to define the Blue Ocean Strategy,
- focusing on a broad vision,
- reaching beyond the boundaries of existing demand,
- the principle of maximizing of the size of the blue ocean,
- Price Corridor of the Mass,
- determining the price level inside the Price Corridor of the Mass.

The Blue Ocean strategy has the potential to create and implement new solutions and enable to avoid direct competition and attract new customers by providing valuable proposition. However, it requires to understand the market and can involve risks. For this reason, there is a need for further research.

The second step is to apply the technique of offering new value, which states that the value proposition should be based on an implementable business model. For this purpose, the Business Model Canvas was used, which is a tool that describes how an organisation creates and delivers value. The Business Model Canvas is combined with another tool, the Value Proposition Canvas, which provides a perspective on the details of building value for customers. Subsequently, it was proposed to combine the two mentioned methodologies and to include their effects in the Quality Function Development (QFD). This is particularly useful in the context of risk minimisation, so it can be implemented in the risk management system of the new solution concept.

3.4.3. Project for improving the assessment and selection of new solution options

The defined model includes technological, ergonomic and economic criteria. A characteristic feature of the model is the integration of risk as one of the evaluation criteria in the selection of option (Fig. 3.3.).

Based on the previous stages, three options were considered:

1. Creating a new sharpening station.
2. Modernising the existing sharpening station.
3. Modernising the existing welding bay.

After identifying the options and defining a number of technical, economic and ergonomic criteria, the weighting factors for these criteria were determined.

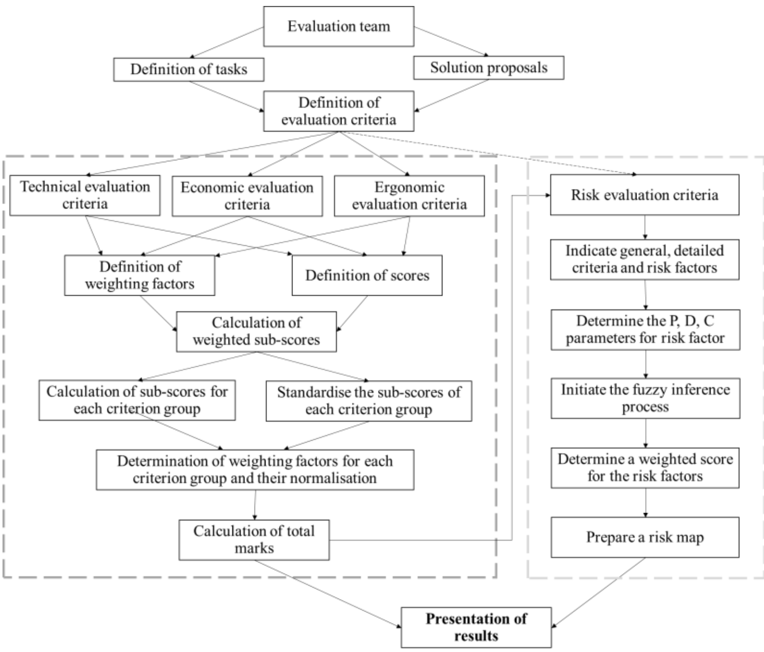

Fig. 3.3. Multi-criteria evaluation model complemented by risk assessment using fuzzy logic [own elaboration]

As a result of the process, overall scores were calculated and the best option from three variants was selected.

Tab. 3.1. Calculation of overall grades [own elaboration]

	WEIGHT	***Partial mark***	***Weighed mark***	***Partial mark***	***Weighed mark***	***Partial mark***	***Weighed mark***
Technical criteria	0.422	0.68	0.286	1.00	0.422	0.84	0.353
Economic criteria	0.355	0.99	0.353	0.83	0.296	1.00	0.355
Ergonomic criteria	0.223	0.89	0.200	1.00	0.223	0.60	0.133
Overall marks			**0.838**		**0.941**		**0.840**
Ranking of option			● 3		○ 1		◑ 2

There are several conclusions that can be deduced from the research, among which it is important to mention the role of technical criteria, in this case - the need to maintain attractive purchase costs and the concentration on keeping the costs associated with operating the equipment to a minimum.

Risk analysis is an integrated part of the new solution implementation process and can help to minimise negative impacts of new project. It performs a crucial role in the implementation process of a new solution, in terms of identifying, evaluating and managing potential risks as well as minimising negative consequences. Including risk analysis in the early phases of a project helps to identify and resolve problems before these become major barriers in the implementation process of a new solution.

In order to perform the risk evaluation using fuzzy sets, the set of criteria related to implementation was identified. Within each criterion, the specific risks that exist within it were identified. The result of the risk assessment leads to conclusions regarding the decision to exclude the solution because of an unacceptable level of risk, or to continue analysing the proposed solution and put it to an implementation phase.

Within each criterion, there were identified risk factors related to the type of risk. There were identified parameters of P (probability), D (detectability) and C (consequence) and determined the range of linguistic values:

1. Probability: almost impossible, low, medium, high, very possible
2. Detectability: impossible, low, medium, high, very possible.
3. Consequences: very small, small, medium, large, very large.

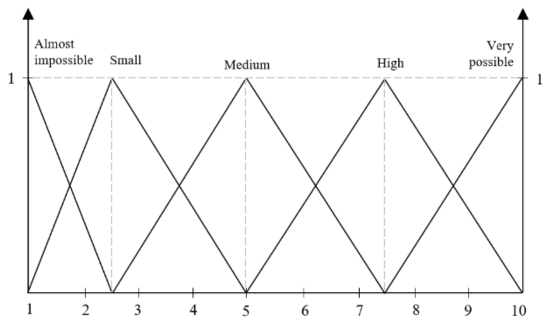

Fig. 3.4. Definitions of a fuzzy set regarding values for probability input variables [own elaboration]

The values of the P, D and C parameters are inputs. The correlations between them (Table 3.2.) show that the risk factor assessment depends primarily on the risk consequences.

Tab. 3.2. Rule base for a fuzzy inference system [own elaboration]

DETECTABILITY \ PROBABILITY	Practically impossible	Small	Medium	High	Very possible	Practically impossible	Small	Medium	High	Very possible	Practically impossible	Small	Medium	High	Very possible	Practically impossible	Small	Medium	High	Very possible	Practically impossible	Small	Medium	High	Very possible
Impossible	VS	S	S	S	S	S	M	M	M	M	M	M	B	B	B	B	B	B	VB	VB	VB	VB	VB	VB	VB
Small	VS	VS	S	S	S	S	S	M	M	M	M	M	M	B	B	B	B	B	B	VB	VB	VB	VB	VB	VB
Medium	VS	VS	VS	S	S	S	S	S	M	M	M	M	M	M	B	B	B	B	B	B	VB	VB	VB	VB	VB
High	VS	VS	VS	VS	S	S	S	S	S	M	M	M	M	M	M	B	B	B	B	B	B	VB	VB	VB	VB
Very possible	VS	VS	VS	VS	VS	S	S	S	S	S	M	M	M	M	M	M	B	B	B	B	B	B	VB	VB	VB
CONSEQUENCES	Very small					Small					Average					Big					Very big				

The model constructed in MATLAB provides an example of calculating risk using linguistic variables and fuzzy sets. This model uses fuzzy sets to assess risk in three steps: definition of fuzzy sets, assessment of risk based on specific cases and presentation of results. Probability, detectability and consequences were described using fuzzy sets. Then risk scores were defined, each with specific values for the linguistic variables. For each example, there are calculated risks. The fuzzy sets allow the determination of the degree to which a value belongs to each set, which influences the result. Example of graph obtained in MATLAB is shown in Fig. 3.5. Example risk assessments:

I. Low probability, high detectability, low consequences – risk assessment obtained from MATLAB: 0.02.
II. High probability, low detectability, high consequences – risk score obtained from MATLAB: 0.07.
III. Very possible probability, very possible detectability, very large consequences – risk score obtained from MATLAB: 0.90.

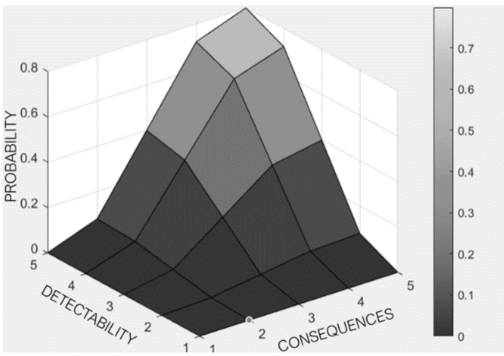

Fig. 3.5. Example graph obtained in MATLAB [own elaboration]

3.4.4. Project of production system structure

For the selected solution variant, a model in BPMN notation was created to design the relationship of the elements in the production system. The model was built in Bizagi Modeler.

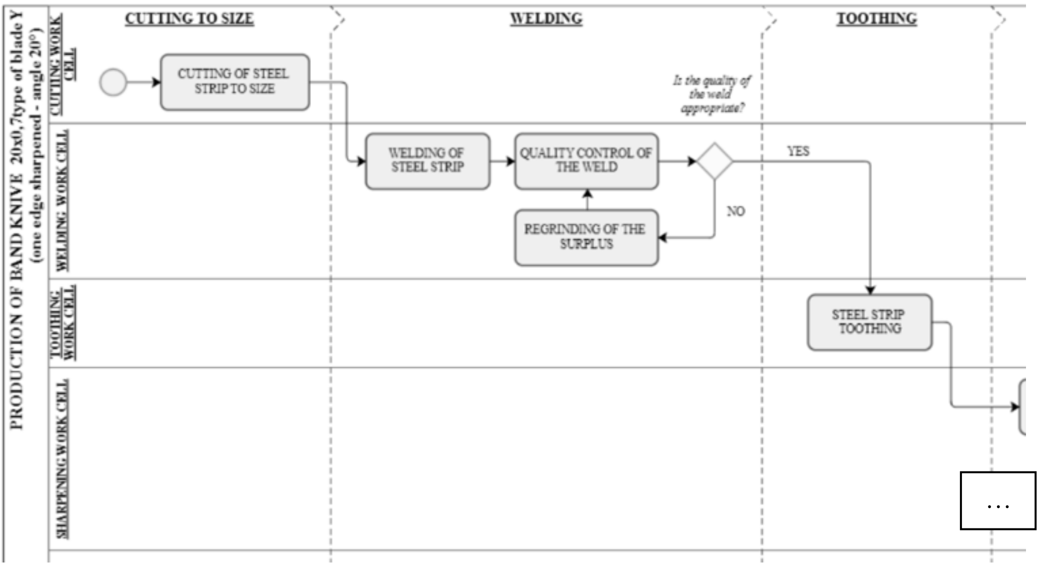

Fig. 3.6. Extract of the BPMN notation selected series of band knives [own elaboration]

The elements in the above model fall into the following categories:

- process location objects,
- flow objects,
- connection objects,
- additional diagram elements.

3.4.5. Improving the organisation of material flow in a modified production system

The main problem identified in the research area, which led to a project to improve the organisation of the material flow, was the problem with flow of materials for the production of band knives under the conditions of the new solution selected as a result of an earlier stage of choosing the best solution taking into account the risk evaluation.

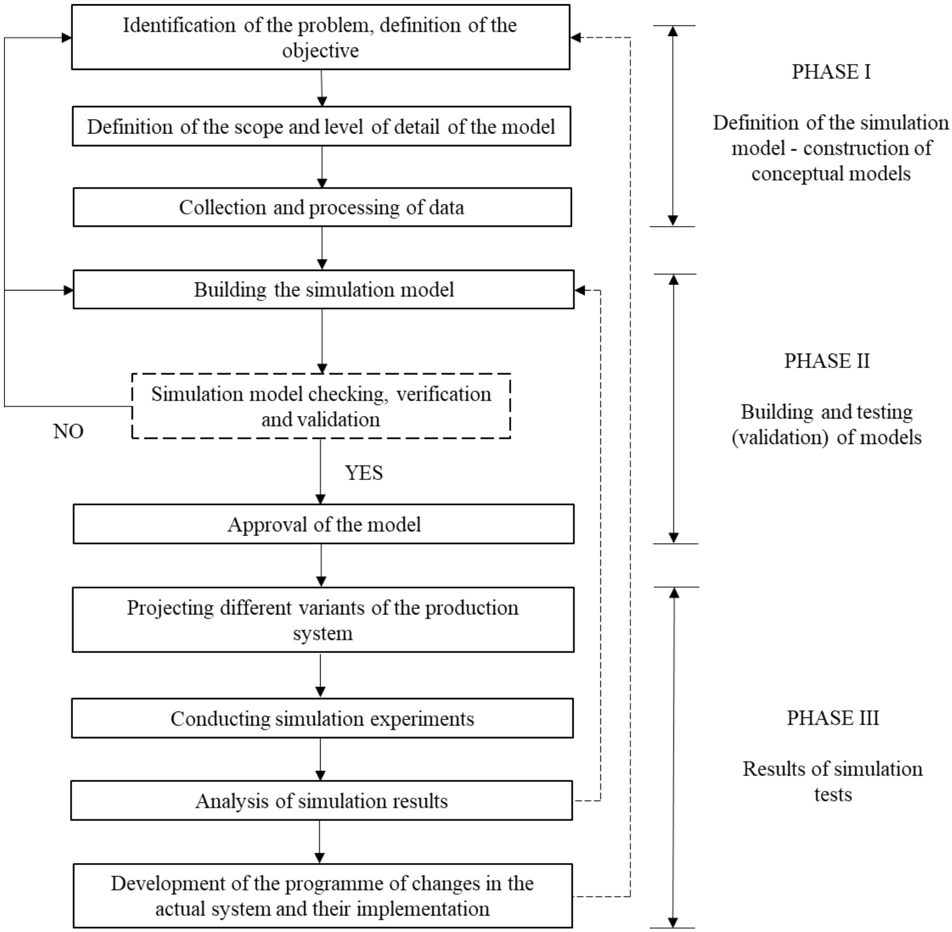

Fig. 3.7. Steps of building a simulation model and implementing a project based on it [own elaboration]

At first, two different material flow scenarios were simulated. A comparison of the subsequent simulations showed reductions in production time for the different types of band knives, indicating increased process efficiency. Simulation analysis including production variant testing allowed to identify the interaction between the various perspectives of production changes and to assess operational efficiency. The simulations resulted in the following results:

- the average production time was reduced by 35% (Fig. 3.7.),
- the average waiting time decreased by 36%.

The most significant difference in terms of average production time compared to the base version is the almost 56% shorter average production time.

Average production time [hrs]	Variant I	Variant II
TYP_15X	4.84	2.68
TYP_16Y_2	5.88	4.13
TYP_16Y_2.5	2.27	1.58
TYP_16Z_2	7.93	5.86
TYP_16Z_2.5	4.63	3.25
TYP_17Y_10	4.74	3.36
TYP_17Y_12	2.71	2.02
TYP_17Y_6	2.56	1.86
TYP_19Y	6.03	4.27
TYP_19Z	9.94	7.66
TYP_20Y_12.5	4.85	3.48
TYP_21R_2	2.26	0.60
TYP_21R_4	2.29	0.92
TYP_21R_6	2.30	0.94
TYP_21X_2	6.51	3.86
TYP_21X_4	5.50	3.18
TYP_21X_6	0.45	0.45
WP_22Y_12.5	4.93	4.18
WP_23Z_12.5	2.98	3.60
WP_23Z_16	5.06	4.31
WP_23Z_20	3.15	3.78
WP_24R_10	4.89	2.27
WP_24R_4	4.86	2.24
WP_24R_6	3.86	1.81
WP_24R_8	2.49	1.15
WP_24X_10	3.80	1.75
WP_24X_4	2.36	1.01
WP_24X_6	3.75	1.71
WP_24X_8	5.57	2.47
Average time	**4.26**	**2.77**
Difference	35%	

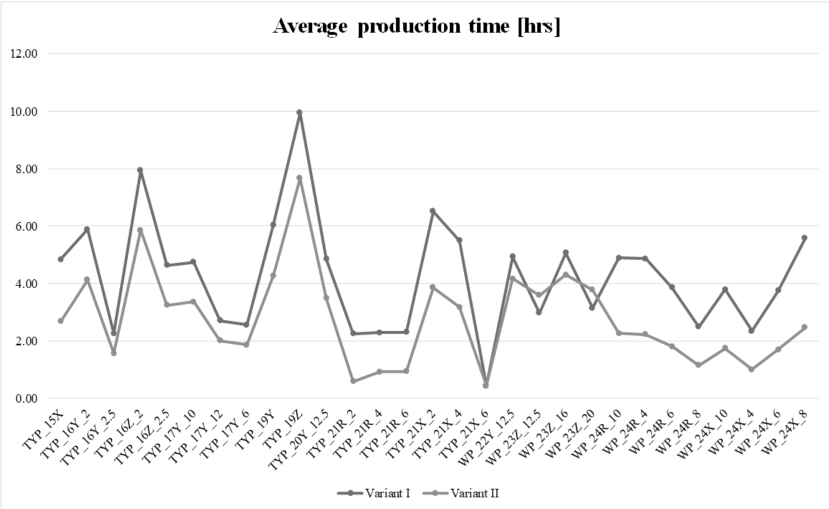

Fig. 3.8. Comparison of production time [own elaboration]

The simulation, which aimed to reduce the production time of a cyclical order by 2 hours, is another example of improving the organisation of material flow. As successive iterations were performed, different strategies were tested to understand their impact on the functioning of the process and the generated results. The variants with different availability of resources used for the analysed order were tested, bearing in mind the current capabilities of the company. Also, among other things, modifications were made to 'First Creation', which defines the moment when the units start to be generated in the simulation.

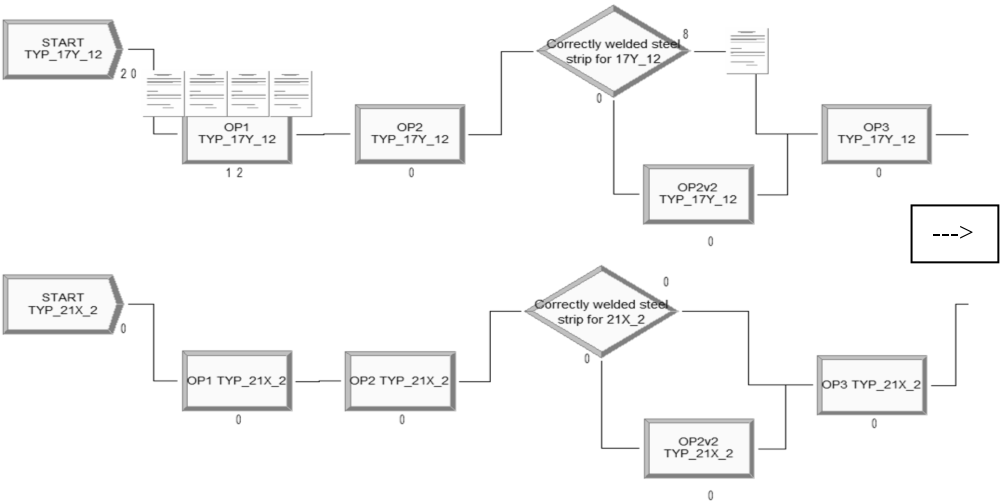

Fig. 3.9. Excerpt of the initial model created in Arena Simulation [own elaboration]

The iterative approach allowed for progressive improvement of the model, adapting it to the requirements. As successive iterations were made, better results were achieved. The iterative approach allows various scenarios to be explored in order to understand the impact of different parameters on the results.

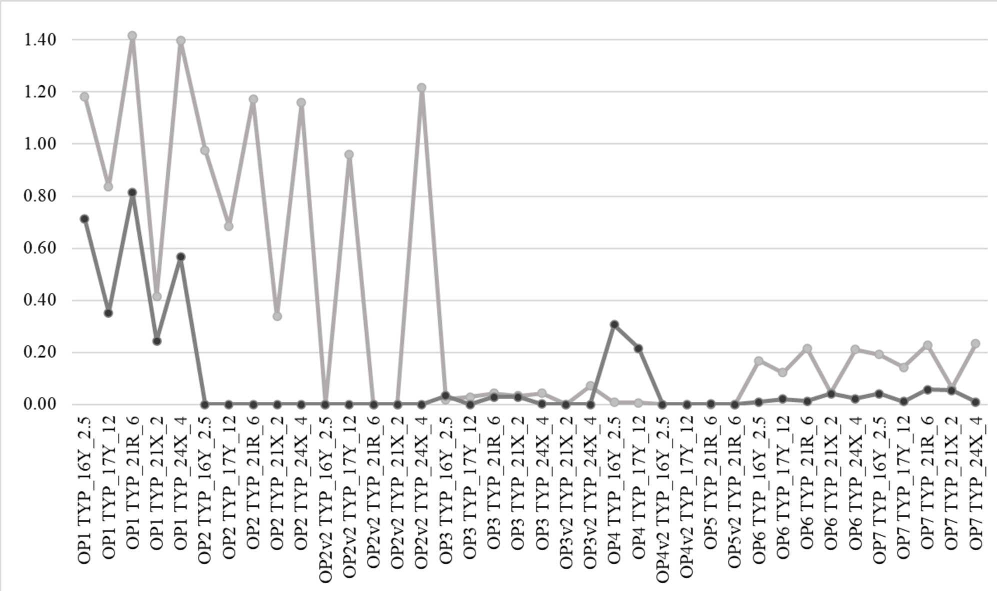

Fig. 3.10. Comparison of waiting times [own elaboration]

3.4.6. Improving the production process through implementation of multi-station working

One of the options for improving the production process flow is the introduction of multi-station operation when justified. The technological sharpening nest consists of three stations (m=3) with different loading/unloading times "a", machining times "t" and transition times "b".

Table 3.3. Simulation of results [own elaboration]

	a	*t*	*b*	*(a+t)*	*(a+b)*
Station 1	30	130	20	160	50
Station 2	30	280	20	310	50
Station 3	30	205	20	235	50
				Cycle time: 310 sekund	Operator time in full cycle $\Sigma(a_i + b_i) = 150$ sec

Knowing the required operations and their appropriate times, the number of machines, denoted as n' can be determined.

$$n' = \frac{(a+t)}{(a+b)} \tag{3.2}$$

The machines will be idle because the number of machines operated by the operator is n' = 2.07, so from this it follows that $m > n'$.

The next step is to determine the machine idle times I_m and operator idle time I_o for one cycle T_c.

$$T_c = \begin{cases} (a+t) & when \; m \le n' \; (operator\ idle) \\ m(a+b) & \; m > n' \; (machine\ idle) \end{cases} \tag{3.3}$$

$$I_m = \begin{cases} 0 & when \; m \le n' \\ T_c - (a+t) & \; m > n' \end{cases} \tag{3.4}$$

$$I_o = \begin{cases} T_c - m(a+b) & when \; m \le n' \\ 0 & \; m > n' \end{cases} \tag{3.5}$$

The calculations showed that cycle time is T_c = 450 seconds, idle time for machines I_m = 140 seconds and operator I_o = 0.

It was assumed that the operator's hourly cost C_o is 25 EUR and the machine's hourly cost C_m is 35 EUR.

$$TC(m) = \begin{cases} \dfrac{(C_o + mC_m)(a+t)}{m} & when \; m \le n' \\ (C_o + mC_m)(a+b) & \; m > n' \end{cases} \tag{3.6}$$

$$\phi = \frac{TC(n)}{TC(n+1)} = \frac{(C_o + nC_m)(a+t)}{n[Co+(n+1)Cm](a+b)} = \left(\frac{\varepsilon+n}{\varepsilon+n+1}\right)\left(\frac{n'}{n}\right) \tag{3.7}$$

As a result of calculations ε = 0.71 and ϕ = 0.76, it was deduced that two machines should be operated by an operator to minimize costs. This is because If ϕ < 1 then $TC(n)$< $TC(n+1)$ then n machines should be assigned per operator, and if ϕ > 1 then $TC(n)$ > $TC(n+1)$ then $n+1$ machines should be assigned per operator.

3.4.7. Discussion of the obtained results

The more challenging market conditions in which companies operate and the factors that determine their activities are resulting in the necessity for changes in management processes.

The use of multi-criteria evaluation of options was a fundamental component of the solution evaluation and selection phase. It allowed for developing a compromise to find a solution that is favourable from the point of view of technical, economic and ergonomic criteria, which in this case were the basis of choice. Consideration of risk as one of the evaluation criteria in the selection of the optimal option was an important factor in the rationalisation of production systems.

Production process simulations allow for early identification of problems and reveal potential for change. Material flow simulation allows the identification of disruptive factors in production systems in order to systematically improve these areas.

Implementing material flow simulation at the right time helps to identify the right direction before real production knowledge becomes available.

The developed solution represents a comprehensive approach that can provide the business with the opportunity for long-term growth and many significant achievements.

3.5. CONCLUSION

The proposed methodology considers the range of factors affecting the process of implementing new technological solutions and provides information in the form of key recommendations for selecting the best solution and its implementation. The findings of the research provide practical suggestions for the modern companies. The approach will contribute to greater efficiency in the delivery of innovative solutions and enable the effective implementation of future projects. The results of these projects provide references for organisations confronting the challenges of creating and implementing the technological solutions.

Future research can should focus on exploration of ways to integrate new technologies into existing production processes and developing methods and tools for the integration of new technologies into existing production processes. It is especially interesting to extend future research by including risk evaluation in the perspective of flow time analysis in process simulation. Integrating risk evaluation into subsequent research will enable more complete understanding and improvement of the process, minimizing potential negative impacts. The expected results will result in motivation for further improvement and continued growth. The discussed areas form an integral part that together determine effective management and business operations. The effective combination of the design of new technological solutions, project management, organisation of production and managing business costs is the basis for achieving competitive advantage.

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