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Preliminary communication

mSIPOC - Work Design Procedure for Complex Industrial Production Process

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Abstract: Despite nearly two centuries of efforts by scientists and engineers to enhance the efficiency of production processes, today's production processes continue to be inefficient and wasteful. As the production process's complexity increases, the working designer's ability to identify all losses and inefficiencies in the process decreases. Therefore, implementing a procedure that will enable a higher-quality work design is crucial in such production processes. This paper aims to develop a procedure for work design, especially in complex production processes, which will eliminate waste and optimise the process before the implementation. Additionally, the developed procedure ensures the identification of all necessary activities so the production process can proceed without stoppages and interruptions. The development of this procedure is based on the results of an analysis of scientific papers dealing with this topic and on the synthesis of procedures aimed at eliminating problems that result in inefficiency and ineffectiveness of work activities. The developed procedure has been tested in two production processes, and the results confirm achieving the set goals.

Keywords: complex production processes; eradication of waste; optimisation; SIPOC; work design

1 INTRODUCTION

Work design is defined in [1] as the "content and organisation of one's work tasks, activities, relationships, and responsibilities". The term "job design" signifies the narrower focus, and "work design" denotes a broader perspective that links the job to its wider environment [2]. At the same time, tasks and activities are constituent parts of the job. There is only a symbolic difference between activities, tasks, jobs, and work in industrial production, mainly where assembly lines exist. For example, in the automotive industry, no matter which model of car is assembled, the activities of one workplace are almost the same. This means that techniques for designing someone's job could be found in literature behind different terms: "work design", "job design", "task design", "task allocation", "function allocation", and so on.

A literature search reveals over 17000 articles about "work design" [3]. Still, most of those articles are focused on the “soft” side of work design: motivation, ergonomics, safety, burnout, employee well-being … The reason could be that most authors expect our natural intelligence to identify and order every needed activity in the best/most efficient way. In most cases, that is correct, but in the case of a complex production process (although there is no formal definition of the complex industrial production process, in this manuscript it is considered to be a production process with at least 10 production activities (humans can hold a maximum of 7 ± 2 facts in memory at one moment) and more than 2 subjects/workers in the process), things quickly go wrong and can be very expensive. It is well documented that complex work systems often fail to deliver their anticipated benefit [4]. A similar conclusion is that a "number of unintended and dysfunctional consequences" [5] are embedded in the production process this way.

If a product is to be mass-produced, even the slightest loss per piece represents a considerable amount of money, so it is of crucial importance to design the most effective, waste-free production process. "Despite the evidence for the benefits of well-designed work, large-scale studies … conclude that poor quality work designs remain rather common" [6]. Also, much research has been developed during the last century in human work design; the results seem unsatisfactory [7]. Finally: "For all the investments that have taken place and seem set to continue, and despite substantial reductions in the cost of computing power, it is apparent that many technical innovations are substantially less effective than intended" [8].

Knowing this, everyone is expected to try to design efficient work - work without losses. However, in the Lean Production (LP) literature, there is ample evidence that production processes are full of waste (process efficiency, that is, value added (VA) time divided by lead time is usually about 1%). A formal procedure for designing the core part of the work is needed to prevent losses and unintended consequences.

The rest of the manuscript is structured as follows. The second section provides a detailed description of a strategic approach to the literature review and the analysis of the selected papers. Section three is devoted to presenting the methodology for the developed procedure (modified SIPOC - mSIPOC). Testing of the mSIPOC is conducted in two real organisations and the results are presented in section four. The last section contains a conclusion with an emphasis on the strengths and weaknesses of the mSIPOC.

2 LITERATURE REVIEW

Scholar's use many terms for designing jobs in one workplace: job design, work design, activity design, task design, task allocation, function allocation … We decided to start the literature review with the most general term: "work design". By "article mining", it will cover and converge on all the most significant articles about all the mentioned terms.

Literature review on this topic is problematic because there are more than 17000 published articles regarding work design [3], so the decision is made to narrow the search by looking at only the first 100 articles in Scopus and WoS, filtered with the keyword "work design", sorted by (a) relevance and (b) citation. Because the authors' intention is to analyse the articles published anytime, but the most recent list as well, (a) a list of any time published articles and (b) a list for the last 5 years are made and analysed:

- Scopus: anytime, sorted by relevance - first 100 of 408 articles,

- Scopus: last 5 years, sorted by relevance - 56 new articles,
- Scopus: anytime, sorted by citations - 72 new articles,
- Scopus: last 5 years, sorted by citations - 42 new articles,
- WoS: anytime, sorted by relevance - new 45 from first 100 of 1478 articles,
- WoS: last 5 years, sorted by relevance - 34 new articles,
- WoS: anytime, sorted by citations - 78 new articles,
- WoS: last 5 years, sorted by citations - 75 new articles.

That is a total of 502 articles. Those articles are briefly read (title, abstract, keywords and sometimes even the introduction and conclusion parts of the article). Only 38 articles have some connection with the core part of work design - how to produce designed products with minimum waste. Those articles are read in detail, and the work of the authors of those articles, a list of used literature, and a list of articles that cited specific articles are read in detail as well. After that, 88 (50 new with 38 from the initial list) relevant articles are identified as a basis for detailed analysis.

"… stage for work design research was set by economic perspectives on the efficiencies of specialisation and division of labour (Babbage, 1835; Smith, 1776). Early in the 20th century, Taylor's (1911) time-and-motion studies in scientific management brought the design of work to the attention of organisational scholars" [9].

After those early works, most articles focus on the "soft" side of work design (e.g., motivation, ergonomics, ecology). In [10], the author identified 4 types of work design approaches:

- motivational approach: focus on job enrichment, enlargement, and characteristics of motivating jobs as well as from theories of work motivation and psychological principles from sociotechnical approaches
- mechanistic approach, reflecting classic industrial engineering, emerged with recommendations from scientific management, time and motion study, and work simplification (Barnes, 1980; Gilbreth, 1911; Maynard, 1971; Mundel, 1970; E Taylor, 1911) cited in [10]. It is oriented toward human resource efficiency and flexibility outcomes such as staffing ease and low training requirements,
- The biological approach emerged from biomechanics, work physiology, anthropometry, and much of the ergonomics literature,
- The perceptual-motor approach, deriving mainly from experimental psychology, emerged from research on human factors engineering, skilled performance, and human information processing.

In [11], the questionnaire (Work Design Questionnaire -WDQ) is developed to measure work characteristics collected from previously published articles. The questionnaire addresses 21 categories, grouped into 4 clusters:

- Task characteristics (1. Work scheduling autonomy, 2. Decision-making autonomy, 3. Work methods autonomy, 4. Task variety, 5. Significance, 6. Task identity, 7. Feedback from job).
- Knowledge characteristics (8. Job complexity, developed a measure to tap those work characteristics, 9. Information processing, 10. Problem-solving, 11. Skill variety, 12. Specialization).
- Social characteristics (13. Social support, 14. Initiated interdependence, 15. Received interdependence, 16. Interaction outside the organisation, 17. Feedback from others).
- Work context (18. Ergonomics, 19. Physical demands, 20. Work conditions, 21. Equipment use).

In [12], the authors presented the SMART model of work design. Their focus is on "soft" characteristics of the work design ("key psychological aspects of work design"). The model consists of five "higher order factors" of work design:

- Stimulating work characteristics (perceived task variety, perceived skill variety, perceived problem-solving demands, and perceived information processing demands),
- Mastery work characteristics (perceived job feedback, perceived feedback from others),
- Autonomous work characteristics (perceived timing autonomy, perceived method autonomy, and perceived decision-making autonomy),
- Relational work characteristics (perceived task significance, perceived beneficiary contact, and perceived social support) and
- Tolerable work characteristics (low levels of perceived role overload, perceived role conflict, and perceived work–home conflict).

After reading selected articles, it is concluded that the most widely used technique for work design is Method-Time Measurement (MTM), developed by Maynard and others in the late 1940s (Ma et al., 2010). MTM is widely criticised for being a very time-consuming task. To mitigate that problem, MTM-2 was developed by the Swedish MTM Society and in 1965, it was accepted by the International MTM Federation as an international standard [13]. Based on MTM-2, the Sequence-based Activity Method (SAM) is developed. Many techniques were developed based on SAM. For example, in [14], ErgoSAM is presented. However, it is focused on ergonomics. ErgoSAM is a tool for detecting high musculoskeletal loads early in planning. It applies to existing processes and workplace designs that have not been implemented. From the article, it is impossible to conclude if it is suitable for optimising the work process to eradicate waste.

Further, in [15], it is stated that "The proportion of basic functions in a process is an absolute measure of the method level. 70% of the base functions of a cycle time can be considered "world-class". Normally, you find 30 - 40% basic functions in the initial state." (translated from Swedish). So, we need to develop a method that will enable us to identify (almost) all the activities at the beginning of the work design process.

In [16], the author presented the Method Design Concept (MDC), a tool that can increase the share of Basic Functions (BF) or Value Added (VA) activities in total working hours or lead time (LT). There are three crucial points in MDC: (1) the objective of the process and activities, (2) the definition of inputs and outputs of the activities and (3) BF / VA activities.

Analysis of the collected scientific articles revealed these disadvantages of existing techniques:

- does not guarantee the identification of all necessary production activities,
- there is no incorporated optimization,
- there is no incorporated risk analysis,
- most new research papers do not address cost reduction, efficiency improvement and
- most new research papers focus only on worker motivation and well-being, not on costs and efficiency.

As a result of this analysis, the hypothesis is formulated as:

It is possible to develop a procedure for designing an efficient manufacturing process that ensures the identification of all necessary production activities and enables:

- identification and elimination of existing waste,
- identification and mitigation of risks to the environment, health, and safety and
- determination (estimation) of production costs,

while also being favourable to the well-being of the production workers.

Based on that hypothesis, the goal of this article is defined as:

"Develop a procedure for work design that will enable:

1) identification of all necessary process activities,
2) design of the whole process with minimal waste,
3) design of the process that will have the shortest possible time / finished within the time defined by tact time,
4) design of the process that will hold within a minimal/acceptable level of risk,
5) design of the process that will pay attention to workers' well-being and satisfaction, and
6) design of the process with maximal efficiency and minimal costs."

3 METHODOLOGY

"The general philosophy is that there is probably one best way to do the job given the current technology, and it is most likely to find or approximate this best way through a systematic, empirical (that is, scientific) approach rather than intuition" [17].

"Work design is usually needed when a new manufacturing system is to be created, in a greenfield situation, or more frequently when a change to an existing system is foreseen, in a brownfield landscape" [18]. The following situations should be added as well:

- Work procedures and Maintenance activities for new machines,
- Changed work procedure due to newly identified risks,
- New way of working due to problem-solving activities or because of some accidents,
- Preparation for Industry 4.0/digitalisation or introduction of robots in the production process, when it is needed to eradicate all the waste in the process first,
- Need for standardisation and documentation of existing work procedures and
- Some changes in context/organisational culture.

There are three approaches to industrial work design. The technology-centred approach promotes increased automation, while the human-centred approach relies on humans. The socio-technical approach takes a middle ground [19].

The most common procedure in industrial work design is the technology-centred approach, which follows the linear sequence of system development [20].

During the activity specification, the principle of "minimal critical specification" [21, 22] should be followed. Only strictly necessary activities should be defined on the highest level without losing the essence of the task. Thus, the worker will have room to demonstrate his/her knowledge and skills.

The suggested procedure is developed considering the Mechanistic approach [10] and the Sociotechnical principles for system design, given in [8, 23].

This procedure was inspired by the Method Design Concept [16]. It is also completed using Lean Thinking (LT) and SIPOC. Because it is presented in a table similar to a SIPOC table, we have named it "Modified SIPOC for work design", or short: mSIPOC.

The mSIPOC implies teamwork. A multidisciplinary team should conduct the work design, and workers who will perform the design should be part of the team. One reason is their practical knowledge, and another is to prevent harmful job crafting [24]. It should be noted that behind harmful job crafting is not malevolence but a lack of knowledge about many influencing factors. So, participation in a team could be seen as an opportunity for learning and development for them. Additionally, by doing this, many job crafting ideas will be incorporated into the work procedure in this stage and aligned and optimised.

At the beginning of work design, it is necessary to become familiar with the organisation's external and internal context and communicate it between team members. The next step is learning about all constraints that must be obeyed. After that, all goals must be clearly defined. The final preparation step should focus on expectations from the work to be designed (e.g., cost, reliability).

mSIPOC could be used at any level of the details, from the highest level, as SIPOC is usually used (3 to 7 subprocesses), to the lowest level, as MTM is intended to do. The most beneficial is when it is used at a slightly higher level than MTM. If there is no data, mSIPOC could be applied gradually from the highest to the lowest level. First, the whole process is defined through 3 to 7 subprocesses, and then every subprocess could be worked out through separate mSIPOC tables. If that level of detail is not enough, each activity from subprocesses could be defined through its mSIPOC table. The procedure could be applied till a satisfactory level of detail is achieved.

The mSIPOC is presented in the form of a table (Tab. 1). The procedure is designed so that the application can start at any point, but we suggest that it start at the activity that presents the core reason for doing that work.

mSIPOC has four distinctive phases:

a) Phase I: definition of activities (steps 1-15),
b) Phase II: optimization (steps 16-27),
c) Phase III: implementation (steps 28-32) and
d) Phase IV: deoptimization.

The first three phases are presented in the algorithm (Fig. 1) and the fourth phase refers to the production process when production workers' well-being is in focus.

Table 1 Modified SIPOC table

Supplier	Input	Process									Output	Customer
		Activity	Workplace	*t*	€	Waste	Risk	VA	NNVA	NVA		

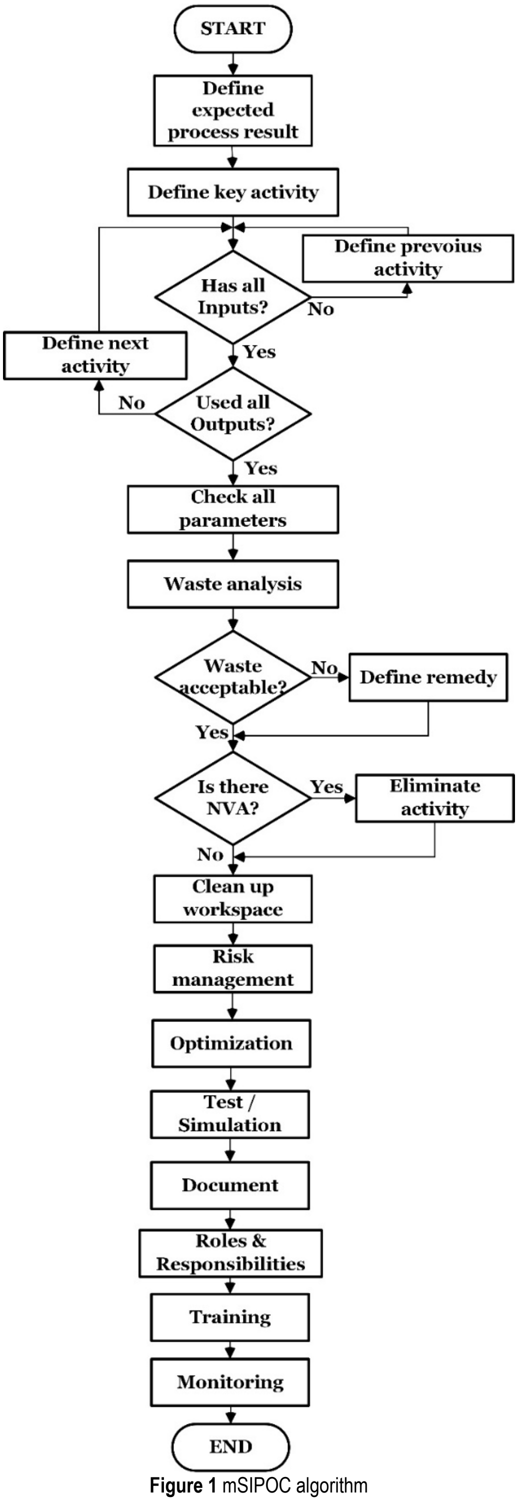

Figure 1 mSIPOC algorithm

The sequence of activities when defining the procedure is as follows:

1. **Define expected process result**: defining the key result that is to be achieved (result - the state that represents the essence - the reason for carrying out the procedure; this represents the "Output" from the key activity), this definition of the result must be following organisation mission, vision and strategic goals, for example result of production process could be: product, passed quality control, 100% correct, packed, ready to send, or for the maintenance intervention after equipment failed: machine repaired, as good as new (regarding productivity, precision, safety …),
2. **Define key activity:** defining the task/"Activity" that achieves that result (brainstorm method for achieving this - if suitable, generate more than one idea - select better/best),
3. **Define key activity:** defining the "Workplace" that will conduct the activity (workplace can be human, automated machine or robot - possible use of HABA-MABA list: Humans-Are-Better-At … Machines-Are-Better-At …), considering skills and capabilities of worker and how challenging task can be [25],
4. **Define key activity:** defining the necessary "Inputs" for that activity (parts, materials, tools, information, people ...), but also all the specific parameters that the inputs must satisfy (place, condition, quantity, value of a specific parameter, position, orientation ...),
5. **Define key activity:** defining the "Supplier" for each of the inputs (supplier is, in most cases, the previous "worker" that produces required Input, it can be human, automated machine or robot),
6. **Define key activity:** defining the remaining "Outputs" from the activity (e.g. waste material after the activity),
7. **Define key activity:** defining the "Customer" of those outputs (e.g. who will remove the waste material) - the user can be human, automated machine or robot,
8. **Define key activity:** defining/estimating the activity's required duration/time ("*t*"). If there are already some similar activities, one can use that data for estimating time, or it is possible to use some techniques for time estimation, like one presented in [26] or any other that suits one's need,
9. **Define key activity:** defining/estimating of the price/cost ("€") of the activity; because the production process could not influence the cost of the purchased parts/materials, that cost does not have to be used in these calculations, but cost of work, energy, consumables, depreciation of the value of the tools and machine must be part of the calculations; an exception could be made in the situation where some of these costs are estimated to be negligible and can be omitted,
10. **Define key activity:** identifying the "Risks" that a specific activity brings with it and evaluate it; when risk analysis is conducted, it is necessary to define what kind of risk will be analysed: risks regarding quality, safety, ecology, human factors [27], employee wellbeing [28, 29] etc. Specialists for those specific areas should conduct risk assessments for their area of expertise; if organization does not have a formal risk management system, it is possible to develop one just for this situation, for example: use FMEA for risk evaluation, develop tables for risk assessment (just for severity and occurrence - risk is measured with those

two values) and establish limit for an acceptable level of risk, that is the value of RPN - Risk Priority Number

11. **If not, all Inputs are present - Define previous activity:** definition of the prior "Activity" that should provide "Input" for the key (next) activity (it is necessary to define all elements for that activity: input, supplier, time, cost, waste, risk, output, and customer), this activity is added before the activity that will use the output of this activity,
12. **If not all Inputs are present - Define previous activity:** repeating the addition of prior activities that provide input for subsequent activities until the first activity is reached, which is the signal for initiating the work; all inputs for every activity must exist as an output of some prior activity; if that is not the case, that means that some activity is not included in the designed work - it should be added (this is part of the control mechanism that ensures identification of all necessary activities),
13. **If Outputs are not used - Define next activity:** definition of the activity that should take measures about the output(s) from the key (next) activities (it is also necessary to define all the elements that are defined for the critical activity: input, supplier, time, cost, waste, risk, output, and customer)
14. **If Outputs are not used - Define next activity:** repeating the addition of activities that take action with the outputs of previous activities until the last activity is reached, which is the activity after which the state in the system is identical to the state before starting this procedure,
15. **Check all parameters:** checking whether all the required parameters of the input to the activities completely match the output parameters of some previous activities - if they do not match, it is necessary to add the activity that will provide it (e.g., the required tool exists, but it is in the wrong place or part is on the right place, but not heated to the required temperature, so it is necessary to define the activity of bringing the tool to the required place or heating that part), checking pairs of Inputs and Outputs is the most crucial feature of mSIPOC - it is the control mechanism that ensures identification of all necessary activities,
16. **Waste analysis:** identification of the possible losses/"Waste" in each activity, classify possible waste per LT classification of waste (Mura-load imbalance, Muri-overload, and Muda: unnecessary transport, excessive inventory, unnecessary movement, waiting, overprocessing, overproduction, scrap, and unused human potential),
17. **If waste is unacceptable - define remedy:** for each identified possible loss/waste (if it is unacceptable - organization can set the limit of unacceptable waste at any value, but if at the end is not satisfied with result, it is always possible to return to this step and change the limit), it is necessary to find a different way of carrying out the activity, which would eliminate or mitigate that waste (if this essentially changes the observed activity, it is necessary to carry out an analysis of the subsequent activities, in order to find whether the time was disturbed by the previous way of carrying out the entire procedure and if this is the case, it is necessary to solve this discrepancy); if team has at least one member with thorough understanding of LT and definitions of the waste, it is possible to identify most of the currently present and identifiable waste from the production process; by elimination of the waste efficiency of the process is raised and the cost is lowered, elimination of the waste is the part of the process optimization,
18. **If there is NVA - eliminate activity:** assessment to which group of activities each of the defined activities belongs: VA (value added) - an activity that is key to the effectiveness of the designed work, without which the work would not be complete and would not produce the desired effect (in [16] it is called BF - Basic Function), NNVA (necessary non-value added) - an activity that itself does not contribute to the desired effect of the procedure, but creates the conditions for it and NVA (non-value added) - an activity that does not contribute to the effect of the procedure and does not affect the conditions for it, and can/should be eliminated (in [16] both NVA and NNVA are called AF - Auxiliary Function),
19. **If there is NVA - eliminate activity:** elimination of all identified NVA activities if possible, and analysis of whether the procedure can be carried out in its entirety and whether the desired result can be achieved; by elimination of the NVA efficiency of the process is raised and the cost is lowered, elimination of the NVA is the part of the process optimization,
20. **Cleanup activity:** checking if each "Input" is produced in some "Activity" and if it is appropriately stored/disposed after use (if not, add missing/adequate activity); every Input in one activity (part and values of specific parameters) must be produced in some previous activity, also, every Output must have some activity that uses it as Input; example for this can be maintenance activity of bearing replacement: for mounting new bearing, maintenance technician must have new bearing, heated to 110 °C, if he has bearing, but not heated to that temperature (crucial parameter is temperature in this case), activity of heating the bearing must be added before activity of mounting; also, this maintenance activity will "produce" disassembled failed bearing that cannot be left on the site, but must be properly disposed, if no disposal activity is defined (no activity is using disassembled failed bearing as Input), somewhere after disassembling failed bearing, disposal activity must be added; this example shows how it is not possible to "forget" heating and disposal activity,
21. **Cleanup activity:** checking if each "Output" is used as intended and if it is appropriately stored/disposed after use (if not, adding of missing/adequate activity must be conducted),
22. **Risk management:** After defining all activities, engineer for ecology must analyse each activity, and when he/she finds any that can endanger environment (it is assumed that organization has defined level of environmental protection it is aiming for), he/she should initiate either changing that activity in the safe way or new, protective activity should be added at the proper place (protective measures may create conditions for a new risk!); regarding health and safety

issues, engineer for health and safety also has to analyse each activity, and if he/she finds anything that can harm worker or user (again, it is assumed that organization defined what level of worker/user protection it is aiming for), he/she should either modify activity in the safe way, or should add protective measure/activity in the proper place; also, he/she should define necessary health and safety equipment / device as an Input for activity that requires it; besides ecology and health and safety, organization can choose to conduct any other kind of risk assessment analysis, like possible financial loss, criticality to product quality …; level of protection is the same as the term used in risk management theory: "risk appetite", which is used to define level of potential loss that the organisation is willing to tolerate and is capable to endure without serious consequences,

23. **Optimization:** grouping/sorting of tasks based on subject (workers/machines/ robots), place or resource, taking care of the timing of related tasks. For example, if more than one thing is needed from the warehouse, those tasks should be grouped and parts obtained during one visit (by doing this it is possible to notice that some workers/resources … have a lot of periods of waiting - one form of waste, so it should be checked if some activities could be grouped, eliminate waiting time and free that resource for some other job and improve its productivity),
24. **Optimization:** calculating the load of each worker/machine/robot and reallocating some tasks if necessary and possible, in order to make a more balanced allocation and thus shorten the overall execution time, if the load of one worker is bigger than the takt time, it is necessary to either introduce one more worker or find the way to reduce that time (conduct kaizen or kaikaku, or even some creative techniques for problem-solving) or reallocate some activities until sum for all workplaces drops below allowed value,
25. **Optimization:** optimizing the overall time of the process by using the Ghant chart, CPM or PERT technique (finding the best order of the activities and thus the shortest time for finishing the work),
26. **Optimization:** calculating the sum of the costs of the entire process, (as said earlier, these costs are all operational costs without purchasing costs of parts and materials, but if organization wishes to have the final cost of the process/product, it is easy to add purchasing costs to this sum),
27. **Optimization:** if the sum is higher than the allowed total cost, it is necessary to find activities that generate unacceptably high costs or any activity in which costs can be easily lowered, and try to find a way to reduce those costs (again conduct kaizen, kaikaku or creative techniques),
28. **Test/Simulation:** simulating the implementation of the procedure (pilot project) in reality, and confirmation of the functionality and effectiveness, as well as the estimated values of all significant variables (e.g., costs, values of KPIs),
29. **Document:** develop complete documentation of the defined procedure,
30. **Roles and responsibilities:** assigning roles and responsibilities for the implementation of protective measures,
31. **Training:** conducting training and,
32. **Monitoring:** monitoring the achieved results.

This way of defining a procedure not only ensures the implementation of the work procedure "without surprises" but also holds the potential for optimising the procedure even before the first implementation. Also, the detailed description and embedded control mechanisms make it suitable for automating/developing supporting software.

The mSIPOC procedure for work design offers opportunities for learning and development for each team member, which is identified as a "relatively thin" area in present research [30].

After designing the core of the work, if there are possibilities, it is advisable to "deoptimise" it ("if the motivational properties of work are improved, satisfaction with the work increases, but the efficiency with which work is performed … tends to decrease" [31]), by including NVA activities that will have a positive effect on "soft" side of work like satisfaction, motivation, wellbeing … [2, 32-35]. Although that step is partially done with risk mitigation/elimination, it is necessary to make workers' lives easier and more enjoyable. A good reference point for job enrichment is the integrated work design framework [36]. However, it is necessary to determine the maximum level of deoptimisation/loss of efficiency so as not to lose the competitiveness of the process. If the Industrial/Organizational psychologist was not part of the team until now, he/she should be added to the team now [37]. Also, "… new forms of working systems will emerge, especially the field of direct human-robot-interaction generates challenges in human-centred task design." [38], this procedure can be used to prepare a production system for introducing robots into the production process.

In [39], the requirements for a task allocation method are given. There are 20 criteria, and mSIPOC fulfils 15 of those criteria entirely and 5 partially: (I - be usable early in the design process: ✓; II - have a structured and systematic format: ✓; III - allow iterative use: ✓; IV - cover allocations to the human, to the machine, and to a combination of human and machine: ✓; V - cover allocations between humans in different roles: ✓; VI - specify decision criteria: ✓/☒; VII - consider the trade-offs between the decision criteria: ✓/☒; VIII - examine the content and quality of the human's job: ✓/☒; IX - enable its users to make informed choices: ✓/☒; X - enable quantitative evaluations to be made of the alternative choices: ✓/☒; XI - incorporate the concept of dynamic allocations dependent on real-time contingencies: ✓; XII - encourage participative use and use by end-users: ✓; XIII - require minimal training and support: ✓; XIV - be applicable to environments with similar characteristics to naval environments ✓; XV - be adaptable to different situations and tailorable for unique application: ✓; XVI - cover process issues (i.e. how the method works): ✓; XVII - cover content issues (i.e. the issues considered) ✓; XVIII - be easy to learn and usable: ✓; XIX - be consistent with existing methods and techniques in use: ✓; XX - be capable of use in new and existing sites: ✓).

Finally, it is not advisable to define work to the smallest details (like MTM tends to do) because there should be enough space for the learning curve to do its magic and job-crafting (a worker can contribute to work design by incorporating his/her habits and experience) [40, 41].

mSIPOC can be applied to a workplace with more than one worker (part of the production process) or the whole production process.

In [42], authors argue that work design should involve both "socio" and "technical" elements. In mSIPOC, they are covered partly simultaneously and partly in sequence.

4 CASES

The developed work design procedure is tested in two processes. The first case refers to the existing process, but the organisation introduced an assembly line, so it was necessary to redesign the existing work procedure.

The second case refers to producing a new model in the existing product family.

In the first case, we used an Excel spreadsheet to take care of the inputs and outputs. If needed Input has been produced in some previous activity, it is coloured green (it can be seen in Tab. 2), but if it does not exist, it is black. It should be noted that in this case, Excel is checking exact wording of the specific Input in the Output column. Similar checking is done with Outputs, where the specific Output is coloured in blue if it is used as Input in some of the following activity and remains black if it is not (see Tab. 2). Also, because the company intended to make a PERT technique for this case, we defined optimistic, pessimistic, and most likely time and calculated expected time. This was possible because there were the necessary time values from the previous production process. Part of the defined Excel table is presented in Tab. 2.

There were 92 production activities identified, and none of them was NVA. According to sales data, they were selling on average, 250 products per day; that is, their tact time is 106,8 sec., so we assumed that the acceptable maximal utilisation of one workplace is 100 sec (93,6 %) per one cycle.

The benefits of using mSIPOC in this process are:

- calculated average worker utilisation is 62,29%, so it is evident that there is room for improvement, even with this level of work effectiveness,
- despite low average worker utilisation, 7 of 27 workplaces are overburdened; for 6 workplaces, it is possible to reallocate some activities and bring their utilisation to acceptable levels, but for 1 workplace, it was not possible, so they accepted to find a way to speed up some activities.

It is illogical that there is only 62,29% utilization of the workers and 7 workers are overburdened. This happened because of the company's "culture" where it is normal for neighbouring workers to help each other when one is late. This led to situations where worker B is leaving his post to help late worker C, and worker A is leaving his post to finish worker's B job. Because of this "culture", company never made thorough analysis of utilization of every worker. With this experiment and application of mSIPOC, company became aware of that and made reallocation of all activities.

Table 2 Part of the defined excel table for case 1

	A	B	C	D	E	F	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1		Designat	Title	Input	Prior ac	Designat	Activity Content	Designat	W.Plc.Title	a	m	b	t	I	Waste	Designat	Risk Description	VA	NNV	NVA	Output	Designat	Title
2	1			Production plan		A001	Issuing order	W-PP	Production planner	1	1	1	1	0,0024					x		Bill of material	L-01	Logistician 01
3	2	W-PP	Production planner	Bill of material	A001	A002	Uzimanje ramova iz skladista	L-01	Logistician 01	80	90	120	93,333	0,1768	Transport		- povreda radnika - ostecenje rama		x		Ramovi	WP-01	Sacmarenje
4	3	W-PP	Production planner	Bill of material	A002	A003	Uzimanje profila za obruce iz skladista	L-01	Logistician 01	15	20	30	20,833	0,0395	Transport		- ogrebotine i posekotine		x		Profil za obruc	WP-02	Obruc
5	4	W-PP	Production planner	Bill of material	A003	A004	Uzimanje zbica i glavcina tockova	L-01	Logistician 01	15	20	30	20,833	0,0395	Transport		- teret - povreda ledja		x		Zbice i glavcine tocka	WP-03	Zbicanje
6	5	W-PP	Production planner	Bill of material	A004	A005	Uzimanje nalepnica za tockove	L-01	Logistician 01	15	20	30	20,833	0,0395	Transport				x		Nalepnice za tockove	WP-04	Nalepnicarke
7	6	W-PP	Production planner	Bill of material	A005	A006	Uzimanje guma iz skladista	L-01	Logistician 01	50	60	100	65	0,1231	Transport		- udisanje isparenja guma		x		Gume	WP-05	Gume
8	7	W-PP	Production planner	Bill of material	A007	A008	Prikupljanje materijala za izradu sajli	WP-07	Sajle	5	6	10	6,5	0,0082	Transport				x		Materijal za sajle	WP-07	Sajle
9	8	L-01	Logistician 01	Ramovi	A002	A009	Postavljanje 20 ramova na jelku	WP-01	Sacmarenje	50	60	90	63,333	0,065	Un.Movement				x		Ramovi postavljeni na jelku	M-01	Sacmarenje
10	9	WP-01	Sacmarenje	Ramovi postavljeni na jelku	A009	A010	Sacmarenje	M-01	Sacmarenje	25	30	40	30,833	0,0316			- udisanje prasine - klizav pod zbog sacme	x			Ramovi ocisceni	WP-01	Sacmarenje
11	10	M-01	Sacmarenje	Ramovi ocisceni	A010	A011	Transportovanje 20 ramova do farbare	WP-01	Sacmarenje	3	5	8	5,1667	0,0053	Transport				x		Ramovi kod farbare	WP-08	Farbar
12	11	WP-01	Sacmarenje	Ramovi kod farbare	A011	A012	Postavljanje 20 ramova na konvejer	WP-08	Farbar	45	60	90	62,5	0,0789	Un.Movement				x		Ramovi na konvejeru	M-02	Farbara
13	12	WP-07	Sajle	Ramovi na konvejeru	A012	A013	Farbanje	M-02	Farbara	90	130	180	131,67	0,1662			- opekotine - udisanje isparenja boje	x			Ramovi ofarbani	WP-08	Farbar
14	13	M-02	Farbara	Ramovi ofarbani	A013	A014	Skidanje ramova sa konvejera na palete	WP-08	Farbar	10	12	15	12,167	0,0154	Un.Movement				x		Ofarbani ramovi na paleti	WP-08	Farbar
15	14	WP-07	Sajle	Ofarbani ramovi na paleti	A014	A015	Transportovanje 20 ramova do nalepnica	WP-08	Farbar	3	5	8	5,1667	0,0065	Transport				x		Ofarbani ramovi kod nalepnica	WP-09	Nalepnice
16	15	WP-07	Sajle	Ofarbani ramovi kod nalepnica	A015	A016	Lepljenje nalepnica	WP-09	Nalepnice	250	300	480	321,67	0,33	Un.Movement			x			Ramovi sa nalepnicama	L-02	Logistician 02
17	16	WP-08	Farbar	Ramovi sa nalepnicama	A016	A017	Transport ramova sa nalepnicama u montazu	L-02	Logistician 02	60	80	100	80	0,1263	Transport				x		Ramovi sa nalepnicama u montazi	WP-10	Ram - glavcina za pedale
18	17	L-01	Logistician 01	Profil za obruc	A009	A018	Secenje profila za obruc	WP-02	Obruc	4	5	6	5	0,0059			- ogrebotine	x			Iseceni profili za obruc	WP-02	Obruc
19	18	WP-02	Obruc	Iseceni profili za obruc	A018	A019	Savijanje profila za obruc	WP-02	Obruc	12	15	20	15,333	0,0182			- ogrebotine	x			Savijeni profili za obruc	WP-02	Obruc
20	19	WP-02	Obruc	Savijeni profili za obruc	A019	A020	Spajanje profila za obruc	WP-02	Obruc	8	10	15	10,5	0,0124			- ogrebotine	x			Spojeni obruc	WP-02	Obruc
21	20	WP-02	Obruc	Spojeni obruc	A020	A021	Transportovanje obruca do CNC busilice	WP-02	Obruc	5	6	8	6,1667	0,0073	Transport				x		Spojeni obruc kod CNC busilice	M-03	CNC busilica
22	21	WP-02	Obruc	Spojeni obruc kod CNC busilice	A021	A022	Busenje obruca za zbice	M-03	CNC busilica	100	120	150	121,67	0,1536			- opekotine od opiljaka - ubodi i ogrebotine od opiljaka - upadanje opiljka u oko	x			Izbusen obruc	L-02	Logistician 02
23	22	M-03	CNC busilica	Izbusen obruc	A017	A023	Transport izbusenih obruca kod tockova	L-02	Logistician 02	80	100	150	105	0,1657	Transport				x		Izbusen obruc kod tockova	WP-04	Nalepnicarke
24	23	L-01	Logistician 01	Zbice i glavcine tocka	A018	A024	Spajanje zbica i glavcine tocka	WP-03	Zbicanje	55	60	70	60,833	0,072				x			Sklop glavcine	WP-04	Nalepnicarke

Prior to this experiment, the company did not have established formal risk management procedures. Risk analysis conducted in mSIPOC showed that one workplace was exposed to grinding dust (despite an existing vacuum system for collecting dust), and one workplace was exposed to excess heat (the process of powder coating the product frame). The company accepted redesigning those workplaces and introducing additional protective measures.

In the second case, the company developed a new model in the existing product family and wanted to define its production process. In this case, we decided to experiment. We formed two teams: one of the experienced planners (who are developing production plans as their regular job), who will develop production plans the "old way", and another formed of inexperienced planners, who will use the mSIPOC model. Both teams got identical bills of material for the new model. Also, teams got data about the necessary time for completing assembling activities for similar models. The main result from the experiment was that the inexperienced team, using the mSIPOC model, developed the production plan with almost the same efficiency as the experienced team (the difference in the production time is less than 4%). The only differences were in slightly different estimated times for assembly activities of new/modified parts (the new model in a family of many similar products - many parts are the same) and the way they tried to solve 1 overburdened work position: the inexperienced team solved the situation by involving one more worker, and the experienced team solved it by developing new tool that will help to shorten the necessary assembling time for that workplace.

When considering the set goals regarding the mSIPOC procedure, these two cases corroborated that they are fulfilled completely (Tab. 3).

Table 3 Cases confirmation of achieved goals

Goals for mSIPOC method	Case 1	Case 2
1) identification of all necessary process activities	Yes	Yes
2) design the whole process with minimal waste	Yes	Yes
3) design of the process that will have the shortest possible time/finished within the time defined by tact time	Yes	Yes
4) design of the process that will hold within minimal/acceptable level of risk	Yes	-
5) design of the process that will pay attention to workers' well-being and satisfaction	Yes	Yes
6) design of the process that will have maximal efficiency and minimal costs	Yes	Yes

5 CONCLUSION

Despite almost two centuries of research and more than 17000 scientific articles on work design, we still lack a reliable method for designing efficient work processes.

In this paper, we presented the Modified SIPOC procedure for work design (mSIPOC), which has its roots in the Method Design Concept (MDC) [16], Lean Thinking, Risk Management, and SIPOC.

Based on the defined hypotheses, research objectives are set, and the developed mSIPOC procedure fulfils all that is required:

1) Identification of all necessary process activities:
2) Embedded control mechanism (steps 11-14) checks if any prior activity prepared necessary inputs for every following activity, and if all outputs from prior activity are used by some following activity; if whole process passes this control, that means that all process activities are defined.
3) Design of the whole process with minimal waste.
4) Steps 16-19 deal with waste. Those steps force process designers to focus on every production activity and search for waste or NVA. If any is found that activity should be redesigned. If the team/process designer is skilled in identifying and eliminating waste, designed production processes will be with minimal waste.
5) Design of the process that will have the shortest possible time/finished within the time defined by tact time.
6) Steps 8, 23 and 24 of the mSIPOC are intended to estimate the duration of every activity and check whether the selected employee can finish his job (can be in charge of more than one activity) on time. Besides that control, in step 25 is recommended the application of PERT of CPM techniques for finding the shortest execution time for the whole process.
7) Design of the process that will hold within a minimal/acceptable level of risk.
8) Steps 10 and 22 of the procedure are designed to identify and eliminate most of the risks. Again, how many risks will be identified depends on the knowledge and skills of the team/designer.
9) Design of the process that will pay attention to workers' well-being and satisfaction.

A fully optimized process could be very stressful for the workers, so the mSIPOC procedure foresees stress mitigation for workers (improvement of the process in the field of workers' well-being and satisfaction) but because it has a negative impact on process efficiency, it is called deoptimization,

1) Design of the process with maximal efficiency and minimal costs:
   Steps 8 and 9 are dealing with estimation of the duration and costs of the production activities and steps 23 - 27 are dealing with optimization of those values. If controls reveal that those values are exceeding targeted values, it is necessary to redesign critical activities and achieve those targeted values. By doing this, designed production process will be of maximal efficiency and minimal costs.

Based on the above, it can be concluded that the developed procedure for work design - mSIPOC completely satisfied the set requirements and confirmed hypotheses.

mSIPOC can be used when work (re)design is needed in every situation. It is designed to be applied in complex work situations, but it is suitable for every situation. Procedures could be applied in simple work situations as well, but they could be too time-consuming for that task, so it is not advisable to use it in simple work situations. An exception could be in the situation where organization wants to have detailed documentation of its production process (even the most simple one) because mSIPOC could be a focal point for all other necessary documentation (mSIPOC must contain all parts from the Bill of materials, list of all workers necessary for the job, all activities for Work order and Work instructions, all tools and safety equipment for Requisition, interdependence of all activities and all times for planning and scheduling).

In [43], the authors asked many questions regarding introducing new technologies (especially AI) to someone's work. "… most occupations in most industries have at least some tasks that AI could replace, but there is no occupation where all the tasks could be replaced. Such research means that the already existing trend that humans and digitalised machines/robots work alongside each other and depend on each other will intensify, calling into question how tasks, jobs, work, and technology should be designed as a whole" [43, 44]. mSIPOC has the potential to do even that job successfully because AI (together with executive elements like CNC machines, AGVs, manipulators or robots) can be treated as a single worker.

Weak spots of mSIPOC could be:

- a time-consuming process, so it is not suitable for simple production processes.
- it requires some practice in the area of waste identification and elimination (the ideal situation will be the process without waste, but it is not possible to eliminate all of the waste from the process, so the real goal is to come the closest to that ideal state as possible) and
- it requires knowledge of risk management and lean production.

mSIPOC is tested in two cases, and results show that it could help even inexperienced planners develop a sound production plan with minimal waste and optimal production sequence.

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