Int j simul model 21 (2022) 3, 465-476
Original scientific paper

QUICK WORKPLACE ANALYSIS USING SIMULATION

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Abstract
Modelling and simulation is a highly progressive area that can create significant financial savings for companies that use it. Simulations can be used in the production area to analyse or verify certain decisions and conditions, on the basis of which correct measures can be taken. However, modelling is a highly time-consuming and therefore costly process, which narrows its use for decisions in high-priority processes. The content of the article is a description and results of the created tool designed for quick analysis of the workplace using simulation. The entire process of functioning was described through Unified Modeling Language (UML) diagrams. Siemens's Tecnomatix Plant Simulation software was used to create the tool. The tool itself was compared both to the length of creation of the mid-size simulation model and the time variance of model creation in a standard way. The tool can be used to reduce the time needed to create a model that is used to analyse the selected workplace, which ultimately increases the productivity of the simulation expert.
(Received in May 2022, accepted in July 2022. This paper was with the authors 1 week for 1 revision.)

Key Words: Workplace Analysis, Computer Simulation, Object-Oriented Modelling, TX Plant Simulation

1. INTRODUCTION

The current market environment focuses on ensuring that the solutions are addressed as quickly as possible, with the least possible consumption of human potential, money spent, and resources needed to solve the problem [1]. In production in accordance with Industry 4.0 [2], there are several pathways in optimisation, for example, process technology optimisation [3, 4], logistics processes [5, 6], organization [7, 8] or materials [9]. Among the innovative elements brought about by Industry 4.0 is the widespread use of simulation software [10]. Simulations are currently used in many industrial enterprises, including small and medium enterprises (SMEs), for the verification, improvement, and creation of new products, processes, or technologies in the enterprise [11, 12]. The application of simulations can also be found in many service delivery systems where the implementation and test of a system design solution in a real environment is expensive or restricted due to safety issues. A healthcare system is a suitable example of the simulation application [13, 14]. As such, simulations are key to improve and evaluate system performance. The use of simulations in company practice can also bring us many other benefits, such as rationalising the number of workers at workplaces; accelerating material flows by adjusting routes; minimising the time needed to produce products at selected workplaces; detecting waste in production [15, 16] or realised ergonomic analyses to improve satisfaction in the workplaces [17, 18]. The simulations also allow optimisation of the manufacturing system in the context of a multi-objective optimisation problem [19]. Their use will therefore be not only in systems that are now effectively deployed like collaborative workplaces [20], but also in systems that will be based on reconfigurable manufacturing systems that will use fast capacity change and will need fast verification [21, 22].

Today's simulation software allows even an average trained worker to obtain results from the simulation model after creating a model. However, the big drawback of simulations is that they cannot produce quick and easy outputs for us, just as individual tools for quick workplace analysis (e.g., MTM-1, value steam mapping, workplace ergonomics, work measurement) can produce in a relatively short time, but they also bear their own flaws. This creates the need for a tool that can be implemented into the simulation environment, which filled the shortcomings of large-scale simulations, as well as the shortcomings of individual current methods for workplace analysis. Such a tool should, as a matter of principle, operate at two levels, either as a separate end element or as a quality basis ready for further processing in other analyses and simulations. At its core, the article deals with the design of a tool that fills the gap between large and lengthy simulations. This tool provides the properties of simple and wide usability, scalability, compatibility, speed, and clarity in the field of results. The primary purpose of such a tool is to conduct a quick analysis of the workplace using simulation, with the possibility of implementation into any industrial environment using simulation software. The tool itself was created and experimentally verified, and the results from it were compared with the classic way of modelling and simulation.

2. MATERIAL AND METHODS

The very concept constituting the structure of the tool was based on the basic requirements for the characteristics of such a tool, namely quick processing and selection of the necessary indicators, compatibility with any workplace, compactness for one user, clarity of results, and making the obtained data available for other analyses. The tool was created using Siemens's TX Plant Simulation tool [23]. The software was chosen because it provides the needed flexible programmable environment in which the required tool elements can be applied, which may still be built and adjusted.

2.1 Designing a quick workplace simulation algorithm

The objective design of this tool used the principles of object-orientated modelling [23]. The basic objects contained in the basic TX Plant Simulation library are used in this tool to create objects.

These were selected based on functionality that future objects should have, all taking into account the general use of objects in the tool. The creation of objects constituting the tool is aimed at defining new functions of the basic elementary objects of the simulation software so that, by their common function, they allow the specified criteria of the tool function to be fulfilled. Already in the proposal on which the overall basic concept will be based, and on which the basic expectations of the operation of the tool will also be based, certain phases and individual steps arise. These individual phases and steps are ranked in sequence, either according to logic or the importance of processing. Fig. 1 reflects the separate steps in solving the specified task using the Quick Analysis Tool.

One of the most important added values of the tool was the inclusion of connections in the product work plan. These connections can be defined at different levels, depending on the area analysed. The closer principle of this division is shown in Fig. 2.

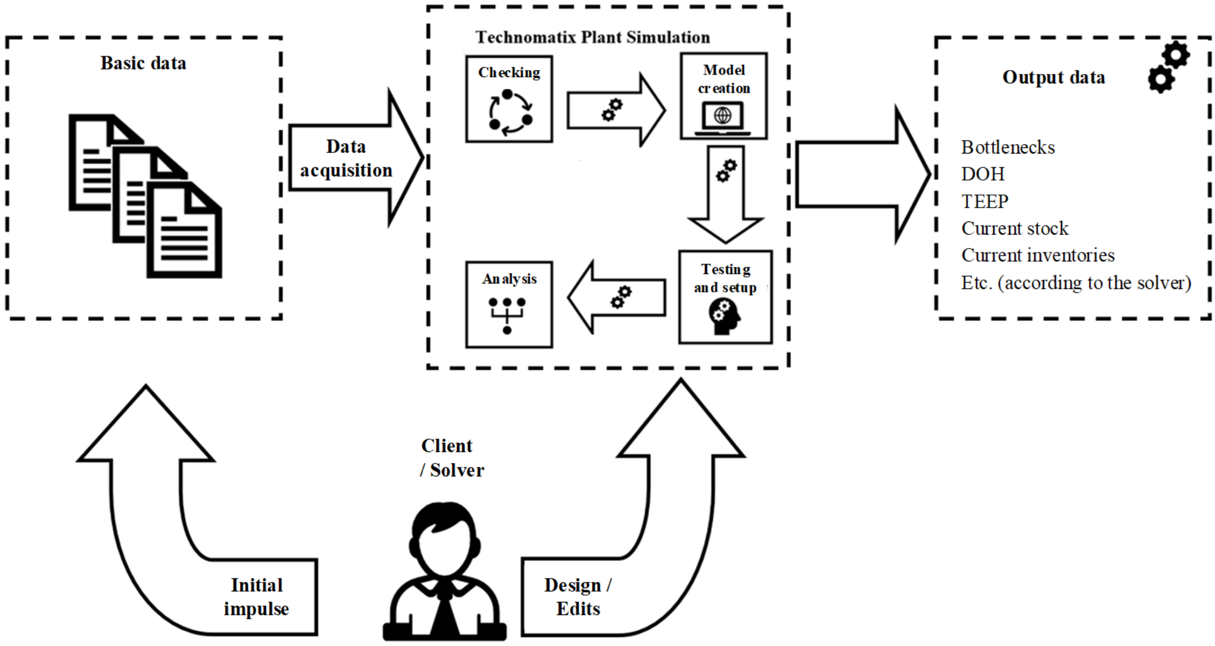

Figure 1: The principle of how the tool for quick workplace analysis works.

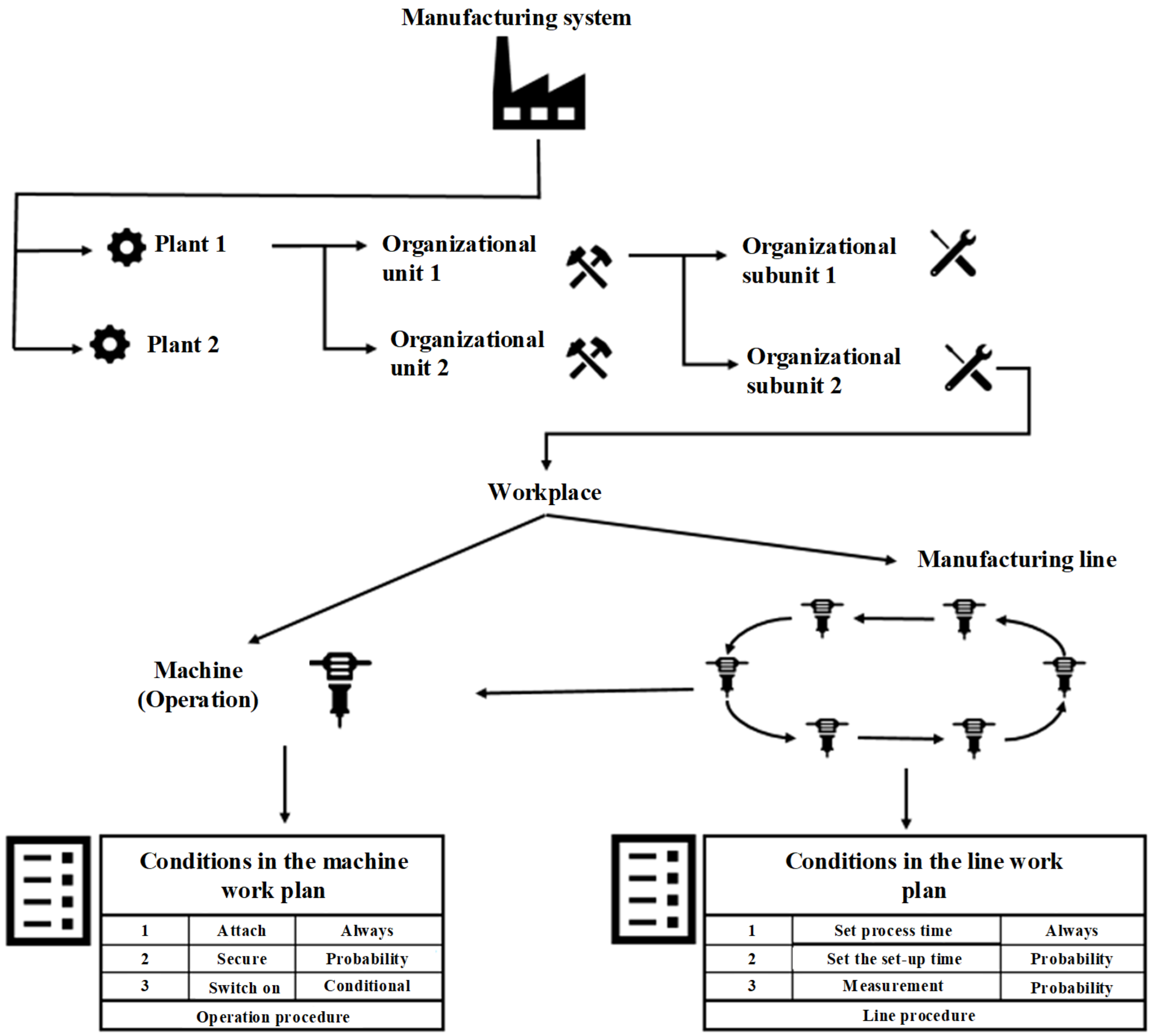

Figure 2: An example of the implementation principle for conditions from the line to the machine.

Fig. 2 shows how individual connections between the different processes should work in principle. Using their specifics, these connections define the entity's transition through individual processes or through lines, depending on the degree of analysis performed. A significant advantage of using these conditions was a clear definition of time consumption, for example, of a worker or a machine. The tool also used the tracking logic of the selected element, which offers the solver the ability to observe the transition of a complex object step by step. The resulting functionality of the element allows the individual passage of the devices with their settings to be observed at any time in the process. The entity is governed by the workflow associated with it. As part of this procedure, it passes through individual workplaces as they follow the product work plan and adjust the element to the final condition.

2.2 Developing tool objects for quick workplace simulation

The initial step for the creation of the model is to obtain the necessary documents for its development. These documents are understood to be the basic data from which the model itself is formed. It is appropriate to maintain the data itself in a well-defined structure, together with a clearly defined distinguishing element according to which the data can be combined and searched. Such browsing elements clearly define a particular set of data we call keys. We can also define the principle of this key so that, based on it, we can go through the entire complex data set and search only for specific records belonging to a given key. Such keys may include, for example, a material number, a specific machine, or a selected worker.

The tool used material number and production process as key search elements when working with basic data, which are associated with each product and contain complex detailed data, e.g. on components, units, and specific types of materials.

Since the collected data is isolated as sheets, it is necessary to modify and process the data retrieved. This option can be defined to the following base points:

- BOM Decay – This point can be defined as the process by which the BOM and customer demand for a given production unit define a list of all the material numbers, components, and materials that are subject to analysis. This BOM decay is described in the UML diagram of data processing in part A. 1. See Fig. 3.
- Delete redundant records – This section is tasked with removing the redundant data that is contained in the basic tables. Removal is carried out on the basis of material numbers from the BOM decay from the previous point, which are compared to the underlying data. This makes it possible to delete basic data from unnecessary records. This step will ensure that the data that remains in the tables is actually used in the system we are monitoring. The formats of this cropped data remain in their original shape. The internal logic is described in the UML diagram of data processing part A. 2. See Fig. 3.
- Selection, formatting, and trimming of duplicates of selected data – It is advisable to format data in data-driven simulation models into data formats that best describe possible attribute values. This avoids errors or incorrect loading of attribute values. The elementary principle of this selection is described in the UML diagram in part A. 3. See Fig. 3.

The final part of data processing and preparation focuses on the elimination of duplicates. In the process of processing and selecting data, there is a process of duplication of some records. If such errors were not corrected, there would be significant errors in the modelling process [24]. Therefore, you must remove these duplicates before you can implement them.

The entity created has certain attributes and specific marking elements that it bears throughout the production process. One of these attributes is the material number that generates the workflow of the entity. This fundamental data will be assigned to the entity (material, component, or product) upon its creation in the generator.

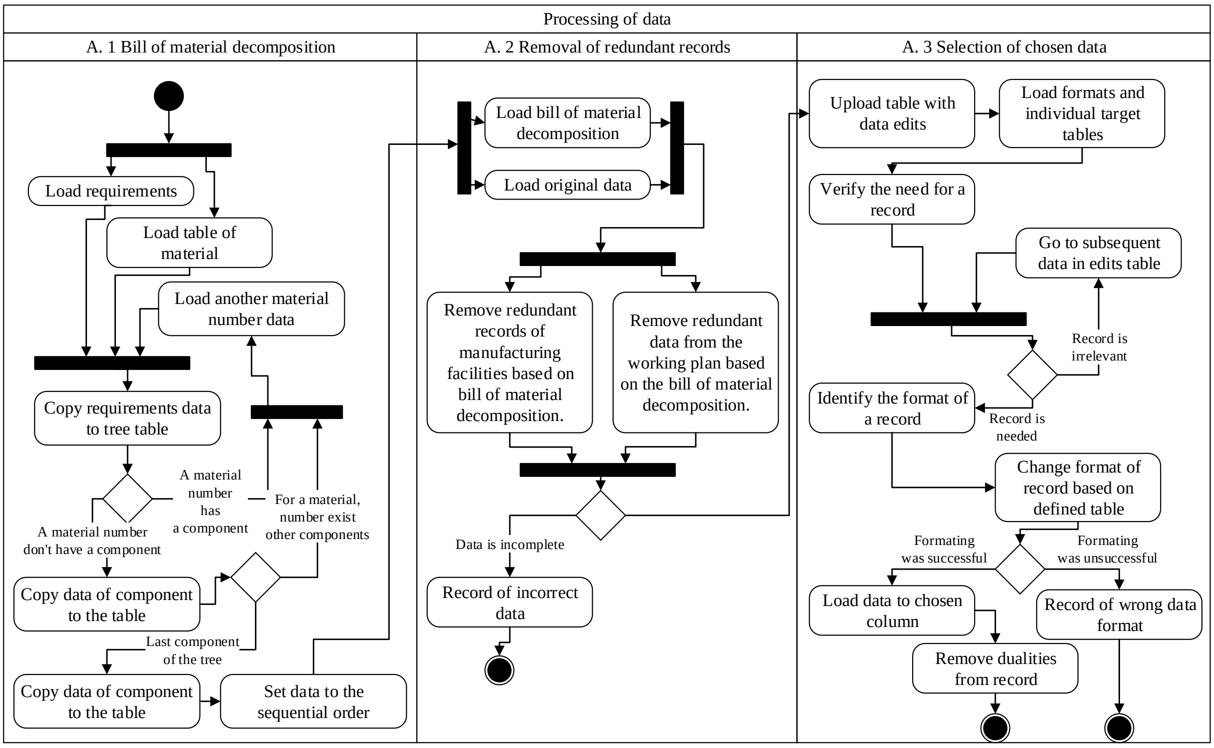

Figure 3: UML diagram of data processing activities, part: A. 1 – BOM decay creation, A. 2 – Data cropping, A. 3 – Selected data selection.

The operation of an entity through autonomous processes affects the connections that are contained in the work plan between the processes. The Workplace Quick Analysis Tool recognises three basic links within the work plan. The individual ties we recognise are:

- Connection always ("Always") – With the condition always, there may be two basic variants. The first variant that may occur is that the operation proceeds directly and thus always follows the previous operation. The second variant that may occur is that multiple operations are followed in parallel by one previous operation. If the parallel branching converges again into one link, the following operation may occur only when all parallel operations have been completed, not just one.
- Probability connection – Probability connection has two different variants. The first connection tracks the percentage probability of passing through a process. This presents the possibility that we have several different devices that can produce the same product. This means that the processing distribution of an entity may not be even, but it can be managed according to the ratio that determines its percentage distribution. The second variant of the connection also deals with the ratio, but it is only a percentage of the probability of a single operation being stopped. This kind of connection can be used very well, for example, to determine the percentage of pieces sent for inspection.
- A conditional connection is an operation based on a given rule or event. For example, this connection can be used for a change operation where the morning shift can use another device to cultivate an entity as an afternoon change but editing an entity using the morning change device is the same as editing an entity using an afternoon shift device. This link may also serve to indicate the start of production of a particular production batch. By its very nature, this type of condition is very close to the probabilistic condition, but in contrast, it is not governed by the numerical range of probability but by the rule.

An essential element of the production system within the model is the working station or process [25]. This process is created on the basis of a separate object in which other elements are contained. The process consists of basic elements that are:

- entry and exit to the production process, station,
- in the process, the station provides the operation itself or a set of operations on the product,
- buffers in front of and behind the station; they can also be used as input and output buffers for products,
- variables specifying the selected workplace,
- methods that are designed to control the overall logic of the process they create.

The process is an essential element of the actual creation of the simulation using the tool. Based on these processes, an elementary model of the image of the workplace is built. Processes follow their internally defined logic. This logic determines the processing time of individual entities according to predefined parameters and also affects their flow in the model environment. The material flow of entities between processes is managed according to the work schedule. The basic principle of the logic of the station can be divided into three basic areas, which are more closely described in the UML diagram of activities for the logic of the process (see Figs. 4 and 5). Part A. 1 shows the principle of two methods located at the station. These methods prioritise the time spent on the device, according to the entity's work schedule. In addition to setting the time, these parts also have the task of verifying that the process through which you want the entity to progress is correct. Should the next process be the same as the current one, it is a multiple transition or task sequence in one workplace. The principle of sending entities to other processes based on their interdependencies is described in parts A. 5, see Fig. 4, and in A. 6, A. 7, see Fig. 5, of the UML diagram of process activities. Individual activities reflect the internal structure of the logic of the work plan enriched with ties. Part A. 5, see Fig. 4, of the UML diagram of process activities, displays the logic of the transition based on the probability connection. The principle of decision-making is based on the principle of generating a random number. This generated number then acts as a value for continuous probability intervals. Along with the branch, the branch label or number that the connection uses are assigned to the entity. The marking of a given branch is carried by the entity until the branch disappears by switching to another branch.

Part A. 5 also shows how the entity handles arriving at the end of its work plan. Where you can clearly see a decision function where either the entity is sent to the next process or the entity is sent directly to the output from the model until the work schedule of that entity is terminated. Part A. 6, see Fig. 5, describes how, as a matter of principle, connection always works under the conditions implemented in the tool. When a connection is easy to run every time an entity carries a branch record, a connection number is not logged. This is because the entity is maintained by the connection number the entity has reached, and we cannot alter the record since it will disturb the process' smooth flow.

But when an entity comes out of a branch, the property record changes to zero, which means that the entity came out of the branch of that connection and continues without it in the zero-record work plan.

Part A. 7 focuses on the definition of the parole, see Fig. 5. This principle of redistribution of an entity is very similar to probabilistic distribution, but with one fundamental difference. The distribution of the principle to which the branch of the entity is issued is based on the conditions defined in the workflow. Individual conditions can be defined according to a large number of criteria bound either to modify an entity or to properties that an entity has. As well as probabilistic custody and in parole custody, there is a so-called round-the-year bond that the entity may or may not meet. Processes are complemented by graphic elements, or so-called visual indicators. These markings, depending on their defined colour, show the current state of the process. Such a graphic element can already visually indicate to us where there are certain delays or where we create bottlenecks in the production process. Also, such graphical adjustments allow us to monitor the entity's transition through the production process up to its output in the form of a finished part. Process generation is provided by a method that generates their position in the selected model based on coordinates and assigns their attributes to them. The possibility of using automatic model generation makes it possible to eliminate the routine activity of creating model objects, which can be automated and thus reduce the time it takes to assemble it.

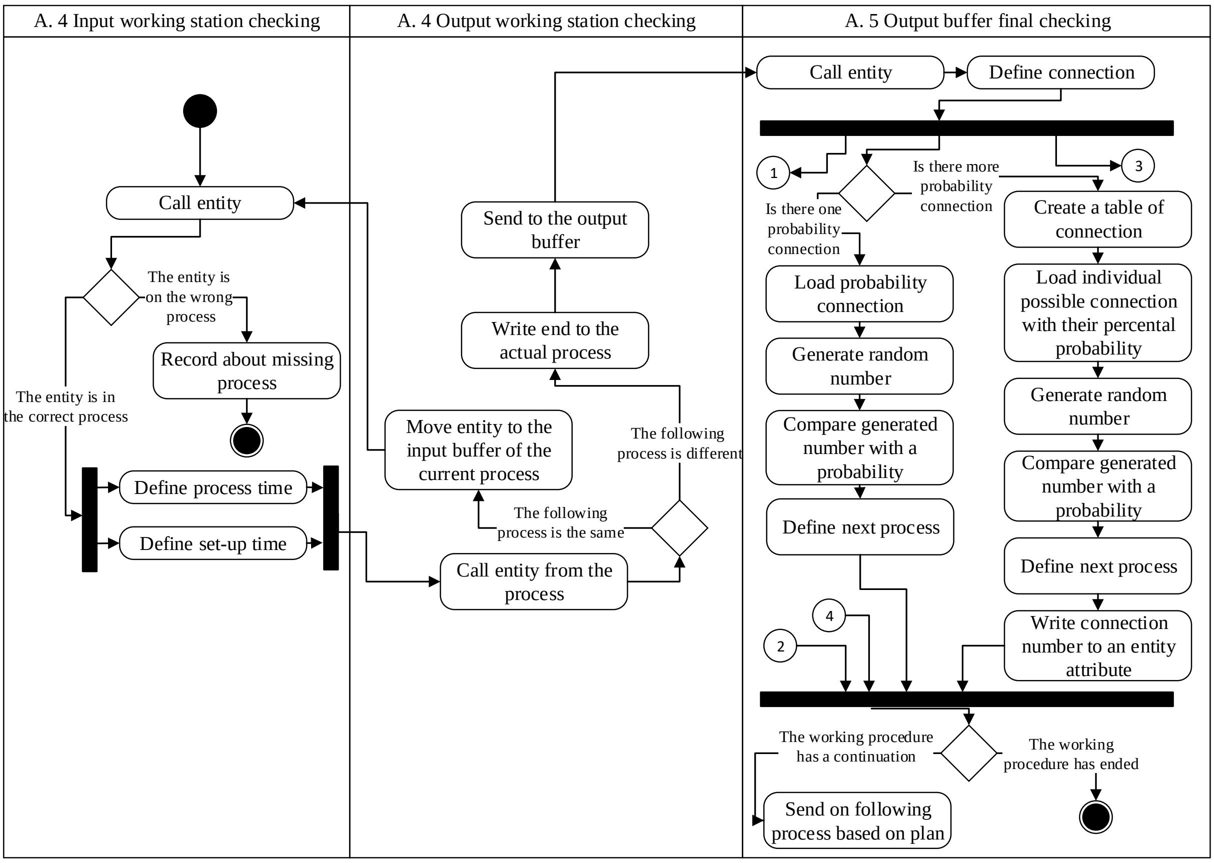

Figure 4: UML diagram of process activity's part: A. 4 – Input and Output working station verification, A. 5 – Final output buffer verification (probability connection).

In the tool, you must also define a specific resource that produces individual entities in the model. In the tool, the input and creation of individual entities is subordinated to the needs and their respective data, which are defined at the very beginning of the creation of the model. The relevant attributes of each entity are assigned from basic data. Each entity carries its own, its own, its own, workflow in the production process. Entity generation is realised automatically based on the needs set by the customer and therefore, the source is not specifically managed. This means that the overall need set by from the customer affects only the sequence of individual entities produced. This need, therefore, does not only have to address the total single volume of output produced at the same time, but may also focus on the time intervals at which a given smaller part of the need is to be implemented These time intervals dictate the order of manufacturing batches, which may impact the total production time of a certain defined necessity.

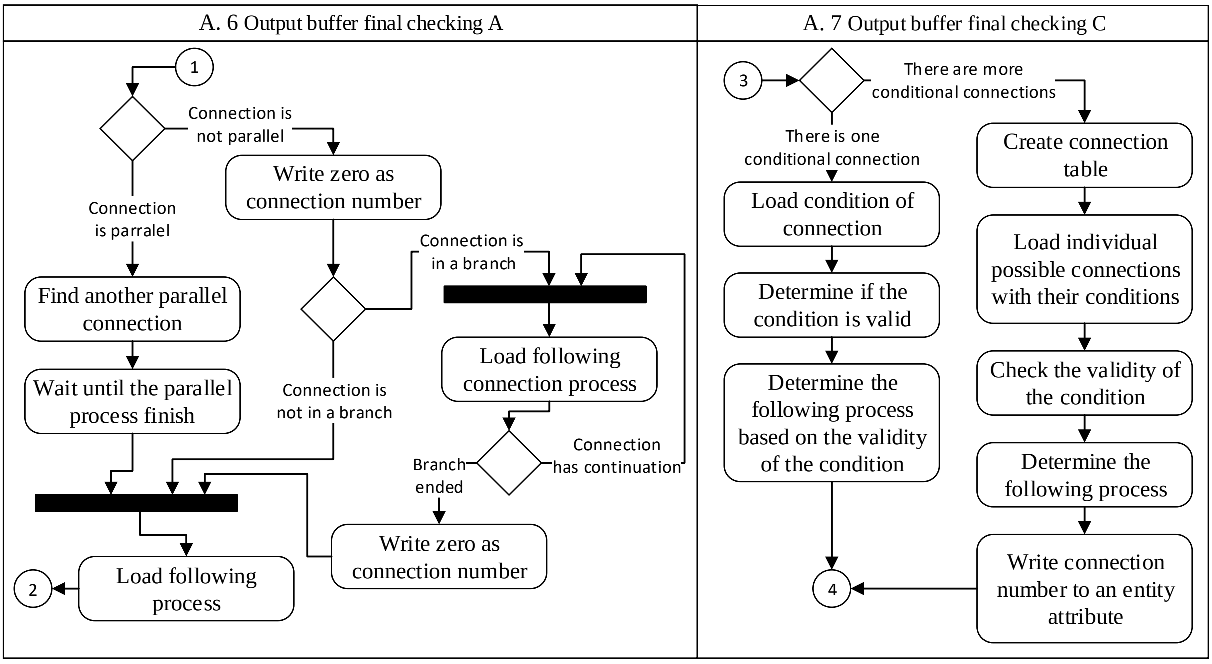

Figure 5: UML diagram of process activities, part: A. 6 – Final check of the output buffer A (connection always), A. 7 – Output buffer final check C (conditional connection).

3. SIMULATION RESULTS

The basis for verifying the benefits of the tool created is based on a practical comparison of time consumption for the creation and simulating of the model, as well as an expert estimate of time consumption. The analysis of the technical design of the tool itself focuses on comparing the general working type of model created using the tool. An example of a model created by the tool and used for experiments is shown in Fig. 6.

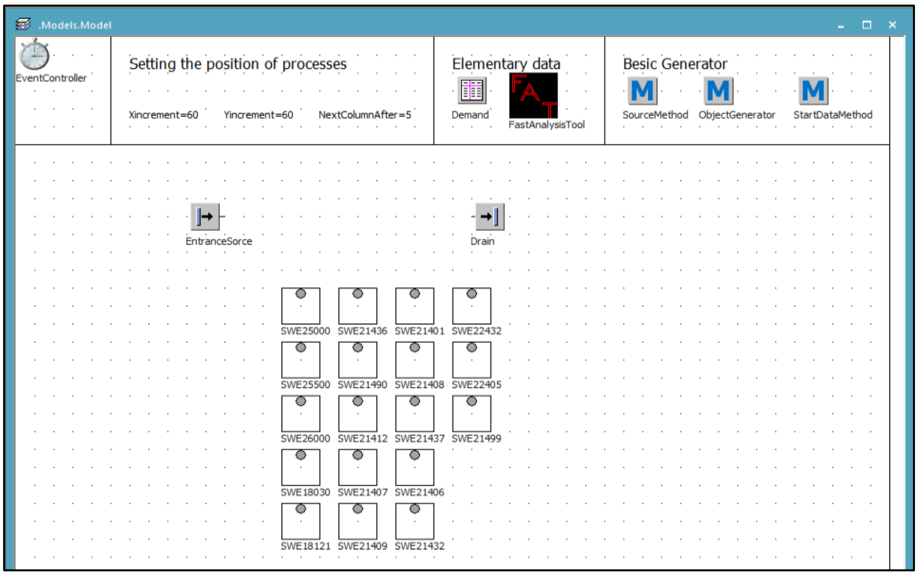

Figure 6: Creating a tool for quick analysis of the workplace with a generated layout for comparison.

The overall evaluation of the tool must also take into account the time needed to develop the tool itself. The actual creation and integration of the proposed too, according to the defined methodology for its creation, is estimated to be approximately 20 days in implementation with the help of a worker with expert experience in the field of modelling and simulation. This time estimate of the duration of integration, is created in consultation with modelling experts within the digital factory concept. The basic data that was used to verify the technical evaluation of the tool, comes from the source data – namely from the BW data warehouse. The monitored tool was observed and evaluated as two separate parts, which dealt with the processing of basic data for the model and the construction of the basic structure of the model from the available data. The size of the simulation was divided into three basic sizes depending on the number of machines and also the product dimension type. The example model seen in Fig. 6 itself is defined by its size at the level of the medium simulation. The actual comparison of time consumption was carried out in the same example workplace as the experimental verification of the functionality of the tool. The observation itself monitored the time required for data processing and modelling using standard methods as well as the proposed tool for quick analysis of the workplace. The overall assessment of observation was introduced in Table I.

Table I: The results of a comparison of simulation processing methods utilising the regular approach and the recommended tool.

Parts of the sample simulation time analysis	**Methods of processing the sample simulation**	
	Standard method	Tool for quick workplace analysis
Data processing time (hour)	27	14
Processing time of the sample model (hour)	20	9
Total time required to process the simulation (hour)	47	23
Total time consumption difference (hour)	24	

The results of the observation of data processing and the creation of the sample model showed that the total average time saved in data behaviour using the tool is 13 hours, which is 1.63 days, and the saving in processing the sample model is 11 hours, which is 1.375 days. The total time difference that arises when using the tool and the standard processing method is 24 hours. Consequently, the time consumed when using the tool accounts for 48.94 % of the original time needed for processing using the standard method.

In carrying out this observation, account should also be taken of the time needed to develop the tool itself, which will be reflected in the time return on the tool. To express this return, the sums of the average times for data behaviour and model execution using the tool and the standard method were used, together with the time estimate of the tool development complexity, see Fig. 8. From the graph, we can clearly observe the turning point in the formation of models. This point is achieved in 312 hours and 6 simulations from the current start of modelling in the standard way and also using a tool to which the time needed for implementation has been added. Within the time consumption of the tool application, it was also necessary to define the total time variances for the remaining two sizes of the simulations performed, namely small and large. When defining the time variance of the use of the tool itself, it should be taken into account that the tool is a newly formed element and its time variances for the individual simulation sizes are based on a time analysis of the medium simulation and expert estimate of the simulation specialist. In Fig. 7, by blue is marked the total number of models created using the quick workplace analysis tool and by orange is marked the number of models constructed in the standard way. The time variances of the formation of individual simulation sizes in the standard way were also obtained on the basis of documents from a simulation specialist.

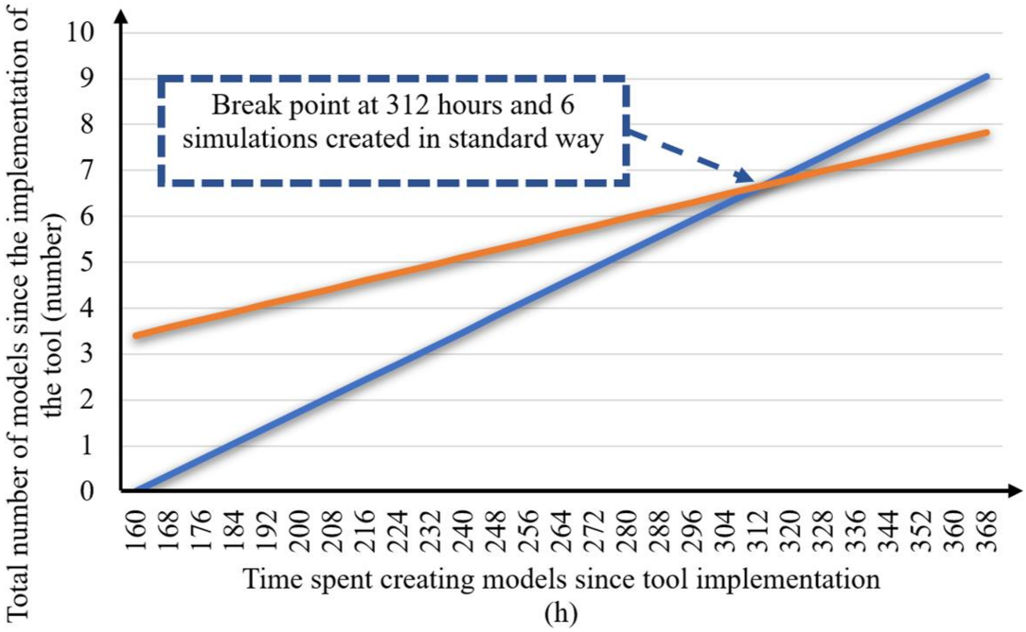

Figure 7: Elaboration of time return for the implementation of the quick workplace analysis tool.

For the total time intervals of each simulation size when executed using the tool and in the standard way, together with a description of the distribution of the individual remaining sizes, see Table II.

Table II: Time variations for simulation model realisation using the tool and the standard method divided by individual simulation sizes.

	Simulation model sizes		
	Small	Medium	Big
Number of machines (pcs)	up to 10	up to 50	over 50
Number of dimensions type (pcs)	up to 100	up to 1000	over 1000
Time consumption in data processing and modelling in the standard way (day)	4 to 8	6 to 14	10 to 30
Time consumption during data processing and creation using the proposed tool for quick workplace analysis (day)	1 to 3	1 to 5	1 to 10

From the table, we can calculate the predicted trend in the time-consumption of modelling using the tool and using the standard method. We can see that with the increasing size of the simulation, the overall time savings generated by the tool itself also increase. By contrast, the time required to use the tool practically coincided with application on a smaller model in the standard way. Based on these outputs, we can conclude that it makes sense to use the tool most in medium and large simulations, where its potential will be fully demonstrated. From an economic point of view, the financial quantification of the proposed tool would be very inaccurate and would not have a real basis. This is because the tool can be applied in any enterprise, which means that each enterprise has a different hourly rate per worker or specialist in simulations and material flows. Therefore, the implementation of the tool for these enterprises would have different values for the estimated savings generated.

4. CONCLUSION

The degree of digitisation of enterprises extends to all spheres and areas of the business structures pursued. This means that the different areas in enterprises that have been separated up to now are gradually merged and interconnected, although they may have had many functions in common. If a business wants to integrate a deeper sphere of digitisation, it must look for ways to link these areas and, as far as possible, improve and accelerate them. As one possible solution to this issue, the integration of simulation into the field of analysis of individual workplaces was offered, where flexibility, versatility, adaptability, and many other advantages of simulation can be used. The aim of the article was to describe the proposed tool for quick workplace analysis using simulation. As such, the tool is designed for rough and fast analysis of the selected workplace according to solver requirements in order to achieve the highest quality outputs possible. The design tool is generally applicable to any workplace or device. Its scalability and versatile use for analysis offers the possibility to fill the current gap between the current analyses used and simulations focused on one selected workplace. By integrating it into simulation software, the tool has permanent development potential. This potential is especially evident in the fact that the tool can be constantly replenished and improved with new modules and objects. At the same time, however, they can also enrich themselves with the existing elements of the tool with new functionalities, extending their usability, or also with elements that fill the causal flaws in the original objects. The potential development of the tool will allow its wider use in the enterprise, which is accompanied by an increase in the overall scope of the tool itself.

ACKNOWLEDGEMENT

This article was created with the support of the VEGA project: VEGA 1/0225/21.

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