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INFLUENCE OF DISPLAY MODE ON DISTANCES IN SOFTWARE TECNOMATIX PLANT SIMULATION

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Keywords: distances, modelling, simulation, Tecnomatix Plant Simulation

Abstract: The article presents the results of comparing the two principal display modes in the software Tecnomatix Plant Simulation. Currently, there is an increase in the application of modelling and simulation in industrial practice. Behind this are the new features of the simulation software and the growing number of users who control the simulations. The complexity of the simulation for the simulator is derived from the complexity of the system and the required degree of accuracy. The accuracy itself depends on the abstraction and reduction of the elements of the simulated system. Tecnomatix Plant Simulation software is a widely used tool that allows for multiple display modes, each with its specific purpose. The article aimed to determine the deviation between the individual display modes experimentally and outline their specific use based on abstraction and reduction level.

1 Introduction

Currently, modelling and simulation as part of the digital factory are experiencing a boom in use. This has to do with the increasing computing power of computers, the increasing simulation software functions, and the increasing number of trained staff. The use of simulation is in the frame of digital factory strategy where the company works with digital 3D models of real production, making changes and optimising them. Modelling and simulation are important areas of the digital factory that allow businesses to answer questions about modelled processes. Modelling is the process of creating a simulation model based on available information about the real system. Based on the layout of the real system and its abstraction, we are creating a model on which experiments will be carried out later [1,2]. The model is created based on a layout where the static and dynamic objects that make up this model are inserted. The model is a simplified version of the real system containing all its essential parameters. On this model, we conduct experiments in order to obtain information about the real system. Simulation is a representation of the real system and its dynamic processes in the model. As has already been said at the outset, the simulation aims to obtain information for the real system, with its subsequent optimisation [3,4]. Basically, it is about preparing, implementing and evaluating individual experiments through a simulation model and realised by simulation runs. Therefore, the simulation is used to support decision-making processes and verify the implications of individual decisions prior to their actual implementation. As the most common scenario analysis of the results from the simulation, the run is considered the what-if analysis. Operational managers can simply perform what-if analysis as a part of a decision-making process [5,6]. In general, the difficulty of modelling, which results in a model, depends on various indicators. Specifically, determining the model and the required degree of abstraction is one of them. If, for example, we take into account only a line for simulation, where only means of production and conveyors are installed, then a simple simulation is sufficient that neglects the dimensions of these devices. However, let's take into account workers who perform free movement and must avoid objects whose position changes over time. It is necessary to create a model that also takes this state into account in the simulation. Tecnomatix Plant Simulation is a dynamic simulation software that allows you to model at different levels of abstraction and reduction. In general, it allows display in both 2D-only and 3D-only, the usage of which is currently dependent on the required model properties. At its core, the article describes 2D only or 3D only modes for

Tecnomatix Plant Simulation, their comparison and application with obtained achievements.

2 Tecnomatix Plant Simulation

It is a simulation tool from Siemens that allows simulation and optimisation of production and logistics systems and their processes. Through Tecnomatix Plant Simulation (TPS), it is possible to optimise material flow, resource utilisation and logistics at all levels of planning in the company. Tx Plant simulation as a discrete event-controlled program takes points in time (events) into consideration that are of importance to the further course of the simulation. Such events may, for example, be a part entering a station or leaving it or moving on to another machine [7]. Hierarchical modelling allows us to optimise processes, flows and resources for selected parts of the system (individual devices) or the system as a whole (enterprise). The digital models make it possible to conduct experiments and incorporate the various required changes according to the question "What would happen if?". This tool allows increasing productivity, optimising the number of workers and their activities, verification of the new layout, removal of bottlenecks areas, optimisation of logistics, reducing the work in progress of production. By carrying out testing in the digital model without interference with the real system, the pressure resulting from the possible threat to the running of the production process is being exerted.

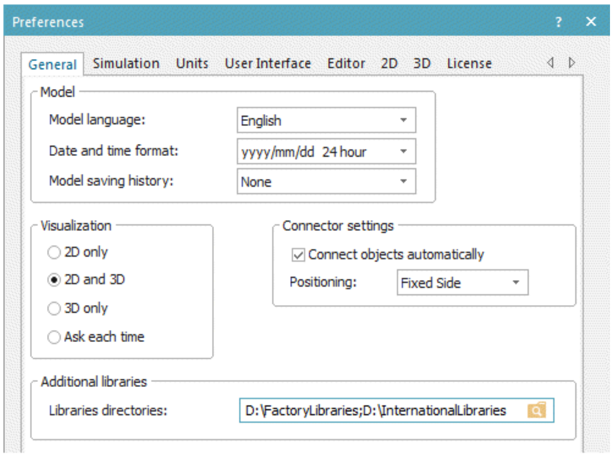
In general, these benefits can be obtained from employing simulation [8]:

- Enhance the productivity of existing production facilities.
- Reduce investment in planning new production facilities.
- Cut inventory and throughput time.
- Optimise system dimensions, including buffer sizes.
- Reduce investment risks by early proof of concept.
- Maximise use of manufacturing resources.
- Improve line design and schedule.

The simulation outputs will provide information on making quick and reliable decisions during the production and early stages of process planning. The program can be imported from other programs, such as MS Office formats (Layout in .pdf format or databases in xlsx format).

2.1 *Description of display modes*

Platform Tecnomatix Plant Simulation enables three types of display 2D-only, 3D-only, and combination (2D and 3D) views. Each of the views has its dominant application, which is defined by the degree of abstraction required. However, the post will only deal with the 2D-only or 3D-only display. The select and switch between views window are on (Figure 1).



(a)

(b)

Figure 1 Switch between modes
(a) using Preferences; (b) using Open 2D/3D

2.2 *2D environment*

Modelling in 2D introduces the most important tasks of the modeller's face when creating a simulation model. The display is designed for models with a higher degree of abstraction and reduction, especially where the object's size for the entity may be neglected. When working in 2D, you can navigate to 3D with those objects after inserting objects, but after changing the view, we find that the dimensions are the same for each object in that class. Precisely because of the recurrent activities of workers, it is necessary to create a so-called footpath in order to keep the distance of the worker's walking in the performance of activities.

2.3 *3D environment*

The view in 3D introduces the possibility to visualise the material flow and see differences between simulation objects, animable objects, graphic groups, state groups, state graphics, and graphics of the selected object. This type of display is suitable if we need to model objects with medium abstraction and reduction of elements. This means that the object behaves as one in the basic frame, even if it has a multi-part graphical structure, but the overall dimensions of the object are preserved. Based on [8], the dialogue Show 3D Graphic Structure shows the graphics in a tree structure that visualises the 3D simulation object but not the content of this simulation object. In this mode, when defining the free movement of workers, the worker bypasses the obstacles and behaves like when moving in a physical layout. In this mode, you can also create an animation of objects using Graphic groups. Graphic groups define a possible visual representation of an animate object and have a unique name for this object. This is similar to the 2D icons of the simulation objects. A graphic group can be permanently shown or hidden to enable switching between alternative graphic groups. Each simulation object or animate object contains at least one external graphic group named default and optionally any number of alternative or additional graphic groups, which you can show or hide independent of each other. The visibility of the graphic groups is a 3D object property that can be inherited and the entire graphic structure. This type of display and modelling is especially suitable for visually satisfactory model display, especially when presenting to investors or senior management, where we want to subdue our simulation-obtained results. If necessary, the model with minimal abstraction and number of reductions uses different software, namely Tecnomatix Process Simulate.

2.4 Comparison of 2D-only and 3D-only views

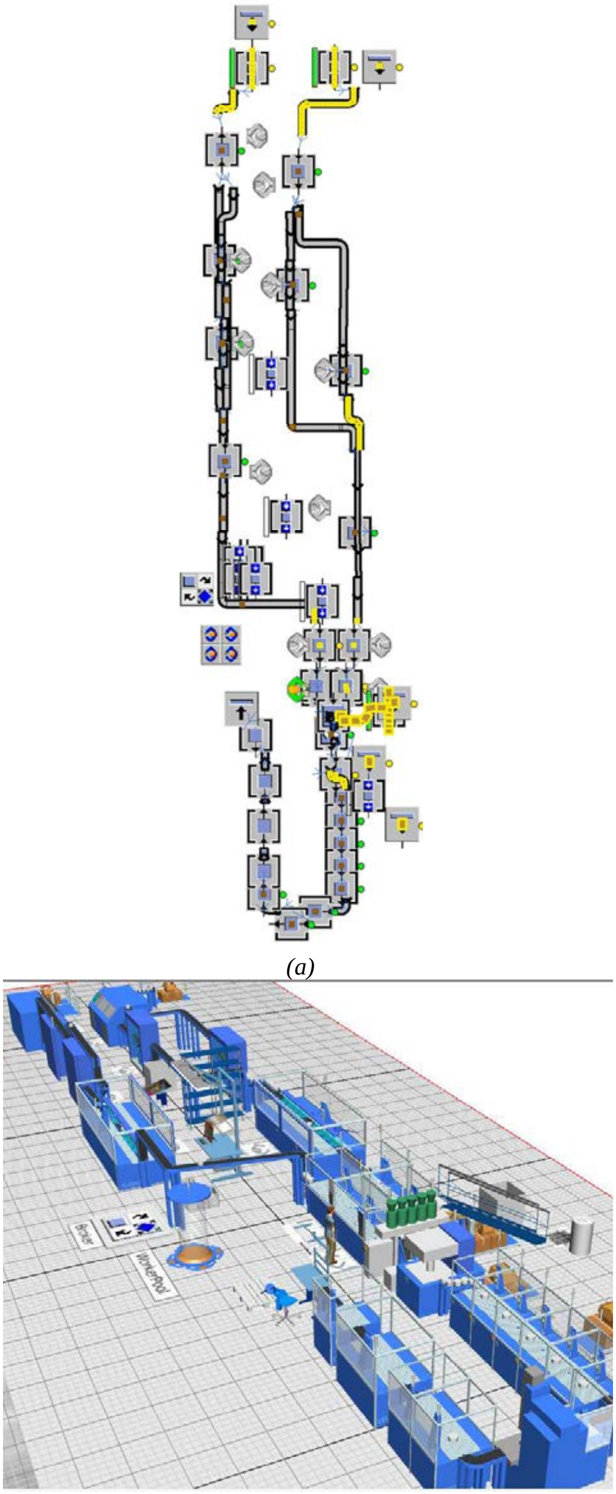
Whether 2D-only or 3D-only in Tecnomatix Plant Simulation, each view has its specific features and functions. Individual functions, especially in 3D mode, allow modifying the size of an object, which in 2D, for example, is only possible directly in the object's parameters. The comparison of functions and modes is in (Table 1).

Table 1 Comparison of Tecnomatix Plant Simulation function and modes [8]

Function	3D Only	2D Only
Axes origin of the scene	objects can be inserted anywhere, the grid adjusts its size	upper left corner of the Frame window objects can only be inserted within the displayed grid, starting at the position 0.0
Standard Graphic of certain Information Flow Objects	small icon next to label	large icon next to label
Ribbon	Yes	Yes
File Menu	Yes	Yes
Ribbon > Start	Yes	Yes
Ribbon > Debugger	Yes	Yes
Ribbon > 3D > Edit	Yes	No
Ribbon > 3D > View	Yes	No
Ribbon > 3D > Video	Yes	No
Ribbon > Frame > General	No	Yes
Ribbon > Frame > Icons	No	Yes
Ribbon > Frame > Vector Graphics	No	Yes
Ribbon > Method > Edit	Yes	Yes
Ribbon > Method > Tools	Yes	Yes
Ribbon > DataTable > List	Yes	Yes
Context Menu of the Class Library	3D-related commands only general and 3D-related commands	no 3D-related commands general and 2D-related commands
Dialog Window of the Objects > Menus	3D-related commands only general and 3D-related commands	no 3D-related commands general and 2D-related commands
Ribbon > Icon Editor > Edit	No	Yes
Ribbon > Icon Editor > Animation	No	Yes
Ribbon > Icon Editor > General	No	Yes
Dialog of Length-oriented Objects > Tab Curve	No	Yes
Display Panel	No	Yes

3 Results

A simple simulation model has been created to verify the accuracy of previous claims, consisting of several objects of different sizes in real conditions. The first model is created in 2D graphics and neglects the dimensions of objects, while the worker can move freely. The second model is created in 3D graphics and takes into account the dimensions of objects. (Figure 2) depicts 2D-only a 3D-only models.



(a)

(b)

Figure 2 Display in (a) 2D-only; (b) 3D-only

The results of simulation runs are contained in (Table 2), where 100 simulation runs were conducted for each model for a period of one shift, i.e. 7.5 hours.

Table 2 Comparison of the 2D-only and 3D-only simulation model

View	Distance travelled (m)
2D-only	73225.33
3D-only	73708.61

The results show that 3D displays also consider objects' size more suitable for the worker's free movement in space without a defined footpath. The results obtained in this way are more accurate and reflect the actual situation. The difference in views is 0.66%.

4 Conclusion

Speed in verifying different solutions is most important if the processes are characterised by uncertainty about the final result. By applying simulation, we can get a really accurate picture of the outcome of these uncertain processes, and we can simulate the behaviour itself. The simulation application also solves the problems of estimating the results of large investment projects, which equally positively affects the costs that would arise in the future due to bad decisions. The costs and time requirements for implementing the simulation project themselves depend on the degree of abstraction and reduction of the model elements. The article describes an experiment conducted in Tecnomatix Plant Simulation software that was tasked with detecting results that can be achieved when using individual mods of the display, namely 2D-only and 3D-only, and the impact of the abstraction of elements on accuracy. The core of the article was to describe the views in software and compare these two views, assessing the accuracy that we can achieve with individual views on a model example. In this particular case was, the difference between example models 0.66%.

Acknowledgements

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SIMULATION, DIGITAL TECHNOLOGIES AND THEIR IMPACT ON WORKERS

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Keywords: digitization, computer simulation, industrial engineering, workers
Abstract: This article provides information about the impact of the development of simulation possibilities, digitization and technologies on workers. This article aims to present possible problems for workers with the adoption of new technologies. They must increase their knowledge and skills about information technologies to understand the functioning of the software and their modules because by the time they must control and set them. This article can also give readers answers to how solution phases of simulation projects can be changed and how computer simulation can help solve problems with unstable situations of many workers in the workplace. We also present recommended phases of the simulation project that will help create scenarios, which will help reduce the impact in a risk situation.

1 Introduction - Computer simulation

Computer simulation is one of the most effective tools to support training, education and decision-making at all company levels. An essential task of computer simulation and digitization of processes and documents, in general, is not only to improve clarify selected production and logistics processes, but also to improve working conditions of employees or readiness of workers to perform their work in the operation, so that they do it correctly, safely and without high physical load. Workers are the most important part of any industrial society.

Modern technologies and the development of software solutions enable a combination of software solution tools and technologies to simulate the movement of workers in the plant. In combination with wearable sensors, such solutions allow the system to first simulate and evaluate how workers in a given production, logistics, the warehouse can work and then determine the optimal location of production equipment and machinery to maintain optimal employee working conditions.

For example, the Tecnomatix Plant Simulation software solution, which is used at the Department of Industrial Engineering, allows us to simulate the work of workers performing various tasks in production and logistics, such as moving material, performing production operations, repairing machines, setting up machines, etc.

When simulating workers' work, it is possible to use several objects and settings so that workers in the simulation move or perform activities as in reality. Therefore, it is important to ensure that the new workplace will prevent unnecessary resource waste and create a safe working environment for employees [1-6].

Advantages of using simulation to simulate the work of workers, e.g.:

- Creating a complex and real environment in a 2D / 3D environment.
- Possibility to simulate the real way and direction of a worker walking around the workplace.
- The creation of a computer simulation does not interrupt the worker's work in a real environment, so it is safe and does not burden the minds of workers.
- The dynamics of the computer simulation environment will show the possibilities of work performance walking directions and choose the most advantageous routes or ways of performing work, e.g. maintenance activities.
- Simulations and experiments focused on workplace innovations - development of new trends and change of workplaces, verification of new procedures, etc.

Disadvantages of using computer simulation:

- Financial demands - high costs of purchasing computers, hardware and software.

- Time-consuming - creating a complex 3D simulation model or 3D scans may take several months if 3D models are not available.
- Data collection - is necessary to obtain additional data necessary for the proper operation simulation model, e.g. width aisle length, aisle directions, walking speed employee, priorities at work, etc.
- Staff training - the evaluation of the results of simulation runs can be affected workers work, and wrong decisions can ultimately cause workers' health or psychological problems.

2 Workers and digitization in the future

Various types of production and robotic systems are already characterized by the ability and properties to process any type of components parts with predetermined production procedures and customer requirements. However, a necessary feature of modern production systems is flexibility and thus the ability to adapt to unexpected changes in plans or production operations. The new generation of production systems is therefore primarily about intelligent and flexible production systems affecting the work of workers. Concerns and potential problems that already affect the work of workers include, for example:

- Lack of understanding of the behaviour of these digital technologies.
- Insufficient dissemination of accurate and quality information between company levels.
- Insufficient knowledge of staff in statistics, mathematics and incomplete evaluation of business models.
- Rapid development of technologies and their effort to adapt causes companies low return on investment.
- Not enough awareness of the current state of machinery, equipment, technological equipment, etc.
- Lack of tools for application development and software solutions, costly purchase of licenses and software.
- Attitudes of employees - Careful holding employees for several years common practices that refuse to change, etc.

As mentioned in the introduction to this article, it is necessary to start preparing workers for the gradual emergence of new digital opportunities that are offered to businesses. Intelligent manufacturing and smart products, their development already includes a wide range of various other options, including, for example, sensor integration, integration of a new generation of artificial intelligence technologies, advanced manufacturing technologies (e.g. hybrid production systems), lean manufacturing, digital manufacturing, agile production, networked manufacturing, cloud manufacturing, intelligent manufacturing, and more. However, the too rapid advancement of selected technologies causes companies to face many problems in practice in promoting intelligent technologies into production, but also among workers, specifically by developing their technical skills and emotional intelligence.

An example of supporting the development of workers' technical skills is Amazon [1], which is committed to helping at least 29 million people around the world improve their skills through free Cloud Computing training to keep up with technological and software advances and, above all, not be afraid of these technologies, disillusionment, alarm messages, etc.

In order to further develop the technical skills of employees, it is necessary to find out the real state of their experience, and it may not be at the level they present. The skills that employees will need to acquire in the future include, for example [7-9]:

- Creation of protocols for new versions of software/hardware.
- Creation of new digital content usable in the factory (for example, 3D models of manufacturing, tools for using augmented reality and so on).
- The creation of a computer simulation does not interrupt the work of the worker in a real environment, so, it is safe and does not burden the minds of workers.
- Developing digital security, cyber forensic tools (such as Network Miner, Encrypted Disk Detector, Autopsy, etc.) and other techniques.
- Development of digital communication in factories (for example, by using Mobile Employee Communication Apps).
- Use advanced problem-solving computational techniques (for example, software for a risk impact assessment on operations).
- Integration of various digital tools to improve customer choice of products over the Internet (e.g. in the form of Face-Scanning).
- Integration of digital tools into products and handling units, e.g. sensors on pallets, etc.
- Developing knowledge of data mining (e.g. in the form of predictive algorithms) etc.

Based on the statistical report from the 2020 year, issued in the year 2021, by the MHI Annual Industry Report, we can say how technologies probably industry will change over the years [7]. These reports are divided into four timeline parts, and the first one is in use today; the second part is dated from 1 to 2 years, the third part is dated from 3 to 5 years, and the last part is dated from 6 years and more.

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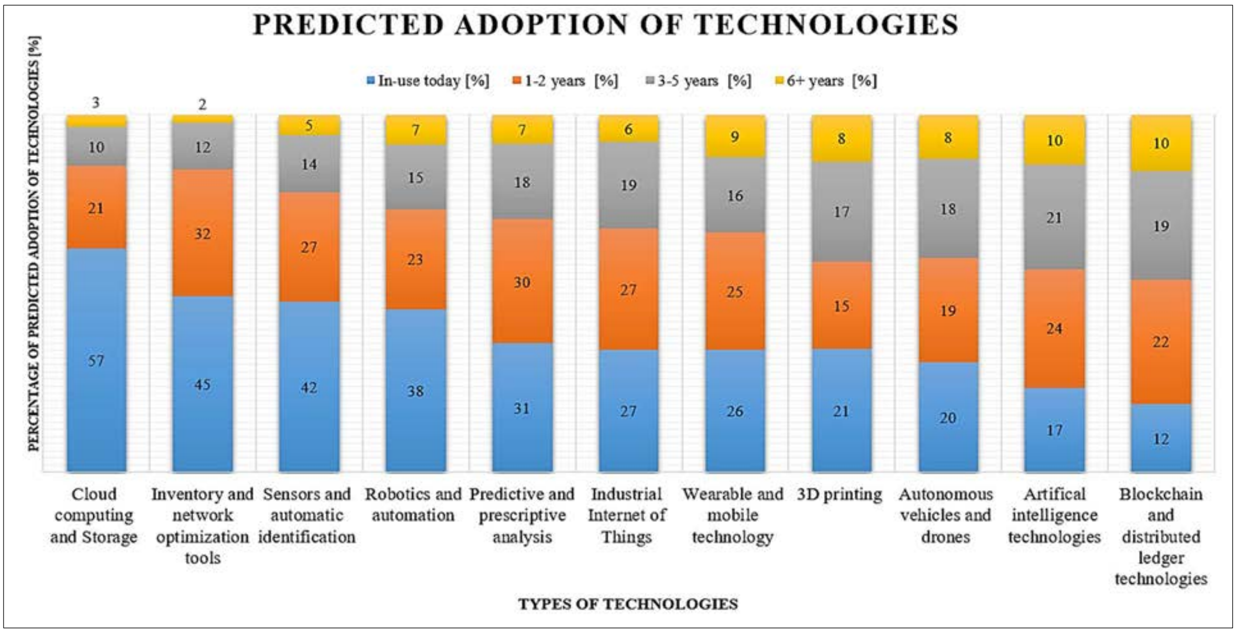

Figure 1 Graph of investment in products and services

In Figure 1, it is possible to see a result graph of the responses of 1000 supply chain and manufacturing leaders to find out which technologies they want to focus on after the pandemic. Also we can assume how they want to transform and improve their processes by adopting of new digital technologies. Based on the results of a survey conducted by the MHI organization over the next three years, the companies will focus on automation technologies, robotics, warehouse equipment and mobile devices, development of ergonomics and software solutions, sensors and information technologies, also for wearable technologies.

2.1 Operator 4.0 in the context of digital technologies

The central theme of today is the implementation of innovative and disruptive technologies supporting digital humanism. It is essential to realize that people and their potential are at the heart of progress in an age of growing digital businesses and digital workplaces. The industry's overall development is aimed at further simplification and streamlining of human activities, relieving people of manual work, their collaboration with machines, robots, etc. With the introduction of the Industry 4.0 concept, some types of work activities are transformed or eliminated. As work activities change, so do the skills and knowledge requirements of employees. The work environment and all factory processes will operate based on a Smart factory using a Digital Twin factory (digital, virtual and real enterprise), collaborative robotics, management and decision-making systems based on real-time monitoring and gathering information throughout the factory system.

Even in today's advanced period, peoples remains an essential element in every production or non-production process. People are irreplaceable in their flexibility and ability to handle a wide range of diverse tasks quickly. With the growing demands on the quality of production and constantly increasing production, the demands on employees' physical and mental strain also increase. With the advent of Industry 4.0, the requirements for the knowledge of employees and their work preconditions are gradually changing. Some types of work activities will be transformed or eliminated soon. This change towards the digitization of the factory and the high share of automated activities (Figure 2) is also changing the nature of the procedures used. Operator 4.0 concept is generally focused on building relationships based on trust and human-machine interactions. This interaction will allow smart system-based businesses to leverage the power and capabilities of smart machines and strengthen their operators with new skills and technological support to take full advantage of the production capabilities of the Industry 4.0 concept.

Figure 2 Innovative technologies in the factory [3]

Operator 4.0 concept is also defined by expanding its skills with the help of innovative technologies in production systems. These technologies already used by several factories today include augmented reality, virtual reality, collaborative robotics, wearable sensors, tablets and cloud solutions, and exoskeletons.

Practical training and coaching of employees with the support of new technologies offered by the Industry 4.0 concept will serve not only to increase the qualifications of workers, which is a necessary condition for keeping pace with the development of world production. They will primarily serve to effectively prevent the development of occupational diseases and accidents. An example of technology that is already used successfully in the field of staff training is virtual reality.

3 Simulation project

As described above, it can be seen that the development of knowledge will be a key point for the further growth of workers' knowledge development. Methods of computer simulation allow estimating the expected throughput and usability of the system and all elements included in the system [2]. Such a development can also affect the way the simulation project is created and its phases.

Figure 3 shows the phases of the simulation project, which already incorporates the possibility of preparing a solution team and ways to evaluate the results of simulation of workers' work.

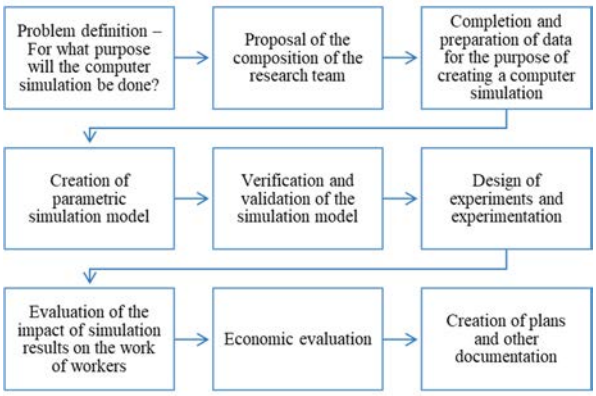

Figure 3 Proposed phases of the simulation project (Author: Monika Bučková)

Description of the above phases:

- **Phase 1: Defining the problem, setting the goal -** In this phase, it is necessary to determine the problem that needs to be solved with the help of simulations. For example, the use of the worker is not sufficient, shortening the paths when picking goods, improving the method of picking goods, improving maintenance processes, improving assembly processes, and then also warehousing and logistics processes, etc.
- **Phase 2: Proposal of the composition of the solution team and its preparation** – During the solution of such a simulation project, it is appropriate if employees from different company levels are involved in its solution, not only the manager and the creator of the simulation. The presence of these workers is important if the problem is to be addressed in-depth, as they bring knowledge, experience, ideas, and suggestions for improvement or just have information on how workers behave in the workplace. In this step, you can also use training using virtual reality.
- **Phase 3: Data collection -** This phase can be performed even before creating the parametric simulation model because it is necessary to obtain information about employees and the workplace, which can then be time-consuming to collect and evaluate. Between the data can be include, e.g. proposal of the number of workers at the workplace, work shifts, break times, working hours, routes of movement of workers, waiting for the operator to order, speed of their movement, performance, etc. For the needs of simulation of the selected process, it is necessary to add detailed information about the selected process (e.g. workplace location, dimensions, taking into account ergonomics, production process, assembly plans, etc.), handling equipment (e.g. a number of handling equipment, speed, charging method, method of storing semi-finished products, etc.), or method of planning (e.g. use of ERP or SAP software), etc.
- **Phase 4: Creation of a parametric simulation model -** By parameterizing a simulation model, it is possible, e.g. change data values from a clear dialogue box or enter data into a table created by simulation software or users.

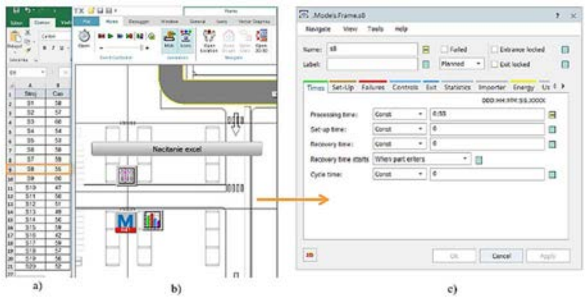

Figure 4 Connection of Ms Excel and Tecnomatix Plant Simulation software (Author: Monika Bučková)

The example of a model shown in Figure 4 a) is parametrically set to retrieve data from tables created in MS Excel. In Figure 4 b) it is possible to see also a macro called "Načítavanie excel (Loading excel)" by pressing the macro will start the data loading command from the table from MS Excel, after which the data from the table will be overwritten, in the setting table of machines – Figure 4 c).

- **Phase 5: Simulation model verification and validation -** During the verification process, it is possible to verify that the computer model is in line with the objectives for which it was created and that its results are sufficient to make decisions about assessing the impact of risk on business processes. The validation step helps to compare the actual data with the model's outputs if the company has such data [5].

- **Phase 6: Proposal of experiments and experimentation -** If the risks from the previous phases of the methodology are known, and what consequences they can have on the processes, it will speed up and streamline the process of creating and modifying the simulation model. It is thus possible to design experiments of the type, e.g. how the different number of workers in the workplace will affect the performance of the production system, how many workers are needed to service the warehouse, how will the assembly process be affected by an unexpected order with high priority, etc.
- **Phase 7: Evaluating the impact of simulation results on employee work -** As mentioned, computer simulation results can influence managers' decisions. By modifying workplaces or shortening routes for picking goods, etc., it is possible to improve the working conditions of employees and reduce their fatigue and exhaustion. Computer simulations and experiments can help managers see how the system behaves when the number of employees is lower, how many products they are able to produce, how maintenance is performed, technical service with different numbers of employees with other priorities, and so on.
- **Phase 8: Economic evaluation -** The final report from the simulation must contain a detailed description of the created simulation model together with all its elements and settings, evaluation of input data collection, results of simulation runs, etc.

4 Conclusions

It is necessary to use software that can analyze several potential solutions and select them with the best output parameters. The application of different types of innovations and Industry 4.0 implementation supports evolution systems in which interaction and integration achieve business independence elements [4]. For example, they help create and accelerate the development of information technologies (Internet of Things, Cloud Computing, e-learning systems, etc.).

Companies and organizations such as MHI monitor events and developments in companies by making reports; they also monitor what technologies companies will be interested in and which way they will move into the future. That is why it is necessary to increase the knowledge level of employees and improve working conditions at workplaces.

Using digital factory tools such as computer simulation helps reveal the risks such as rapidly spreading diseases, dangerous working conditions, high physical burden on workers, etc. It is impossible to solve them by computer simulation. Still, it is possible to experiment with data with different situations and then choose and consider variants of how to respond to these situations with the help of statistical results. All types of processes and products will be modified and developed in the future, and these activities should be aided by new information technologies to achieve a competitive advantage [8]. Of course, not every worker will work, e.g., computer simulation, because it is financially demanding. But it is appropriate for employees to increase their knowledge in basic software solutions and information technologies.

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