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The use of programmes for the digitization of production clusters

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Keywords: digitization, production cluster, software products.
Abstract: This article deals with a hot topic for successful entrepreneurs - digitalization and its use in industrial enterprises. The article includes a comparison of digitization and visualization software for manufacturing clusters. The comparison takes into account factors such as student license, user level as well as the hardware required. The last part of the paper includes the creation of a model of the production floor using the selected software. This is a production hall which is part of the Technical University of Košice.

1 Introduction

Every entrepreneur wants to constantly improve, to improve his position on the market. One form of improvement is to improve the technologies used or to focus on changes in the field of visualization.

Digitalization means a huge step forward, a technological shift of the company. It is of great importance for the entrepreneur [1]. It helps him to discover the shortcomings in his business, save time, costs and make his enterprise more efficient. Due to digitalization, an entrepreneur can easily use various advanced software applications in the field of marketing, online sales. It also helps in communication, i.e. an entrepreneur can improve his communication with customers as well as the internal one, between the employees.

Other benefits of digitalization can include increased productivity of production - to produce more, cheaper and of course easier [2].

The reason for this is the fast, efficient and flexible collection and creation of information between individual machines.

2 Software for creating models of production clusters

Among the software products for digitalisation, SketchUp, Tarakos and Factory design were compared.

2.1 Factory design utilities

Autodesk Factory Design Suite (Figure 1) is a software, used to create technical models in 2D and 3D form. Using the software is mainly used to design production halls, workshops and production lines. The core products of the software package include AutoCAD Architecture, Autodesk Navisworks, and Autodesk Inventor, which is enhanced with Autodesk Factory Design Utility. It provides users with better parametric options that are specific to individual manufacturing and factory environments. The package also includes a digital library of manufacturing and peripheral of equipment that allows you to select the necessary equipment to the production layout.

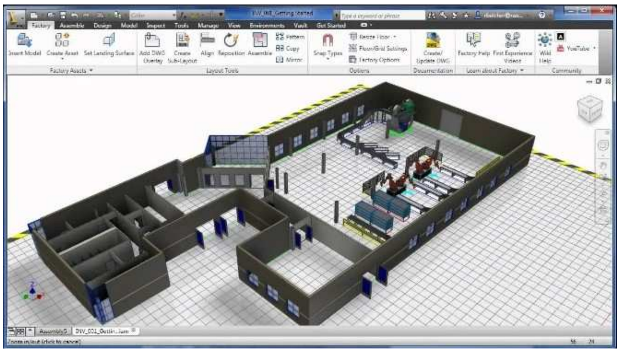

Figure 1 Software Factory design utilities

2.2 SketchUp

SketchUp is a 3D modelling program models (Figure 2). It allows users to work online in browser or by installing on computer. It is licensed by the American company Trimble Navigation [3]. The use of this software brings a huge number of possibilities not only for professionals as well as beginners in various fields - construction, architecture, engineering and other completely free of charge or after payment of a fee is the portfolio of tools offered to the user is extended.

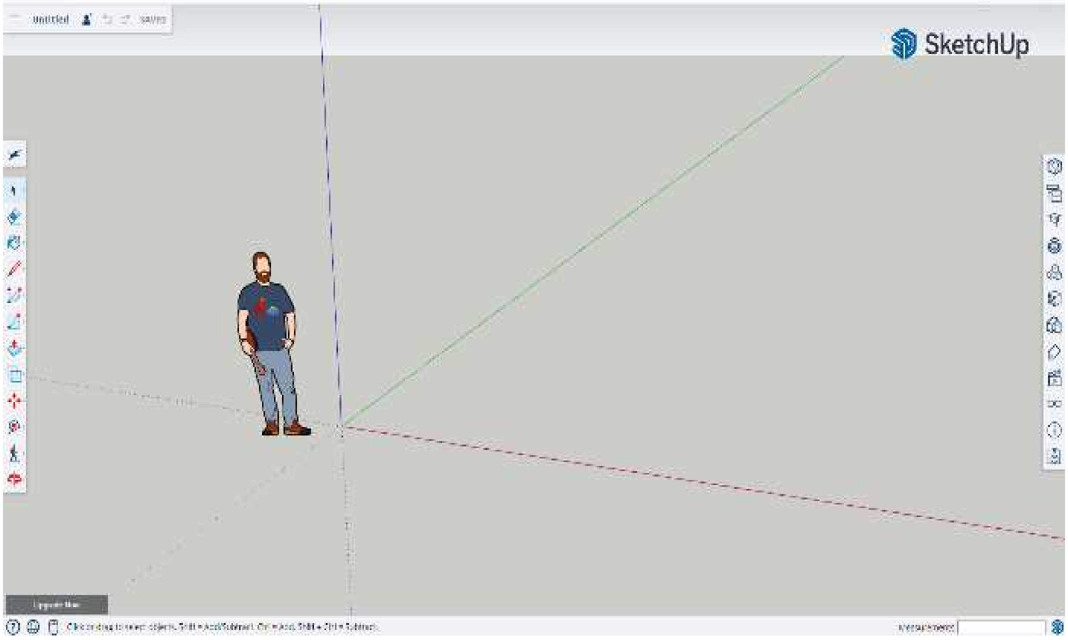

Figure 2 Software SketchUp

2.3 Tarakos

This program was designed by the tarakos team GmbH, which focuses on technical and dynamic 3D imaging (Figure 3). This group develops 3D software tools for planning, animation and simulation of logistics, material flows and production systems. Their programs are used especially for the digitization of factories. Software tools tarakos are characterized by their extensive libraries industry-specific libraries with simple and intuitive operation.

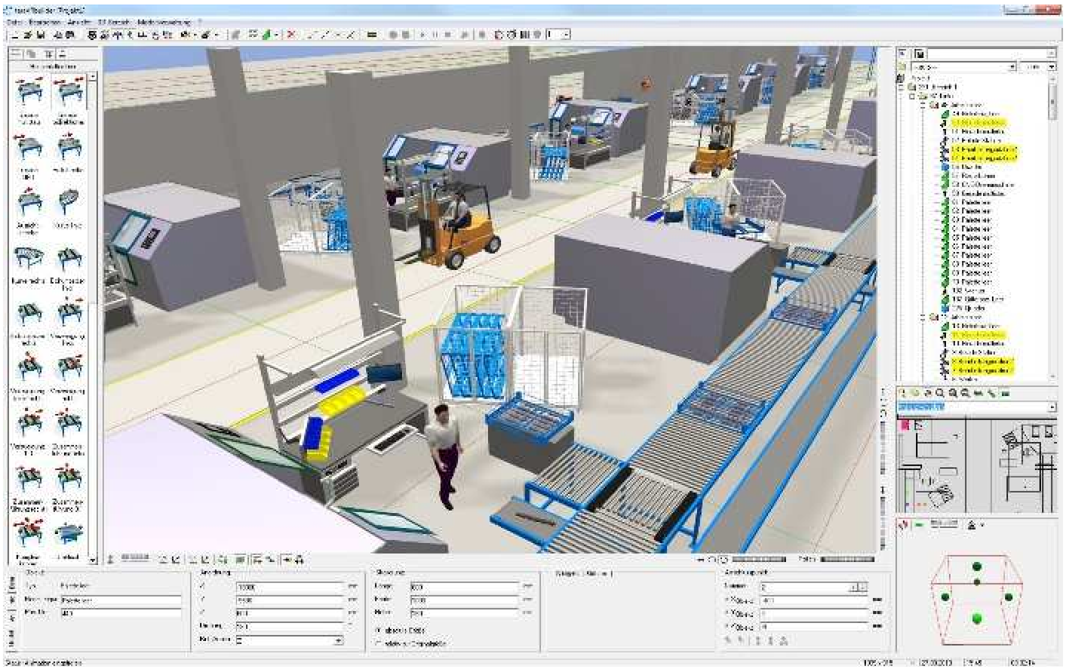

Figure 3 Software Tarakos

3 Software programs for production hall visualization

In this section, Twinmotion and Lumion software were compared.

3.1 Lumion

Working in Lumion 3D (Figure 4) requires no training and after 15 minutes you can learn how to create images, videos of 360 panoramas (including VR) in high resolution that are ideal for client presentations [4]. From adding thousands of trees and textured buildings to rendering high-resolution images in poster format. Lumion is compatible with any 3D CAD program. The idea behind Lumion is extended compatibility, ensuring that simple and fast architectural visualization is available to every architect and designer, planner regardless of 3D or CAD modelling software.

Figure 4 Software Lumion

3.2 Twinmotion

Twinmotion is 3D software (Figure 5) that can be used to create high-quality images, panoramas and standard or even 360° VR videos [5]. This software was primarily designed for professionals in the field of architecture, construction, urban planning and landscape design, yet it is very easy to learn and use, regardless of the size and complexity of the project, material, computer skills of the user. The transition from BIM model to VR experience in just three clicks is achieved by the user thanks to the direct synchronization with Archicad. The user interface is really simple, with the main model cantered in the middle of the screen. Movement in the environment is done using the mouse also the arrow keys on the keyboard. Instructions are given at the top of the screen. Tools and program functions are listed on the sides of the screen. On the left side and at the bottom there are basic tools whether add-ons, equipment or advanced options such as lighting, weather changes or determining the exact location of an object. On the right side we can find a list of embedded device objects.

Figure 5 Software Twinmotion

Table 1 lists the main advantages and disadvantages of the three programmes for digitising production systems. The programs introduced in Chapter 3 were compared, namely: SketchUp, Tarakos and Factory design unilities.

Table 1 Comparison of digitization software

Software	User level	Student license	+	-
Factory design utilities	Advanced user	YES	Wide output format options	High demand for hardware
Tarakos	Advanced user	NO	Windows and iOS compatibility	more demanding user level
SketchUp	beginner	Free basic version	User level	Fewer output format options

Considering the user level, the student license and the planned interfacing with visualization software, SketchUp is the most suitable alternative.

Table 2 Comparison of visualization software

Software	User level	Student license	+	-
Twinmotion	Advanced user	YES	Wide output format options	High demand for hardware
Lumion	Advanced user	NO	Windows and iOS compatibility	more demanding user level

Table 2 highlights the differences between Twinmotion and Lumion software. After taking into account the advantages and disadvantages, Twinmotion was used for the visualization itself.

4 Visualization of the production hall of the Technical University of Kosice

The first step before creating a digital model of the production hall, which is part of the Technical University of Košice, was a tour of the premises, which consisted of documentation of the relevant machinery and equipment, their layout and finding out the actual dimensions. A basic model was created in SketchUp (Figure 6), in which the hall space was created and the production machinery and equipment added [6].

Figure 6 Creation of the hall space in SketchUp

This program also allowed for the modification of the exterior wall (Figure 7).

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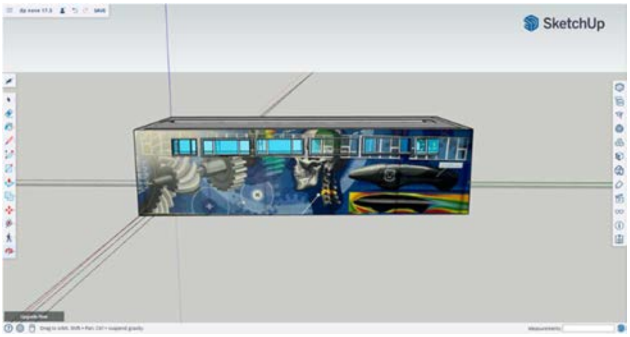

Figure 7 Adjustment of the external wall

Figure 8 Production hall in Twinmotion

Subsequently, the created model was transferred to the Twinmotion environment, which allowed several further modifications and additions (Figure 8).

The above additions and modifications in Twinmotion are shown in Figure 9.

Figure 9 complete environment of the production hall

5 Conclusions

The experience, knowledge and financial resources of the entrepreneur play a big role in deciding on a software product. However, the choice also depends on the business itself. Some programs are better suited for businesses in the architectural field, others for industrial production. In this paper, SketchUp and Twinmotion software were used to digitise a model of a production hall, as they were the most suitable of the software compared for digitising manufacturing clusters. SketchUp includes tools to create the manufacturing floor space as well as a library with a menu of different machines and equipment. Twinmotion gives a more realistic look to the model, adding workers, animations, sound effects of individual machines and equipment. Another great advantage of Twinmotion is its connection with virtual reality, which gives a better view of the created model.

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Simulation of the process of emptying the storage tank into road transport vehicles

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Keywords: storage tank, bulk material, modelling, simulation.
Abstract: Handling bulk material is specific and has different needs than handling piece goods. Bulk material requires a space that is adapted to both filling and emptying of such type of material. It is necessary to dimension the storage tanks in order to ensure an efficient production process. Emptying the storage tank also depends on the transportation of the bulk material to the production process. Road transport trucks must be adapted to transport bulk material, and the vehicle's capacity is the most important for emptying. In addition, it is necessary to monitor the performance of the filling equipment and the emptying technology. In terms of labour input, this process can be effectively monitored with the help of simulation. The simulation model, created in the ExtendSim 10 program, graphically displays various options for setting the emptying process parameters.

1 Introduction

In mining and metallurgy, the occurrence of storage tanks in the main processes is an integral part of the logistics flow. The storage tanks create harmony between the individual activities of the logistics flow, for example, the supply and removal of material and technological processes of other types. The storage tanks protect the bulk material from the weather and ensure its efficient transfer to the means of transport. It is customary and given by the technical conditions to carry out supply through the upper opening of the storage tanks and emptying through the lower openings [1].

Several viewpoints on the division of storage tanks are presented in the literature. However, the fundamental division is into two groups. These are low bunkers or high silos. As a rule, bunkers have a smaller capacity and are mainly used for the seasonal storage of all bulk materials. The horizontal placement of bunkers can be above ground or underground. Large-capacity silos are used for long-term storage. However, they are limited to small fractions of bulk material, close to fine grains [2].

Designing a storage tank is a process whose output should be the storage tank's capacity. The capacity depends on the process of filling and emptying the storage tank. These activities are affected by the following parameters [3]:

- The hourly performance of the filling equipment determines the method and speed of supply.
- The character of emptying, continuous or interval.
- Truck capacity.

Regarding labour input, the design process can be effectively monitored using simulation. The simulation model, created in the ExtendSim 10 program, provides fast creation of material supply and removal graphs. Graphical outputs allow us to assess the sustainability of the production process's efficiency and reveal insufficient parameters that should be adjusted. The article aims to show the possibilities of using simulation to reveal the unsustainable process of emptying the storage tank if trucks are used for subsequent manipulation. If such a process is detected, it is crucial to propose measures that could help eliminate the undesirable state and, at the same time, verify them by simulation.

2 Methodology

2.1 Designing the capacity of the storage tank

During the design of the storage tank, two ways of determining its capacity may occur. If we already have a storage tank ready for storage, we calculate its volume mathematically by substituting the dimensions into the formula. In other situations, however, we do not have to have the storage tank available yet, but we know the rules and regularities of the process for which the storage tank must be designed. In this case, it is necessary to determine the storage tank's volume precisely so we do not inadvertently create a bottleneck in the process. During the design, we have to combine mathematical calculations and create graphs of the change in the amount of raw material during the use of the storage tank. By combining these two activities, the dimensions of the storage tank can be determined and, depending on them, its volume [4].

The authors of this publication discuss the storage tank design methodology in detail and propose the following algorithm as a suitable method [5]:

1. Defining the input data for the calculation,
2. Design of the shape and dimensions of the storage tank outlet,
3. Calculation of the permeability of the opening - the hourly performance of the outlet opening,
4. Calculation of the storage tank emptying time,
5. Calculation of the time of filling the storage tank with the amount of material for one means of transport,
6. Calculation of the minimum amount of material in the storage tank before loading,
7. Construction of a graph of the supply and removal of material from and to the storage tank,
8. Determining the maximum amount of material in the storage tank,
9. Calculation of the volume of the storage tank,
10. Determination of storage tank dimensions.

However, in this article, we will not manually mark the storage tank emptying, as it is assumed in point 7 of the algorithm. We will replace the long and unnecessarily laborious activity with an automatic graph drawing in the simulation software. Inputs and other calculations represent the necessary actions to set the simulation model parameters correctly.

2.2 Creation of graphic results

In logistics and other sciences, we can call simulation a method in which we transform the chosen process into a model corresponding to reality and perform experiments on it. We can describe the results of experiments as a set of statistical data based on which we can appropriately choose measures to influence the process [6]. A simulation is a suitable tool for evaluating the efficiency of the production process, determining the need for raw materials, planning, rationalising activities, and bottlenecks, or evaluating proposed measures [7].

Currently, many simulation programs are used, such as TECNOMATIX, SIMUL8, WITNESS, STEELA, ExtendSim or ARENA. These simulation programs can also be divided into purely discrete ones, e.g. TECNOMATIX, purely continuous, e.g. STEELA, or complex, e.g. ExtendSim [8].

ExtendSim is a block-oriented simulation program. The simulation models created in the program can be both continuous and discrete. The advantage of the program is the possibility of creating combined models. Program blocks are divided into Value, Item, Chart, Rate, Utilities, Report and Reliability libraries. The individual blocks of the libraries are made up of a single programming language. They require minimal user experience with programming, making it easier for creators to work with their models. Users can edit library blocks. Frequently, their graphic editing is mainly needed, with the aim of better understanding the model. The easiest way is then to create hierarchical ones from basic blocks, such blocks can combine several blocks or just one [9]. An overview of some essential blocks for the model created to solve this task is in Table 1.

2.3 Choice of the type of raw material transport

The storage tank is filled by a continuously working device and emptied periodically. The raw material is loaded into the means of transport from the storage tank. The entire process described so far is highly dependent on the transport and, thus, the type of transport chosen [3]. Transport in such cases can be carried out by a conveyor belt when it is necessary to adapt the simulation to continuous emptying. More discreetly focused simulations are created when using rail or road transport. The use of rail transport requires increased attention when filling wagons and assembling the train set.

This article will focus on road transport, specifically dump trucks. The 6x6 TATRA single-sided tipper, shown in Figure 1, was chosen as a model vehicle. Its payload can be 25,000 kg, reaching a speed of 60 km/h [10].

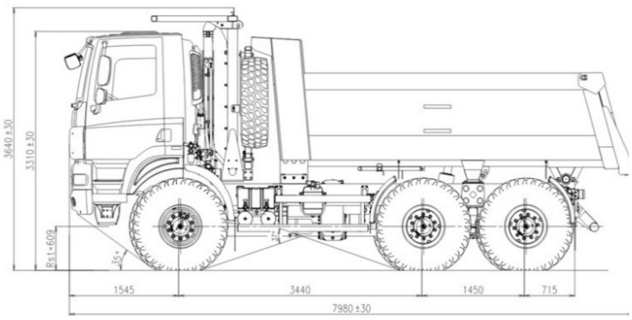

Figure 1 25t one-sided tipper, [10]

Table 1 Blocks of the ExtendSim simulation program, source author, amended [9]

Block	Function	Hierarchical block
Executive	It must be in the left corner. Controls the simulation time.	——
Create, Queue	They simulate the arrival of vehicles in the model.	
Get	Passes information from the vehicle to the stack.	——
Activity	Holds the vehicle for the necessary time.	——
Exit	Removes the vehicle from the simulation model.	——
Holding Tank	Holds and recalculates the value of the raw material.	
Constant	Generates a constant value.	
Line chart	Creates graphs during simulation.	——

3 Results and discussion

The first step in creating the simulation model was to perform calculations according to the model from the authors [5]. The following characteristics were entered or calculated based on the formulas:

1. hourly performance of the continuous filling device = 180 t.h-1,
2. vehicle capacity = 25 t,
3. performance of the discharge hole of the storage tank = 560 t.h-1,
4. storage tank emptying time = 2.7 min
5. vehicle handling time = 4 min,
6. time to fill the storage tank with the amount of material for one vehicle = 8.33 min,
7. a minimum amount of material in the storage tank before loading = 16.89 t.

A simulation model created using the previous parameters is shown in Figure 2.

The simulation model in Figure 2 is continuous-discrete. The arrival and departure of trucks are simulated discretely, and the flow of raw material in the form of values is continuous with recording at specific time points. The regular arrival of dump trucks models a hierarchical block with a truck icon. The get block reads its capacity and sends the request to the storage tank.

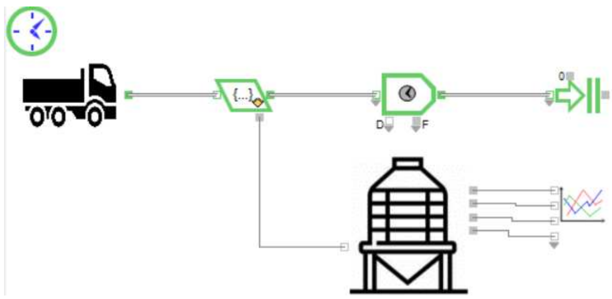

Figure 2 Simulation model of storage tank emptying

The activity block simulates the delay during the storage tank's loading, handling, and emptying. Within the hierarchical block with the silo icon, some blocks fill the storage tank regularly with the value generated in the constant block. Holding tank accumulation blocks accumulate values for plotting curves in the graph. The first experiment in Figure 3 was performed without changing the parameters calculated before the simulation. The duration of the simulation is one work shift, i.e. 450 minutes.

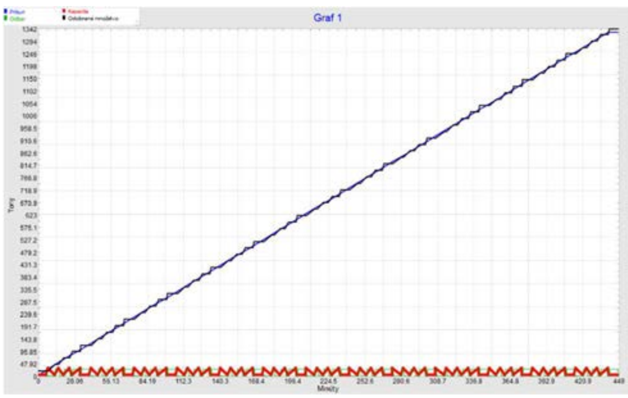

Figure 3 Results of experiment 1

The amount of raw material in the storage tank during the simulation is not enough to cover the needs of the following activities. During the simulation,

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67 vehicles were filled with a consumption of 1,341.89 t, which means that the vehicles were not fully loaded. The filling device added 1,325 t. The process set up in this way is not sustainable in the long term. The ideal situation would be if, at the end of the shift, there was again a minimum amount of material in the storage tank before loading.

We can approach this ideal state either by changing:

1. performance of the filling equipment - by increasing,
2. manipulation time – by increasing,
3. the capacity of means of transport - by reduction.

Figure 4 shows experiment 2, when the performance of the filling equipment is changed from 180 t/h to 230 t/h.

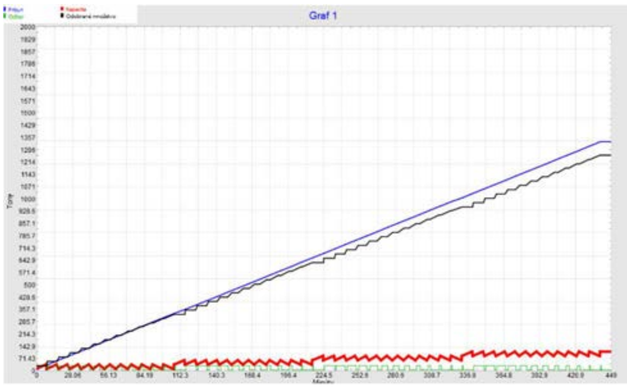

Figure 4 Results of experiment 2

For simulation, the value of the minimum amount of material in the storage tank before loading was recalculated to 22 t for the specified values. However, more than this change is needed, so the arrival of cars was extended from every 6.7 minutes to 9 minutes. The graph shows that the storage tank capacity will slightly increase to 100 t (red curve), and the raw material supply (blue curve) will exceed the withdrawal (black curve).

Figure 5 shows experiment 3 when changing the vehicle to a vehicle with a capacity of 15 t while maintaining the original conditions. For simulation, the value of the time to fill the storage tank with the amount of material for one means of transport was recalculated for 5 minutes. With such a change, the capacity reaches a value of up to 330t at the end of the simulation. It follows that there is no need to reduce the vehicle's capacity by up to 10 t.

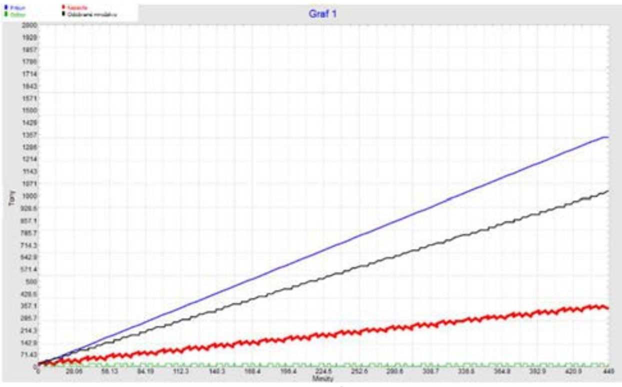

Figure 5 Results of experiment 3

None of the experiments carried out led to the achievement of an ideal state. Experimentation should continue towards balancing storage tank filling and emptying. After experiment 3, it is not necessary to change the means of transport, but rather to change the filling device or the storage tank does not need such a large outlet opening.

4 Conclusions

When we read the maximum amount of material in the storage tank and convert the given amount into a volume using the bulk weight of the raw material, we obtain a value for determining the dimensions of the storage tank and its capacity and thus complete the algorithm from the second section.

The experiments show the development of stocks in the storage tank based on calculated values according to available formulas. None of the experiments managed to approach the so-called ideal state. The most appropriate way to achieve such a state is by combining proposed measures. Other solutions may include changing the filling device or reducing the emptying hole. Such combinations also mean deviation from the values calculated according to the usual formulas.

In addition to the above examples, in practice, storage tanks can be emptied into vehicles of different types and capacities. For example, different train sets with different numbers of railcars can be loaded. In this case, the replacement of the train set must also be considered. In other cases, continuous conveyor belts can also be used.

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The possibility of using 3D laser scanning as support for reverse engineering

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Keywords: 3D laser scanning, reverse engineering, 3D modelling.

Abstract: This paper describes laser scanning technology as a tool for reverse engineering. The content includes theoretical starting points and knowledge about 3D models, reverse engineering and laser scanning. Furthermore, a method of reverse engineering using 3D laser scanning is proposed, compared with the standard reverse engineering process. The main contribution is comparing the use of hardware in the form of a scanner and software for post-processing.

1 Introduction

Reverse engineering using 3D laser scanning has been known in industrial practice for more than ten years. However, technologies, hardware and software solutions developed a lot during these ten years. Organizations of various natures have designed and applied reverse engineering process and combinations. With the advent of 3D laser scanning, this process has become faster and more efficient. This work aims to describe what is represented by the term 3D model, reverse engineering and 3D laser scanning. The following section describes the proposed reverse engineering process using FARO Focus hardware and software in conjunction with Bentley's MicroStationV8 graphics software. At the end of the work, a comparison of the proposed process and the process used by a competing company is given.

2 Methodology

2.1 3D model

After 3D modelling creates a 3D representation of any surface or object by manipulating polygons, edges and vertices in a simulated 3D space. 3D modelling is accomplished by hand using specialized 3D production software that allows the artist to create and deform polygonal surfaces or by scanning real-world objects into a set of data points used to represent the objects digitally. 3D modelling is used in various fields, including engineering, architecture, entertainment, film, special effects, game development, and commercial advertising. 3D modelling uses software tools, such as computer-aided design (CAD) programs, to create 3D digital representations of objects [1].

Although 3D modelling software is based on a complex set of mathematical functions, programs automate calculations for users and have tool-based user interfaces. 3D models are the output of 3D modelling based on various digital representations. Boundary representation (B-rep) uses mathematically defined surfaces such as cones, spheres, and NURBS (non-uniform rational base splines) connected by topology to represent objects as watertight volumes accurately. B-rep models are the preferred solution for engineering and many 3D modelling applications for the design, simulation and manufacturing of consumer and industrial products. Faceted models approximate surfaces using connected planar polygons and are the preferred solution for less accurate, high-speed shape representations used in games, animations, and digital mockups [2].

Virtual 3D models can be turned into physical objects using 3D printing or traditional manufacturing processes. Models can also be converted to static images using 3D rendering, commonly used to create photorealistic displays for sales, marketing and e-commerce applications. 3D models can be created through a reverse engineering process in which 3D scanning technology is used to create digital replicas of real-world objects, including manufactured parts and assemblies, free-form models designed from clay, and human anatomy [3].

2.2 Reverse engineering

Reverse engineering is one of the progressive technologies of production systems. It represents a technological process using which it is possible to create a CAD model of an existing product or draw documentation according to specific customer requirements. It is used to create drawings of spare parts, the relevant technical

documentation that is either destroyed, incomplete, or never created [4]. Likewise, creating a complex hand-shaped model from modelling clay or other prototype parts. The data obtained can be used to produce parts with a small number in a batch on a 3D printer.
Use of reverse engineering:

- creation of drawing documentation of prototype parts,
- shortening the development and innovation cycle of the product,
- modernization of the production process,
- design of new parts adapted to existing parts,
- update drawing documentation of pressing forms.

Digitization, as the main activity in the process of reverse engineering for the field of engineering products, and the collection of input data from a real object is possible in several ways, such as manual measurement, semi-automatic measurement with a touch probe, laser surface scanning, optical 3D surface scanning or CT scanning [5].

Currently, the most used digitization method for reverse engineering is laser scanning of the surface using a 3D laser scanner. Thanks to powerful technologies and a proven methodology for 3D measurement and 3D digitization, we can transfer complex shaped objects from the real world to digital form. Virtual 3D models are characterized by high accuracy, a prerequisite for their effective use in CAD systems. We digitize accurate models from the level of a polygonal network (mesh) and mathematically described objects (surfaces, holes, bevels) to editable models in CAD systems, all using combined contact measurement and scanning techniques and advanced reverse engineering methods.

2.3 Laser scanning

Laser scanning, especially 3D, is one of the technologies of reverse engineering, which represents a modern approach to the digitization of spatial information about an object, which can be used for 3D product and production systems, with a focus on the very realization of objects (industrial, artistic and historical), with demanding focusing. Accessible and dangerous spaces, animation and creation of 3D and simulation models [6,7]. We divide the digitization process according to the following steps:

Step 1 represents scanning preparation. The described technology represents high dimensional accuracy of 3D models up to 3 mm. However, we consider 2-5 cm to be sufficient accuracy. Subsequently, this accuracy affects the quality of the scan. At the beginning of each project, it is necessary to agree on all the conditions under which the models will be created or how they will be used in the future. The model can be helpful, for example, for reorganization or production planning, creating object libraries or analyzing static structures.

Step 2 is the creation of a reference grid. Before the actual scanning, reference points must be placed throughout the hall to create a reference grid. Each reference point is located at a specific location and has its coordinates and marker. This creation of a reference grid is later used when stitching scans and specifies the future virtual model. In the future, the business can use the reference grid to accurately position production equipment, conveyors, transportation systems, etc., created in the 3D model. When placing reference points, it is essential to distribute them so that there are not enough (minimum of three) needed to accurately position the scanner in space. From one scanning position, it is essential to see at least four reference points, the distance of which is less than fifteen meters from the scanner.

Step 3 represents laser scanning. The origin of the coordinate system is at the center of the scanning mirror in the device. The software can automatically recalculate the transformation matrix so that all reference points have an absolute coordinate system. The core of the entire system is a built-in operating system that ensures the collection and storage of all data, scanning and simple data transfer to an external computer. This technology enables efficient, fast and accurate scanning of the entire production hall. Scanning is not only about a black and white photo but also about a color representation of measured spatial points - scans [7].

Step 4 represents the registration and connection of scans. Each scan point has five values: reflection, X, Y, Z and distance from the scanner. After scanning, it is essential to link the scans. This process creates a panoramic image, and each point shows one coordinate. FARO Scene Software for scanners from FARO is used for connecting scans, their overview and navigation in the scanning hall, measuring the distance and dimensions of objects, and exporting points to the CAD system. A FARO Scene is a graphical representation of visual perception used to compare reference points against which other objects can be evaluated. The goal of registration is to place individual scans in a predetermined coordinate system and link them and insert them into a fixed single coordinate system. A correctly registered (record of scans consists in their linking) scan is uniformly placed at the level of the "z" axis with other scans and with the correct link to other scans.

Step 5 represents the export of data from the graphic presentation to the CAD system. Usually, the data is exported to the CAD system: AutoCAD, MicroStation, Intergraph, CATIA, etc. With the help of 3D scans, a new medium is created that is a true reflection of reality. This medium is rendered into a CAD drawing that represents reality. This drawing is divided into layers according to the nature of the drawn object and can be dimensioned. Various parametric object libraries like TriCAD are used to reduce modelling time. This library consists of an extensive catalogue of 3D objects such as pipes, ventilation systems, electrical wiring, steel structures, conveyors, transportation systems, etc. [8].

This 3D laser scanning process works with FARO Focus brand scanners.

3 Results and discussion

The reverse engineering process begins with selecting a tangible object for which it is necessary to develop technical documentation. An object can be a component, assembly, machine or building, ventilation, pipe system, etc. For research purposes, a set consisting of six components was chosen. This assembly serves as an intermediate piece for a piping system in an industrial plant. The first step is to disassemble the assembly from the entire system and store the assembly in the area where the 3D laser scanning will be performed. Next is the creation of a reference grid around the assembly. A reference grid consists of an arrangement of reference points. In this case, reference bodies are spheres. From every position of the scanner, the sphere has the same shape, which makes it an ideal reference body. After the creation of the reference network, i.e. after the placement of the reference bodies, 3D laser scanning follows. The positions of the scanner are selected according to the need to focus the object and according to the rules of the reference network. After scanning and data transfer to the FARO Scene software, the scans are registered. After the overall registration, a 3D point cloud (Figure 1) of the real object is created.

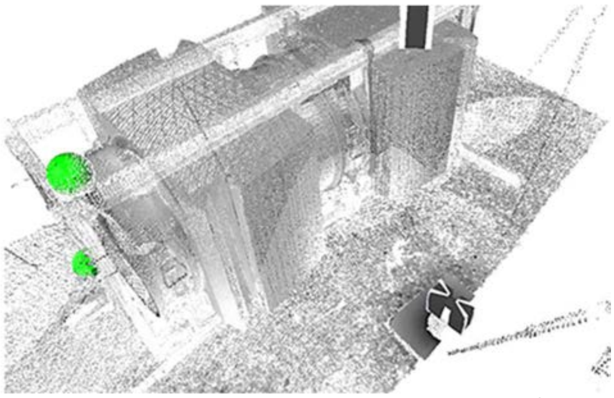

Figure 1 3D point cloud displayed in FARO Scene software

The next step is to create a 3D model in the MicroStation V8 software environment (Figure 2). The point cloud is exported from the FARO scene software to the graphics software.

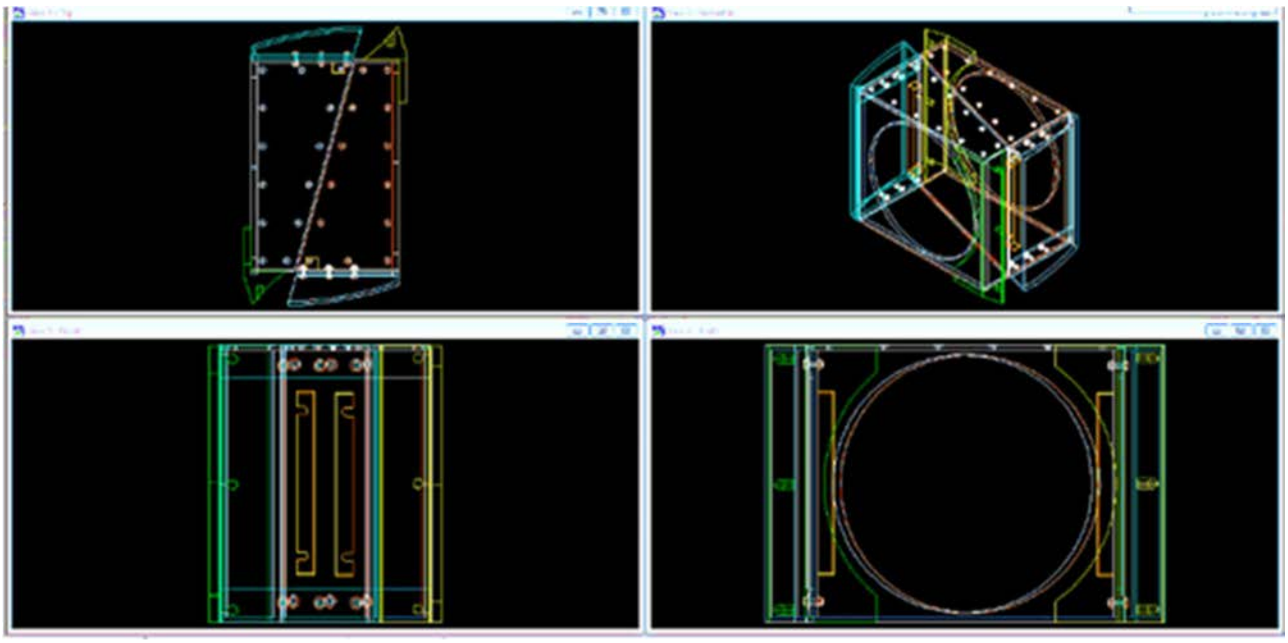

Figure 2 3D model of the assembly in the MicroStation V8 software environment

In graphics software, a 3D model is created according to the actual object, in the exact scale and the real position relative to the zero point. This 3D model is measurable and dimensional and can be seen in figure 2 in the MicroStation V8 environment [9]. This graphics software offers modelling in all six views of the body. Four are primarily used, top, front, right and isometric.

Without a doubt, we need to check the accuracy of the data before completing the reverse engineering process. It is possible to export the created 3D model in VRML format to the FARO Scene software (Figure 3). The exported model can be placed in a point cloud and visually checked for deviations and inaccuracies between the dimensions of the actual object and the model. When creating technical documentation, the deviation should not exceed 1 mm. In this environment, moving the entire cloud and inspect the model from all sides is possible. We can also target these deviations using a set of measuring tools in the software.

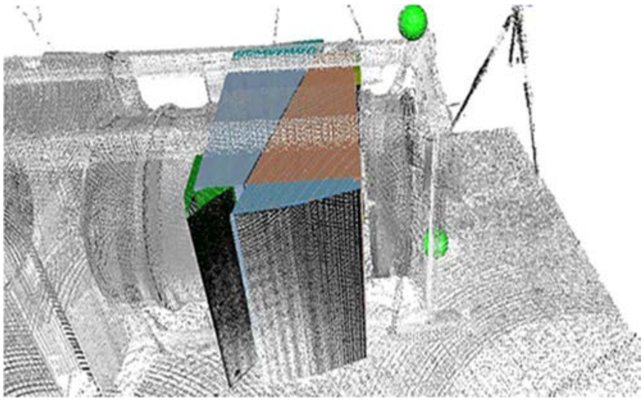

Figure 3 Displaying the 3D model in the point cloud in the FARO Scene software environment

If the model passes inspection, the final output and the last step of the reverse engineering process is the drawing documentation. Drawing documentation, as part of technical documentation, is used in 2D. This 2D drawing can be created in MicroStation V8 simply by exporting the visible and hidden edges in each view that the creator needs to create the 2D drawing. The drawing is created in HLN format, which is a 2D drawing format. However, other software cannot process it effectively, so after creating a 2D drawing, it needs to be exported to DGN format to work flexibly for further use, such as construction.

4 Conclusions

The proposed procedure differs from the standard procedure used for reverse engineering. To compare the standard 3D laser scanning process used by a competing company and a competitively capable reverse engineering process, table 1 was compiled.

Table 1 Comparison of standard and proposed reverse engineering process

Process parameter	**The standart process**	**The proposed process**
Use of 3D laser scanning	Yes	Yes
Brand of scanners used	Leica Camera AG	FARO Focus Laser Scanners
The price of scanners	Higher	Acceptable
Scanning accuracy	Good	Very good
Point cloud software	Leica Cyclone	FARO Scene
Compatibility of cloud computing software with graphics software	Medium	High
The price of software for working with the cloud	High	Medium
Graphics software used	AutoCAD	MicroStation V8
Controllability of the software when creating 3D models	Hight difficulty	Medium difficulty
Compatibility of graphics software with other graphics software	Very low	High
Saving models to standard formats	Low	High
Creating a 2D drawing from a 3D model	Yes	Yes

The proposed procedure with the use of hardware and software from FARO Focus and MicroStation V8 graphics software from Bentley brings the possibility of better and more accurate targeting of objects, high compatibility of used software with the possibility of fast data transfer and model export to all standard formats for the use of models in graphics, visualization and simulation software. It also precisely controls the model's dimensions by comparing the actual condition displayed in the points cloud.

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Simulation of material flow using vertical transport by a double-action mine hoist

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Keywords: hoisting equipment, simulation, model, experiment.
Abstract: Vertical transport with the help of mining hoisting equipment in the deep mining of mineral raw materials is an essential part of the entire complex of intra-company transport at every mining plant. This paper aims to simulate the material flow ensured by double-action hoisting equipment. ExtendSim was used as a simulation tool, which combines the possibilities of discrete and continuous simulation and is used by researchers in various fields. The paper presents a simulation model of the material flow - coal transport from the underground to the surface. The paper also presents the results of the experiments performed on the created simulation model, too. The simulation model is a suitable auxiliary tool for the decision-making process or analysis of the current state and rationalization.

1 Introduction

As one of the logistics processes, the transport process currently has an irreplaceable place in the logistics systems of companies and the supply chain. The common goal of transport, both internal and external, is to satisfy customers' needs, i.e. move the material at the right time, to the right place and in the required quality with the effective use of means of transport and equipment.

In the mining industry, intra-company transport has an important position. In underground operations, various transport systems are used for horizontal transport (mining rail transport, rake and belt conveyors, suspended transport, trackless mining transport, etc.). Vertical transport with a mine hoist is often used in deep mines to transport material from and to the underground. Mine hoisting machines are complex machinery used to raise ore and waste rock and transport personnel, materials and various mining equipment between the mine surface and its underground. A standard hoisting machine consists of a hoist drive, headframe, ropes, conveyances (cages or skips), and control and safety devices. [1]

Definitions of the basic concepts of vertical transport are given in several publications [2]. Mine hoist can be categorized from several systemic perspectives. For example, the categorization by the maximum rated velocity: the category of large mine hoist machines with a rated velocity above 3 $m.s^{-1}$ and the category of small hoisting machines with a rated velocity below 3 $m.s^{-1}$. According to the method of transport, we differentiate [3]:

A) Single-acting mine hoist. They are characterized by the fact that only one transport container is suspended from the rope. They make it possible to perform mining from any horizon without pushing the transport containers. Compared to double-acting mine hoists, they have half the performance - capacity.
B) Double-acting mine hoist. They are used much more often than single-acting mine hoists. During transport, two transport containers are used, which can be hung on two hoisting ropes of a double drum hoisting machine to both ends of one rope or several hoisting ropes when using a hoisting machine with a friction disc. With this method, drum hoisting machines ensure transport from any horizon, allowing the hoisting rope to be lengthened or shortened. In the case of mining using a friction disc, dual-action transport can only be done from one horizon.

Sometimes combined mine hoists are used, characterized by having different transport containers suspended on both ropes in drum equipment and on both ends of the rope in friction disc transport.

Designing mechanical parts of the mine hoist begins with proposing hoisting machine parameters (identification of an appropriate machine type, calculation of its basic parameters, mining capacity, transport velocity, required output, etc.). For this purpose, manufacturers use special computer software to create several optimization alternatives [4].

This paper aims to present a simulation model of the material flow when using a double-action mine hoist. Simulation as a scientific method is now widely used in research and practice. Currently, they are used for the creation of simulation models in various areas (transportation systems, handling systems, production systems, urban planning systems, logistics systems, ecological problems, etc. [5,6]), several simulation tools such as Witness [7], Tecnomatix Plant Simulation [8], Extend [9] and others.

This paper will use the ExtendSim simulation tool [10]. This simulation system combines discrete and continuous simulation capabilities and is a popular simulation tool for PC_MS Windows and Macintosh computers. This tool was used by several authors in simulations in various fields [9,11,12].

2 Methodology

To apply the simulation and create a simulation model, it is necessary to conduct a thorough analysis of the material flow. In this case, the flow of coal from the underground to the surface was analyzed, which is ensured by a skip double-acting mine hoist with a friction disc used in Slovak mining operations. The material flow is shown in the formalized diagram in Figure 1. As can be seen from Figure 1, the coal is stored in the underground bunker. Coal is poured into the storage bunker via a discharge ramp from a mine railway wagon. Coal is filled from the bunker using a belt scale into a skip transport container. After loading the coal into the skip container, the skip container with coal is hoisted to the surface, where the coal is unloaded through the lower opening in the skip container into the storage bunker, from where it is then moved using belt conveyors for further processing. Since the flow of coal is provided by a double-acting mine hoist (two skip container), it is essential to point out that in that moment of loading coal into the skip (1) underground, coal is being unloaded from the skip (2) on the surface.

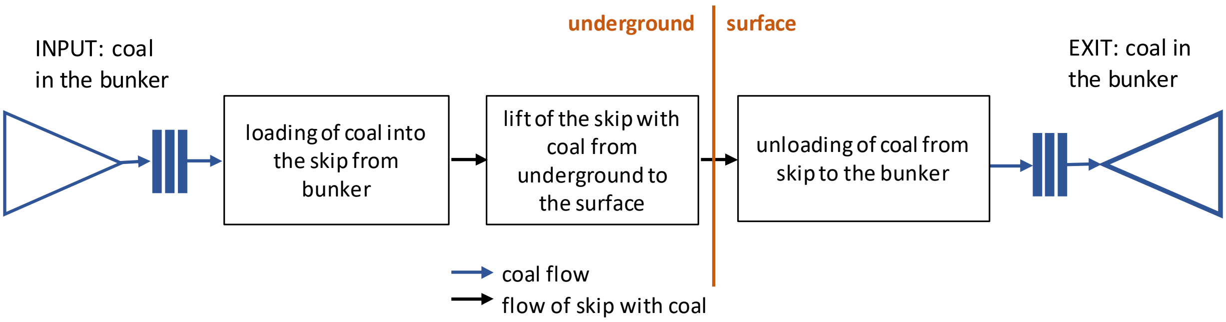


Figure 1 Flow of coal from the underground to the surface

Blocks from libraries were used to create simulation models. "Item.lix", which contains blocks for creating discrete simulation models, and "Plotter.lix" – blocks that allow displaying the progress of the simulation.

The blocks used to build the model are explained in Table 1. In shows the Print Screen of the created coal flow simulation model shows Figure 2

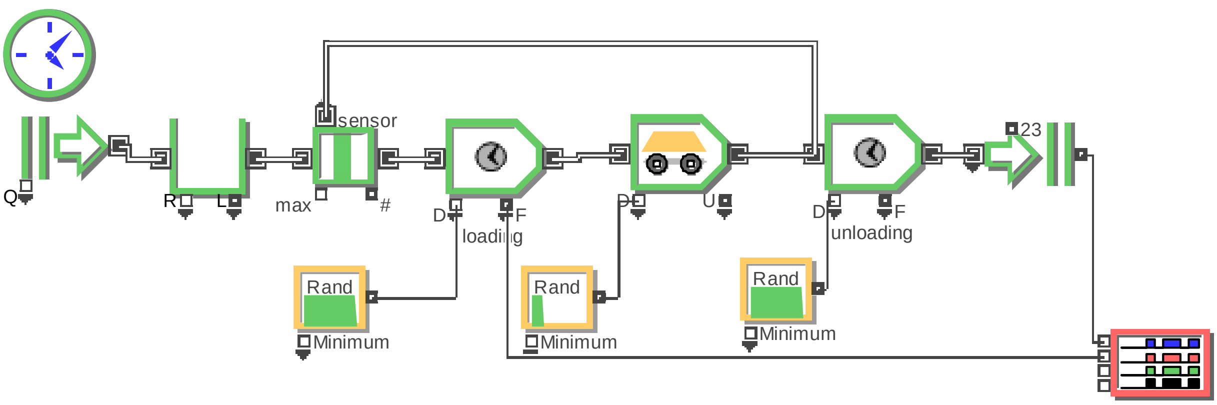
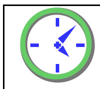
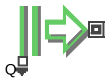
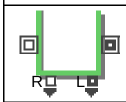
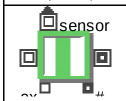
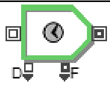
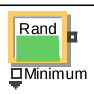
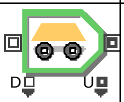
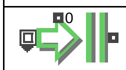
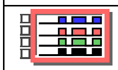


Figure 2 Print Screen of the simulation model

Table 1 Used blocks

	"Executive" – block for controlling the simulation time.
	"Create" - the block generates inputs to the simulation model. In this case, it generates coal batches.
	"Queue" - a bunker, represents a series of generated inputs (coal batches) waiting for loading.
	"Gate" - the task of the block is to ensure that the request enters the process at the moment the previous request completes the "Transport" block, i.e. that, in this case, ensures that both loading and unloading occur within the one-time interval.
	"Activity 1" – the block delays the element for a specific time, representing the activity of loading coal into the skip. "Activity 2" - the block will delay the element for a specific time, representing the activity of unloading coal from the skip.
	"Random Number" - blocks generate inputs (times) of activities (loading, lifting, unloading)
	"Transport" - transports elements from one place to another, representing the relocation (lifting) of a batch of coal from the place of loading to the place of unloading.
	"Exit" - request output, number of unloaded coal batches
	"Plotter, Discrete Event" - the block from the input values draw graphs of the simulation and writes the values of the monitored inputs into a table.

3 Results and discussion

Several experiments were performed on the simulation model. The input data was obtained directly from the operation. The time of loading and unloading coal to and from the skip container is 90-120 s for a weight of 10 tons of coal. This interval was entered into the "Random Number" blocks as input for the "Activity" blocks. The hoist time of the skip container was measured in the range of 45-50 s. The interval was entered in the "Random Number" block for the "Transport" block.

Several experiments were performed on the simulation model. Experiment A for a simulated time of 1 hour. Experiment B for a simulation of 5 hours and 30 minutes corresponds to the real working time on the mine hoist. The average results from the experiments are summarized in Table 2.

Table 2 Used blocks

Experiment	**A**	**B**
Simulated time [hours]	1	5,5
Number of loaded skip containers	24	130
Number of hoisted skip containers	24	129
Number of unloaded skip containers	23	129
Block using "loading" [%]	68	69
Block using "Transport" [%]	32	31
Block using "unloading" [%]	69	68

Figure 3 shows one of the outputs of Experiment A. The blue curve represents the number of unloaded batches of coal, and the red curves represent the number of loaded batches and their duration. It can be seen in the figure that the first batch of coal was unloaded at the moment when the second batch of coal was loaded underground. Figure 4 shows one of the outputs of Experiment B.

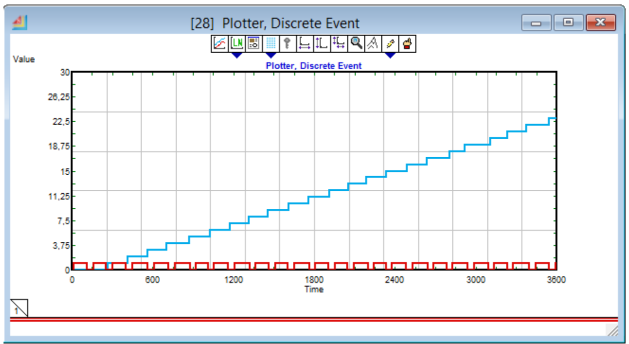


Figure 3 Graphical results of Experiment A

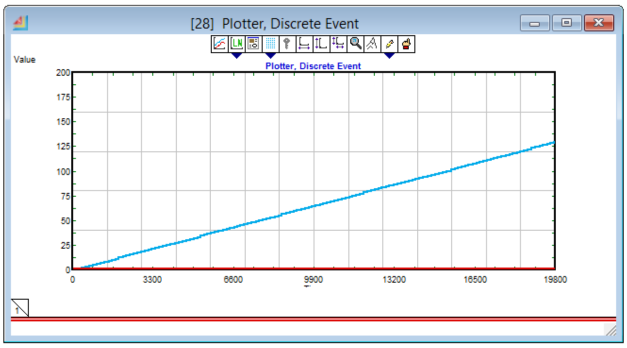


Figure 4 Graphical results of Experiment B

3 Conclusions

The simulation model simulates the material flow ensured by vertical mine transport, which is realized by a double-action mine hoist.

The result of the simulation experiments is the number of coal batches that were moved from the underground to the surface during the simulated time and the utilization of individual blocks, too. The number obtained in this way can be used to calculate the mine hoist's hourly capacity and the mine hoist's daily capacity. The simulation model is a suitable auxiliary tool for decision-making, either when designing new systems or evaluating existing ones. Expansion of the model is also possible with other activities, or it may represent other activities that should be addressed in future research.

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