

# Creating a simulation model for an automated logistics system

*Stefan Jovčić*<sup>1,\*</sup>, *Petr Průša*<sup>1</sup>, *Gabriel Fedorko*<sup>2,\*</sup>, *Alena Večeřová*<sup>3</sup>, and *Momčilo Dobrodolac*<sup>4</sup>

<sup>1</sup>University of Pardubice, The Faculty of Transport, , Studentska 95, Pardubice, Czech Republic

<sup>2</sup>TU Košice F BERG, Logistics Department, Park Komenského 14, 040 01 Košice, Slovakia

<sup>3</sup>College of Logistics, Palackého 1381/25, 750 02 Přerov, Czech Republic

<sup>4</sup>University of Belgrade, The faculty of transport and traffic engineering, Vojvode Stepe 305, Belgrade, Serbia

**Abstract.** This research paper deals with the creation of simulation model of an automated logistic system in Tecnomatix Plant Simulation. The crucial element of the theoretical part of the paper is the factual basis for automated logistic systems whose purpose is their practical use, the process of creation or classification. An important part of this section is simulation and their models, especially discrete. Realization of simulations was not possible without software tool named Technomatix plant simulation. The practical part is then focused on building a functional model suitable for experimentation.

## 1 Introduction

Nowadays, the realization of the Virtual Factory (VF) is the strategic goal of many manufacturing enterprises for the coming years [1]. Simulation is an important tool for planning, implementing, and operating complex manufacturing systems [2]. Simulation is an approximate imitation of a studied phenomenon or behaviour of a given system in the virtual space with the use of its so-called simulation model. Simulation models are used to reduce the risk of failure while implementing significant changes into the existing manufacturing systems. Upon generating the model, a simulation analysis is performed to determine particular elements of the process. Computer simulations are identified as the most popular tools for the analysis of the possibilities that optimise processes in production engineering [3].

In various industries, such as mechanical, electrical engineering and automotive industry, an effective functioning of logistics processes is one of the leading objectives in most companies. In order to ensure the accuracy and quality of a production process, it is necessary to properly arrange production machines, interoperable storages for finished products [4].

Simulation is the method by which the real system is replaced by its simulation model. Experiments are then performed on it, the results of which are applied retroactively. For

---

\* Corresponding author: [stefan.jovcic93@gmail.com](mailto:stefan.jovcic93@gmail.com)

example, it is used to solve problems with complex mass-serving systems. These are systems characterized by differential equations. Simulation can be described as an important predictive tool for dealing with complicated logistics systems. This prediction follows, depending on changes in internal and external conditions.

The simulation has a number of positive features that make it possible to: find out the current state of the system, time modify system, in terms of acceleration or deceleration system to analyze, revealing greater efficiency, system optimization, to propose a reorganization, confront different alternatives [5].

Among the disadvantages are: problems with description of decision rules, quantification of variables, selecting boundaries and limits of the system.

In order to lead a successful production enterprise complex technical systems have to be planned and their efficiency monitored. One of methods for control of production planning is factory simulation. Simulations are executed in order to control and monitor several trends of process optimization such as product life cycle, maintaining demands for quality and lot sizes, increase of flexibility in order to increase product complexity and variety [6,7].

The huge amount of simulation software available can be paralyzing for new users. The softwares listed below are only a sample of simulation tools often used for logistics processes, but there is a quantum of them on the market. Since logistics operations fall into the section of discrete simulations, software tools are focused in this direction. Most commonly used simulation tools include ExtendSim Simulation Software, SIMUL8 Simulation Software, Tecnomatix Plant Simulation, or WITNESS System Simulation Modeling Software. These tools share the fact that they allow you to visualize the data you have acquired with several options. The display options that are offered are either simple or advanced views in 2D, and 3D views. With such a model in any view, it is also possible to watch the animation.

Some of the individual components are manufactured, some are purchased and then assembled. It is necessary to efficiently control such a chain and to predict its efficiency to ensure optimal efficiency. Computer simulations are one of the optimization options [8].

## 2 Description of the automated workplace

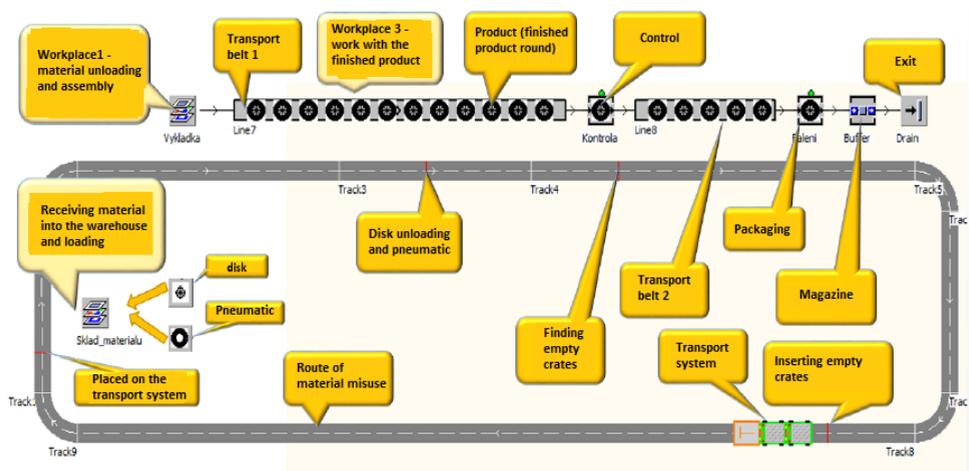
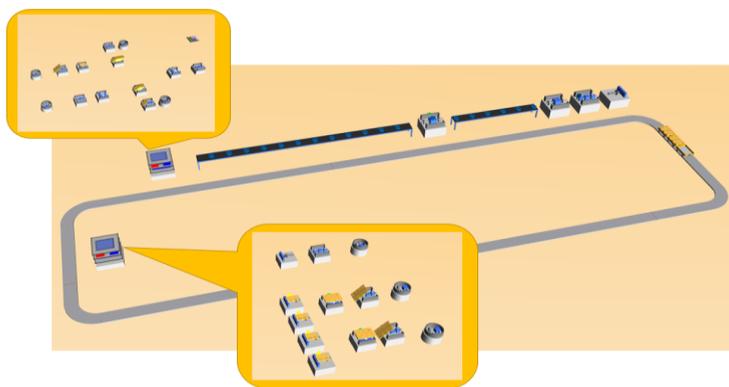


Fig. 1. The described model of the proposed workplace. Source: Autor

The proposed workplace introduces (Fig. 1) the use of simulation for the possibilities of experimentation. Designed and realized workplace is dedicated to the assembly of bicycles

for children's toys. This is a simple process when a component is assembled from a component. The system is operated by a logistics train (a two-wheeled tractor) characterized by the Milk run system. The feature of this system is the continuous circulation around individual workplaces in order to simply and efficiently serve these points.

The diagrams in Fig. 1 and Fig. 2 describe the layout of the assembly hall. The work takes place in three workplaces located in one hall. At Workplace 1, material is taken to the warehouse and the material is loaded for transportation to the assembly site. Workplace 2 then assembles the two components. The finished products then travel along the track to the control section. After checking, the second line goes to the packing section, followed by packed wheels in the tray and for export. It is important that each component of the system is tuned together to avoid unnecessary downtime.



**Fig. 2.** The model proposed work in 3D. Source: Autor

For a clearer idea of how the workplace looks and works, its individual elements are briefly described here. Components for assembling the finished product are plastic discs and rubber tires. Both rubber tires and plastic discs are not produced in this workplace but are imported from suppliers. The specification of attributes for the creation of entities of plastic discs and rubber tires in Tecnomatix Plant Simulation is shown in the Table 1. The attributes of the rubber tires are a radius of 2.5 cm and a height of 1 cm. The plastic discs have a radius of 1.5 cm and a height of 1 cm.

**Table 1.** Dimensions of imported components.

Components	Length [m]	Width [m]	Height [m]
Tires	0.05	0.05	0.01
Disks	0.03	0.03	0.01

The product is a bike of a toy car and consists of two components - rubber tires and a plastic rim (Table 2). The finished wheel has a diameter of 5 cm and a height of 1 cm. The manipulation units for this simulation are used crates measuring 1x 1x 0.15 meters. Crates are capacitively defined separately for discs and especially for tires. Trolleys can be tire-loaded in the number of 20 to 15 pieces. For disks the capacity of these crates is 34 pieces per 15 pieces.

**Table 2.** The values of the handling units.

Handling unit	Length [m]	Width [m]	Height [m]	Capacity of pieces
crate tires	1	1	0.15	20x15
crate disk	1	1	0.15	34x15

The transport system (Table 3) is implemented through an intelligent automated tractor with two trolleys. Tractor parameters are 1.5 meters long, 1.1 meters wide and 1.5 meters high. This automated tractor can then travel at a speed of up to 0.5 meters per second, Fig. 5. Both trolleys are defined in the same dimensions as 1.5 x 1.2 x 0.5 meters and at a speed corresponding to the speed of the tractor, i.e. 0.5 m.s<sup>-1</sup>.

**Table 3.** Traffic system values.

Element	Length [m]	Width [m]	Height [m]	Speed [m.s <sup>-1</sup> ]	The number of crates
Tractor	1.5	1.1	1.5	0.5	0
Truck 1	1.5	1.2	00.5	0.5	3
Truck 2	1.5	1.2	00.5	0.5	3

The part of this transport system is the route where the truck travels.

**Table 4.** The Lengths of sections.

Section	Length [m]	Width [m]
Truck 1	1	1
Truck 2	15	1
Truck 3	11	1
Truck 4	22	1
Truck 5	1	1
Truck 6	9	1
Truck 7	1	1
Truck 8	48	1
Truck 9	1	1
Truck 10	9	1

In total, it is composed of ten sub-sections with different lengths, Table 4 shows the dimensions of all sections, the length of the whole route being one meter wide is 118 meters.

Red marked sections mean that there is an operation. In the third section, the components are unloaded from the transport system. In the fourth section, empty carts are loaded. In the eighth section, empty crates are unloaded. The tenth section is then characterized by loading full crates with new components.

The transport lines (Table 5) are characterized by a belt conveyor, the first being 19 meters long and the other 8 meters long. Both are characterized by the same belt width and 1 m.s<sup>-1</sup> movement speed. Also important are the distance between finished products, which is 0.5 meters.

**Table 5.** Dimensions of lines.

Line	Length [m]	Width [m]	Speed [m/s]
Line 1	19	1	1
Line 2	8	1	1

Material warehouse or Workplace 1 is a system of partial activities where the primary step leads to the finished product. This unit will have separate parts necessary for the assembly of the final product, ie bicycles for children's cars.

Unloading or Workplace 2 consists of several sub-operations to assemble the final product.

Inspection is the site through which all finished products pass. It is defined here by a constant operating time of 1 second per piece of finished product.

Packaging, as in the case of an inspection, when it is the site through which the finished products are packed. The operating time per piece is 1 second.

The stack serves as a fuse in the event of an outage, the capacity is set to a negative value. The value of -1 indicates that the stack is defined for infinitely large capacity.

The output is a necessary element for the correct completion of the assembly process, so it is necessary to insert it here.

### 3.2 Material flow

This material flow begins with the delivery of material to the warehouse, the scheme in Fig. 3. The process takes place at Workplace 1 (Material Store). Tires are loaded onto the crate (Assembly 4) and shipped to the buffer (Buffer 4). From there, the components are loaded onto the trolley. The same is true for disk loading, the operation time is 60 minutes, for Assessment Workplace 1. During this time, Workplace 1 is able to dispatch 12 crates with both discs and tires.

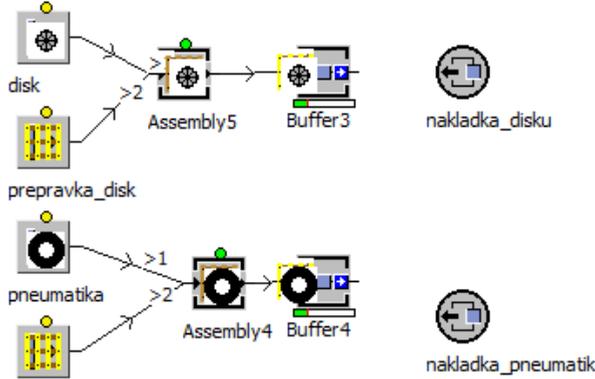


Fig. 3. Iconic Representation of Relationships at Workstation 1 (stock of material). Source: Autor

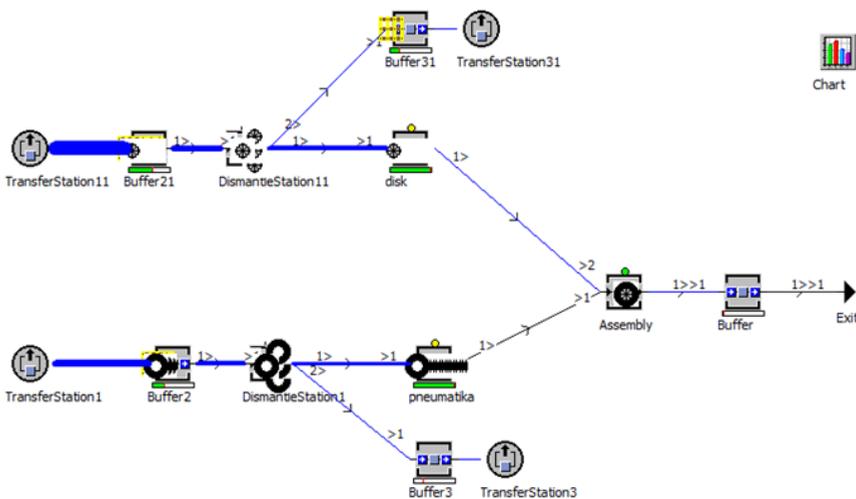
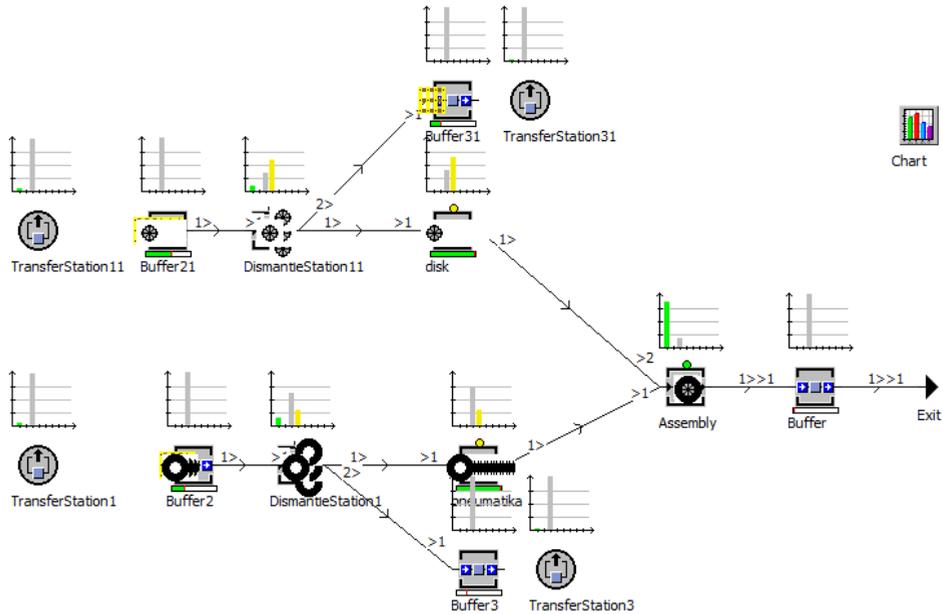


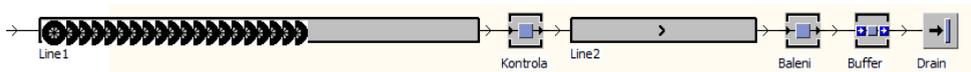
Fig. 4. Iconic representation of relations at Workplace 2 using the Sankey diagram. Source: Autor

The components are therefore stored in crates and further wander on two trucks with a tractor. Thanks to this automated logistics system, the components can arrive at their destination - Workplace 2 (Fig. 4). This is characterized by their unloading, followed by assembly. In nearly one hour, the workplace is capable of producing 51 pieces of wheels. Figs. 4 and 5 illustrate the material flow, using the Sankey diagram and the Bottleneck analyzer, at Workplace 2 (Fig. 5).



**Fig. 5.** Iconic representation of relationships at Workstation 2 using a narrow space analyser. Source: Autor

The last section of the flow is Workplace 3 where final operations are under way to package, check and dispatch the finished product (Fig. 6).

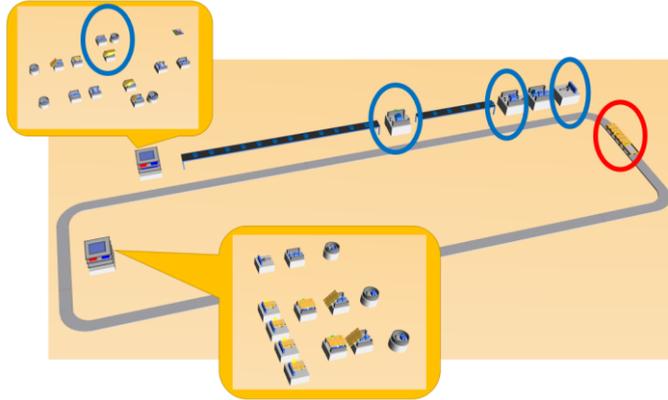


**Fig. 6.** Iconic Representation of Relationships at Workplace 3. Source: Autor

### 3 Simulation experiments

#### 3.1 Experiment 1 - Changing the speed of the transport system

The simulation model (Fig. 7) created here is subjected to several attempts to demonstrate the complexity of the system. Changes to this system are tracked depending on the experiment. The results obtained can then provide information on potential pointers to optimize the monitored system.



**Fig. 7.** Marking the change (red) and the consequences (blue). Source: Autor

**Table 6.** Assessment Workplace 1 for the 1st experiment.

Activity / MUs	Operating time [min]	Value [pcs]
<b>Tire Load on Crate (Assembly 4)</b>	60	11 -- > 11
<b>Transporter Tank Tray (Buffer 4)</b>	-	4
<b>Load Discs on Crate (Assembly 5)</b>	60	11 -- > 11
<b>Transporter Disk Tray (Buffer 3)</b>	-	4
<b>Tire crate</b>	-	12 -- > 12
<b>Crate disks</b>	-	12 -- > 12
<b>Tires</b>	-	192 -- > 192
<b>Disks</b>	-	384 -- > 384

The first experiment is based on a change in the speed of the transport system. The original speed of  $0.5 \text{ m}\cdot\text{s}^{-1}$  of the entire system, which is referred to as the two-trolley tractor assembly, has increased to  $2 \text{ m}\cdot\text{s}^{-1}$  (Table 6). The tables below serve for better orientation in the recorded changes.

**Table 7.** Assessment Workplace 2 for the 1st experiment.

Activity / MUs	Operating time [min]	Value [pcs]
<b>Tray for unloaded tire on the carrier (Buffer 2)</b>	-	10
<b>Tire Unloading (Dismantle Station 1)</b>	8 -- > 8	128 -- > 128
<b>Tire buffer (Buffer 3)</b>	-	120
<b>Tray for in-tray disks (Buffer 21)</b>	-	10
<b>Unloading the crates (DismantleStation 11)</b>	5 -- > 5	137 -- > <b>133</b>
<b>Disk tray (Buffer 31)</b>	-	80
<b>Assembly (Assembly)</b>	52 -- > 52	51 -- > 52
<b>Finished wheels</b>	-	51 -- > 52
<b>A stack of finished wheels</b>	-	130

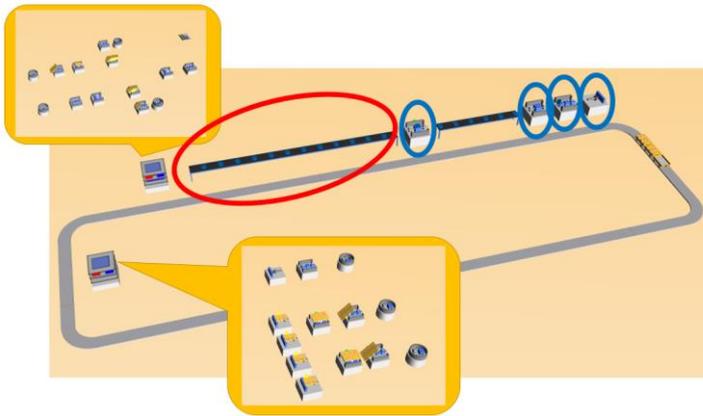
The increase in speed had no impact on Workplace 1 (Table 6), the values remained. On Workplace 2 (Table 7), as in the first one, there was no significant change. However, there was a change in performance when unloading disks from the crate (blue highlighting in Table 7). Here the number of pieces from the original 137 pieces dropped to 133. However, Workplace 3 (Table 8) made changes, with these changes increasing operating time for control linked to performance gains. A similar change was observed at the packing station as in the case of an inspection where the increase in time by one minute showed an increase in production by one piece.

**Table 8.** Assessment Workplace 3 for the 1st experiment.

Activity / MUs	Operating time [min]	Value [pcs]	Length [m]	Speed [m.s <sup>-1</sup> ]
<b>Line 1</b>	-	-	19	1
<b>Control</b>	17 -- > <b>18</b>	16 -- > <b>17</b>	-	-
<b>Line 2</b>	-	-	8	1
<b>Packaging</b>	2 -- > <b>3</b>	1 -- > <b>2</b>	-	-
<b>Output of finished wheels</b>	-	1 -- > <b>2</b>	-	-
<b>Tray finished wheels (buffer)</b>	-	∞	-	-
<b>Transport system</b>	-	-	118	0.5 -- > <b>2</b>

### 3.2 Experiment 2 - Changing the belt length on the line 1

In the second experiment (Fig.9), the strip length was shortened on line 1, a change in Table 9 indicating that the belt was shortened by 14 meters.



**Fig. 9.** Marking the change (red) and the consequences (blue). Source: Autor

**Table 9.** Assessment Workplace 1 for the 2nd experiment.

Activity / MUs	Operating time [min]	Value [pcs]
<b>Tire Load on Crate (Assembly 4)</b>	60	11 -- > 12
<b>Transporter Tank Tray (Buffer 4)</b>	-	4
<b>Load Discs on Crate (Assembly 5)</b>	60	11 -- > 12
<b>Transporter Disk Tray (Buffer 3)</b>	-	4
<b>Tire crate</b>	-	12 -- > 12
<b>Crate disks</b>	-	12 -- > 12
<b>Tires</b>	-	192 -- > 192
<b>Disks</b>	-	384 -- > 384

Because Workplace 1 precedes line 1, which was shortened (from the original 19 meters to just 5 meters) and which travels round already made, was not mentioned on the site monitored no change (Table 9). Similarly, there is also Workplace 2 (Table 10), where the change was not recorded as well.

**Table 10.** Assessment Workplace 2 for the 2nd experiment.

Activity / MUs	Operating time [min]	Value [pcs]
tray for unloaded tire on the carrier (Buffer 2)	-	10
Tire Unloading (Dismantle Station 1)	8 --> 8	128 --> 128
Tire buffer (Buffer 3)	-	120
Tray for in-tray disks (Buffer 21)	-	10
Unloading the crates (DismantleStation 11)	5 --> 5	137 --> 137
Disk tray (Buffer 31)	-	80
Assembly (Assembly)	52 --> 52	51 --> 51
Finished wheels	-	51 --> 51
A stack of finished wheels	-	130

**Table 11.** Assessment Workplace 3 for the 2nd experiment.

Activity / MUs	Operating time [min]	Value [pcs]	Length [m]	Speed [m.s <sup>-1</sup> ]
Line 1	-	-	19 --> 5	1
Control	17 --> 41	16 --> 41	-	-
Line 2	-	-	8	1
Packaging	2 --> 26	1 --> 26	-	-
Output of finished wheels	-	1 --> 26	-	-
Tray finished wheels (buffer)	-	∞	-	-
Transport system	-	-	118	0.5

The greatest effect of this change was observed at Workplace 3 (Table 11), when the following steps (control - line 2 - packaging - tray - output) increased their values. This was an increase in both operating times and quantity in pieces. The change affected a number of steps but was also effective. The total output of the finished product rose up to 26 times.

## 4 Conclusion

The experiments carried out reported their influence on the system, which was unfortunately not as expected. In all cases, the change was monitored only in the inner circle from the center of change. Specifically, it was a short domino effect, with the effect of one or a few follow-up changes.

The first attempt, based on an increase in the transport system speed from 0.5 m.s<sup>-1</sup> to 2 m.s<sup>-1</sup>, resulted in a change in Workplaces 2 and 3. On Workplace 1, there was a decrease in the unloading of disks from the crate. For the following Unit 3, the decrease was insignificant as there was an increase in control and packing values. The unit was also increased in wheel production. From the second attempt performed by the belt shortening at the first line, the following finding was obtained. The shortened 1st line resulted in a multiple increase in total production. The information gathered suggests that it is not enough to change a few parameters to achieve bigger changes, for example in the form of higher production, but other parallel processes need to be used. This created model is set to resist certain fluctuations. Whether for example the changes that have been made in the dual (changing the speed of the truck with the trolleys, shortening the conveyor belt line) or something else. It is essential to focus the changes globally and with greater quantity.

Simulation is the process of creating a computer model of a real system. Because it is an imitation of reality, it is possible to consider different possibilities, to experiment, to find a narrow place and shortcomings and to positively influence a number of factors. These factors may include, for example, an increase in production, a reduction in downtime, or the verification of planned changes that may lead to future business problems.

The present paper is a part of research grant projects VEGA 1/0063/16, VEGA 1/0403/18, KEGA 018TUKE-4/2016.

## References

1. F. Caputo, G. Di Gironimo, A. Marzano, *Con. Int. de Ing. Graf.* **18**, 13 (2006)
2. Y. Arunkumar, P. Rajashekar, S. Mohankumar, *Int. of Eng. Res. and Dev.* **1**, 5 (2012)
3. M. Kikolski, *Ec. And Man.* **8**, 10 (2016)
4. Z. Cujan, *Op. Eng.* **6**, 6 (2016)
5. H. Bossel, *Modeling and Simulation* (Springer, Wiesbaden, 1994)
6. Z. Car, B. Barisic, M. Krsulja, *Vyr. Inz.* **8**, 6 (2009)
7. S. Maricic, Z. Car, K. Ueda, *Eng. Rev.* **28**, 10 (2008)
8. D. Tucek, I. Novak, *Scient. Pap. of the Uni. Pard.* **36**, 11 (2016)