Software Support for Optimizing Layout Solution in Lean Production

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***Abstract* – As progressive managerial styles, the techniques based on "lean thinking" are being increasingly promoted. They are focused on applying lean production concepts to all phases of product lifecycle and also to business environment. This innovative approach strives to eliminate any wasting of resources and shortens the time to respond to customer requirements, including redesigning the structure of the organization' supply chain. A lean organization is created mainly by employees, their creative potential, knowledge, self-realization and motivation for continuous improvement of the processes and the production systems. A set of tools, techniques and methods of lean production is basically always very similar. Only a form of their presentation or classification into individual phases of the product lifecycle may differ. The authors present the results of their research from the designing phases of production systems to optimize their dispositional solution with software support and 3D simulation and visualization. Modelling is based on use of Tecnomatix's and Photomodeler's progressive software tools and a dynamic model for capacitive dimensioning of more intelligent production systems.**

***Keywords* – lean production, production process, supporting software tools, lean logistics, layout solution**

DOI: 10.18421/TEM71-05
https://dx.doi.org/10.18421/TEM71-05

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Received: 15 November 2017.
Accepted: 19 January 2018.
Published: 23 February 2018.

1. Introduction

Sustaining competitiveness of production in globalized markets places more and more emphasis on complex quality and timely delivery of products at the lowest possible price.

A direct impact on a minimization of costs associated with material handling also has an appropriate distribution of machinery and equipment that contributes to better company management. Another way of making more effective production is to implement lean production as a systematic approach that prevents unnecessary wasting of resources by continually improving processes. Significant benefits for the organization can be achieved by integrating these two ways of optimizing costs and production systems. An increasing number of products are emerging on the market to make it possible for designing of production systems with interactive 3D imaging solutions, with an option of modelling and simulation. The software offering comprehensive solutions that are fully customizable is becoming more and more popular. An advantage of software on this basis is the ability to create an innovative and more effective layout solution, a comprehensive production system in a virtual environment without the need to pause production that is subsequently used after optimization. Our research of the layout of machines and devices has been carried out Tecnomatix software in the intelligent system. A part of the visualization itself is a creation of 3D models using photogrammetry, their subsequent implementation into the Tecnomatix software and comparison with the models created in this program. The final layout solution with elements of lean production is fully visualized and has been implemented under specific operating conditions.

2. Lean production as a tool for optimizing production processes

As part of the "Industry 4.0" concept, an increasing emphasis is placed on making more effective every component of the production process characterized by a set of technological, manipulative, control and management activities [1, 6]. The underlying idea is an overall reduction in expenditures at each phase of production, despite the fact that average wages and taxes have an increasing tendency. If the company desires to succeed in a competitive environment, it has to optimize and rationalize the production processes better than the competitors. One of the progressive optimization tools is the "lean production".

Lean production is a systematic approach that identifies weaknesses and it prevents consequently unnecessary wasting of resources by continual improvement of the processes. The term wasting in this context means all the activities that do not bring any added value [2]. The main task of lean production is therefore to eliminate wasting in every part of the production, that is, from the first customer contact, through all supply networks, the production process itself to the dispatch of the finished product to the customer. This entire process has to be cost-effective, flexible with the utmost regard to customer needs. However, this does not mean a self-serving reduction in costs but rather a maximization of the added value to the customer. It can be said that what exactly the customer desires is done with a minimum number of activities that do not increase the value of the product or the service [3]. The lean production process itself is made up of a wide range of procedures and tools designed to create an optimally set and stable production process with minimal procurement costs, maintenance costs, energy, and also employees.

The basics of this method were laid down in Japan where this method was called "direct production", as it was a shortening of the way from the producer to the customer, accelerating the production of new products and spurring production [4].

This method does not come with a new production model but it promotes an implementation of necessary activities for the first time, faster than the competition and with lower costs. A practical application of intelligent logistics can increase company's profit faster and with less effort.

Basic principles of lean manufacturing are:

- Understanding values from the customer's point of view.
- Value Stream Analysis.
- Reduction of waste.
- Continuous flow.
- Implementation of pull system.
- Perfection.

Lean manufacturing tools include JIT (Just In Time), Jidoka (Autonomation, Automation with human intelligence), Kanban, Kaizen, SMED (fast change of tools), Poka-yoke (fail-saving), Visualization/organization of workplace which our research is oriented on and presented in this paper. The phases are distinguished in the implementation of lean production:

- Preparatory phase.
- Diagnostic phase.
- Strategic phase.
- Stability phase.
- Action phase.
- Evaluation phase.

3. Software support for leaning production by optimizing workplace layout

A variety of software products have been used for a long time for simulation, optimization and visualization of production processes. The advantage of using these products is that simulation takes place in a virtual environment outside the workplace which means a significant financial savings compared to real-world experimentation. Tecnomatix and Photomodeler software tools have been used to optimize the layout solution within our research.

Tecnomatix is one of the components of Siemens PLM software. It helps to facilitate understanding of the production systems and the overall concept of the company. The producer defines it as a complete portfolio of digital factory solutions, linking all producing disciplines from the design to the production. We can include among the main benefits [7, 8]:

- Higher company productivity.
- Performance optimization.
- 3D design and company visualization.
- Analysis and optimization of logistics.
- Simulation of the production capacity of the company.

Tools in the Tecnomatix series enable industrial companies to use a concept of a digital company in practice, i.e. to plan and to design production, to design, to verify and to optimize processes and production resources in a digital environment.

Exact digital modelling, simulation, and 3D spatial visualization enable professionals who collaborate on development to visualize and analyse future production processes. Such an assessment will make key decisions possible to be implemented and approved in time and on the basis of a broader understanding. This reduces errors that would otherwise arise only when the production started.

Digitization makes processes possible to be made faster and more accurate while simulation and optimization will ensure in the development phase that an error-free product is produced for the first time without a need for additional costly and time-consuming changes in real production.

The Tecnomatix package includes Process Designer which is designed for planning, optimizing the production process, and creating a spatial layout for the production system. If we design a new production system or optimizing the current one, it is necessary to define an innovative product in the first step.

The next step is to define an individual sub-set of the product and what resources we need for its configuration, Fig. 1. When we know what we are going to produce and with which technologies we can run production planning and determine the production process [7].

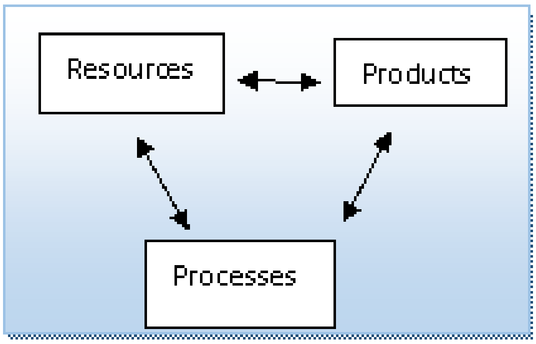

Figure 1. A system interaction of source-products-processes

A comprehensive understanding of interactions among products, resources and processes including the spatial layout of the production system, helps to prevent errors and gives a detailed view of the planned production process. Information derived from a tree structure, Fig. 2, makes it possible to make initial proposals on the course and the use of resources, material flow and the entire production process [5, 7].

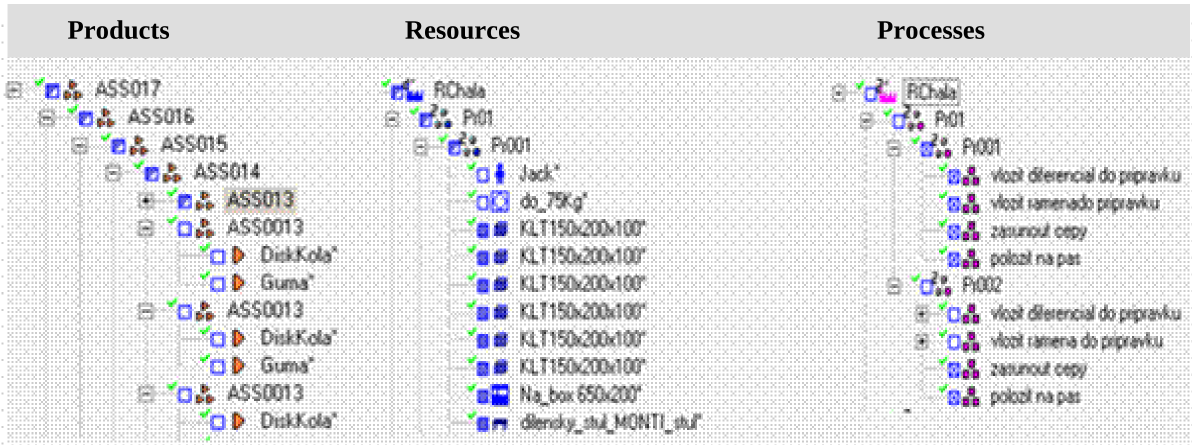

Figure 2. Tree structure Product-Process-Resources (PPR) of kernel

After assigning time to individual operations and defining a spatial layout, it is possible to verify the design's accuracy using Process Simulate tool which is then used to verify spatial layout and eliminate potential problems. An example of simulation output is in Fig. 3.

One of the possibilities of creating 3D models of real objects is digital photogrammetry. 3D models of machines and devices can be created in Photomodeller software from images created with a digital camera. The first step is to calibrate the camera because the individual cameras have a different focal length and lens distortion. The calibration itself consists of printing A4 calibration sheets that are placed on the floor in 5x3 grid. It is necessary to use a tripod and to turn off additional camera functions to ensure photographs homogeneity for better picture quality.

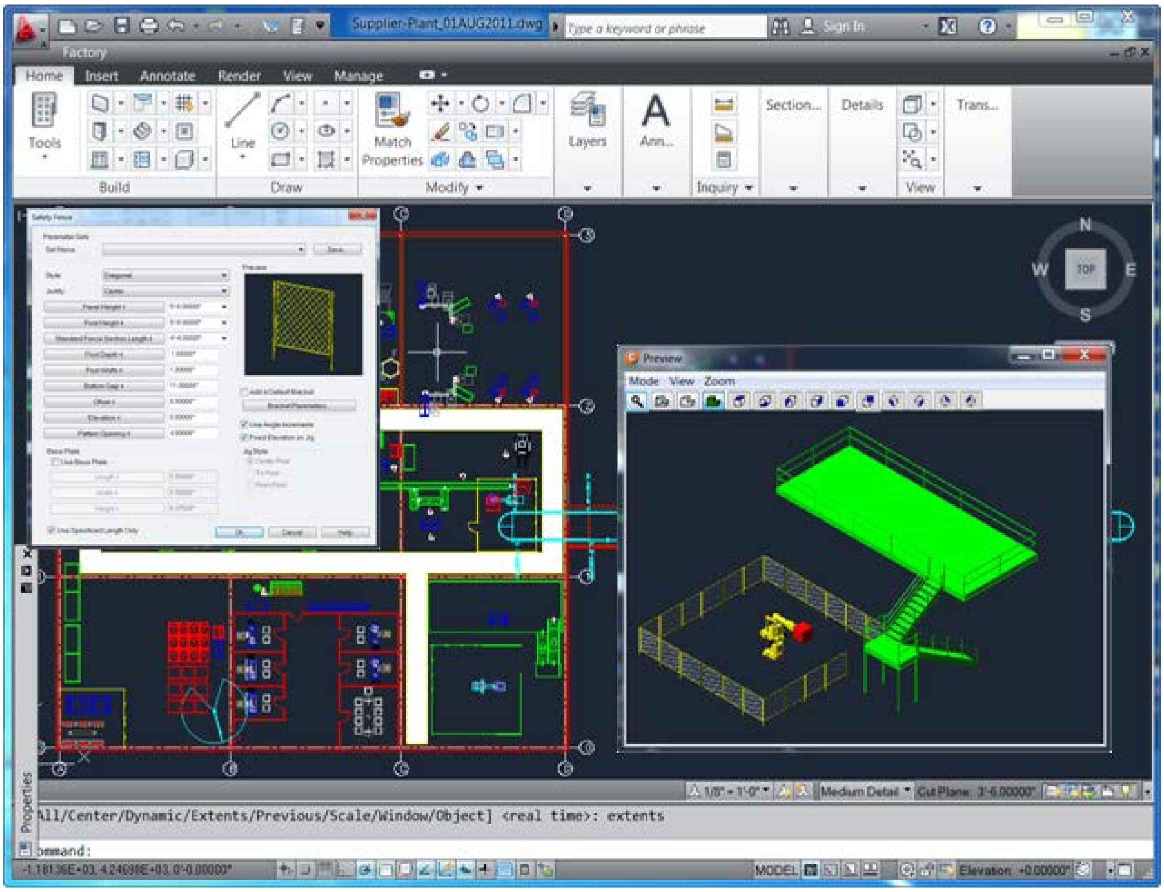

Figure 3. Dispatch verification process

The first series of photos are taken from all four sides while the camera is in the horizontal position. Other series of photos are created when the camera is rotated by 90 degrees each time. The photographs are processed by the software and the calibration for the particular camera is saved, Fig. 4.

Modelling is performed using a calibrated camera. The object has to be scanned from multiple angles so that each point is at least two photographs. Subsequently, the selected point is marked on all scans [7].

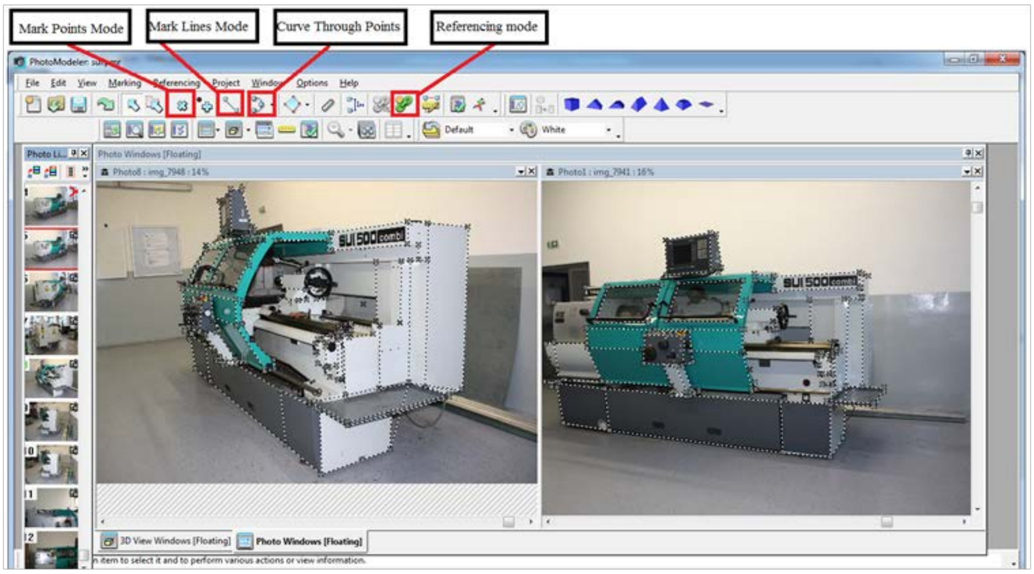

Figure 4. Photomodeler environment

The points need to be connected in the next step to form a wire model of the object, Fig. 5.

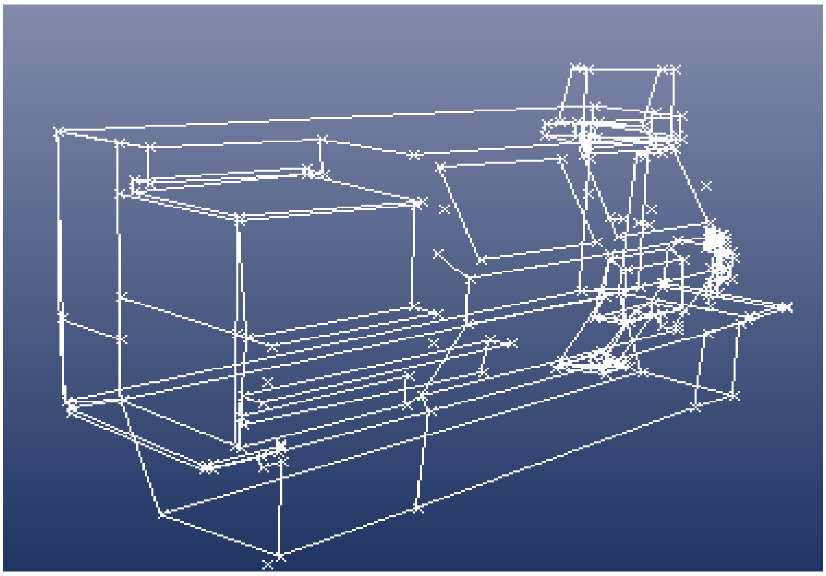

Figure 5. The wire model of production device

The last step is to use textures from photographs to create the final 3D model which can be used to specify the exact dimensions, Fig. 6.

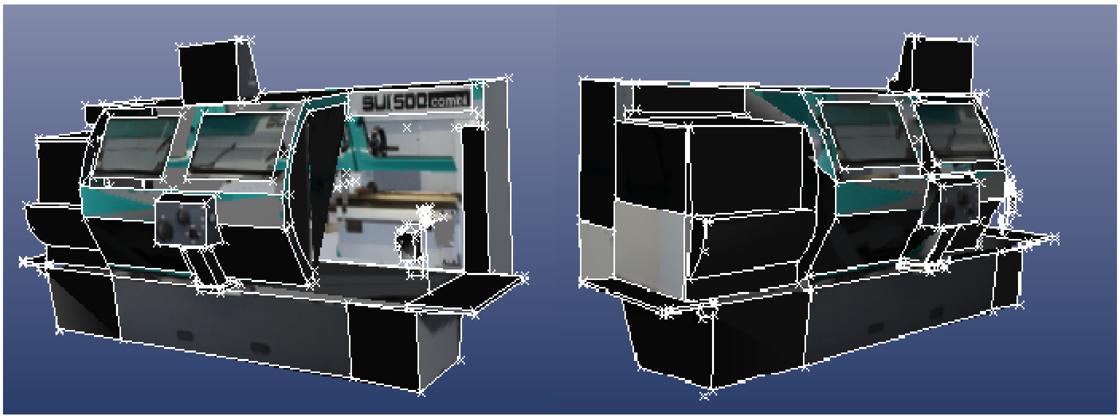

Figure 6. 3D model of the lathe

It is possible to assemble a 3D model of all devices in the production system as well as the production system as a whole in this way.

4. Capacity calculations for modelling the structure of the workplace

A processing of detailed capacities calculations, the number of production and handling equipment according to exact plan can be implemented in a:

a. Static form (static capacitive calculation – CC of DRV): The static capacitive calculation reflects an average need of machines and workplaces in the projected unit for the whole selected period.
b. Dynamic form (dynamic capacitive calculation - DCC): Dynamic capacitive calculation, Fig. 7, is characterized by indicating an immediate need of machines and workplaces at a pre-selected time period.

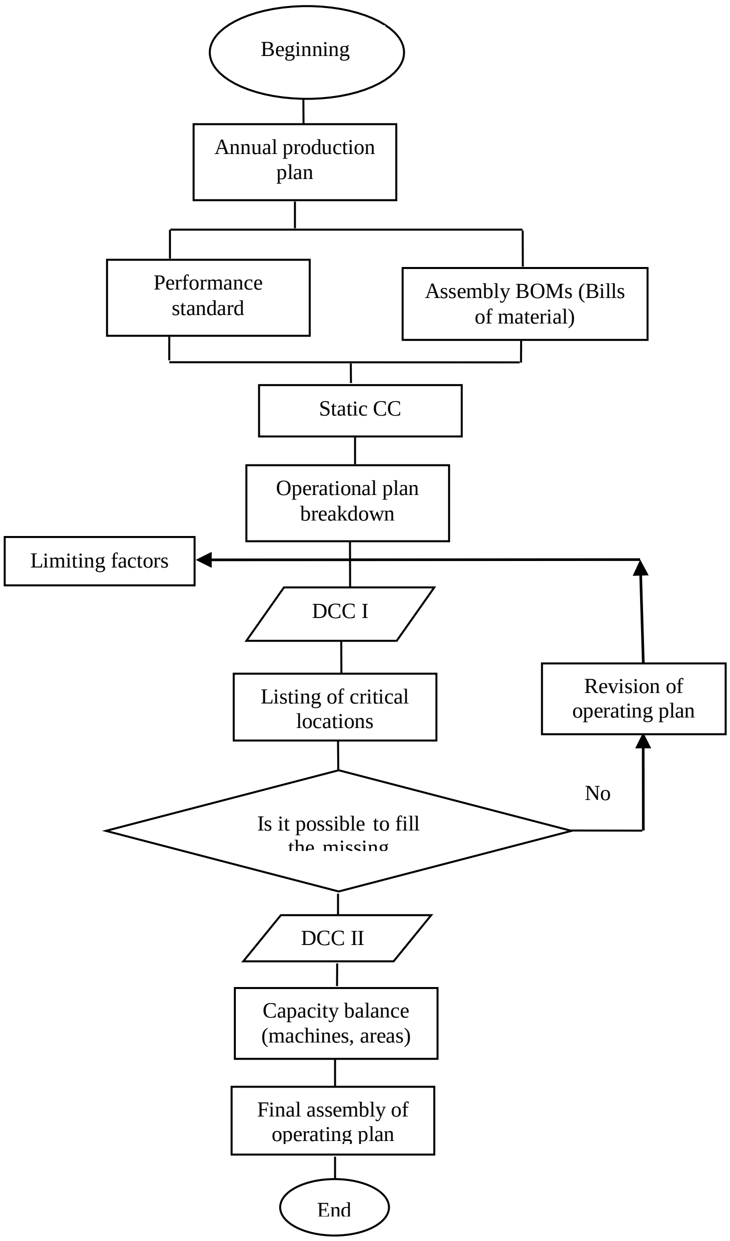

Figure 7. Flow diagram of the use of dynamic capacitive calculation

A calculation of capacitive requirement of one workplace per type of the final product is determined by the formula:

$$k=\frac{N*Q}{E_f*K_{pn}} \qquad (1)$$

Where:

N - Performance standard (man-hour/pc).
Q - Produced quantity.
E_f - Efficient production fund (h/year),
K_{pn} - Fulfilment of standards $\left(\% * \frac{1}{100\%}\right)$.

If a larger quantity of the final products is produced, the formula will have the following form:

$$k=\frac{N_1*Q_1+N_2*Q_2+...+N_n*Q_n}{E_f*K_{pn}} \qquad (2)$$

Depending on a need to determine the quantity of employees (k_v), machines (pcs) or workplaces (k_p), we substitute E_{fr}, E_{fs}, E_{fp}, efficient funds according to the determined change.

5. Capacitive calculation of machine requirement

When calculating capacity requirement for the machines, an operating coefficient K_0 has to be taken into account. The operating coefficient takes into account the number of employees serving one machine, so $K_0>1$ applies. In practice, however, the opposite case occurs when several machines are serviced by one employee, then $K_0<1$ (for example, if the machine is operated by three employees $K_o=\frac{1}{3}$). The formula for calculating the machine then takes the form:

$$K_s=\frac{N*Q}{E_{fs}*K_{pn}*K_0} \quad (3)$$

N expresses the product performance standard which we calculate as follows:

$$N=\sum_{i=1}^{m}\sum_{j=1}^{n}\left(T_{ac,ij}+\frac{T_{bc,ij}}{d_i}\right)*q_i*\frac{1}{60} \text{ (man-hour/execution)} \quad (4)$$

Where:

m- A number of parts produced in the workplace.
T_{ac}- Time (min).
T_{bc}- Time of preparation and termination related to the production batch.
d- Size of production batch.
q- A number of equal parts needed for one final product.

The machine's capacitive calculation and the number of machine usage predate the number of machines. The use of a machine is then calculated as a ratio between the theoretically calculated requirement and the determined number.

$$\eta=\frac{k_{teor}}{k_{det}}*100\ (\%) \quad (5)$$

Also important is the use of the machine:

$$\eta_s=\frac{N*Q}{E_f*K_{pn}*K_0*k_{skut}}*100\ (\%) \quad (6)$$

The use of the machine depends directly on the predetermined change. Cross-checking is used again by comparing the hours worked at the selected workplace and the efficient time fund of the workplace. We shall then determine the actual monthly use of the machine from the formula [3, 4].

$$\eta_s=\frac{H}{E_f*n}*100\ (\%) \quad (7)$$

Where:

H - Real monthly hours worked.
E_f -Effective monthly fund of the machine.
N- Number of working machines.

Permeability of workplaces: Capacitive workplace permeability calculations are used to determine the maximum achievable production volume of a workshop, line, or plant.

Capacity permeability of the workplace means the highest number of the most important products that pass through the workplace for the planned time unit (usually per year).

$$Q_{max}=\frac{n*E_f*K_{pn}*K_0}{N} \quad (8)$$

Where:

Q_{max} - The permeability of the workplace.
N - Number of machines per work piece in pc.
E_f - Efficient Time Machine Fund in h/year.
K_{pn} - The coefficient of performance fulfilment.
K_0 - The operator ratio.
N - Product performance standard in Ps/year.

If more than one equally important product is produced at the workplace, then the maximum achievable production volume is determined as the sum of the pieces of the individual products.

$$\sum Q_{i\max}=Q_A+Q_B+...+Q_z \quad (9)$$

6. Conclusion

The created 3D models and the capacitive dimensioning model can be then imported into simulation software that supports the following formats: 3ds, 3dm, csv, dxf, fbx, igs, kml, kmz, las, ma, ms, obj, stl, wrl.

The selection and optimization of layout solution of the machines and equipment is becoming more and more important as it is a prerequisite for effective and intelligent production in general. The lean production model which is used by the vast majority of multinational also plays a quite important role. For example, at the end of 2011 Volkswagen Slovakia was awarded the prize for the fastest automobile production in Europe. It is possible to achieve excellent results by using these methods because by its superiority, it increases the overall value of production processes and the production system as a whole.

The current boom of computer technology and its associated software products has also hit the area of designing production workplaces in the form of 3D imaging of designed and optimized solution [9]. This creates a proposal for an innovative layout solution that can be further optimized using simulation. Specific models of individual machines, devices, and the system as a whole can also be created in other graphical software and subsequently implemented into simulation software, enabling for faster visualization of variants of the selected solution. A great advantage of visualization is a clear interpretation of the results and the benefits of the proposed solution.

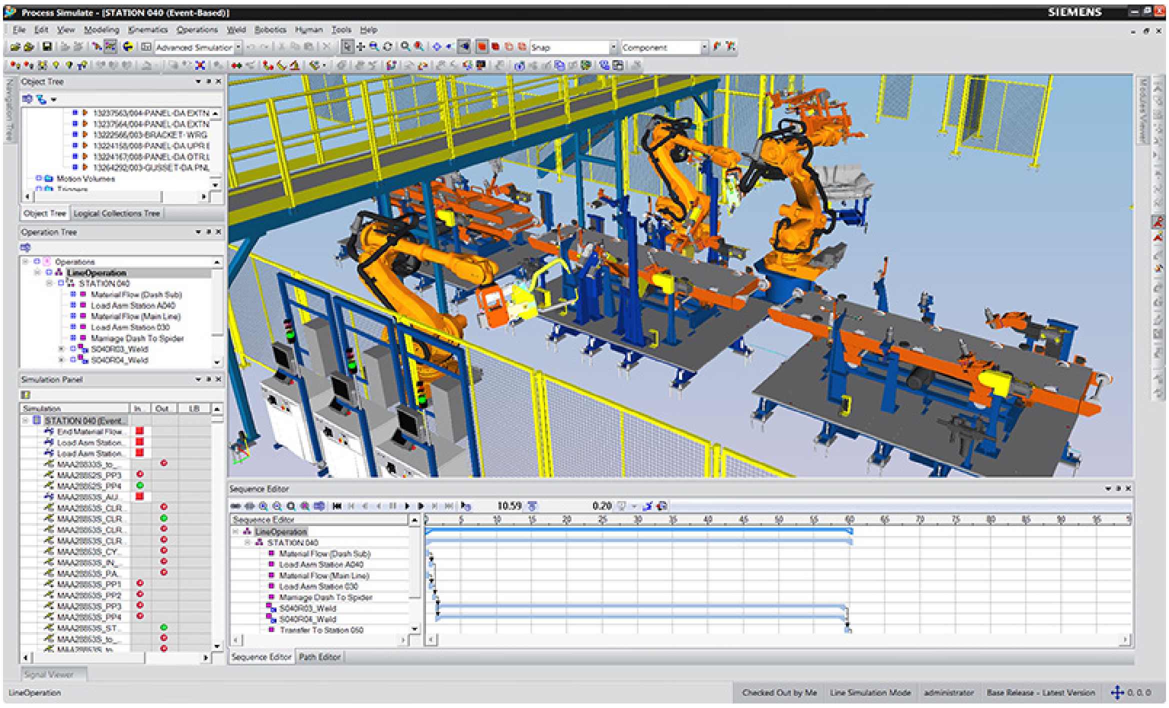

Figure 8. Output from the simulation of the production system layout solution

An application of the latest theoretical-methodical knowledge and software products in the area of deployment methods and lean production, results in more effective manipulation logistics of production processes and the production system as an intelligent whole, Fig. 8.

Acknowledgement

This work has been supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic (Project VEGA 1/0251/17)

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