

ACTA SIMULATIO

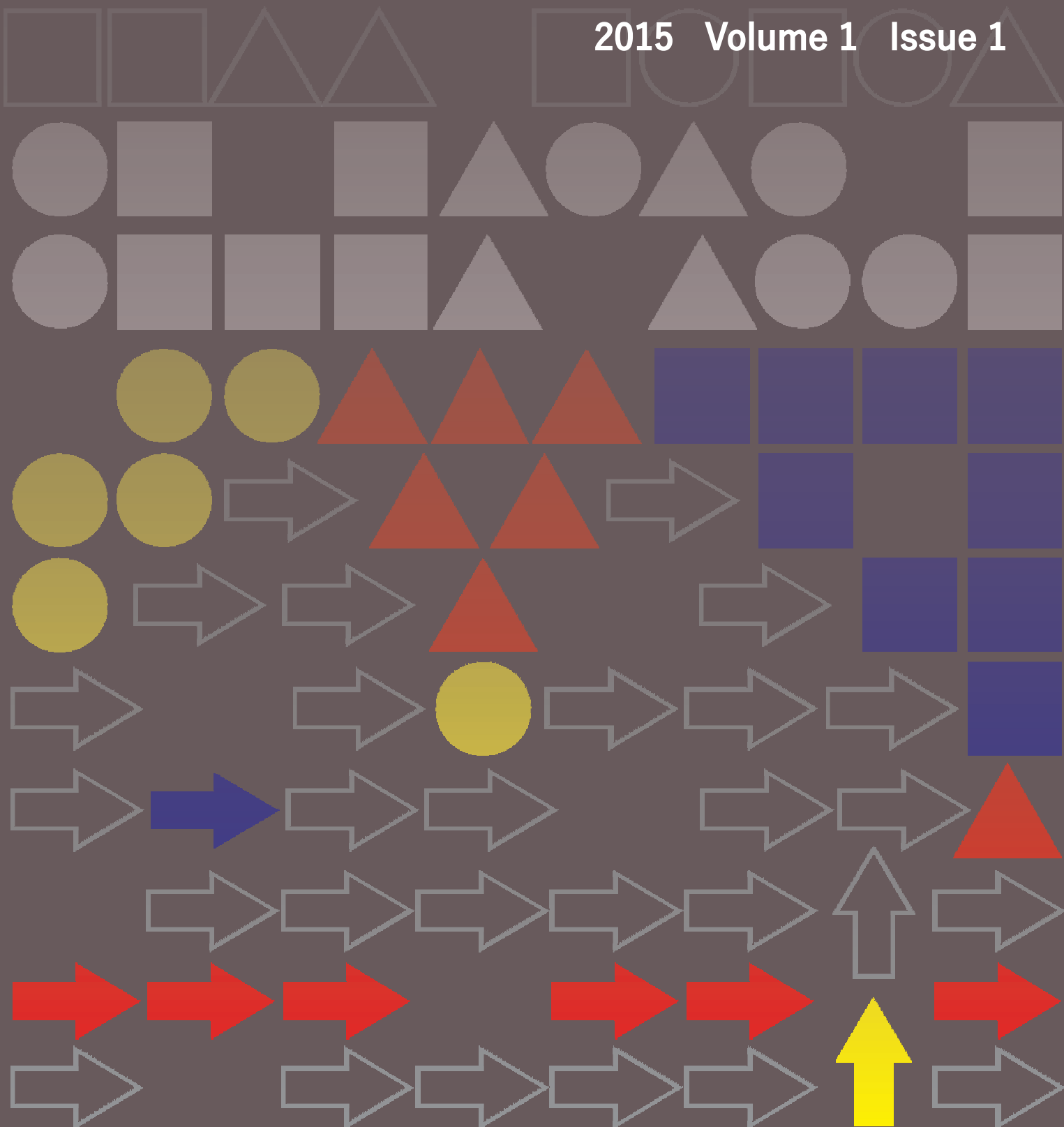
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Miriam Pekarčíková

TU of Košice, Faculty SjF, Institute of Technologies and Management, Department of Industrial Engineering and Management, Némcovej 32, 042 00 Kosice, e-mail: miriam.pekarcikova@tuke.sk

Peter Trebuňa

TU of Košice, Faculty SjF, Institute of Technologies and Management, Department of Industrial Engineering and Management, Némcovej 32, 042 00 Kosice, e-mail: peter.trebuna@tuke.sk

Marek Kliment

TU of Košice, Faculty SjF, Institute of Technologies and Management, Department of Industrial Engineering and Management, Némcovej 32, 042 00 Kosice, e-mail: marek.kliment@tuke.sk

Radko Popovič

TU of Košice, Faculty SjF, Institute of Technologies and Management, Department of Industrial Engineering and Management, Némcovej 32, 042 00 Kosice, e-mail: radko.popovic@tuke.sk

Keywords: optimization, flow, efficiency, diagram, graph

Abstract: Paper deals with the use of graphical methods in industrial practice. In the case study gives concrete expression to the use of a Gantt chart and CPM method for improving the efficiency of logistic support in company which implements a new production line. It is a way to optimize various related activities, which creates conditions for the overall effective project management in company.

1 Introduction

Management of the process itself is a complex and in addition dynamic operation for the planning, management, evaluation results and feedback control. The holder of these activities is usually chief executive, whose role is to ensure target system behaviour. To effectively manage multiple projects is necessary systemic approach and adequate availability of equipment and software in company. In this case may be helpful just the graphical project management method, shown below.

The main precondition for effective use of graphical methods in project management is to meet all the technical and methodological conditions as the definition of the subject, the objectives, resources, capacity, financial security and other related matters. What is important is the positive attitude of the management for the use of such methods in the business and correct staff motivation in this area.

In the lower part of the article is prepared case study in which was used just graphical tools in the context of optimizing the logistics flow in the company.

2 Stages of preparation the logistic flow optimization

Table 1 describes the various activities to be carried out prior to completion of logistic flow optimization. Therein are specified tasks which include individual

stages of realization, the sources from which they derive the information necessary to ensure that the sub-targets will be direct to fulfill the main objective. Who is responsible for fulfilling the tasks of the stages, through which it ensures that no one shy away from responsibilities and duration of each stage.

These preliminary stages of implementation of logistic flow optimization are general and lasting 58 days.

Stages of implementation the production line to logistic flow optimization

In following table (Table 2) are proposed stages that describe the individual actions to be taken to realize the intro Duration of activities introducing the production line in order to optimize logistic flow is 27 days.

Tab. 3 shows the timetable for the introduction of the production line in order to optimize logistic flow, which contain the individual actions to be taken to realize the introduction of a new production line. It is necessary to observe the sequence of individual steps, duration of operation, the beginning and end of each activity.

Subsequently was the Tab. 3 displayed using a Gantt chart (Fig.1), which shows processed the forward scheduling? It is scheduling to the earliest possible starting date.

Also was through the method CPM created the network diagram (Fig. 2) of the process in which is shown the critical path. Critical path shows the activities to be carried out on time, if there is a delay in the implementation of some of the activities

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of non-compliance occurs upon completion of the introduction of the production line designed to optimize material flow. And its activities: 1, 2, 5, 6, 7,

8, 9, 10, 12, 13, 14, 15, 16, 17. The duration of action is 85 days.

Tab. 1 Phases of preparation of the introduction of the production line

	Title	Task	Resources	Result	Responsible	Time/days
1.	creation of a project team	people's choice	database of company	team of project	director	5
2.	goal setting	getting to know definition of work results	Debate	matrix powers and responsibilities, targets for implementation	team leader	3
3.	analysis	analysis of the external environment Analysis of the internal environment analysis of future processes	Internet, documentation	description of processes	team leader	10
4.	variants of solutions	proposals	computer simulations, documents	variants	team leader	20
5.	analysis of options	analysis of financial, personnel, time, risk intensity	results of its own analysis, documentation	selection of the most suitable alternative	team leader, director	12
6.	method of implementation	establish the budget, personnel, time	documentation	implementation plan	team leader, director	8

Tab. 2 Phases of logistic flow optimization

	Title	Task	Resources	Result	Responsible	Time/days
1.	preparation for the introduction of the production line	request for bank loan salutation of production equipment suppliers salutation of persons interested in old production equipment salutation of supplier of handling equipment negotiation of contracts	internet documentation		team leader, director	13
2.	removal of production facilities	supply of handling equipment removal of old production facilities production facilities for the manufacture of aluminum products, transfer to storage	documentation		team leader	3

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	Title	Task	Resources	Result	Responsible	Time/days
3.	supply of production facilities	supply of production facilities	documentation	production line	team leader, supplier	5
		Installation and deployment of production facilities				
		staff training				
		importation and deployment of production facilities for the production of aluminum products				
		painting of escape routes				
4.	trial operation	removal handling equipment	documentation standards	production line ready to run	team leader, quality controller	5
		testing of production facilities				
		correct deficiencies				
5.	start of production	full operation of the production line	documentation	increase of productivity	team leader, director	1

Tab 3. Timetable for the introduction of the production line to optimize logistic flow

	Activity	Predecessor	Duration	Start of the activity	Finish of the activity
1.	Project: new production line	-	58 days	20.4. 15	8.7. 15
2.	Request for bank loan	1	10days	9.7. 15	22.7. 15
3.	Salutation of production equipment suppliers	2	1day	23.7. 15	23.7. 15
4.	Salutation of persons interested in old production equipment	2	1day	23.7. 15	23.7. 15
5.	Salutation of supplier of handling equipment	2	1day	23.7. 15	23.7. 15
6.	Supply of handling equipment	2;5	1day	24.7. 15	24.7. 15
7.	Removal of old of production equipment	4;6	2days	27.7. 15	28.7. 15
8.	Removal of production equipment for the production of aluminum products into stock	4	2days	24.7. 15	27.7. 15
9.	Supply of production equipment	3;7;8	2days	29.7. 15	30.7. 15
processed 10.	Installation and deployment of production equipment	9	3days	31.7. 15	4.8. 15
11.	Staff training	3	5days	24.7. 15	30.7. 15
12.	Importation and deployment of production facilities for the production of aluminum products	10	1day	5.8. 15	5.8. 15
13.	Labelling of escape routes	12	1day	6.8. 15	6.8. 15
14.	Removal of handling equipment	12;13	1day	7.8. 15	7.8. 15
15.	Testing of production equipment	11;14	2days	10.8. 15	11.8. 15
16.	Correct deficiencies	15	2days	12.8. 15	13.8. 15
17.	Full operation of production line	11;15;16	1day	14.8. 15	14.8. 15

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	Task name	Duration	Start	Finish	Predecessor
1	Project: new production line	58 dny	20.4.15	8.7.15	
2	Request for bank loan	10 dny	9.7.15	22.7.15	1
3	Salutation of production equipment	1 den	23.7.15	23.7.15	2
4	Salutation of persons interested in old production equipment	1 den	23.7.15	23.7.15	2
5	Salutation of supplier of handling equipment	1 den	23.7.15	23.7.15	2
6	Supply of handling equipment	1 den	24.7.15	24.7.15	2;5
7	Removal of old of production equipment	2 dny	27.7.15	28.7.15	4;6
8	Removal of production equipment for the production of aluminum	2 dny	24.7.15	27.7.15	4
9	Supply of production equipment	2 dny	29.7.15	30.7.15	3;7;8
10	Installation and deployment of of production equipment	3 dny	31.7.15	4.8.15	9
11	Staff training	5 dny	24.7.15	30.7.15	3
12	Importation and deployment of production facilities for the	1 den	5.8.15	5.8.15	10
13	Labeling of escape routes	1 den	6.8.15	6.8.15	12
14	Removal of handling equipment	1 den	7.8.15	7.8.15	12;13
15	Testing of production equipment	2 dny	10.8.15	11.8.15	11;14
16	Correct deficiencies	2 dny	12.8.15	13.8.15	15
17	Full operation of production line	1 den	14.8.15	14.8.15	11;15;16

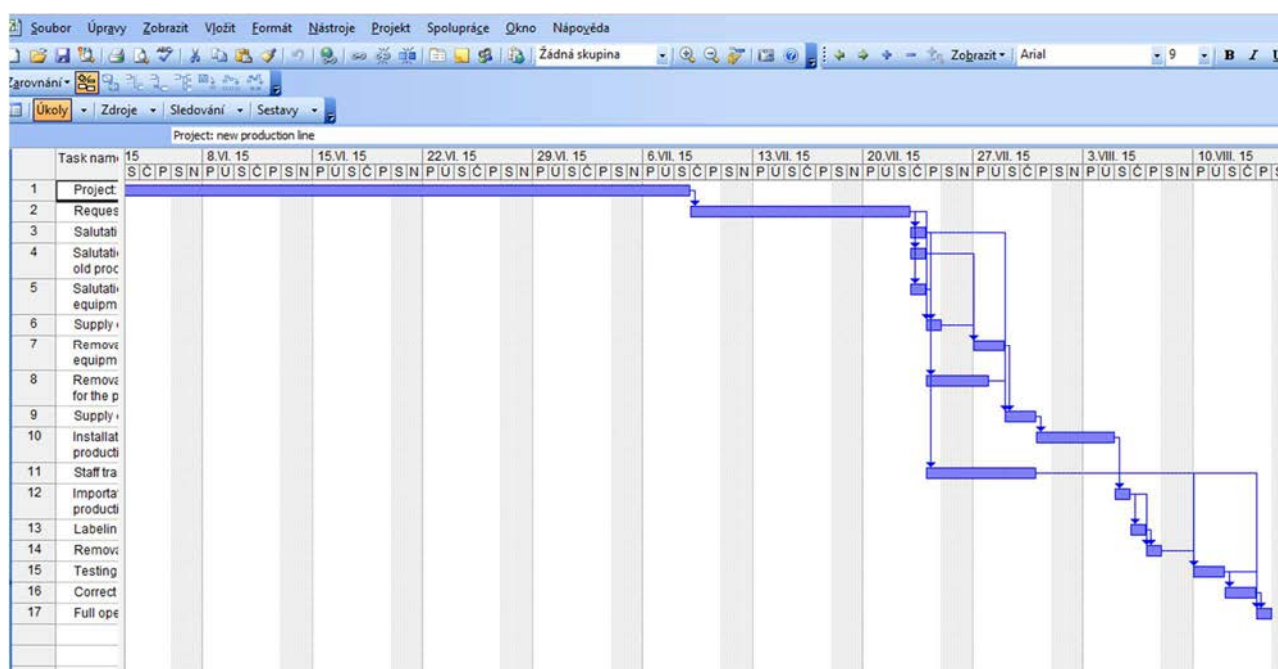


Fig. 1 Gantt Chart for the introduction of the production line to optimize logistic flow

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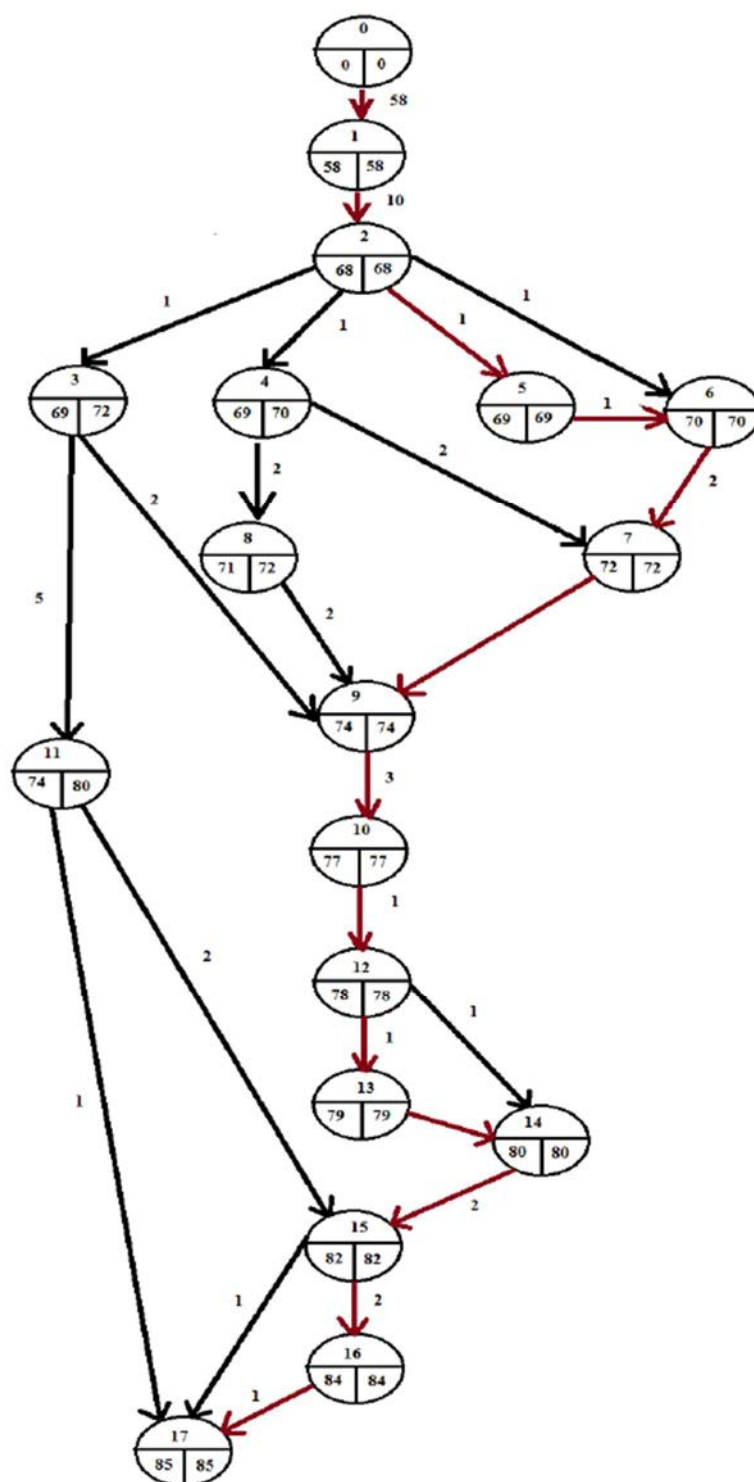


Fig. 2 Use of critical path method to optimize logistic flow

Conclusion

By the case study solving was applied Gantt chart to show during the various project activities and their ensuring in terms of resources - financial, personnel,

time capacity. Activities are captured in horizontal line segments that are defined on the timeline. Graph depicts for each activity period in which this is done. The Gantt chart has been drawn up with the help of MS Project. This is a clear set of project management in company.

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PROCEDURE FOR DRAFTING A PROJECT AND SELECT THE MOST APPROPRIATE VARIANTS OF SIMULATION MODELS FOR OPTIMIZING ASSEMBLY LINE DOORS OF CAR

Marek Kliment; Peter Trebuňa; Radko Popovič; Miriam Pekarčíková

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Marek Kliment

TU of Košice, Faculty of Mechanical Engineering, Institute of technology and management, Department of Industrial Engineering and Management, Nemcovej 32, 04 200 Košice, marek.trebuna@tuke.sk

Peter Trebuňa

TU of Košice, Faculty of Mechanical Engineering, Institute of technology and management, Department of Industrial Engineering and Management, Nemcovej 32, 04 200 Košice, peter.trebuna@tuke.sk

Radko Popovič

TU of Košice, Faculty of Mechanical Engineering, Institute of technology and management, Department of Industrial Engineering and Management, Nemcovej 32, 04 200 Košice, radko.popovic@tuke.sk

Miriam Pekarčíková

TU of Košice, Faculty of Mechanical Engineering, Institute of technology and management, Department of Industrial Engineering and Management, Nemcovej 32, 04 200 Košice, miriam.pekarcikova@tuke.sk

Keywords: simulation, optimization, variant, statistics, project

Abstract: The content of this paper is a proposal for assembly line doors of car and their components. It describes the Procedure for drafting a project for evaluate the suitability of alternatives using simulation models of these variants workplaces. These of variants each other qualitatively and quantitatively compares and describes effective and optimal. At the beginning of post briefly describes the theoretical knowledge of the field of simulation and clarifies their advantages and disadvantages.

1 Simulation and its use

The notion of simulation is presented as statistically - research method, which follows from the nature of the system under examination, from which are obtained information on the researched system. Output data using computer simulations give a realistic picture of the documents that are necessary for the development of downstream analyzes. The cycle uses the simulation model at an early stage is to build the model to the real system, where they carry out the necessary experiments. These are then interpreted correct results, which are constantly optimized to improve the understanding of the actual or future system. Computer simulation does not allow obtaining direct, optimal results, respectively. their solutions. Therefore, it is applied as a support system. With his help is possible to test different effects carried on the simulation models. The result is a solution that can help improve productivity and quality. The object of each generated simulation process is to identify the goals that are helpful to achieving specific results. When simulating systems, objectives determined by the structure of planning, experimentation and subsequent evaluation. By help clearly defined objectives simulating and experimental systems, it is necessary to ask questions such as:

- What is achieved by a given stimulation?
- How much time is required to the simulation?

- Which aims are achieved using simulation?
- Why is needs aim achieved by the help a simulation?
- Who is responsible for target a simulation?

The main advantage of simulation lies in its method of interpretation of the simulated process. By using in the currently available simulation software can convert simulation in the process of the desired time (several minutes) to obtain the amount of output information in the form of the output message, such as use of machinery, downtime, efficiency, critical path.

Processes in which a suitable resp. inappropriate applied simulation are shown in Table 1.

Table 1 Suitability for use simulation in processes

Suitability for use a simulation	Inappropriateness for use a simulation
If it is necessary in a short time draw conclusions behavioral processes, which in real time was a longer	Simulation can be administered less accurate results than direct mathematical analysis
Creating a virtual presentation behavior of the new system using the selected animation	The need for financial resources exceeds the limit

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Experimentation using simulation process does not disrupt the functioning of the real system	Been studied system can be addressed a mathematical way (analytically)
The use of simulation for verification of the analytical solutions - process control	Insufficient and inaccurate information to support the simulation experimenting
Removing badly proposed experiment and thus avoiding unnecessary disaster, waste of resources	The credibility and reliability of the models is low - simulation model represents only stochasticky system elements
Properties in under the examination system are changing (changing very quickly, resp. slow)	Required demanding hardware for of complex realistic simulation systems
Use as a tool to gain the experience, resp. workout, training	To create the model required expertise and training
More flexible presentation as mathematical simulation	

2 Proposal phase of the project

In this first phase, propose a model element halls for manufacturing doors, here are formed chosen models of machinery and auxiliary equipment. Designing takes place on the basis of technological production layout together with the implementation of compliance with technological and handling areas. The draft plan view of two variants of the line was used software AutoCAD Architecture (Fig. 1.2)

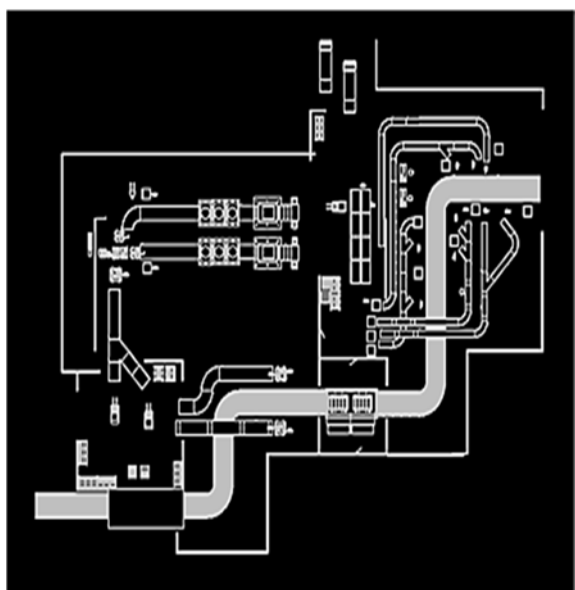


Fig. 1 Proposal layout in variant 1

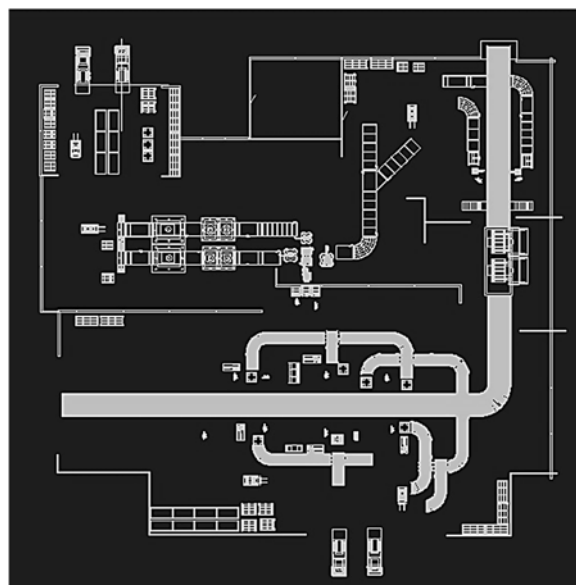


Fig. 2 Proposal layout in variant 2

3 Simulation and a optimization phase of the project

The simulation-optimization phase of the project was used alone simulation tool to create a simulation model of the production line. This tool was a software module Tecnomatix Plant Simulation. When processing simulation models was necessary to know all the components required for the manufacture and installation of doors and according to them layout design workplaces. At the Figure 3 shows the essential components of the door.

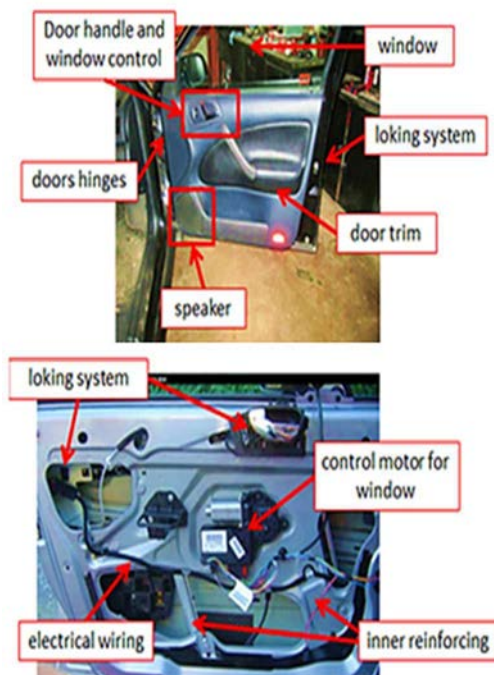


Fig. 3 Parts in the car doors

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3.1 Proposal variants of production

Processing simulation models originated by the insertion of duplicate objects from the tree structure formed on a simulation desktop using drawing documentation of and technological operations.

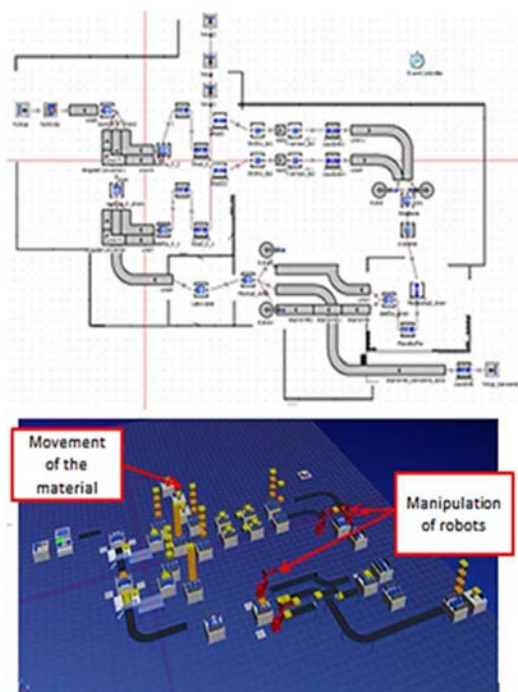


Fig. 4 Simulation model for Variant 1 in 2D and 3D

After entering the time horizons of all objects began tracking simulation process, which had to be constantly tweaking mostly conveyor time structure to achieve the desired parameters of the whole production line. This a lengthy process with the task of removing various deficiencies in the production process. As one variant is not possible to assess whether the correct and most appropriate for the production process, it is necessary to propose at least 2 variants. The second type of layout configuration plant and equipment was specific in that compared to Option 1 has two storages and shorter length of the conveyor to different sections of the production line. The second type of workplace generated 3D model (Fig 5) is different structure and length of the conveyor. Edit conveyor was also treated in a similar manner to the first variant.

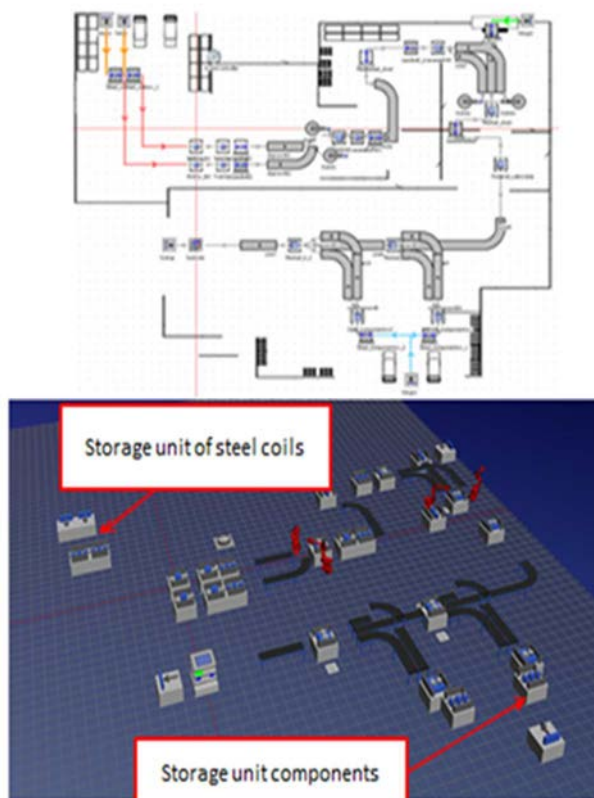


Fig. 5 Simulation model for Variant 2 in 2D and 3D

Manufacturing time of each operation are shown in Table 2. This is necessary to know the times for setting the different elements of the simulation and comparison at change layout workplaces.

Table 2 Manufacturing time of each operation

Operation	Time of the operation (s)	Manipulation time (s)
Shearing	20	2
Surface forming	30	2
Welding	120	10
Door assembly	120	50
Paint Application	300	10
Door dismantling	120	50
Assembly components	180	100
Inserting door and control	300	80
Together	1190 s	304 s

Output statistics needed for the evaluation is obtained by running the quick simulation, which are all referred to objects in the simulation area, the program generates detailed output statistics. Then carries out evaluation and appropriateness of the variant.

When comparing variants of assess data relating to the productivity of individual items in the simulation model, further compare, for example, material flow both

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variants. Table 3 highlights the difference between the two variants, and displays data on the use of machines or individual operations in the manufacture of a door.

Table 3 Comparison of productivity selected Machines

Activity / operation	Variant 1 %	Variant 2 %	The suitability of variant
Shearing press 1	17,27	23,37	V2
Shearing press 2	9,09	23,37	V2
Forming press 1	10,30	30,43	V2
Forming press 2	4,85	30,43	V2
Assembly reinforcement	9,09	33,70	V2
Welding	9,09	32,61	V2
Installation of doors on the car body	18,18	8,70	V1
Lacquering	45,44	21,74	V1
Assembly door components 1	18,18	21,74	V2
Assembly door components 2	18,18	21,74	V2

The evaluation of the output is defined optimum use of machinery and operations in favor of the second variant in ratio of 8/2, which is mainly reflected in the operations of pressing and folding operations along with welding.

Output statistics provide also information on the use of industrial robots KUKA in the manufacturing process of welding and material handling. Are taken into account data in the form of waiting times material when folding door reinforcement in the process of welding and assembly of components for bodywork.

Table 4 Statistics for manipulation KUKA robots

KUKA robots	Variant 1	Variant 2
	Waiting time for material%	Waiting time for material%
KUKA 0	23,28	94,14
KUKA 1	54,84	93,62
KUKA 2	1,85	90,56
KUKA 3	84,52	16,54
Average waiting time	41,12 %	73,72 %

In the process of waiting time in material handling is a useful first indications variant with an average waiting

time 41.12%, compared to the waiting longer variant 2 with a 73.72% average waiting time. The use of robots in material handling in the production process (Tab.5).

Table 5 The range materials handling with of the robots

Variant 1					Variant 2				
Object	Rotation	Empty	Rotation	Loaded	Object	Rotation	Empty	Rotation	Loaded
	Portion	Sum	Portion	Sum		Portion	Sum	Portion	Sum
KUKA	0.08%	2.6565	0.09%	2.9517	KUKA	0.90%	49.7199	0.90%	49.5640
KUKA1	0.29%	9.6565	0.26%	8.7468	KUKA1	0.59%	32.5000	1.16%	1:04.0000
KUKA2	0.12%	4.0000	0.15%	5.0000	KUKA2	0.01%	0.2952	0.01%	0.6695
KUKA3	0.00%	0.0000	0.03%	1.0000	KUKA3	0.07%	3.7133	0.05%	2.6780

From the outputs listed in Tab.5 shows that Variant 2 is optimal, as it provides a greater range of operation of material handling processes compared to first variant. After an evaluation of selected parameters productivity of machines, as well as working and waiting times, along with other generated and selected data and statistics presented simulation software can be considered more appropriate Variant 2.

Conclusions

Simulation software facilitate the activity in decision-making process when comparing different variants of optimization and improvement of production efficiency. With The comparison of statistics, it is clear that in this case is for improve the process of making effective Variant 2. This assessment possibilities of improvement of the production can be conducted at any intended optimization of an existing of production, and also in the design of new production lines and halls. Therefore, the use of simulation and digitization of primary production processes highly preferred option and currently is becoming a necessity. Such verification of optimal variants in the planning process prevent problems during the implementation of production and saves money and time in debugging production factors. It has its advantages even when you are archiving data on the project and the formation of a similar project in the future, these data can be used and thus shorten designing time. The advantage is the fact that the Evaluation Team which working on a project need not be physically gathered at one place and time, but you can share the information and always have on hand the current version in which the project is located. Such backup and data editing helps in managing the full life cycle of the product and production

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SIMULATION AS A PART OF BUSINESS PROCESS MODELING

Radko Popovič; Peter Trebuňa; Marek Kliment; Miriam Pekarčíková

SIMULATION AS A PART OF BUSINESS PROCESS MODELING**Radko Popovič**

TU of Košice, Faculty of Mechanical Engineering, Institute of technology and management, Department of Industrial Engineering and Management, Nemcovej 32, 04 200 Košice, radko.popovic@tuke.sk

Peter Trebuňa

TU of Košice, Faculty of Mechanical Engineering, Institute of technology and management, Department of Industrial Engineering and Management, Nemcovej 32, 04 200 Košice, peter.trebuna@tuke.sk

Marek Kliment

TU of Košice, Faculty of Mechanical Engineering, Institute of technology and management, Department of Industrial Engineering and Management, Nemcovej 32, 04 200 Košice, marek.kliment@tuke.sk

Miriam Pekarčíková

TU of Košice, Faculty of Mechanical Engineering, Institute of technology and management, Department of Industrial Engineering and Management, Nemcovej 32, 04 200 Košice, miriam.pekarcikova@tuke.sk

Keywords: simulation, modeling, process simulate

Abstract: Simulation, especially computer simulation has been in a rapid growth in recent years. Its deployment in practice generally improves production possibilities in many ways. Requirement for computer-simulated production system is to optimize production, where the resolution needs to be ultimately maximizing the savings in production costs and minimizing production time with respect to the quality of the final product. Resources of the computer simulations in the coming years will be increasingly powerful means of competitive producers. Knowledge of simulation and its application in a virtual environment in a connection with real production is already a key tool for the success of many companies nowadays.

1 Simulation of the production processes

Current computer program can imitate the real card game or chess. Process simulation offers computer models of real processes. The model is composed by entering critical operating parameters of real processes (eg. Operational inputs, process flow and resource usage) into the simulation program. By adding specific information on how to change these parameters, the resulting model is able to replace actual process.

Process model allows analysts to monitor the behavior of process from the comfort of the office or lecture rooms, with operations that can commonly take several days or weeks, they are completed within a few seconds. Such a quick process is able to collect and process large amounts of data that would be difficult to obtain during normal operation. Process simulation also helps collect and analyze data, perform with them a variety of experiments and changes without disrupting critical operations running.

Most commercially available simulation packages uses Assay using the "Monte Carlo" method. This method utilizes the principle whereby each successive simulation uses randomly selected combination of input variables from a set of pre-defined input parameters. By implementing simulations in multiple cycles may be using a computer to obtain a large amount of data in a few minutes. This allows analysts to track data for high-speed implementation of operations for greater periods of time

instead of short-term data that would be obtained from the real process. Long-term collection of data offers a much more accurate picture of how performance may vary and importance of processes in terms of time.

An important simulation techniques is a visual computing and logical action. Visualization options allow designers to create high-performance presentation with live animation for the executive management and the owners, so they can watch how the information is transferred or any part of the process before implementing the change and after. The logical action allows users to select different routes and activities based on conditions that are programmatically defined in the model.

2 Simulation possibilities in the Tecnomatix Process Simulate

Simulation of the production processes can be done in many softwares. One of them, especially module of Siemens Tecnomatix software, has many possibilities how to simulate the process. Tecnomatix Process Simulate (Fig. 1) is designed for building new or modifying existing production processes. On the base of simulation you can imagine the future picture of the real production system. 3D Simulation can reflects the actual status and conditions on the running system and of course, after some improvements, it can show the possible figure of the production system. The question about creation of simulation is simple. Engineers need to know, if the

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created simulation will be managed by time sequence (time based) or controlled by signals (event based).

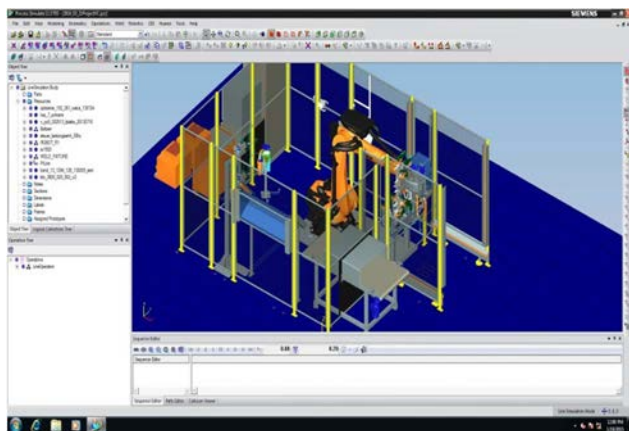


Fig.1 Process Simulate environment

3 Simulation methods

Main build stones of a time-based simulation are resources, products and operations. Time-based simulation is limited by its duration of operation and it is strictly defined to one scenario of a given simulation. Logic of time-based simulations is based on Gantt chart (Fig. 2). It describes a sequence of operations in simulations, so all relationships between operations and duration of each process defined in the operation tree. To build a time-based simulation it is necessary to define kinematics of functional elements (gripper, weld gun, etc.), modeling of all operations (human operations, robotic operations, material flow operations) and create relationships between those operation.

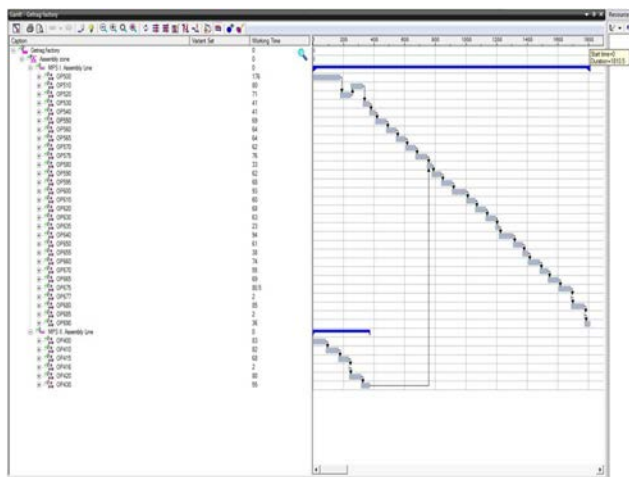


Fig.2 Time sequence – Gantt chart

The Event-Based Simulation module provides a simulation environment that supports the design and verification of sophisticated production stations. The module can simulate production stations where a variety of robots, manufacturing resources, and control devices must function in full synchronization. Process Simulate's

Event-Based Simulation module offers an approach that is much more accurate than conventional time-based (sequence) simulations, creating programs off line and an event-based and flow control simulation that enables you to simulate multiple robots and the surrounding devices in the production station. Using the unique simulation capabilities of the Event-Based Simulation module, OEMs, line builders and system integrators can save time and costs by identifying synchronization and automation problems, long before they start the expensive process of deploying new production stations.

In a conventional time-based simulation, the predefined sequence of operations dictates the simulation of the process. In event-based simulation, the logic of the process and the events that occur during the simulation determine the course of the simulation. The sequence of the operations is only one element of the complete logic definition. Because the events that occur during a simulation can vary, each simulation of the same process can be unique. With a PLC as well as event driven simulation, the sequence of operations is controlled using signal based logic. Various devices are stopped and started through the simulation by setting a signal.

Process Simulate enables the verification of the various segments of the manufacturing process: assembly processes, human labor, welding, continuous processes such as laser welding and gluing a further quantity of robotic processes simulated in the same environment, enabling the simulation of virtual production zones. The simulation emulates realistic human behavior, robotic controllers and PLC logic.

The main functions Process Simulate software module are:

- 3D simulation,
- Static and dynamic collision detection,
- measurement in 3D dimension,
- mapping operations,
- robotic assembly and production planning of roads,
- resource modeling (3D and kinematics)
- simulation of the human tasks
- simulations of discrete and continuous manufacturing processes.
- virtual commissioning

4 Software modules

Siemens software package Tecnomatix has several modules for each area of usage.

Process Simulate Assembly module allows users to verify the feasibility of the assembly process. This technology allows to determine the most efficient sequence of installation, adjustment of supply for the elimination of unnecessary conflict situations and determining the shortest time production cycle. Submodul Assembly Process Simulate provides the ability to choose

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the most appropriate tool for the search process in the tool library, conducting virtual testing and analysis of the consequences of collisions with simulating the full assembly process of the product and tools together.

Module Process Simulate Human (Fig. 3) allows users to verify the design of work stations, verify the achievement of the required safety of the individual parts of a product.

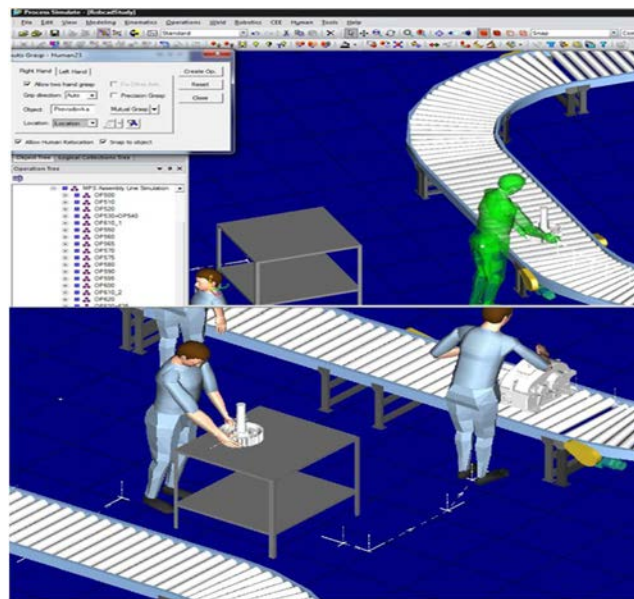


Fig.3 Process Simulate Human

The module offers powerful features for analyzing and optimizing the ergonomics of human activity, thereby providing an ergonomic and safe production process according to industry standards. Using simulation tool of human activity, the user can perform realistic simulation of the human tasks and optimize process times of the production cycle according to the standards of ergonomics.

Process Simulate Spot Weld allows users to design and verify spot welding process with 3D graphics and simulation environment from the beginning of the planning phase up to detailed engineering degrees. The module handles so-called offline programming. This module also enables the simulation of manufacturing of technical tasks such as the distribution of weld spots on individual stations, cycle welding tasks, selection of optimal hot melt guns from the library of existing guns and tools.

Process Simulate Robotics module (Fig. 4) allows users to design and simulate complex manufacturing zones, which are automated with robots. Synchronization of more robot zones with a very complex tasks provides facilitation processes using simulation tools such as assessing cyclical events and control emulator of a particular robot. Robotics simulation tools provide the ability to design without collision path for all robots and optimize their cycle times.

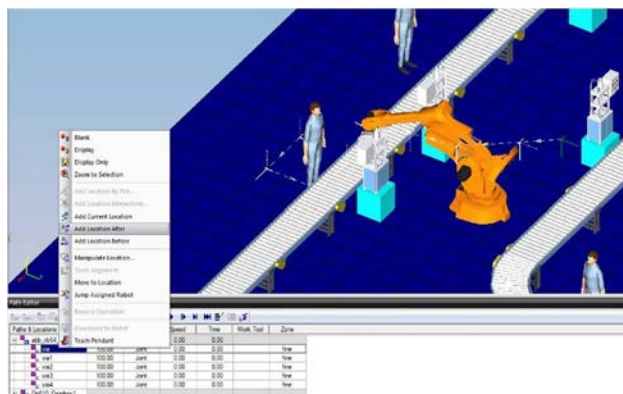


Fig.4 Process Simulate Robotics

Virtual Commissioning Module of Process Simulate allows users to simplify existing manufacturing and technical data from conceptual design to final product manufacture. The module supplies a common integration platform for various disciplines participating in real commissioning of production (mechanical and electrical). Using Process Simulate module Virtual Commissioning users can simulate real PLC code with the actual hardware through OPC and the real robot programs, allowing faithfully virtual commissioning of the production environment.

5 Benefits of using a simulation

Using special software for the virtualization of the production processes have a lot of positives:

- rapid design and deployment of creating a model,
- verify the installation,
- reduces the need for physical verification,
- verify the collisions of robots, automated equipment,
- suitable storage locations, the shelves,
- planning and layout improvements in production.

Most companies looking for savings in purchased materials, overheads, energy. Also focusing on the field of logistics optimization, optimizing material flow, layout of the workplace and human resources is important.

The benefits of optimization in Business processes are:

- reduce the cost of materials handling by up to 70%,
- reduce inventory by 20 to 60%,
- increase the capacity utilization of the space by 30%
- increase in productivity of the current system by 15 to 20%,
- reducing the cost of implementation the necessary changes for a new product to 5 to 20%.

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Conclusions

The goal of simulation is to connect the 3D aspect of the process (resources, parts and operations) to the logic of the process. The Event-Based Simulation better approximates the shop floor process, taking into account many additional elements such as failure scenarios, mixed production, maintenance, and operational problems. In addition to creating a more realistic simulation, event-based simulation enables you to analyze aspects of the manufacturing process that are not possible to analyze in time-based simulations. Tecnomatix Process Simulate has a big offer how to manage production processes by innovative way. Choosing a particular module there is a possibility to design the workplace, design the process, calculating average cycle time, robot-added and non-added values, idle time, analyzing and optimizing a mixed production process in terms of collisions, flow of material, logistics, bottlenecks, time difference between different mixture ratios, analyzing and optimizing maintenance operations, reporting statistics of the process, such as the number of products produced after a given time, the number of times an alternative was applied, etc.

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Review process

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KINEMATICS ANALYSIS OF THE SIX MEMBER MECHANISM IN MSC ADAMS/VIEW

Peter Frankovský

Technical University of Košice, Faculty of Mechanical Engineering, Letná 9, 042 00 Košice, Slovak Republic

Darina Hroncová

Technical University of Košice, Faculty of Mechanical Engineering, Letná 9, 042 00 Košice, Slovak Republic

Ivan Virgala

Technical University of Košice, Faculty of Mechanical Engineering, Letná 9, 042 00 Košice, Slovak Republic

Keywords: MSC Adams/View, mechanism, simulation, kinematics analysis

Abstract: The aim of this article is to develop a functional model of six-member mechanism in ADAMS/View software and his following complete kinematics analysis. We analyze the movement of the members of the mechanism. Kinematics analysis was performed analytically and graphically. The mechanism has been also modeled and solution in the program MSC ADAMS/View. The next stage is the simulation with a set of different parameters to obtain its kinematics analysis. Finally the data gathered in this process is compared and evaluated. Finally, the work presents the results with graphical representation of parameters such as speed, distance and acceleration.

1 Introduction

In addressing the motion of machine parts, machines and equipment it is necessary first to create a kinematics model. Kinematics model of a device schematically captures all its properties which are essential in kinematical analysis i.e. individual members with dimensions, kinematics pairs, and so on. Conventional numerical solution uses vector calculus as the basic mathematical apparatus because the main kinematics variables are vector quantities. For analytical kinematics analysis of movement different coordinate systems may be used. According to the kind of movement we can choose the appropriate coordinate system for that model configuration thus simplifying the solution. Classical numerical solution of movement kinematics is often lengthy and difficult especially for complex kinematics models with different movements. To simplify and expedite the analysis a graphical solution may be used which is nowadays replaced with a solution using computer techniques using various software products. These software products ease the investigator's effort. Investigator enters the model configuration and the input data and the program calculates the required outputs. These data can be presented in a tabular form or the program draws graphical results. One of the software products suitable for kinematics analysis is MSC ADAMS/View program that allows to modeled kinematics chains and solve their motion [1-3].

2 MSC Adams main characteristic

MSC Adams (Automatic Dynamic Analysis of Mechanical Systems) is one of the most widely used multi-function computing software. It helps in simulations of mechanical systems consisting of rigid and flexible bodies connected by different types of kinematics links.

It allows creating dynamic, kinematics and static analysis of the proposed mechanical systems and helps to optimize and improve their properties. The aim of this article is to create a functional model crank rocker mechanism in ADAMS/View software and to make its complete kinematics analysis. The aim is to investigate the movement of individual members of the mechanism and its points.

3 Kinematics analysis of mechanism with vertical motion

Kinematical analysis of the mechanism means to solve kinematical variables of movement of the driven members with respect to the kinematics variables of movement of the driving members. Mechanism is a simple machine used to transform the rotational motion to linear translational motion and vice versa. Kinematical analysis is shown in six-member mechanism which is shown in Fig 1. We determine displacement, velocity, acceleration, angular displacement, angular velocity and angular acceleration of the members of this mechanism in program MSC Adams View.

Mechanism consists of a six links with width 20mm, depth 10mm and lengths: $O_2A = 150$ mm, $AB = 750$ mm, $O_2O_4 = 885$ mm, $CD = 450$ mm and $DE = 400$ mm. Driving link O_2A has a counterclockwise angular velocity $\omega_2 = 1$ (rad/s).

The point A of the member 2 crank moves in a circle with radius O_2A and point B of the member 4 also moves in circle with radius O_4B . The member 3 and 5 are performing planar motion, member 6 moves linear translational motion.

Our task is to determine angular displacement ϕ_{41} , angular velocity ω_{41} and angular acceleration α_{41} of the link O_4B graphically for the crank position indicated

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and then to create a model of a mechanism in MSC Adams/View environment and determine displacement, velocity and acceleration of the member DE.

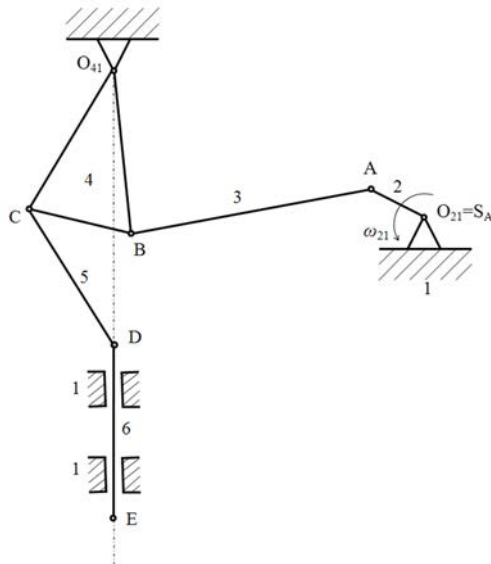


Figure 1 Mechanism with vertical motion

The crank $O_{21}A$ rotates around point O_{21} , motion of the connecting member AB is a general planar motion and member $O_{41}B$ rotates around point O_{41} . When we determine lengths of the members we indicate velocities of the points A and B . The angular velocity of the member 2 is ω_{21} .

The velocity of points A and B can be obtained by using the rule of the viewing angles. Tangent of the angle β_{v21} under which we see the endpoints of velocities from the permanent center of rotation is proportional to the angular velocity of the rotating member. If we denote the angular velocity ω_{21} of the member 2, then for the velocity v_A and acceleration a_{An} at point A shall apply [5, 6]:

$$v_A = \overline{O_{21}A} \cdot \omega_{21} \quad (1)$$

$$a_{An} = \frac{v_A^2}{\overline{O_{21}A}} \quad (2)$$

$$\tan \beta_{v21} = \frac{v_A}{\overline{O_{21}A}} = \dot{\phi}_{21} = \omega_{21} \quad (3)$$

$$\beta_{v21} = \arctg \omega_{21} \quad (4)$$

The velocity v_A lies on the tangent of the trajectory of point A . The velocity vector at the point is shown in the Fig. 2. The velocity at the point B is given by the basic decomposition of the member 3:

$$\mathbf{v}_B = \mathbf{v}_A + \mathbf{v}_{BA} \quad (5)$$

In equation (5) we know the magnitude, direction and orientation of the velocity of vector \mathbf{v}_A . Point B is located on the member 3 and 4. The member 3 performs general

plane motion and the member 4 performs rotational motion around a fixed axis of rotation in O_{41} . Trajectory of the point B is circle with radius $O_{41}B$. Point B is moving relative to the reference point A in the circle with radius AB with center in point A . Equation (5) is solved in a vector diagram in Fig. 3a.

Velocity v_B of the member 4 we determine also with rule of the viewing angles (Fig. 2) :

$$\tan \beta_{v31} = \frac{v_A}{K_{31}A} = \frac{v_B}{K_{31}B} = \omega_{31} \quad (6)$$

$$\frac{v_A}{K_{31}A} = \frac{v_B}{K_{31}B} \Rightarrow v_B = \overline{K_{31}B} \cdot \frac{v_A}{K_{31}A} \quad (7)$$

The velocity v_C of the point C , which lies on the members 4 and 5 construct by the sentences of viewing angle. End point of the velocity vector we see from immediate centre of rotation at the same angle β_v .

The velocity v_D of the point D of member 5 and 6 we established by the basic decomposition of general plane motion 5:

$$\mathbf{v}_D = \mathbf{v}_C + \mathbf{v}_{DC} \quad (8)$$

In equation (8) is the vector \mathbf{v}_C fully understood. The tangent of the vectors \mathbf{v}_D and \mathbf{v}_{DC} we can determine. The trajectory of the point D is the line and trajectory of the point D regard to point C is circle with radius CD . Equation (8) is solved by a vector diagram in the Fig. 3b.

The velocity v_E of the point E is equal to the velocity v_D , because points E and D are lies in the same member 6. The member 6 is moving translational. For the acceleration of the point B we write:

$$\mathbf{a}_B = \mathbf{a}_A + \mathbf{a}_{BA} \quad (9)$$

Each member of the equation (9) we decompose the tangential and normal component:

$$\mathbf{a}_{Bt} + \mathbf{a}_{Bn} = \mathbf{a}_{At} + \mathbf{a}_{An} + \mathbf{a}_{BAt} + \mathbf{a}_{BAN} \quad (10)$$

where:

\mathbf{a}_{Bt} – tangential component,

\mathbf{a}_{Bn} – normal component, can be obtained by Euclidean construction,

$\mathbf{a}_{At}=0$ because $\omega_{21}=\text{constant}$,

\mathbf{a}_{An} – is normal component of the acceleration of the point A , we obtain:

$$a_{An} = \frac{v_A^2}{\overline{O_{21}A}}. \quad (11)$$

The normal component of the acceleration \mathbf{a}_{An} of the point A we construct with Euclidean construction from the velocity of the point A and radius $O_{21}A$ of the trajectory point A based on the know velocity \mathbf{v}_B (\mathbf{v}_{BA}) and the center of curvature of trajectory of points $S_B=O_{21}$ ($S_{BA}=A$) we can construct then the normal component of the acceleration \mathbf{a}_{Bn} (\mathbf{a}_{BAN}).

Wearers of the tangential component of acceleration \mathbf{a}_{Bt} and \mathbf{a}_{BA_t} are collinear with the respective velocity. In equation (10) only two remain unknown \mathbf{a}_{Bt} and \mathbf{a}_{BA_t} .

Therefore we know construct the vector diagram of acceleration, from which we determine the size of the components \mathbf{a}_{Bt} and \mathbf{a}_{BA_t} . Member 4 performs rotational movement around a point O_{41} . When constructing the tangential component of the acceleration at point C \mathbf{a}_{Ct} . We will use the sentence of the viewing angles β_{At} , since we know \mathbf{a}_{Bt} . Normal component of the acceleration of point C \mathbf{a}_{Cn} we construct by the Euclidean construction by velocity v_C and axis of curvature of the trajectory of point C. For acceleration of the point D we obtain the expression:

$$\mathbf{a}_D = \mathbf{a}_C + \mathbf{a}_{DC} \quad (12)$$

we write:

$$\mathbf{a}_{Dt} + \mathbf{a}_{Dn} = \mathbf{a}_{Ct} + \mathbf{a}_{Cn} + \mathbf{a}_{DCt} + \mathbf{a}_{DCn} \quad (13)$$

where $\mathbf{a}_{Dn} = 0$.

In equation (13) we know component of the acceleration at point C, the tangential with \mathbf{a}_{Dt} and \mathbf{a}_{DCt} .

Normal component of the acceleration \mathbf{a}_{DCn} we construct by the Euclidean construction because we know the velocity v_{DC} and center of curvature of the trajectory of point C, $S_{DC}=C$. The tangential components of the acceleration \mathbf{a}_{Dt} and \mathbf{a}_{DCt} are collinear with the respective speeds.

We can construct the vector diagram of acceleration that detects the size and orientation of the acceleration $\mathbf{a}_D = \mathbf{a}_{Dt}$ and $\mathbf{a}_{DCt}(\mathbf{a}_{DC})$.

The member 6 is moving translational. The acceleration \mathbf{a}_E of the point E is equal to the acceleration \mathbf{a}_D , because points E and D are lies in the same member 6, we write: $\mathbf{a}_E = \mathbf{a}_D$.

For angular velocity and angular acceleration of member 3 we write:

$$\omega_{31} = \frac{v_{BA}}{AB}, \quad (14)$$

$$\alpha_{31} = \frac{a_{BA_t}}{AB}, \quad (15)$$

$$\omega_{31} = \frac{v_A}{AK_{31}} = \frac{v_B}{BK_{31}}. \quad (16)$$

The senses of values ω_{31} a α_{31} are designed according v_{BA} a \mathbf{a}_{BA_t} and their location are given to the point A.

Angular velocity and angular acceleration of the member 4:

$$\omega_{41} = \frac{v_B}{BO_{41}}, \quad (17)$$

$$\alpha_{41} = \frac{a_{Bt}}{BO_{41}}. \quad (18)$$

Angular velocity and angular acceleration of the member 5:

$$\omega_{51} = \frac{v_{DC}}{CD}, \quad (19)$$

$$\alpha_{51} = \frac{a_{DCt}}{CD}, \quad (20)$$

$$\omega_{51} = \frac{v_C}{CK_{51}} = \frac{v_D}{DK_{51}}. \quad (21)$$

In Fig. 2 is the model in graphic form with velocities of points A and B.

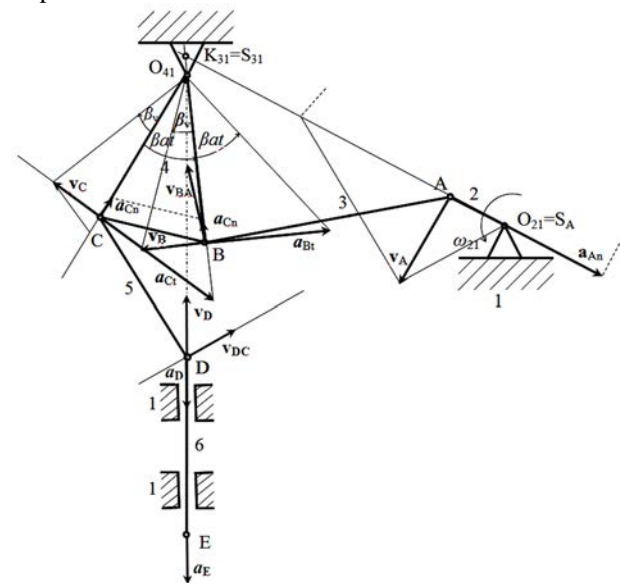


Figure 2 Mechanism with vertical motion - velocity vector of the point A and B

In Fig. 3a is the vector diagram velocity of the points A and B and the vector diagram velocity of the points C and D is on Fig. 3b.

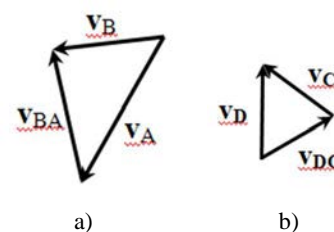


Figure 3 Vector diagram of the velocity a) of the point A and B, b) of the point C and D

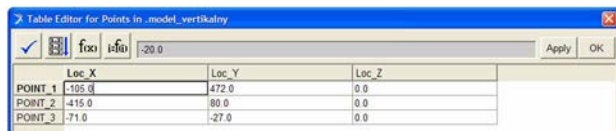
4 Simulation of the mechanism using MSC Adams/View

Six-member mechanism was modeled in MSC ADAMS/View. In the initial window of the program MSC Adams/View we set data folder, name of the project, units and the working grid. We created the individual bodies of the mechanism. We selected the rigid body geometry Link and Plate from the Toolbox.

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We created member 2, 3, 5 and 6 with geometry Link. Member 4 we created with geometry Plate in next points (Fig. 5). We defined the geometry, length, width and depth of the link. As the first we created a member 4 through defined point (Fig. 4). As the first we created a member 4 through defined point (Fig. 4).



	Loc_X	Loc_Y	Loc_Z
POINT_1	-105.0	472.0	0.0
POINT_2	-415.0	80.0	0.0
POINT_3	-71.0	-27.0	0.0

Figure 4 Table editor with Point_1, Point_2 and Point_3

The complete member 4 geometry plate is created on Fig. 5.



Figure 5 Creation of the points of the member 4 of mechanism

The member 4 should be rotated about O_{41} . Then connected the member 3 and 5 geometry Link with member 4 (Fig. 6).

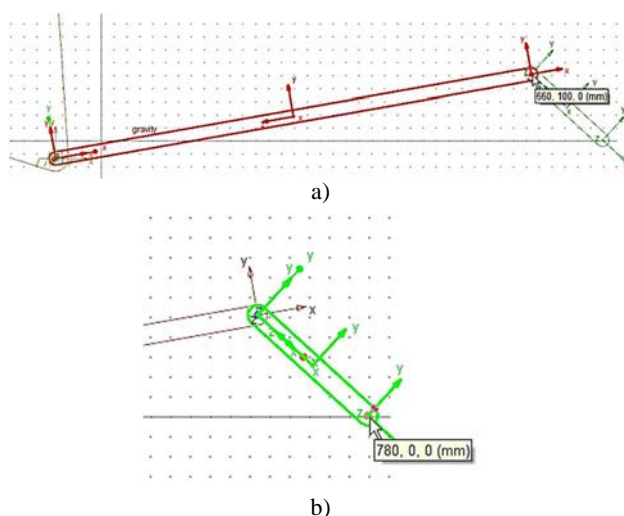


Figure 6 Creation of the model of mechanism: (a) member 3;
(b) member 2

On Fig. 7a is shown member 5 and on Fig. 7b member 6 of mechanism. On Fig. 8a is basic model and on Fig.8b spatial model of mechanism.

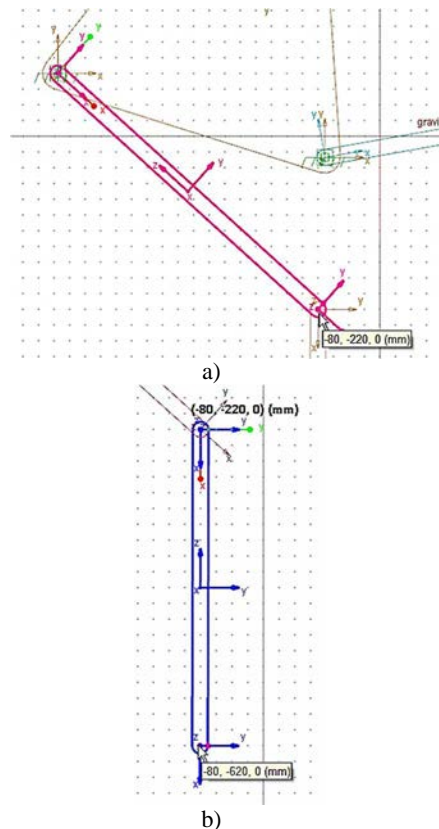
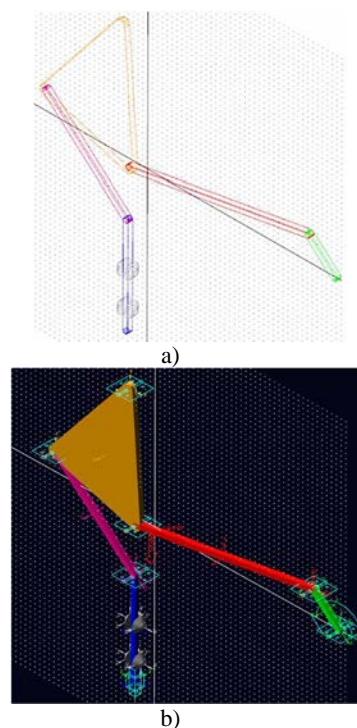


Figure 7 Creation of the model of mechanism: (a) member 5; (b) member 6



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Figure 8 Creation of the model of mechanism: (a) basic model; (b) spatial model

On Figure 9 is shown position, velocity and acceleration of the center of mass of member 3.

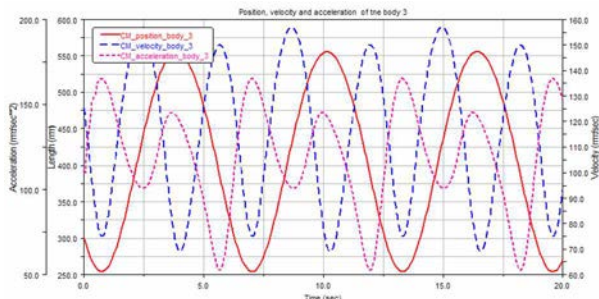


Figure 9 Position, velocity and acceleration of the center of mass of member 3

On Fig. 10 is shown position, velocity and acceleration of the center of mass of member 5.

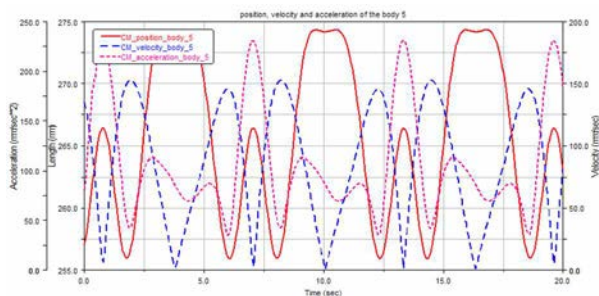


Figure 10 Position, velocity and acceleration of the center of mass of member 5

On Fig. 11 is shown position, velocity and acceleration of the center of mass of member 6.

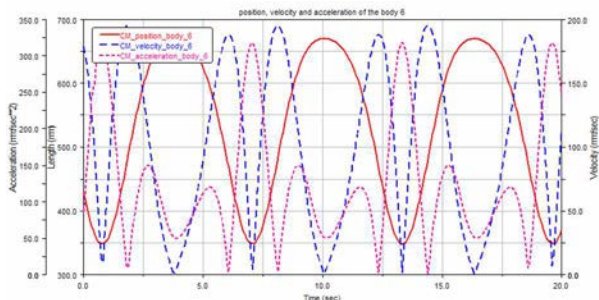


Figure 11 Position, velocity and acceleration of the center of mass of member 6

It is possible determine the result data for angle ϕ_{41} , angular velocity ω_{41} and angular acceleration α_{41} of the member 4 (Fig. 12).

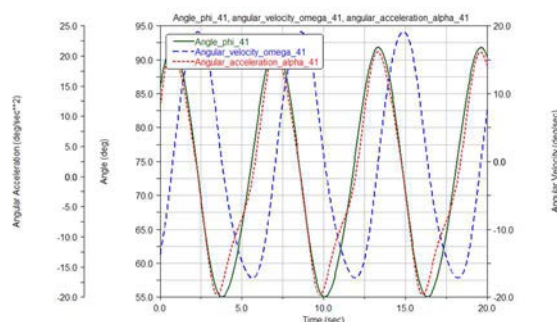


Figure 12 Angle ϕ_{41} , angular velocity ω_{41} and angular acceleration α_{41} of the member 4

In the window of the Postprocessor we selected window with animation of the mechanism and windows with results data in graphics form for angle ϕ_{41} , angular velocity ω_{41} and angular acceleration α_{41} of the member 4 (Fig. 13-15).

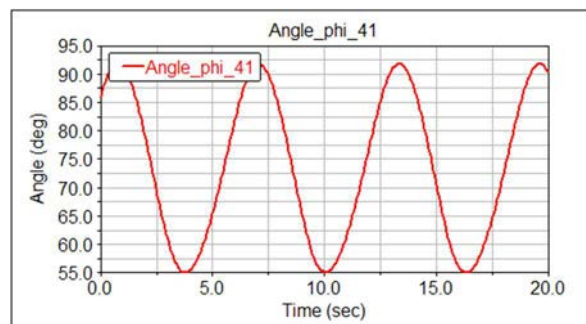


Figure 13 Angle ϕ_{41} of the body 4

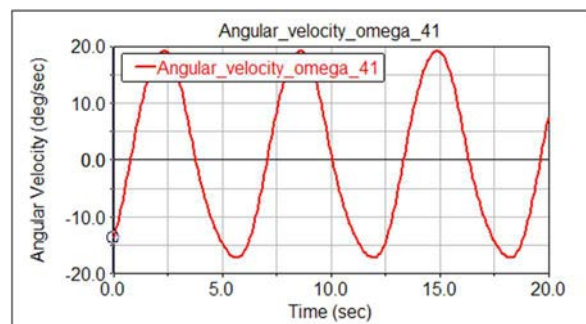


Figure 14 Angular velocity ω_{41} of the body 4

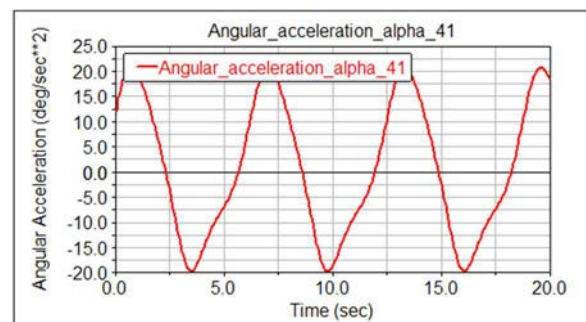


Figure 15 Angular acceleration α_{41} of the body 4

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Conclusion

MSC ADAMS/View contains a specialized interface for creating virtual objects consisting of rigid and deformable parts linked to each other with different kinematics links. This allows create static, kinematics and dynamic analysis of virtual prototypes by computer simulation.

We investigated a functional model of a six-member mechanism. The whole modeling simulation was carried out by simulation program MSC ADAMS/View.

In the work is shown a procedure for solving kinematics problem of the mechanism using analytical and graphical solution and modeling in MSC Adams View. MSC Adams View allows simulate moving of such mechanical systems. Results are obtained in form of time diagram of the desired variables. Tasks are solved numerically model is compiled by using program MSC Adams View [4-7]. The results obtained by the simulation of six-member mechanism of the mechanism were processed by the postprocessor program of MSC Adams/View.

Program MSC Adams/View makes it easy to analyze complex mechanical systems with multiple degrees of freedom. In the paper one module of the number of modules namely MSC Adams/View was used as a tool which allows a better simulation and visualization of the model and easier evaluation of the results obtained. With the module MSC Adams/View they represent a tool that is able to addresses various types of mechanisms with many degrees of freedom. Mastering this methodology provides a suitable tool for solving problems of teaching and practice.

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OPTIMIZATION OF THE INVENTORY BY USING SIMULATION

Gabriela Ižaríková

TU of Košice, Faculty SjF, Institute of Special Technical Sciences, Department of Applied Mathematics and Informatics, Letná 9, 042 00 Košice, e-mail: gabriela.izarikova@tuke.sk

Jana Hrabčáková

Aalborg University Denmark, Engineering Faculty, MSc student in Operations and Supply Chain Management, e-mail: jhrabcakova@gmail.com

Keywords: simulation, Monte Carlo method, optimization

Abstract: The article deals with the simulation, more specifically with the method Monte Carlo. The term as a simulation, simulate, a simulator are well known in many scientific disciplines. Simulation, especially computer simulation has been in a rapid growth in recent years. The simulation is experimenting with computer models based on the real production process in order to optimize the production processes or the system. The simulation model allows to perform a number of experiments, analyze them, evaluate, optimize and afterwards apply the results to the real system. By using the Monte Carlo method it is possible to find the optimal quantity of reserves and to maximize a profit.

1 Introduction

The term simulation is used more often but usually as a synonymous of imitate or pretend. The object, which to some extent imitates the functionality, condition or processes a certain imitation object (as a driving simulator, a simulator of a free fall) refers to as a simulator. With the term of simulation, simulate, simulator we are coming across in many scientific disciplines. Moreover, it is used in various fields: computer systems, logistics and production systems, financial and econometric models, space travel, military operations, urban systems, etc.

2 Modeling and simulation

During designing of production processes many challenges occur, for instance how to solve problems in the process, how to innovate or improve the process. One possibility is to simulate the production process. The simulation is experimenting with computer models based on the real production process in order to optimize the production processes, the entire processes or a system. It enables to experience the behavior of the system after implementation and to see the possible future scenarios and uncover problems. Simulation is not a tool which provides an optimal solution to the problem but it is a support tool that tests the impact of our decisions on the simulated model. The simulation model allows you to perform a number of experiments, analyze them, evaluate, optimize and afterwards apply the results to the real system.

According to the definition a simulation is a research method, which comprised on the examination of a dynamic system. The dynamic system is replaced by a simulator, on which are afterwards performed experiments to obtain information about the original

investigated system. It is a computer simulation, in which the simulator consists of a simulation program - model introduced to the computer.

By using the simulation it is possible to solve several problems, such as: the most convenient management system, the best lay-out of machines, the optimal size of the inventory, determine the number of machines and additional equipment, determining the optimal size of operating machines and equipment, determining the optimal dose size, determine the impact of failures and downtime the manufacturing process, and many other applications.

Some of the reasons for using of the simulation:

- The need for predictions of future action,
- Restructuring of the manufacturing process,
- Confirmation of hypotheses,
- Reduce the risk of decision making,
- Increase the efficiency,
- Elimination of deficiency in the production process without interfering with the real processes,
- Impossibility of implementing the production process (production system does not exist yet, it is not possible to consider a greater number of variants, it is not possible to change any parameters),
- Cost-saving,
- Experiments can cause malfunctions in the equipment,
- Experimentation on a real object is expensive (in terms of money, time).

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During the application simulations two basic rules are used:

➤ The benefits achieved by applying simulation should be greater than the costs required to implement simulation (quantitative and qualitative benefits). The simulation is justified if the direct benefits of simulation are more than the cost of the simulation. On the effectiveness of simulations has a large influence the time when the simulation is carried out.

➤ The simulation should be used in the initial stages of the project process, because the most potential improvements of the system can be achieved in the initial stages, while the costs involved are currently the lowest in the following phases. In the process of implementation and operation exists only a few degrees of freedom for a change. Proper and timely decisions are incomparably greater than the benefits of optimization in subsequent stages of the project.

Simulation is actually mathematical modeling; it means experiment on a real system is replaced by the solution of a mathematical model on a computer. The principle of computer simulations lies in the establishment of a system's simulation model and in the implementation of experiments with simulation model in the correct interpretation and application of the results achieved for improving the real system. The real system is a system which is the subject of our interest. The simulation model is a dynamic model (mathematical, logical, and so on.), which in a way shows current system; its structure and a set of rules under which the model in a way behave (generated data). The models can be divided into mathematical and physical. Before the simulation model is built, is necessary to define the goal of the simulation (cost reduction, reduction of production, optimize deployment of production facilities), and to obtain input data. For defining the goal is mainly used abstraction (by neglecting aspects and elements of the reduction characteristics, the links between them), structuring (decomposition of the sub-systems, while maintaining the hierarchy) and analogue (draw conclusions on the basis of similarities with other systems). The term simulation experiment is a set of simulation runs - multiple repetitions of the basic cycle simulation for a specific time period and parameter simulation with partial evaluation of results. It is therefore a set of the operation's simulation in which a change of input quantities are performed.

2.1 Simulation Monte Carlo

Monte Carlo is an algorithm for simulation systems. Monte Carlo method means the numerical solution of probabilistic and deterministic tasks using many times repeated probabilistic experiments. It is a stochastic method using pseudorandom numbers. The basic objective of is to determine the mean values resulting from the random phenomenon. In order to create a computer model of the phenomenon the sufficient amount

of simulation data needs to be obtained by using statistical methods. There are two approaches to solve problems by the Monte Carlo approach based on geometric probability and an approach based on estimates of the mean random variables. The algorithm method is based on selecting a random number of the specified statistical distribution (Tab. 1) probability distribution if sufficient data can be assessed using the Pearson test (Chi-Square test), Kolmogorov-Smirnov test and a simple visual analysis histogram. In case when no available historical data exists, the probability distribution is determinate on professional judgment.

The actual simulation is a process of random selection of specific risk-factors of the predefined division. Simulation (number of simulation runs is recommended at least 1,000 times) selects a random number and applies it in the model definition. Randomness and objectivity is ensured by the random generator, thus pseudorandom numbers. The simulation output is a probability distribution of the target variable, so the solution is probabilistic in nature and is dependent on what the distribution of the individual values generated. After the simulation, the aggregate statistics of evaluation indicators are created - arithmetic mean, standard deviation, mode, median, and coefficient of variation, the likelihood of gains or losses. The results can be represented graphically.

Table 1 Statistical probability distribution:

Discrete Probability Distributions	Continuous Probability Distributions
➤ Uniform distribution	➤ Uniform distribution
➤ Bernoulli distribution	➤ Normal Distribution
➤ Binomial distribution	➤ Standard normal distribution
➤ Poisson distribution	➤ Exponential distribution
➤ Hypergeometric distribution	➤ Log-normal distribution
	➤ Weibull distribution
	➤ Student distribution
	➤ χ^2 distribution
	➤ Fisher-Snedecorove distribution
	➤ Gamma distribution

2.2 Simulation in Excel

To simulate models in different random processes can use widely available Microsoft Excel spreadsheet (insert function). For generating random numbers can use the command RAND (), we get a random number with uniform distribution in the interval (0,1). To determine the percentage of occurrence of random numbers, for example, in four intervals is used COUNTIF function. To generate the random number in the range, for example

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from 500 to 1000, use the command $\text{INT}(\text{RAND}) * 500 + 500$. Press F9 for another simulation run. (Fig.1,2,3)

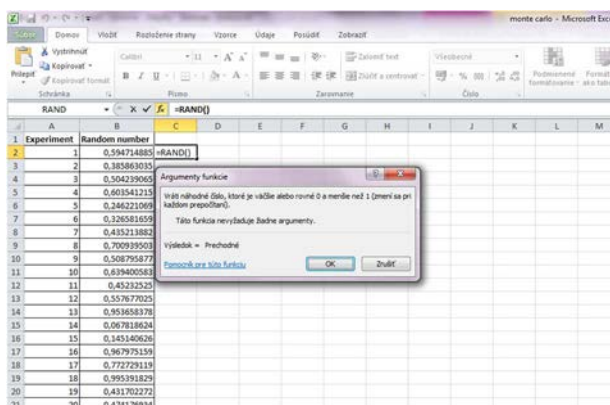


Figure 1 Generating random numbers

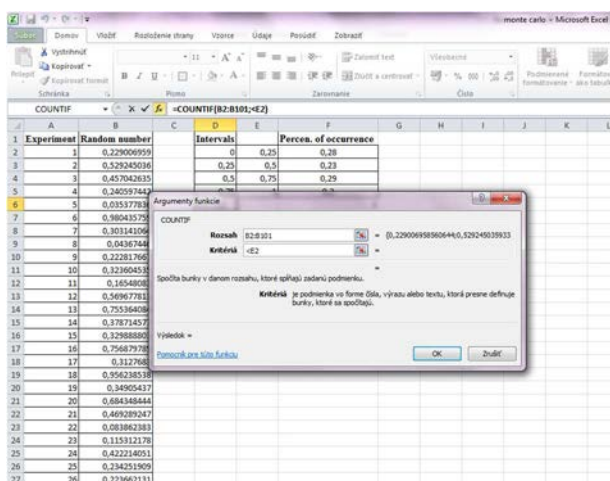


Figure 2 Determine the percentage of occurrence

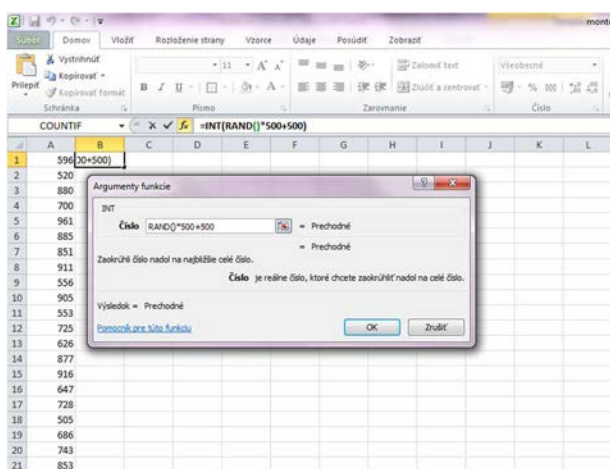


Figure 3 A random numbers from the interval

The above examples can be applied for example to determine the optimal amount of the stock. The warehouse owner buys goods for 20 euros per package and sells it for 30 euros per pack, in the event that it was available on certain date remains merchandise and sells it with 50% discount. This means that if demand for goods greater than the quantity ordered he will come from a lack of profit, but if the demand for goods is less than the quantity ordered, he will lose profits due to discounts.

If the demand is (d) the product is higher than the ordered quantity (q) and the equation the result is

$$Z = (30 - 20)q \quad (1)$$

If the demand is (d) the product is less than the quantity ordered (q) and the equation the result is

$$Z = 30d - 20q + 15(q - d) \quad (2)$$

Demand is a probabilistic variable, as it is known, that cannot be determined profit. Suppose that the demand will be a number from $d \in (500, 1000)$ and order quantity for example $q \in (500, 650, 800, 850, 1000)$. The Monte Carlo simulation performance for the first 10 random attempts to level the ordered quantity $q = 800$. (Tab. 2)

Table 2 Simulation Monte Carlo for $q=800$

Random trials	Ordered amount (q)	Demand (d)	Profit
1.	800	999	80000
2.	800	746	7190
3.	800	842	8000
4.	800	702	6530
5.	800	638	5570
6.	800	521	3815
7.	800	954	8000
8.	800	848	8000
9.	800	659	5885
10.	800	606	5090

➤ $d > q$, if demand $d = 999$ and the quantity ordered $q = 800$, the value of profit is: $Z = (30 - 20)q = 8000$,

➤ $d < q$, if demand $d = 746$ and the quantity ordered $q = 800$, the value of profit is: $Z = 30d - 20q + 15(q - d) = 7190$.

The average value gain of ten random experiments is 6608 € and the maximum profit under these conditions is 8000 € and minimum profit is 3500 €.

The average profit calculated simulation of a hundred thousand repetitions of the quantity ordered $q \in (500, 650, 800, 850, 1000)$ in Tables 3 and 4. The maximum average profit is achieved when ordering quantity 800 packs of goods.

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Table 3 Simulation results for 100 random trials

Ordered amount	500	650	800	850	1000
Average profit (eur)	5000	6017	6646	6401	6516

Table 4 Simulation results for 100 random trials

Ordered amount	500	650	800	850	1000
Average profit (eur)	5000	6151	6626	6644	6144

The maximum profit is achieved when the amount of 800 is ordered. It is depicted in the graph.(Fig.4) and Tables 5 and 6.

Table 5 Probability distribution for $q=800$

Profit (eur)	Probability		
	10 random trials	100 random trials	1000 random trials
3000 - 4000	0	0,04	0,069
4000 - 5000	0,1	0,14	0,137
5000 - 6000	0,1	0,12	0,134
6000 - 7000	0,3	0,13	0,152
7000 - 8000	0,5	0,57	0,508

Table 6 Probability distribution for $q=1000$

Profit (eur)	Probability		
	10 random trials	100 random trials	1000 random trials
3000 - 4000	0,1	0,11	0,137
4000 - 5000	0,2	0,13	0,142
5000 - 6000	0,3	0,13	0,137
6000 - 7000	0,2	0,15	0,119
7000 - 8000	0	0,15	0,137
8000 - 9000	0,2	0,33	0,328

The value of 95% confidence interval for the profit is:

- if $q=500$: $Z = 5000$
- if $q=600$: $Z \in (5783, 5967)$
- if $q=700$: $Z \in (7091, 7242)$
- if $q=800$: $Z \in (6041, 6852)$
- if $q=900$: $Z \in (6323, 7308)$
- if $q=1000$: $Z \in (5761, 6850)$

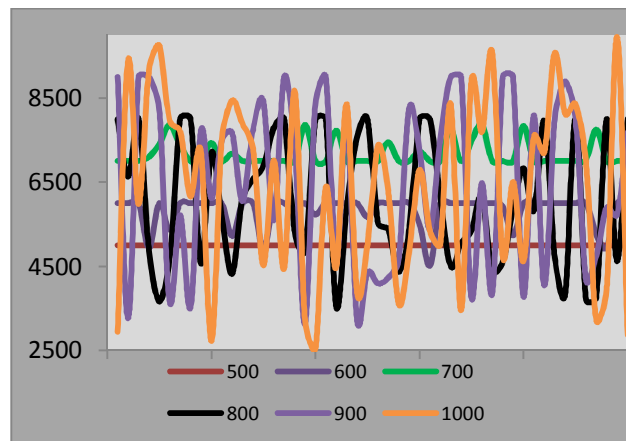


Figure 4 Profit of the quantity ordered

Thus, increasing the number of random experiments, the probability distribution of the frequency of the expected profit to the actual expected value. (Fig. 5)

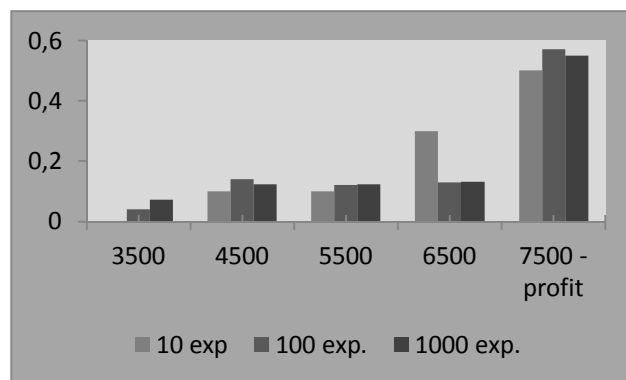


Figure 5 Graph of probability distribution

This example is illustrative demonstration of the principle of Monte Carlo method, thus reselection of the probability distribution of input elements is derived probability distribution of output variables in the model.

Conclusion

The article is an example of using the Monte Carlo, demonstrated the possibility of its usage in order to show a universal method of solving math problems. A simulation is an important and has a stable place in the production process and also in business practice. It is not a tool to solve all the problems, but could be used to quickly optimize and improve. The simulation is not cheap method because requires expensive software, computer time and especially specialists who can properly use it. Nevertheless, the benefits of simulation are many times higher than the cost of the simulation project.

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