ASSEMBLY AND INSTALLATION PROCESS OF TANK TRACKS. ABSTRACTION, ANALYSIS BASIS AND AUTOMATION

Rareş Lucian Marin, Daniela Căruţaşu

"Lucian Blaga" University of Sibiu-Romania, Department of Industrial Engineering and Management
Emil Cioran Street No. 4, Room IM 207, 550025, Sibiu, Romania

Corresponding author: Rareş Lucian Marin, rares.marin@ulbsibiu.ro

Abstract: The necesity of minimizing the production time, to ease the work, and most of all, the need of higher productivity, led to the proposal of the line presented in this paper to be automatized. The problem is approached through the Product Lifecycle Management concept (PLM) and is suitable both for maintenance of the tank tracks and for assembly and mountig of new ones. It is presented the description of the real line along with its simulation, and then the two scenarios of automatization: an analysis of an automatized line with two robotic arms and an analysis of an automatized line with specific assembly and mounting devices.
Key words: automation, simulation, war machine, tracks, assembly, scenarios.

1. INTRODUCTION

We will present in this paper a production line that assembles tank tracks and then installs them on the combat vehicle. The line installs also new tank tracks in the production process, but is mostly used to install reconditioned tracks in the maintenance process. From the research developed in [2] the representative data is presented in the table below:

Table 1. Number of faults for the tank equipment

Operation	Faults
Engine maintenance operations	1045
Transmission maintenance operations	699
Rolling equipment maintenance	541
Electrical equipment maintanance operations	136
Communication maintenance operations	55
Special installation maintenance operations	327
Weapons maintenance operations	132
Turret maintenance operations	60
Armored housing maintenance opperations	5

From Table 1 it can be seen that the rolling equipment (the tracks) is in the top of the faultiest equipments. Because of the heavy duty work, time consuming process and of the low productivity the need of improving the rolling equipment became stringent.
Using Tecnomatix Plant Simulation it has been developed two virtual simulation models testing "what if" automation scenarios with the focus on the productivity of the lines.

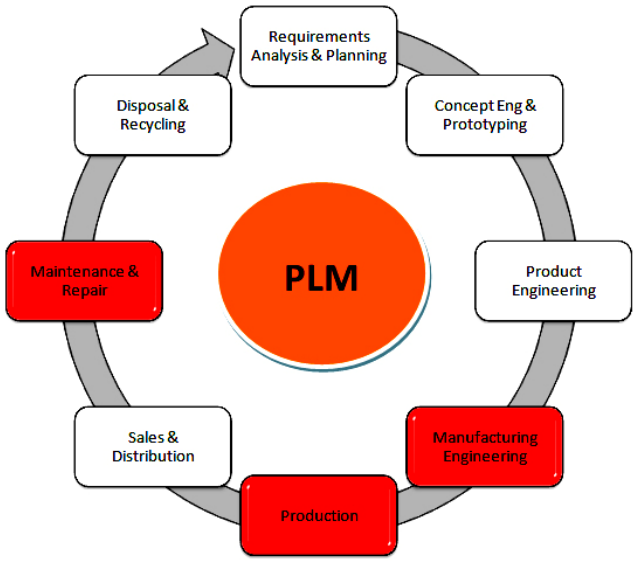

Fig. 1. PLM stages, [5]

Considering the PLM stages presented in fig. 1 we will refer in this paper at the 5th stage by presenting the simulation of the existing production flow but in the same time the reference is also to the 7th stage, because of the possibility of the line to install reconditioned tracks. The last two iportant points of the work refer to the 4th stage by presenting the pre-ramp-up simulation of two "what if" automation scenarios.
For the simulation models we had to abstract the elements of the real production flow to have a more simple, intuitive and easy to use model, considering [1]. Every element of the production flow was modeled using the following three aspects:

1) Name;
2) Intuitive graphics;

3) Specific attributes.

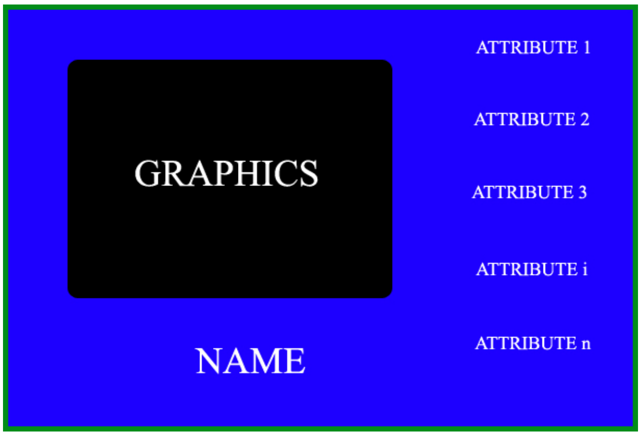

Fig. 2. Simulation object

Having the elements of the production flow defined it has been built the virtual model. By simulating this model, results like: productivity, costs or different production times, can be extracted from the virtual model. This model is practically *an analysis basis for the real production flow.* This basis will be used not just for having a virtual representation of the process, but also for avoiding time wasting cost or productivity calculations, testing different scenarios or getting the values of different variables depending on different intervals of time [4].

Also, the real production flow was simulated to have real values for comparison with the other two automatized models built.

2. STRUCTURE OF THE TANK TRACK

The track is assembled with 5 different elements (figure 3), [3, 6]: 1-skid: 90 pieces; 2-bolt: 180 pieces; 3-strap: 180 pieces; 4-screw: 180 pieces; 5-nut: 180 pieces.

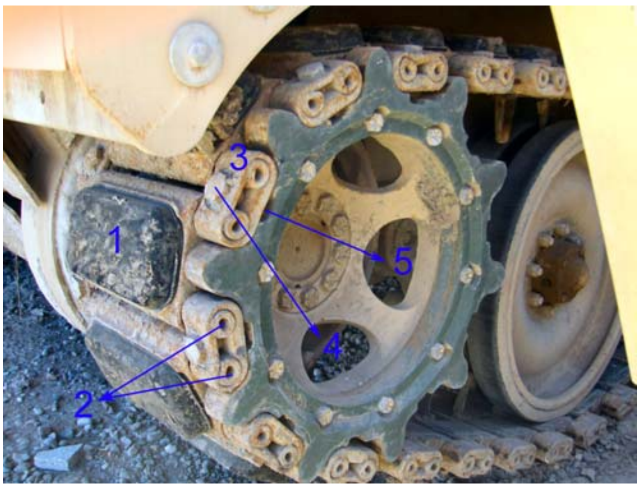

Fig. 3. Tank track structure

One track weights 774kg totally assambled and has an unfolded length of 14m.

3. DESCRIPTION OF THE REAL ASSEMBLY AND MOUNTING LINE

In present, the assembly and mounting of the tank tracks is manually made at two workplaces at which are executed the actions below in the exposed order:

Workplace 1:

1) Assembly of the track:
   a. Assembly of two bolts on a skid;
   b. Assembly of the straps that connect two skids;
   c. Fixing of the straps with screws and nuts.
2) Mounting of the track on the tank:
   a. The tank is towed by other heavy vehicle on the assembled tracks that remained in the same place where were assembled;
   b. The track is manually rolled on the tank roller wheels;
   c. The track is assembled with the last two straps.

Workplace 2:

1) Checking of the assembly:
   a. The tank is driven on a 100 meter distance towords a pre-established landmark;
   b. The deviation must be lower than 2 m.

Table 2. Times consumed with every operation

Operation	Phase	Duration	Operation time
Assembly of two skids	Skid manipulation	15”	2’
	Skid placement	10”	
	Bolt assembly (for every skid one bolt)	10”	
	Assembly of two straps on the bolts ends	25”	
	The straps are fixed with two screws and two nuts	60”	
Assembly of a whole track (90 skids)			
3h			
Mounting of the track on the tank	The track is placed in front of the tank	5’	50’
	The track is mounted on the stretching wheel, roller wheels and driving wheel	8’	
	The first skid is assembled with the last skid of the track with the help of the last two straps fixed with	17’	

	screws and nuts		
	From the stretching mechanism is regulated the tension of the track according with the technological data sheet	20’	
Mounting of two tracks on the tank.			
1h 40’			
Bringing the tank on the tracks		10’	
Total time			
4h 50’			

4. SIMULATIONS

Objects used in the simulation use the structure presented in fig. 2, every object having the following important attributes:

1) Source objects:
   a. Type of created object.
2) Assembly objects:
   a. Assembly table (with predecessors);
   b. Exiting object;
   c. Processing time;
   d. Set-up time;
   e. Recovery time;
   f. Control methods;
   g. Workers assigned;

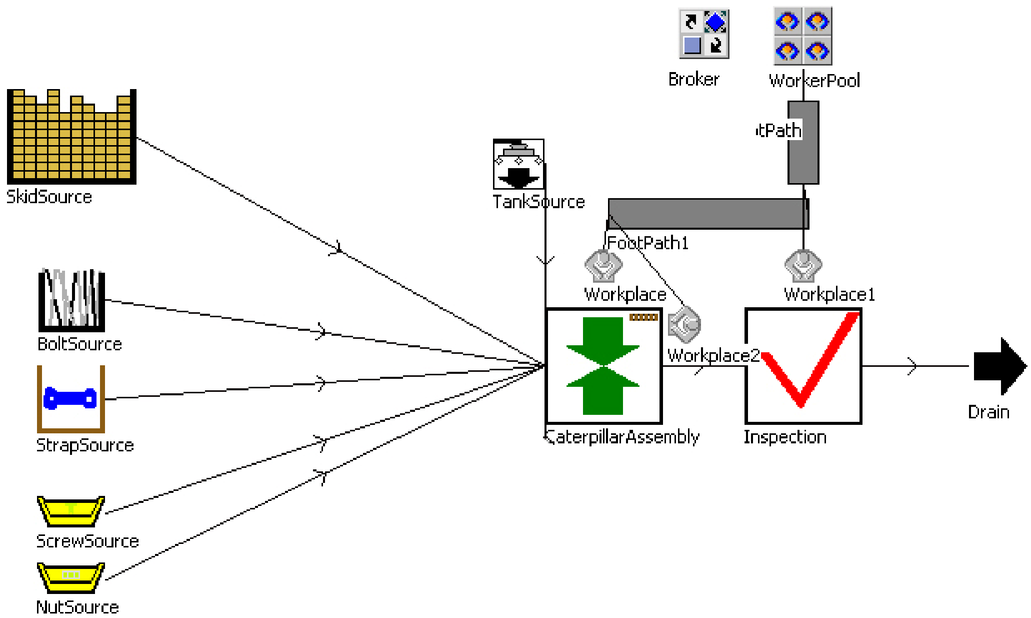

Fig. 4. Simulation of the real production line

3) Process objects:
   a. Processing time;
   b. Recovery time;
   c. Workers assigned.
4) Drain objects:
   a. Control methods.

The statistics presented were made in a time unit of 160 hours (tu).

4.1. Real line simulation

The production flow was abstracted in: 6 sources, an assembly object, a process object, a drain object, a worker pool with three workplaces and a footpath. The sources generate materials until two tracks are assembled, then they are mounted on a tank, all made in the assembly object. On this production structure are used three workers: two for assembling and mounting the tracks and one for driving the tank for the inspection of the assembly. The times presented in *Table 1* also apply in this simulation.

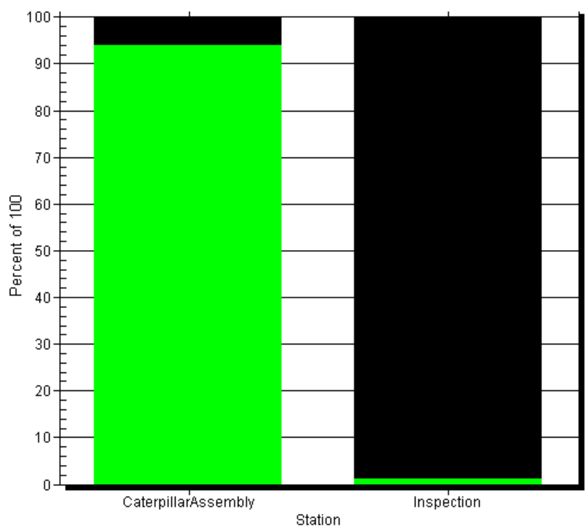

Fig. 5. Activity statistics of the workplaces for the real production line

The activity statistics (fig. 5) for the assembly and inspection objects are:

- For the assembly object: 94% activity, 2% set-up, 4% waiting;

•For the inspection object: 1,5% activity, 98,5% waiting.

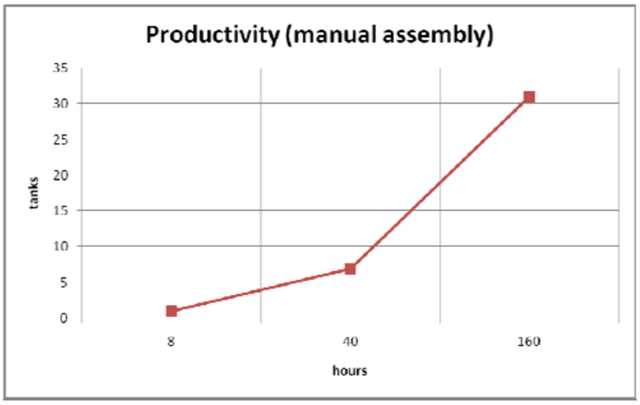

Fig. 6. Productivity curve of the real production line

4.2. Automatic assembly with robotic arms

For this version of conceptual line, the folowing objects were used (figure 7):

• 5 containers placed at a distance of one meter from the assembly line: one for skids, two for bolts and two for straps;

• For manipulation and assembly of the parts from the containers were used two KUKA KR 16-2 robotic arms chosen according to the maximum weight of a manipulated piece and the payload of the robot;

• One roller conveyor 14 m long (as an unfolded track) where the robotic arms assemble the track; the conveyor indexes the position after every skid is assembled;

• Another roller conveyor used for the transportation of the tracks in the mounting area, with two-way rollers for forward, left and right transportation of the track;

• Two winches for bringing the tank over the tracks and for rolling the tracks on the roller wheels of the tank.

In the simulation, this topology is exactly transposed (figure 8) with the following production flow:

Workplace 1:

Automatic assembly of the track:

a) the first robotic arm places a skid on the assembly line;

b) simultaneously are introduced two bolts from one side and another by the two robotic arms;

c) ditto point b) for the straps;

d) the straps are automatic fixed with screws and nuts.

Workplace 2:

Mounting of the track on the tank:

a) ready assembled track is transported to this workplace by the roller conveyor and placed left and right of the line in the mounting position;

b) a worker attaches the winches to the tank which is then brought over the tracks;

c) the same worker changes the clamping of the winches from the tank to the tracks, after the tank was completly positioned on the tracks, in this way the tracks being rolled on the tank's roller wheels;

d) using a special wrench the worker assembles the last straps.

Workplace 3:

Checking of the assembly (see *workplace 2*, point 3).

The speed of the robotic arm was considered 3m/s altough it can reach 5m/s.

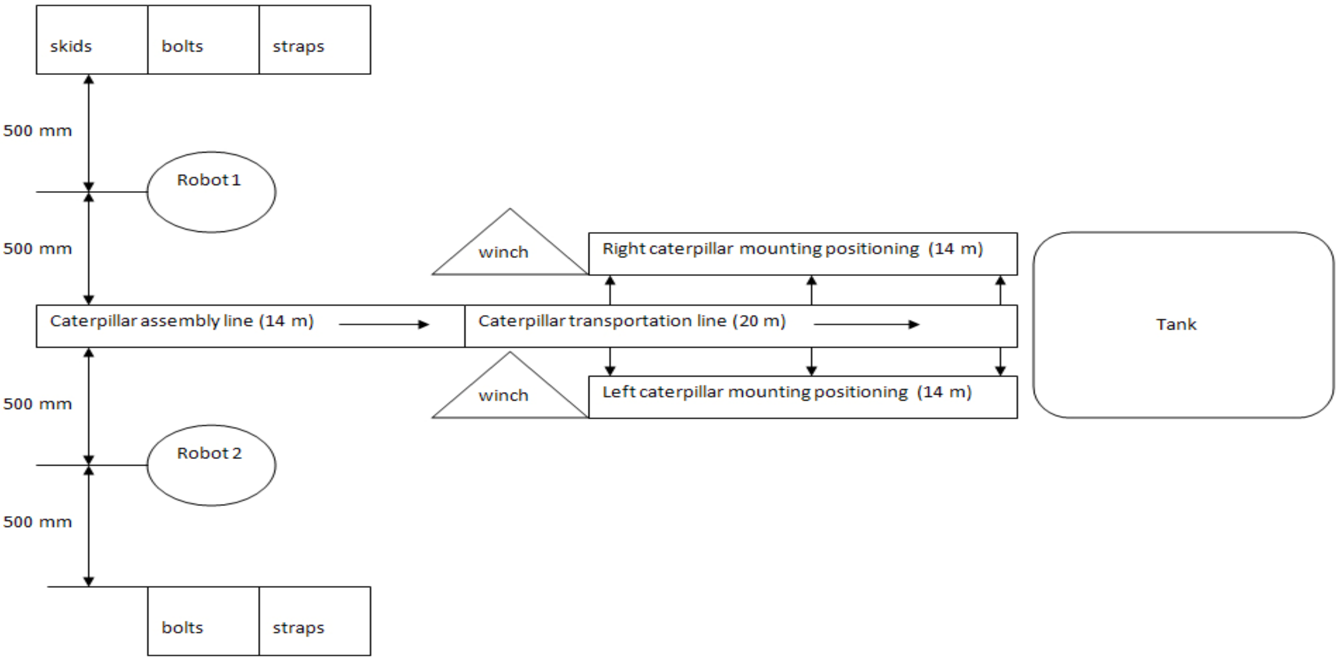

Fig. 7.Topology proposed for the automatized production line with robotic arms

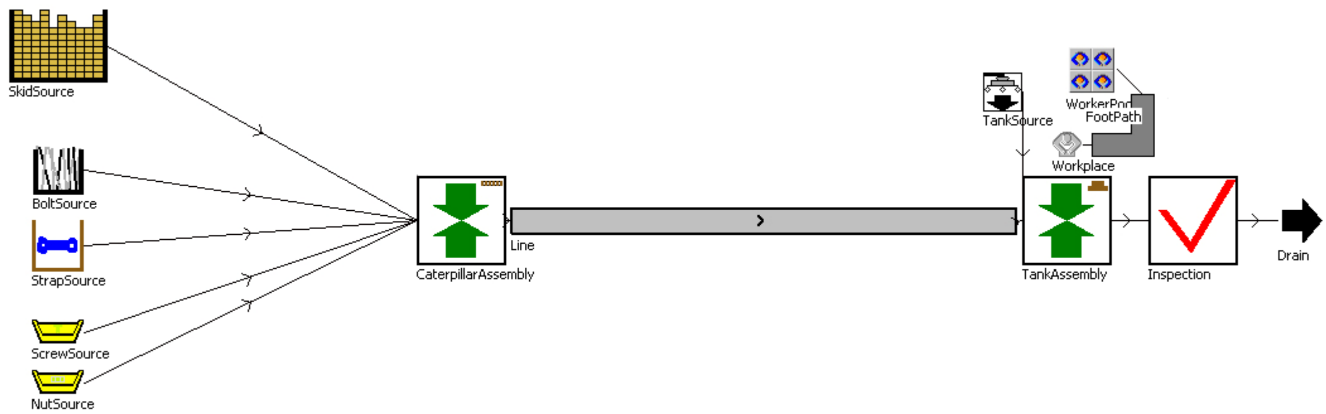

Fig. 8. Simulation of the production line with robotic arms

Table 3. Robotic arm times for assemblying one track

Stage	Stage Name	Time
1	Skid positioning	6,32 s
2	Repositioning for bolts	3 s
3	Bolt assembly	6,32 s
4	Repositioning for straps	3 s
5	Strap assembly	12,64 s
6	Screw and nut fixing	3 s
7	Indexing	3 s
Total working time for one skid		
37,28 s		
Total working time for one track (90 skids)		
55,92 min **Time used in simulation:** 60 min		

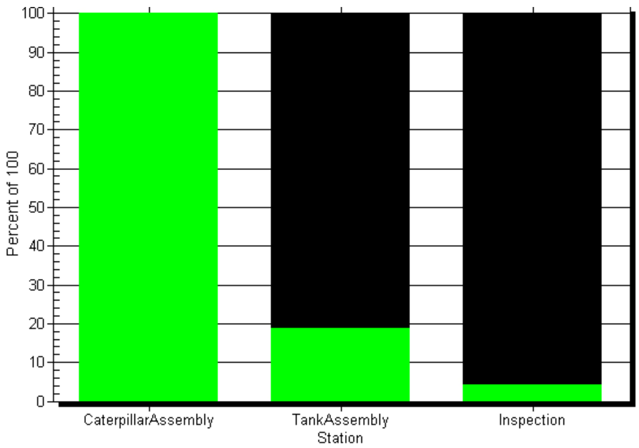

Fig. 9. Activity statistics of the workplaces for the production line with robotic arms

Activity statistics for the stations (figure 9):

- for the track assembly station: 100% activity;
- for the mounting station of the tracks on the tank: 19% activity, 81% waiting;
- for the checking station: 4% activity, 96% waiting.

4.3. Automatic assembly with specific devices

This conceptual line is based on the same topology like the one presented at point 4.2, but the operations in the assembly are highly discretized, for every operation being used a specific device, faster than the robot arms. In fig. 12 there is presented a conceptual specific device (2) for bolt assembly. The bolts (4) are assembled four at a time in two skids (1). The device is permanently fed with new bolts (3).

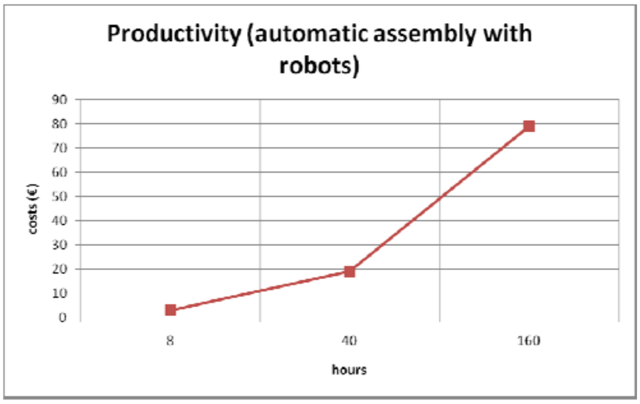

Fig.10. Productivity curve of the production line with robotic arms

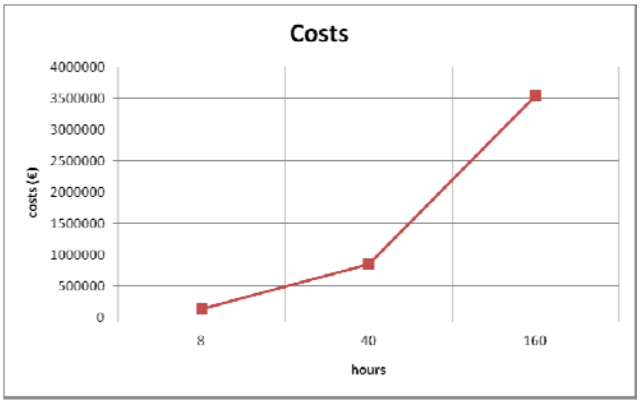

Fig. 11. Material costs curve of the production line with robotic arms

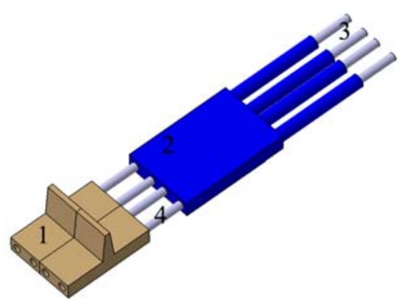

Fig. 12. Specific device for bolt assembly

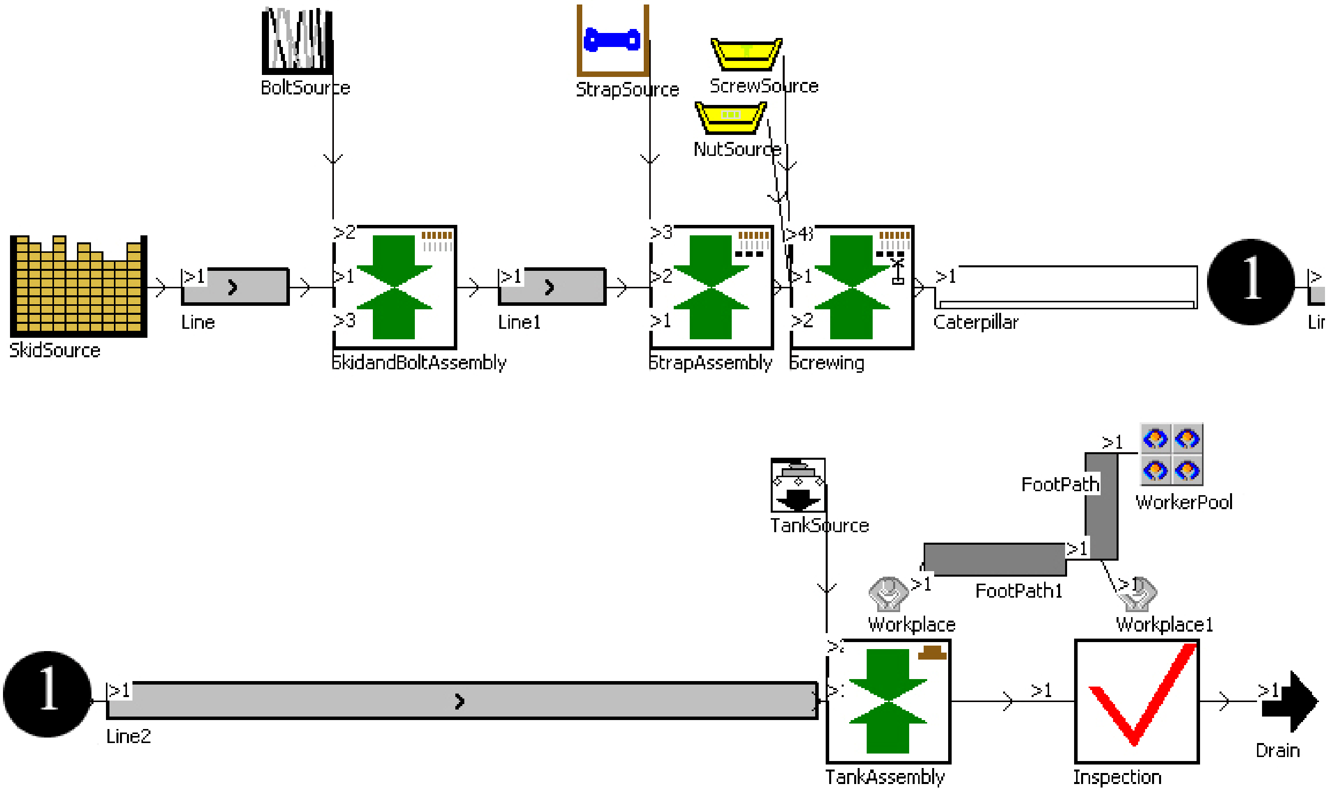

Fig. 13. Simulation of the production line with specific devices

The production flow of the simulation (figure 13) is:

<u>Workplace 1:</u>
Bolt assembly:

a) a roller conveyor transport the skids from the skid source to the bolt assembly workplace;

b) when two skids are positioned at the assembly point a specific device (ex: fig. 12) assembles two bolts at a time in the skids;

c) after the bolts are assembled, the same roller conveyor indexes the skids by moving the assembled ones to the next workplace and inserting two new ones in the assembly position;

<u>Workplace 2:</u>
Strap assembly:

a) the skids with the bolts attatched from the previous workplace are transported in the assembly area of the strap assembly workplace, by the roller conveyor;

b) the conveyor brings the two arriving skids with the assembled bolts so that the first skid touches the last assembled skid that is the last skid on the assembled track;

c) two specific devices attach in the same time four straps linking the last skid from th track with the first arrived skid and the two new skids together;

d) at this same workplace is done also the screwing operation after the skids were linked with the four straps;

e) after the strap assembly and screwing operations are done, the roller conveyor indexes the position for other two skids to be assembled;

f) the track is hold in place for other two skids to be assembled by special stoppers attached to the first skid.

<u>Workplace 3:</u>
Mounting the tracks on the tank:

-this operation follows the same steps like *wokplace 2* from point 4.2.

<u>Workplace 4:</u>
Checking of the assembly (see *workplace 2*, point 3).

In this simulation model are needed two workers: one for mounting the winches on the tank and, then on the tracks in the 3rd workplace and one for the inspection of the newly mounted tracks in the 4th workplace.

This simulation model has the advantage of very fast devices that exceed the slow manual labour and the times that robotic arms waste with positioning moves. The discretized operations allow multiple operations to be simultaneously made.

The drawbacks of this simulation model are: more space needed for installing all the components and, of course, the higher costs for designing and building or purchasing all the needed specific devices.

The sources for parts are fully automated, the only needed operation being the feeding of the sources.

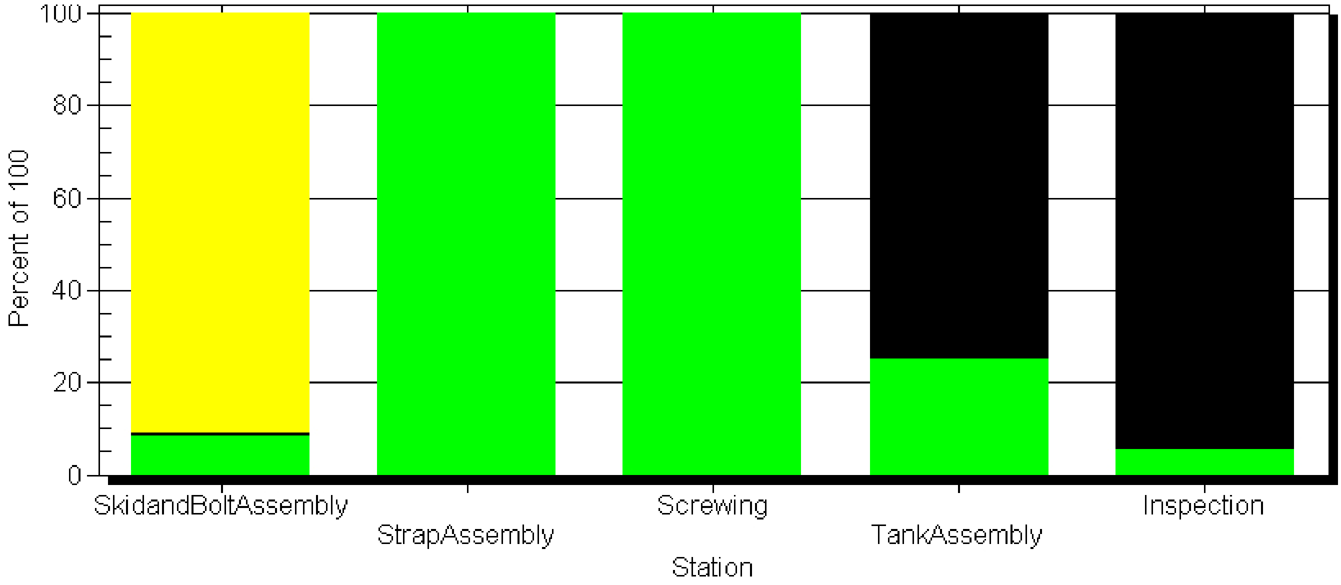

Fig. 14. Activity statistics of the workplaces for the production line with specific devices

Activity statistics for the stations (figure 14):

- for the bolt assembly station: 8% activity, 92% blocked;
- for the strap assembly operation: 100% activity;
- for the screwing operation: 100% activity;
- for the mounting the tracks on the tank station: 24% activity, 76% waiting;
- for the inspection station: 5% activity, 95% waiting.

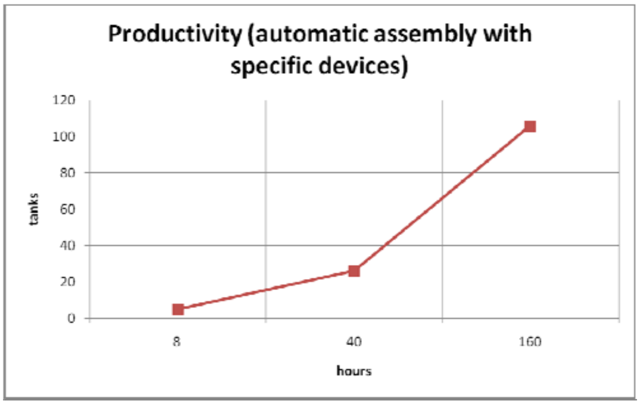

Fig. 15. Productivity curve of the production line with specific devices

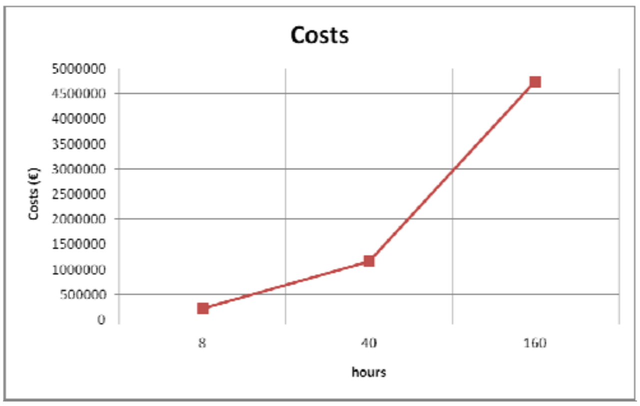

Fig. 16. Material costs curve of the production line with specific devices

5. CONCLUSIONS

The workplaces of the real production flow were abstracted an analysis basis was built and, based on that, two automation scenarios were simulated.
The abstraction was made by analysing the work places in the real production line with the focus on their inputs, outputs and their specific attributes. After the analysis, a generalized model of a simulation object was generated (figure 2).
Using the objects created after the generalized model, the analysis basis for the real production line was built (figure 4). This analysis basis represents a simulation model from which was extracted the productivity of the real line and was generated the material costs curve for a time interval of 160 hours. The analysis basis was build for providing data also for other time intervals and for testing different scenarios.
Having the simulation of the real production line, there were built other two simulation scenarios, adapting the real analysis basis for automation and using objects build after the same generalized model.
The simulation results (figure 17) – 31 tanks/tu for the real line, 79 tanks/tu for the line with robotic arms and 106 tanks/tu for the line with specific devices – reveal that the last scenario is faster than the robotic arms scenario and the real production line. This means that discrete devices, specific for every operation, are desirable for a fast assembly process. The advantages of this scenario are: the use of fast assembly devices and the simultaneous opperations made possible by the high discretization of the opperations in the sistem.
The last automation case also have some drawbacks which are: longer conveyors, more space for installing the specific devices and also more costs for designing, building and/or buying the specific devices.

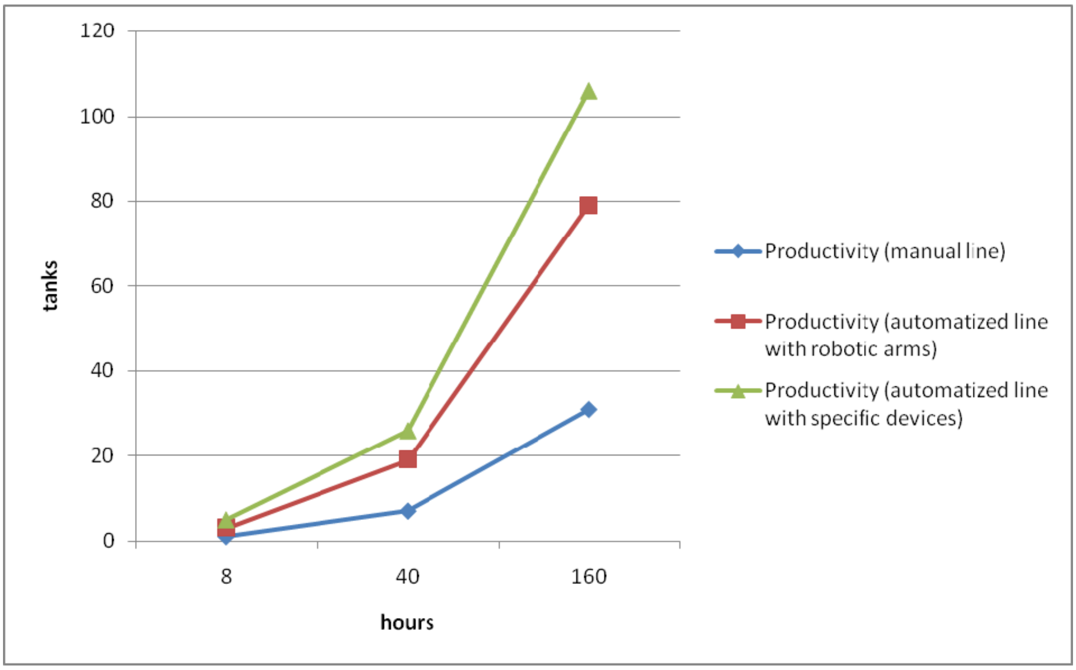

Fig. 17. Comparative productivity curves between the real (manual) production line and the simulated automatized scenarios

Also a drawback is the greater distance through which the parts go through the process, but this is compensated by the simultaneous opperations that are done in the sistem.

An important aspect of the functionality of the line is that it is not used only for assemblying and mounting new tracks on the tanks, but is most used for assemblying and mounting reconditioned tracks, which are among the most frequently damaged parts at a tanked combat vehicle. The fact that new materials or reconditioned materials are used in the assembly and mounting processes doesn't make any difference in the way operations are executed or in the production flow.

The original contribution of the work is the generalized simulation object model, abstracted accordingly with the real production objects, which was used to build the analysis basis of the real production line. Also, the topology of the simulation scenarios and the flow of the process make an original contribution along with all the simulation models, objects, intelligence, graphics and logic of the flow presented in this work.

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