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REAL TIME SIMULATION OF CONVEYING SYSTEM: CASE STUDY

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Abstract

Materialflow simulation is very effective mode to establish feasibility of any complex transport system and to test its parameters. This paper calculate conveying performance in Leoni Kraljevo plant for cable production and then simulate whole process of conveying flow in AutoMOD with all complexity and big number of conveyer trolls. After analyse of simulations data it gives some optimization recommendations.

***Key words**: simulation, conveyor, optimization.*

1 INTRODUCTION

The basic concept of simulation is a virtual environment where real processes can be presented and defined in a production environment. Simulation is a process of real problems and derivation of state processes in the form of experiments. The essence of modeling the real state in the production system is the process of presenting the known real state of production in advance. When modeling and developing a virtual environment, it is necessary to define the input parameters and the goal within the actual experiment. Defining the input parameters in the simulation and presenting the problem means taking over all possible parameters based on the measurements in order for the experiment to be accurately presented. After taking over all the necessary parameters for defining the working environment in the further procedure, a systematic analysis of the flow of transport and logistics processes is approached. The development of the model consists of defining an identical state in the production process and imitating real processes with real times when performing all activities on machines. After imitating the actual process in the production environment, where the experiment and modeling are performed, the simulation of the production process is approached. By performing the simulation, different useful data are obtained that can be used for different purposes depending on the function of the simulation goal. As production networks and transport systems within production become globalized and increasingly complex, there is a need for simulation-based solutions to make the production process known in advance. Software for simulating real events in a production environment is becoming indispensable in defining real processes in a company.

A number of simulation software can be used to simulate processes in companies. In this paper to simulate the conveying systems will be called simulation software autoMOD [1]. This software can be applied to various optimization problems [2, 3, 4].

The application of conveying systems in real time based on simulation in one production environment can be seen in papers [5, 6, 7, 8, 9].

2 SIMULATION CASE STUDY

Company Gama Consulting, has implemented a conveying Sky Track system in Leoni Kraljevo plant for cable production. Layout of the conveying lines has shown down (Fig.1) with parameters given from companies in Table 1.

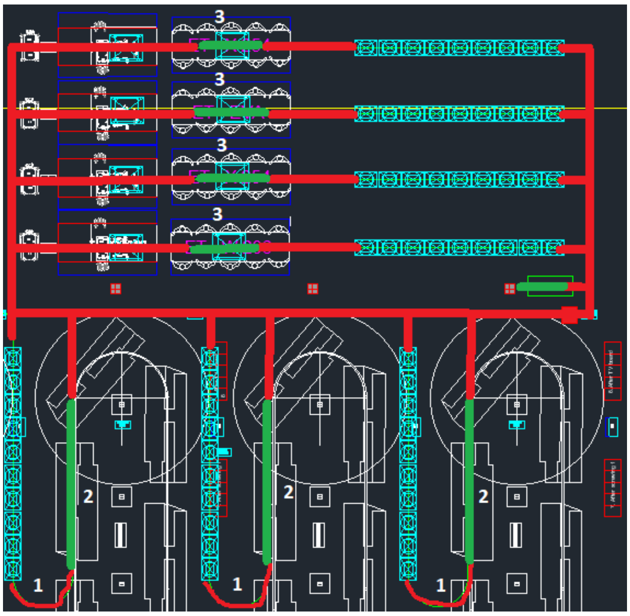

***Fig 1**. Layout of Leoni's Sky Track system*

Conveying system in Leoni plant in Kraljevo for cable production contains trolls driven by humans. Trolls are set at 3 m height and not influence machines on the floor. There are ways at the floor for troll-pulling workers. Trolls speed correspond normal human walking speed.

Loads in this simulation are cables aggregates for car assembly.

Duration of all simulations are 7.5 [h] each – definied from Gamma Consulting, because it is time of one shift.

Trolles with cables (loads) travels from PGTF's to E-boards through complex conveyor system lines. At PGTF's points arrive cables from cable production lines, where cables are loaded on trolls end travel then to E-borads points for testing. Every troll can take all 3 cable types and troll capacity is 1.

This simulation considered 3 different cables types as the plant operate.
Trolls loaded with cables type 1 travels from PGTF1 point to E-board 1, trolls with cables type 2 are going from PGTF2 to E-board 2, and other trolls transport cables type 3 from PGTF3 to E-board 3 & E-board 4 (equally distributed).
Trolls with loads stop allways at scan point for verification.
We did not observe cable production flow and its arrival at PGTF's . It is taken only arrival tact time at PGTF's.

This simulations also doas not considers packing of cables after successful testing at E-boards and further flow of cables after packing.
Simulation presentation doas not represent real shapes of trolls and cables, because it was not goal to have visual fidelity but reliable simulation data.
On the Table 1 below has shawn 9 versions of simulations, required from Gamma Consalting for Leoni compani, with all necessary data.

Table 1 Parameters of Sky Track simulation data given from Gamma Consulting

Cycle	PGTF 1, 2 & 3	operator PGTF 1, 2, 3 → buffer	Buffer places	E - board 1, 2, 3 4	packing table E-board 1234	operator E-board 1234 → buffer	
1	5,6min tact	v = 1,2 [m/s]	3	8min tact	5,6min tact	v = 1,2 [m/s]	medium speed
2	5,6min tact	1,2 [m/s]	5	8min tact	5,6min tact	1,2 [m/s]	
3	5,6min tact	1,2 [m/s]	7	8min tact	5,6min tact	1,2 [m/s]	
4	5,6min tact	v = 1,4 [m/s]	3	5,6min tact	4min tact	v = 1,4 [m/s]	high speed
5	5,6min tact	1,4 [m/s]	5	5,6min tact	4min tact	1,4 [m/s]	
6	5,6min tact	1,4 [m/s]	7	5,6min tact	4min tact	1,4 [m/s]	
7	8min tact	v = 1 [m/s]	5	10min tact	7min tact	v = 1 [m/s]	slow speed
8	8min tact	1 [m/s]	7	10min tact	7min tact	1 [m/s]	
9	8min tact	1 [m/s]	9	10min tact	7min tact	1 [m/s]	

Here we present two analized simulations, Version 3 (medium speed) and Version 6 (high speed). Figure 2 shows start of every of 9 simulations required.
Loads (presented like a box) from PGTF1 are blue, loads (cables) from PGTF2 are yellow and loads from PGTF3 are orange (Fig.2).

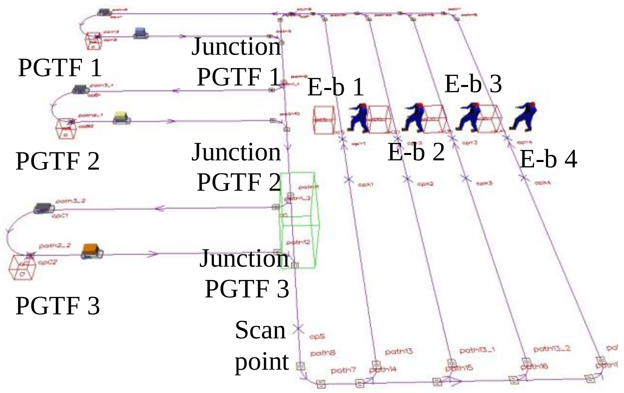

***Fig. 2** Simulation Layout – beginning of simulation flow*

<u>*Medium speed*</u>
Versions 1, 2 and 3 of simulations (medium speed) includes following parameters (definied from Gama Consulting for Leoni company):
Trol speed: v = 1.2 [m/s] – (constant)
Cable arrival tact time at all PGTF's:
T(tact) = 5.6 ± 0.1 [min] – (normal distribution)
Wait time at all PGTF's:
T(pgtf) = 3 ± 0.2 [min] – (normal distribution) – wait time includes total time of all operations at PGTF point (trol lowering, cable taking on, trol lifting)

Scan wait time:
T(scan) = 5 [s] at Scan point / cp5 at Fig.2 /
Buffer operating time at all E-board testing points:
T(E-b) = 77 [s], /cpY1, cpY2, cpY3, cpY4 at Fig.2 /
T(E-b) = (trol lowering time = 30 [s] – connstant,
trol taking off time = 17±2 [s] – normal distriburtion
trol lifting time = 30 [s] – connstant)
Buffer test tact time at all E-boards:
T(test) = 8 ± 0.5 [min] – (normal distribution)

2.1 Simulation calculation for version 3

Calculating cicle time for this parameters – version 3, it gives following results:
Max number of loads (cables) = 80 for every PGTF
Optimal number of recived loads (cables) at PGTF1 = 75 loads (without waiting).
Optimal number of recived loads at PGTF2 = 73 loads (without waiting).
Optimal number of recived loads at PGTF3 = 80 loads (without waiting).
Waiting is possible at many points of trollines, at scan point if there is all Buffer places at E-boards are busy, at Buffer points, at PGTF's points, at 3 junction points…
Calculation includes medium times (without distribution). For example PGTF waiting time is T(pgtf) = 3 ± 0.2 [min] with normal distribution, it means, mean (median) is 3 [min] and variance is 0.2 [min]. For calculation we used only mean value 3 [min], and in simulation we applied normal distribution 3 ± 0.2 [min]. It effects all other values with distribution.

Number of trolls is not limited, and it is over 30 in simulations. It means that every load (cable) cames from production line it will assigned free troll. That is important for calculation and for simulation.

2.2 Simulation analysis for version 3

After accomplished simulation in AutoMOD programe [6], we analize result data.
Afrer 2 hours and 20 min from the start of simulation it begins queuing at Scan point and at PGTF3 junction. It means that most part of simulation part is not regular. After whole simulation of 7.5 hours, there is 60 cables not taken from PGTF 1, 2 & 3. It does not correspond to the real situation. That is why also all other statistic parameters not reliable. At points Buffer1 and Buffer 2 there are 7 trols and 3 trols with cables waiting to test, it will take a lond time to comlete the testing.
Queus representing PGTF's and E-boards, drawn with red wire boxes at Fig.2. PGTF's queus are source of loads (cables) for this simulation, and E-boards queus represent end of the road (abyss) for loads in this simulations.
Statistics data for version 3 simulation are:

Processes:

	total loads	current loads	average loads	max loads	average time [s]
PGTF 1 - Buf 1	80	31	16.14	31	5447.56
PGTF 2 - Buf 2	80	31	16.20	32	5467.93
PGTF 3 - Buf 3&4	80	26	10.05	30	3625.47

Queues:

	total loads	current loads	average loads	max loads	utilization [%]	average time [s]
Space	240	44	10.21	47	-	1148.66
PGTF 1	67	5	2.72	5	54.4	1095.19
PGTF 2	67	5	2.68	5	53.7	1081.35
PGTF 3	62	5	2.65	5	53.0	1153.27
Buffer 1	50	1	0.88	1	87.6	473.55
Buffer 2	50	1	0.88	1	87.7	473.93
Buffer 3	28	0	0.49	1	49.2	474.96
Buffer 4	26	0	0.46	1	46.0	477.77

Workers (resources):

	total loads	average loads	max loads	utilization [%]	average time [s]
r Buffer 1	50	0.91	1	90.8	489.88
r Buffer 2	50	0.91	1	90.8	490.14
r Buffer 3	28	0.51	1	51.0	483.86
r Buffer 4	26	0.48	1	47.6	494.22

Data from simulation - version 3 will not be commented, because it is not regular simulation (see Fig.3). There are many loads not taken from PGTF's because there are large queues at trollines and trolls can not reach PGTF's to take loads. That's why is only 50 loads have reached Buffer 1 & 2, and only 54 loads arrived at Buffer 3 & Buffer 4 combined.
There is 44 loads waiting to reach PGTF's and it disturbes cable pruduction also, stoping cable production lines for certain time or changing tact time or cause a large queues in cable production lines.

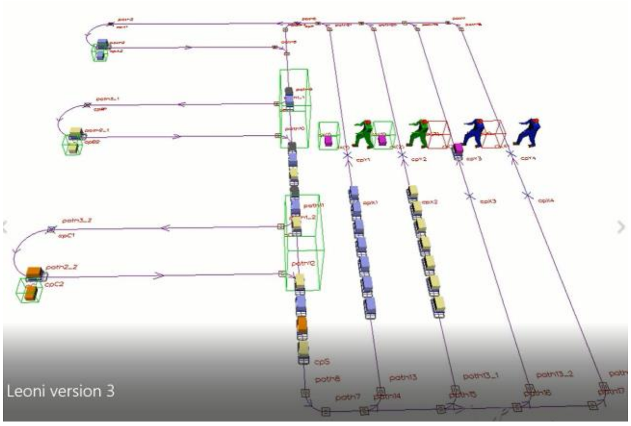

Fig. 3 *End of simulation – version 3*

This parameters are not applicable in real conveying line.
<u>*High speed*</u>
Versions 4, 5 and 6 of simulations (high speed) includes following parameters (definied from Gama Consulting for Leoni company):
Trol speed: v = 1.4 [m/s] – (constant)
Cable arrival tact time at all PGTF's:
T(tact) = 5.6 ± 0.1 [min] – (normal distribution)
Wait time at all PGTF's:
T(pgtf) = 3 ± 0.2 [min] – (normal distribution) – wait time includes total time of all operations at PGTF point (trol lowering, cable taking on, trol lifting)
Scan wait time:
T(scan) = 5 [s] at Scan point / cp5 at Fig.2 /
Buffer operating time at all E-board testing points:
T(E-b) = 77 [s], /cpY1, cpY2, cpY3, cpY4 at Fig.2 /
T(E-b) = (trol lowering time = 30 [s] – connstant,
trol taking off time = 17±2 [s] – normal distriburtion
trol lifting time = 30 [s] – connstant)
Buffer test tact time at all E-boards:
T(test) = 5.6 ± 0.5 [min] - (normal distribution)

2.3 Simulation calculation for version 6

Calculating cicle time for given parameters – version 6, it comes to following results:
Max number of loads (cables) = 80 for every PGTF
Optimal number of recived loads (cables) at PGTF1 = 78 loads (without waiting)
Optimal number of recived loads at PGTF2 = 77 loads (without waiting)
Optimal number of recived loads at PGTF3 = 80 loads (without waiting)
Waiting is possible at many points of trollines, same as in version 3…

2.4 Simulation analysis for version 6

After accomplished simulation in AutoMOD programe, we analize important data.
Afrer about 4 hours and 45 min from the start of simulation it begins queuing only at Scan point. After about 5 hours and 30 min begins queuing and at PGTF3 junction, which slows down trolls arriving at Buffer3 and Buffer4 points (Buffers 1

and 2 are occupied). Afrer 6 hours and 45 min there is 9 trols waiting at Scan point. After whole simulation of 7.5 hours, there is only 1 cable not taken from PGTF 1, 2 & 3. It is almost the real situation. But there is 10 trols with cables waiting in the queue at Scan point and one empty trol going to PGTF3 to take a new cable. Also there is a 7 trols waiting in queue to be testet at Buffer 1 and Buffer 2 each. It requieres a long time to be tested at E-boards 1 & 2 afterwards. Testing E-board tables points 3 & 4 are fast empty.

Statistics data for version 6 simulation are:

Processes:

	total loads	current loads	average loads	max loads	average time [s]
PGTF 1 - Buf 1	80	13	7.54	14	2544.00
PGTF 2 - Buf 2	80	13	7.22	13	2438.00
PGTF 3 - Buf 3&4	80	3	2.47	8	850.00

Simulations confirms that max number of loads are 80, as we calculated.

Queues:

	total loads	current loads	average loads	max loads	utilization [%]	average time [s]
Space	240	0	0.00	1	-	0.00
PGTF 1	80	1	0.13	2	4.4	44.24
PGTF 2	80	0	0.12	1	4.1	41.77
PGTF 3	80	0	0.03	1	1.1	10.71
Buffer 1	68	1	0.84	1	83.9	333.50
Buffer 2	68	1	0.84	1	84.3	334.43
Buffer 3	38	0	0.47	1	46.9	333.69
Buffer 4	39	0	0.49	1	49.2	340.67

Buffer 1 and Buffer 2 has received 68 loads each, and we calculated 78 (without waiting). Because of troll waiting at many points (scan point, Buffer 1 & 2 queues, junctions), we are short for 10 loads. For Buffer 3 & 4 (combined), we are short only 3 loads (38 + 39 = 77), also because of waiting only at scan point and junctions, and not at Buffer 3 & 4 queuelines (as Fig. 4 shows).

Utilization at E-boards (Buffers) is high for 1 & 2 points, but is about twice as small for points 3 & 4, because PGTF 3 supplies both of last two E-boards for cable testing. An average time in queues is similar for all 4 E-boards (Buffers).

Workers (resources):

	total loads	average loads	max loads	utilization [%]	average time [s]
r Buffer 1	68	0.88	1	88.1	349.96
r Buffer 2	68	0.88	1	88.2	350.30
r Buffer 3	38	0.49	1	49.2	349.66
r Buffer 4	39	0.52	1	51.7	353.32

For workers at E-boards (4 workers drawn, for each E-board belongs 1 worker, but in reality every E-board has team of many workers for testing) is utilization high at points 1 & 2 and twice as small at points 3 & 4, corresponding data for queues.

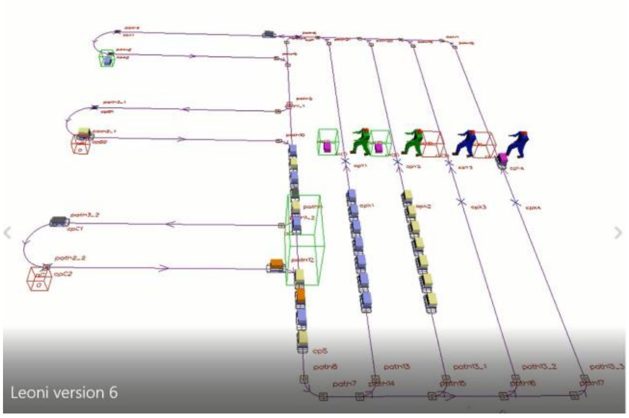

***Fig. 4** End of simulation – version 6*

End of simulation – version 6 shows queues anr Buffer 1 and Buffer 2 points, and queues at scan points and Junction PGTF3, because Buffers 1 & 2 are full capacity and no troll wit cables 1 & 2 types can not reach this two points, and Buffer 3 & 4 points are empty, and workers at E-boards 3 & 4 are not active, but no troll carrying cables type 3 can not pass queues to reach E-board 3 & 4 points.

3 CONCLUSION

For medium speed: Versions 1, 2 and 3 are not applicable in real production line because there is a lot of queues at E-boards (Buffers) points which require additional time to test all the cables after the end of the shift of 7.5 hours, which makes it fast impossible to start next shift.

For high speed: Versions 4 and 5 are almost not applicable in real production line because there is queues at E-board points which require additional time to test all the cables after the end of the shift of 7.5 hours, which makes it difficult to start next shift.

Version 6 is good on taking cables from PGTF's, but there is a big queue at scan point and big queues at Buffer1 and Buffer 2 points.

Version 6 is best so far (versions 1 to 9) to be optimized.

For slow speed: Versions 7, 8 and 9 are not applicable in real production line.

Scan wait time is rellativly small (5 sec) and doas not impact on queues.

All 9 versions could be optimized. But version 6 is closest to be optimized for real production. Suggestions for optimization (if possible) are:

- trols to be in down position at PGTF's when cable arrives (exclude lowering time),
- reducing taking on time (loading from production line to trol at PGTF's),
- increasing PGTF & E-board buffer places to 9,
- reducing taking of (unloading) time from trolls at E-boards,
- increasing trolls lowering and lifting speed,
- implementing medium or high travel speed,
- reducing test time at E-boards,
- using E-boards 3 & 4 for loads from PGTF1 & 2.

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