PROJECT OF AN AGV TRANSPORT SYSTEM THROUGH SIMULATION TECHNIQUES

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ABSTRACT
The aim of the present work is the application of simulation techniques to the project of the handling system of a semiautomatic line for the assembly of electrical switches. In particular, we have studied an Automatic Guided Vehicle (AGV) transport system. The maximum assembly capacity is 48 units per hour:
- Switches single-pole: 25%, 12 units;
- Switches 2 poles: 25%, 12 units;
- Switches 3 poles: 50%, 24 units.

A main line has been designed in order to connect the following stations:
• An input station for the loading of components for the assembly of each kind of product;
• Two machines for the preparation of subgroups;
• A machine characterized by two stations: assembling and testing of all products (physical, electrical and magnetic);
• Two final warehouses; one of finished products and another of products sent back to the testing station by an operator (inspector), through an handling system. We have a worker in each working centre.

1.1 The internal transport system

We have considered a particular type of AGV: ROBOMATIC 500p. This vehicle is a trolley with 3 wheels, wire-guided, suitable for handling loads up to 300 Kp and equipped with a battery to feed the onboard computer and the transfer along the direction of an inductive circuit (FL circuits). It is possible to recharge the battery through the contacts placed under the chassis at the charging stations. The plant is controlled by a Layout Controller: LC2-40/2/1. The data transfer between controller and vehicles, is realized through fixed installations on the floor, the signal frequency modulation FE (6.3 KHz) and the vehicle transmitter AW. There are two stop-points where data about path and destination are transferred to the vehicle, able to communicate its presence, its identification number and the battery recharging conditions. Each trolley, equipped with rollers, permits to load and unload the trays containing the assembly kits, from the warehouse to the assembly area.In order to reduce the problem of balancing the production line and to maximize the worker saturation, a job-shop layout has been chosen. The signals received by each vehicle, are converted by the onboard computer into driving instructions. Starting from the warehouse, the AGVs are able to recognize the workstation for unloading the assembly kit, thanks to a particular code located on the floor. Arrived at its destination, the trolley stops with a precision of ± 25 mm.

1.2 Detailed Design

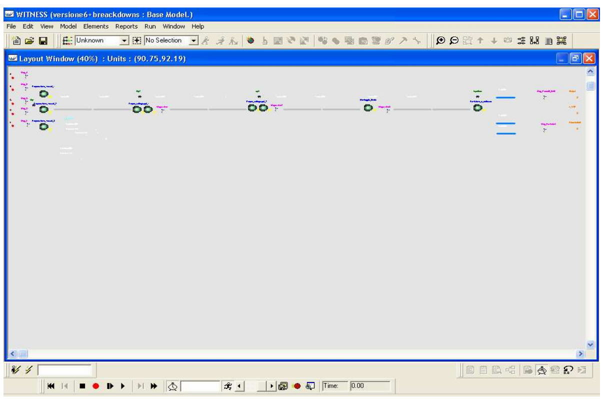
Some authors propose very approximate methods to value the needed number of AGVs; often, these deterministic evaluations don't work correctly. In the following, a particular formulation is used:

$$C = \sum i \frac{Ni \cdot ti}{ni}$$

Where:
C = number of trolleys needed;
Ni = number of load units per hour for each item i;
ni = number of load units carried by a trolley;
ti = trolley transport time, considering its speed and the particular path followed (curves, crossings, arrests, loading and unloading of load units). In the case studied, the number of trolleys calculated is 5.

1.3 Simulation Model

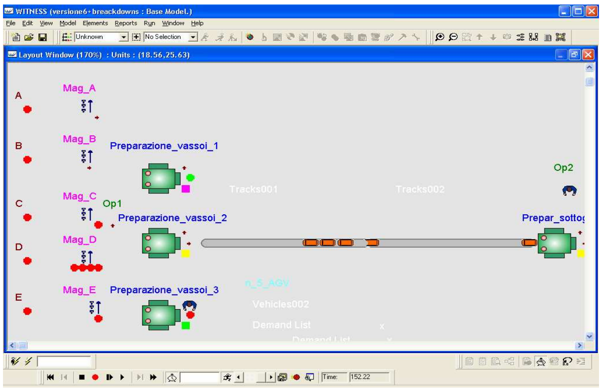
The above deterministic methods are very uncertain, so it is useful their validation through computer simulation. It is necessary to realize a plant model, including all data concerning the geometry of the system and the functional properties of each elementary layout part. The model of the analysed system is shown in the below figure:



We have used the simulation software "Witness", Release 2.

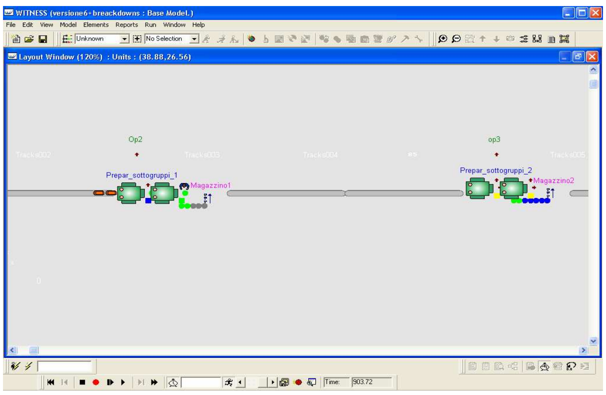
In order to understand the plant model, we describe the main characteristics of each workstation:

• At the beginning of the production line, there are five buffers to storage five different components. Subsequently, in the first workstation, there are three machines to assembly the different trays of switches, characterized by the same box, called component C. To simplifying the model comprehension, the trays characterized by a different switch production cycle, are marked with different colours: green for single-pole, blue for two-poles, grey for three-poles.



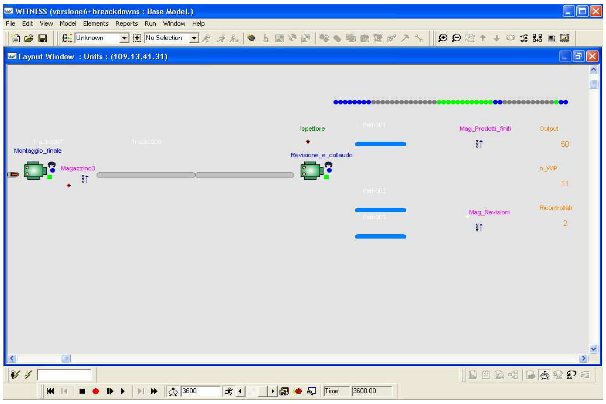
The AGV path starts from the exit of the above machines, where they load and unload the trays.

• In the second e third position, we have two identical workstations, both with two machines to assembly subgroups. Only for the first workstation, we have set a busy_time breakdown, therefore failures happen according to total working time; therefore we have defined the time between breaks (breakdown interval), through a lognormal distribution with an average value of 60 minutes, and the time of reparation (repair time of 3 minutes), made by a specialized worker.



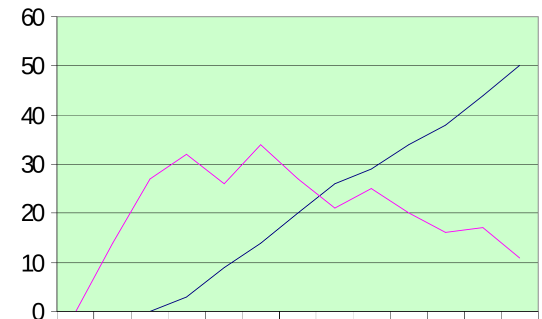
At the exit of each workstation, there is an interoperation buffer (Warehouse 1 and Warehouse 2), useful to separate the different switch production speeds. In the first buffer there are only single and three-poles switches; instead in the second one only single and two-poles switches.

• In the ending part, there is a machine in witch all products are assembled and tested by a worker. At the exit of this workstation there are two different warehouses, one for finished products and another for products sent back by the inspector to the testing station and finally to the warehouse of finished products. To realize the above diversification, in the machine form we have set a particular output rule, called “percent”.



Statistical Reports

Running the simulation, after 60 minutes, we observe 50 finished products realized: 13 single-pole switches, 12 two-poles, 25 three-poles; according to the real production capacity, in spite of the introduction of failure events. So, thanks to simulation, we can verify the correctness of the number of AGVs, previously valued with the analytical method.
The below diagram shows the data about production output and work in progress (WIP):



	0	5	10	15	20	25	30	35	40	45	50	55	60
Output	0	0	0	3	9	14	20	26	29	34	38	44	50
n_WIP	0	14	27	32	26	34	27	21	25	20	16	17	11

Then, we report statistical data relating to each machine and trolley, including delays and failures, in order to suggest possible improvements of the handling system.

- First workstation:

Machine	%free	%busy	%stop	n. operations
1	19.37	5.33	71.25	20
2	24.41	3.33	68.63	14
3	20.34	6.00	69.82	27

- Second workstation:

Machine	%free	%busy	%stop	%breakdown	%reparation	n. operations
1	31.39	36.11	0.00	1.75	0.25	26
2	32.94	31.94	0.00	1.58	1.33	23

- Third workstation:

Machine	%free	%busy	%stop	n. operations
1	46.58	28.06	0.00	29
2	46.58	27.50	0.00	27

- Fourth workstation:

Machine	%free	%busy	%stop	n. operations
1	21.20	71.30	0.00	51

- Fifth workstation:

Machine	%free	%busy	%stop	n. operations
1	70.64	29.36	0.00	50

- AGVs:

Trolley	%free	%called	%transport	%load	%stop	distance	n. loads
1	0.22	44.03	46.69	9.06	42.48	390	5
2	4.23	69.85	19.15	7.36	68.22	388	4
3	2.17	41.26	42.27	14.30	46.90	387	5
4	7.98	10.47	45.91	35.63	44.56	340	5
5	0.73	58.15	38.74	12.97	51.75	337	5

Analysis of Results

Analyzing the statistical reports, we can notice very high stop percentages of the trolleys, causing high values for the first work station too and consequently a reduction of production speed.This problem is mainly due to two factors:

• The single transport path for all trolleys, causing frequent jams of the AGVs;

• Long machine cycle times, causing frequent queues of the AGVs, waiting for loading and unloading products in the workstations.

Both the above causes are non simply to remove, requiring significant economic investments:

- In the first case, it is possible to increase the number of paths for the AGVs, through the creation of new inductive circuits followed by the trolleys;
- In the second case, it is possible to buy new machines of the first workstation, able to reduce cycle times.

Conclusions

The main reason for using computer simulation is the evaluation in advance of changes of the production process, reducing realization time and cost. In the case-study proposed, we have analysed the material handling system of a company assembling electrical switches, using wire-guided vehicles.

Initially, we have calculated the needed number of trolleys through an analytical formulation. Subsequently, we have decided to verify the deterministic result through a simulation model, using a specific software. The simulation software lets us represent graphically the material handling system and confirms a correct choice of the number of AGVs. Subsequently, thanks to the analysis of statistical reports, it was possible to identify the critical points along the production line, characterized by many stops, and to suggest possible solutions to apply.

After the economic evaluation of the technical solutions proposed, consisting of a reduction of machine cycle times and/or an increase of transport paths, it will be possible to create the new model of the production line and to value the productivity increase.

References

[1]. JAMES M. MOORE
"*Progettazione e layout degli* impianti" 19953[a] edizione
Mc Graw Hill New York

[2]. TURCO A.
"*Principi generali di progettazione degli impianti industriali*" 1990
Città degli Studi Milano

[3]. WITNESS MANUAL USER, Release 9.10, AT&T ISTEL

[4]. PARESCHI A.
"*Impianti industriali*" 1998
Progetto Leonardo
Pitagora Editrice Bologna

[5]. DE' ROSSI FERDINANDO
"*Corso di impianti meccanici*"Parte prima 1985 Liguori editore Napoli

[6]. T.H. NAYLOR, J.L. BALITY, D.S. BURDICK, K. CHU, 1968,
Computers Simuation Techniques, John W & Sons, New York

[7]. B. MARTINOLI,
Guida alla simulazione: metodi, linguaggi e modelli di ricerca operativa per simulare processi ed eventi con esempi relativi ad applicazioni aziendali 1988, Franco Angeli Editore

[8]. F. CARON,
Introduzione ali linguaggi e modelli di simulazione, in Simulare per decidere meglio, Milano Convegno IRI 6-7 febbraio 1992

[9]. SAIFALLAH BENIAAFAR,
Intelligent Simulation for Flexible Manufacturing System: an Integrated Approach, Computer & Industrial Engineering, vol.22, n°3. 1992,

[10]. P. BRATLEY, B.L. FOX, L.E. SCHRAGE,
A Guide to Simulation, 1983 Springer New York

[11]. LAW M. AVERIL,
*Simulation Modeling Analalysis,*1991*, II edit,* Mc Graw-Hill

[12]. K.D. TOCKER,
The Art of Simulation, 1963 English University Press, London

[13]. MORGAN, B.J.T.,
Elementary Simulation, 1984 Chapman 6 Hall, London

[14]. D. FALCONE, F. DE FELICE
Simulation For The Sizing Of The Buffer In A Manufacturing Company - SCSC 30th Anniversary The Proceedings of the Summer Computer Simulation Conference - Rheno, Nevada - (USA) 19-22 Luglio1998

[15]. D.FALCONE, F. DE FELICE
Operating planning of production in a mechanical industry through simulation techniques - ESM98- 12th European Simulation Multiconference – Manchester, United Kingdom – 16-19 Giugno 1998