INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

SIMULATION OF A PRODUCTION LINE WITH AUTOMATED GUIDED VEHICLE: A CASE STUDY

Luiz Felipe Verpa Leite
Centro Universitário da FEI, Brazil
E-mail: luizfelipe142@hotmail.com

Robson Marinho A. Esposito
Centro Universitário da FEI, Brazil
E-mail: rma.esposito@gmail.com

Ana Paula Vieira
Centro Universitário da FEI, Brazil
E-mail: anapaula.gem@gmail.com

Fábio Lima
Centro Universitário da FEI, Brazil
E-mail: flima@fei.edu.br

Submission: 31/07/2014
Revision: 03/09/2014
Accept: 21/10/2014

IJM&P

ABSTRACT

Currently, companies have increasingly needed to improve and develop their processes to flexible the production in order to reduce waiting times and increase productivity through smaller time intervals. To achieve these objectives, efficient and automated transport and handling material systems are required. Therefore, the AGV systems (Automated Guided Vehicle) are often used to optimize the flow of materials within the production systems. In this paper, the authors evaluate the usage of an AGV system in an industrial environment and analyze the advantages and disadvantages of the project. Furthermore, the author uses the simulation software Promodel® 7.0 to develop a model, based on data collected from real production system, in order to analyze and optimize the use of AGVs. Throughout this paper, problems are identified as well as solution adopted by the authors and the results obtained from the simulations.

Keywords: Automation, AGV, Discrete event simulation.

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

1. INTRODUCTION

From the 90s, opening the domestic market to imported products and the movement of privatization promoted by the government, spurred investments in industrial automation in Brazil to compete in international industries. Currently, the need to make the industrial processes more lean and competitive is increasingly required due to globalization. For this reason, the flexibility of manufacturing through integration with automated systems and devices should be part of the strategy of industries who wish to excel in the marketplace.

The Flexible Manufacturing Systems (FMS) are fundamental to face competition from competing on a global level, the constant technological advances and ever-changing consumer demand (RAJ et al. 2007). According to GELENBE and GUENNOUNI (1991), flexible manufacturing systems are highly computerized and automated production systems. For these reasons, mathematical programming approaches are very difficult to solve for very complex system so the simulation of FMS is widely used to analyze its performance measures (EL-TAMIMI et al. 2011). The advantages of the simulation in manufacturing systems are also stressed in (JAHANGIRIAN et al. 2010). That article gathered information from 1997 to 2006 in order to map the coverage as well as the trends in the area of the simulation of the manufacturing systems.

Another concept extend this definition to production computer controlled system consisting of several individual machines and workstations, material handling system, system settings and control system, which can process multiple items simultaneously in continuous operation mode for new equipment.

Among these various elements and devices that make up a flexible manufacturing system, mobile robots for handling materials are a key part of the integration of stations and stages of a production process. The AGV (Automated Guided Vehicle) consists in a mobile robots used for transportation and automatic material handling, for example for finished goods, raw materials and products in process. KRISHNAMURTHY et al. (1993) point out that the AGV is a driverless vehicle that performs the tasks of handling of flexible materials and is therefore considered suitable for an FMS environment. Furthermore, they define a system of autonomous vehicles (AGVS - Automated Guided Vehicle System) "[...] consists of a

INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

number of AGVs operating in a facility, usually controlled by a server" (KRISHNAMURTHY, 1993).

The design and operation of AGV systems are highly complex due to high levels of randomness and large number of variables involved. This complexity makes simulation an extremely useful technique in modeling these systems (NEGAHBAN;SMITH, 2014). For these reasons several works explore the FMS simulation using AGVs.

From this context, this paper will focus on the use of AGVs technology in an industry of consumer goods and the development of a model of virtual simulation to explore potential improvements to the system.

The objective of this work is to analyze the use of AGVs integrated into the manufacturing process in an industry of consumer goods. Furthermore, the paper proposes to develop a computer simulation model and validate it through the actual data of the case study, in order to have an additional decision tool to assess possible changes in the process.

In the literature some works deal with the problem of optimizing the use of AGVs in FMS. In (UM; CHEON; LEE, 2009) a simulation of a FMS production system using AGVs is presented. The authors, however, do not possessed real data for the simulation and hypothetic data were used. The authors stressed the benefits of using the software simulation tools for achieving a more efficient system.

A different approach for AGV systems is presented in (JI; XIA, 2010). They considered the AGV not necessarily as a driverless system, demand quantity is measured by the unit of weight or volume, buffer storage does not exist in the system. They have mentioned the application of its model to the operation of delivery express.

Concerning about the AGV control problem, (NISHI; ANDO; KONISHI, 2006) presented a rescheduling procedure can reduce the total computation time by 39% compared with the conventional method without lowering the performance level.

A simulation model of a hypothetical system using AGV which has a job shop environment and which is based on JIT philosophy was developed in (KESEN; BAYKOÇ, 2007). In addition, a dispatching algorithm for vehicles moving through stations was presented in order to improve transportation efficiency.

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

Several aspects of AGV systems are discussed at (VIS, 2006). Among them is the design of the system. It is clear that the design as well as the control system of the AGV is a difficult task. One important point when designing the system is the definition of the number of vehicles. In that subject the simulation helps the designers to take the best decision.

The work presented by (NEGAHBAN; SMITH, 2014) provides a good review in the simulation of manufacturing systems. An important highlight is dedicated to the material handling systems where the AGV appears as an important element. The authors mentioned that the use of the AGVs increases the productivity in manufacturing systems. However, the design and operation of AGV systems are highly complex due to high levels of randomness and large number of variable involved. For these reasons, the advantages of the computational simulation of the AGV are presented again.

An AGV control system evaluation is proposed in (BERMAN; SCHECHTMAN; EDAN, 2009). Again, the benefits of the simulation of manufacturing systems with AGV are presented. The authors used laboratory hardware to validate the simulation of the control system.

This paper contributes with the subject of simulating AGV systems when applies real data from a leader of market industry to do both the investigation of the actual scenario and a simulation of a new proposed scenario. First results of this work were presented in high level conference and this paper represents an extended and revised version after the conference discussions.

2. AGVS – AUTOMATED GUIDED VEHICLES

The AGV has the function to ensure efficient flow of materials within the production system. Production systems must be flexible and must allow the dynamic reconfiguration of the system. The AGV is a key component to achieve the objectives of an FMS (JOSHI and SMITH, 1994). This means that the AGV should provide the required materials to the appropriate workstation, at the right time and in the right amount, otherwise the production system will not perform well, making it less efficient, generating less profit or increasing the operating costs.

In an FMS system, the AGV has the following advantages:

- Driverless operation;
- More efficient control of the production;

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

- Diminishing of the damages caused by manual material handling;

There are several topologies of AGVs when considering the positioning system. It can be quoted the inductive system, the magnetic system and the laser guided system, among others. However, those systems have high cost and are difficult to maintain according to changes of the environment, and it can drive only the designated path by sensors which are placed or embedded in. To overcome those weaknesses, the laser navigation system as a wireless guidance system has been developed (JUNG et al., 2014).

The factory of the case study of this work uses the laser guided vehicle (LGV) (FERRARA; GEBENNINI; GRASSI, 2014). The LGV systems have the advantage of the absence of physical components related to the route. It is guided by mirrors placed on the walls, as presented in Figure 1.

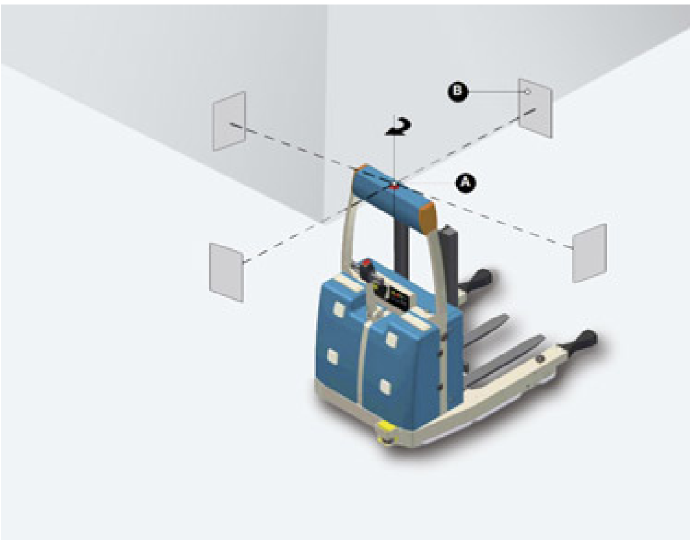

Figure 1: LGV system
Source: system-agv

3. CASE STUDY

3.1. Introduction

The production of toothpastes is the main focus of the company studied. This product has the highest profit margin across the entire range of products manufactured. In addition, it is the market leader in comparison to the competition. The sector that product creams in the factory has received attention and investment in recent years. The aim is to improve the process, guarantying quality and agility in production.

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

To achieve this goal, the company has focused on modernization of machinery and consequently in increasing the level of automation of production. Currently, the sector of toothpastes has 12 production lines, each one composed of two main parts: mounting the tube and filling the tube.

3.2. Problem definition

Given this context of high performance and commitment to further increase the level of automation in the factory, the engineering team, responsible for the continuous improvement of processes, carried out a deep study to pursue opportunities in the area of toothpaste. Due to the considerable increase in the volume of production lines, it was identified that the flow of people, forklifts and other handling equipment also intensified within a limited space, increasing the likelihood of accidents. Therefore it was necessary to develop a project that:

a) guarantee organization and security for material handling in an environment with machines and people;

b) elevate the level of automation in the industry, so that would result in reduced operating costs.

The characteristics of this project are discussed in the following. However, currently there is an additional problem: the material handling system deployed is already overloaded. To this issue, this paper refers to the use of simulation to assess possible improvements, which will be discussed in the final stage of the case study.

3.3. Project features

To reach the expectations of the project, the technology of AGVs presented itself as an ideal solution to reduce risks within the area of manufacturing because this type of equipment eliminates the possibility of human error, compared to use of conventional forklifts. Moreover, the work environment becomes cleaner, organized flow and generates savings over time with the reduction of manpower dedicated to material handling.

We chose the design by the use of LGVs due to its technology capable of providing flexibility, security and accuracy. There are total six LGVs to date, which are responsible for two main operations: remove pallets with products from the lines and take them to the stretch film machine and remove stack of empty pallets and take them to the production lines. This is presented in Figure 2.

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

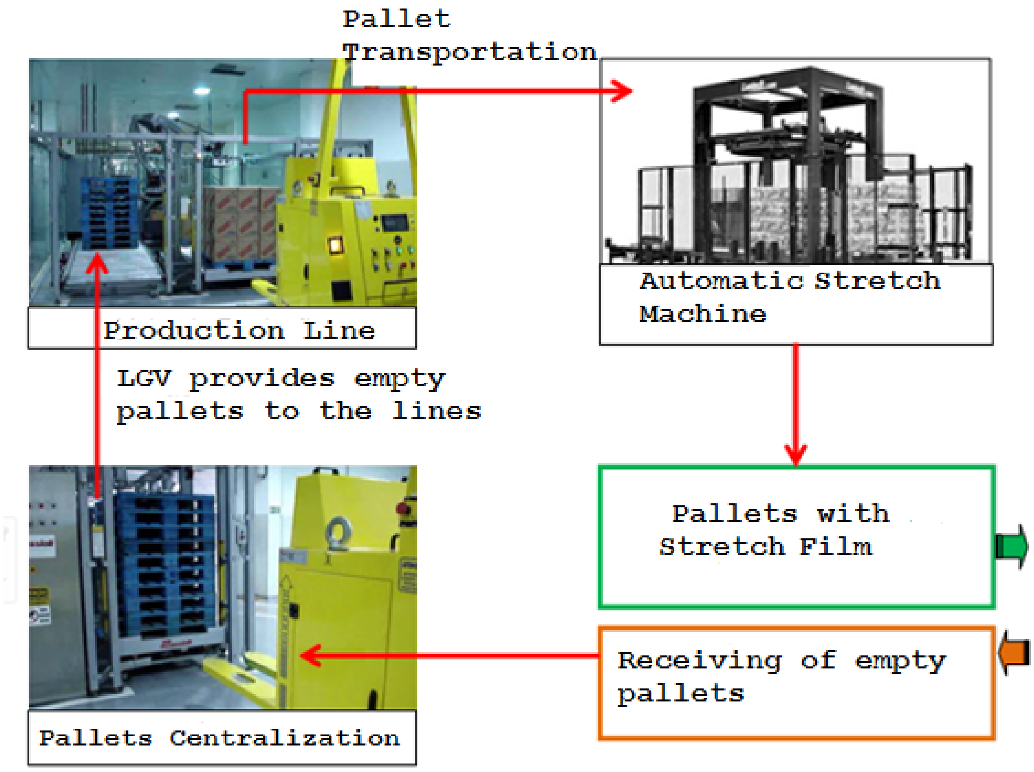

Figure 2: The route for LGVs

3.4. developing of the simulation model

For the development of simulations and scenarios the Promodel® software was chosen. The Promodel® software is used to plan, design and improve new or current manufacturing processes, logistics and other systems. It is software that allows building in a simple and visual way, due to animations, complex logic.

The model was developed in order to simulate the actual situation of the system, which covers the use of LGVs and places where they have interface points, these being: the centralizing machine pallets, the inputs and outputs of manufacturing lines and automatic stretch machine. A CAD picture of the plant was used as background in the Promodel® software. The final model resulted in the simulation environment as presented in Figure 23. The following will be presented as the model was developed in the Promodel® software.

The model was developed in order to simulate the actual situation of the system, which covers the use of LGVs and places where they have interface points, these being: the centralizing machine pallets, the inputs and outputs of manufacturing lines and automatic machine stretch. The following will be presented as the model was developed in the Promodel ® software.

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

The process begins with the arrival of empty pallets in the central inventory, where the same are grouped in stacks of 10 and sent to the pallet centering machine.

From this process, the stacks of pallets are delivered to the 12 production lines using LGV resource. These distributions follow a sequence of priorities, attending first the lines with higher productivity. After supplying the lines, the resources are released using the operation "FREE_LGV1".

After filling the lines with empty pallets, they are waiting until the arrival of the products (Pallet_LX) with 10 Join rule (join if required) so that the empty pallets are released one by one to the stack. With the arrival of the product (Pallet_LX) off the line (LX_out) is made the operation of joining the empty pallet (pallet) with the product by function, "1 PALLET JOIN". After the joint is incremented one unit in line with the counter "VAR1 INC, 1" function, so that the simulation of the counter line show the number of pieces that come out. They use the "GET LGV1" function to capture the first available resource, which will hold the drive line out (LX_out) to the stock of the stretch machine (Stretch_X). Is handling is done with the logic of motion "WAIT 0.5; MOVE WITH LGV1 then free."

With the arrival of pallet_LX in the stock of the stretch machine, LGV resource is released and the pallet is routed to the machine stretch so that it becomes available. In the pallet machine the stretch performs the "WAIT 1" operation, which is the time required for to stretch the pallet and sends it to the inventory. Again the function "VAR_stock INC, 1" is used, that is incremented by one unit in the output total pallet system counter.

With the arrival of pallets in stock, it is forwarded to escape, leaving the system, thus completing the process.

This process occurs for the 12 lines simultaneously. According to information obtained from the company line 10 has priority over the other lines, so that the simulation was defined in the same way.

Based on time-effective production of each line and the number of finalized pallets in this same period, it was possible to determine the real-time release of each pallet per minute for each of the lines.

ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

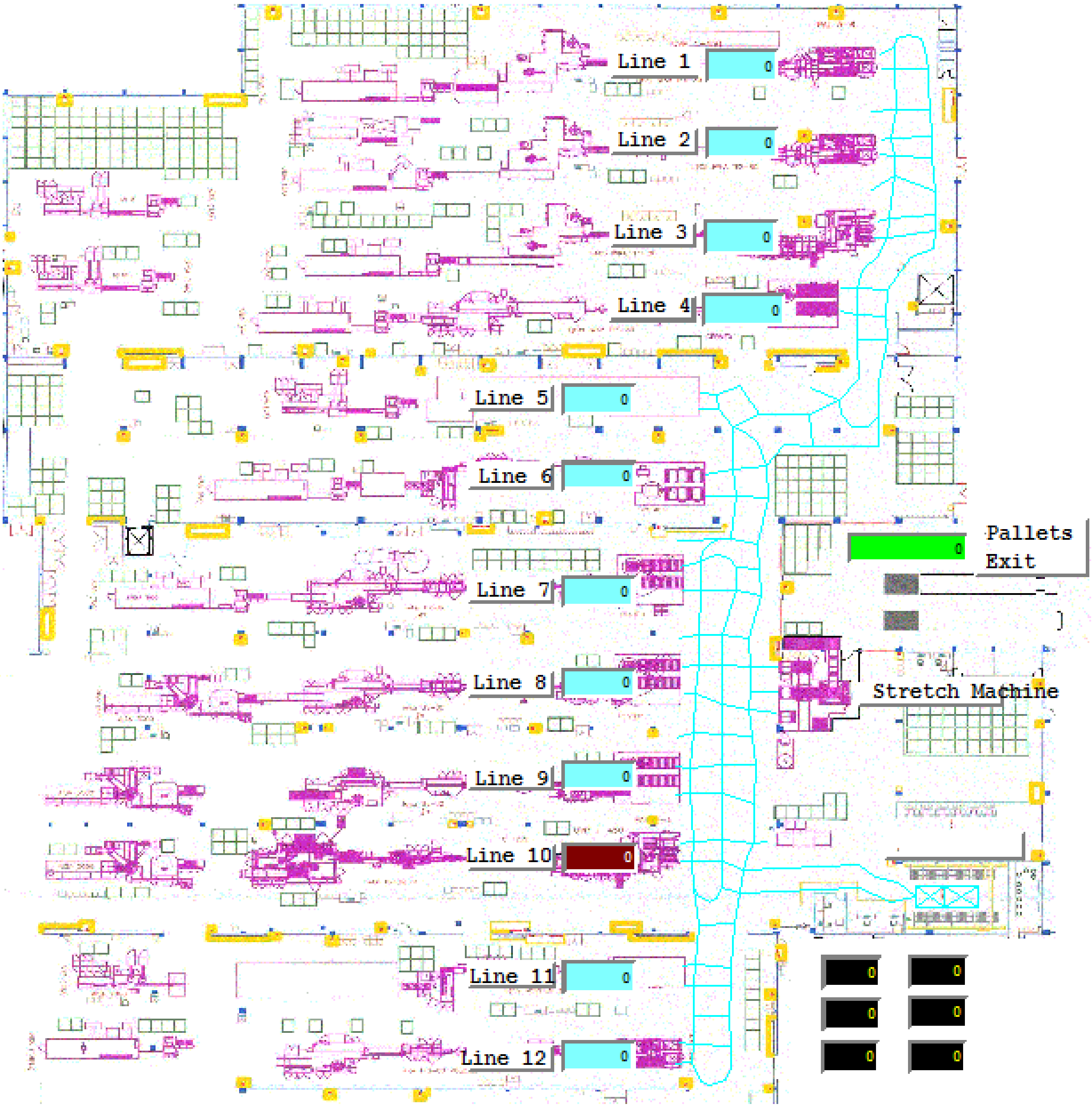

Figure 3: Promodel® simulation background

From these production data, it was projected two scenarios (which will be discussed in detail in the following):

a) Scenario 1 - Current situation, with 6 LGVs and level of production according to the data collected in 2013 in the company;

b) Scenario 2 – same parameters as scenario 1, but with improvements proposed by the authors;

Optionally simulation has added a heating time of 30 minutes. The heating time is a time of preparation which is not considered in the simulation results. It was

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

added to the first line supply with empty pallets so that once production starts, all lines had been already supplied.

A simulation time of 2160 hours was adopted, which corresponds to 90 days or 3 months of production. Considering production 24 hours a day, 7 days a week, there was no need to adopt any stop or set shifts for the employees.

3.5. Simulation scenarios

From the simulation model, two different scenarios were developed for evaluation of proposals and results, which will be described below.

3.5.1. First Scenario: the current production system

The first scenario is the main subject of this work. It represents the current production system. Its main objective is to evaluate the use of LGVs integrated to the manufacturing lines and validate the modeling to compare the results with the actual results of the line. Table 1 presents the resource's analysis considering this scenario.

Table 1 – Resource analysis to the first scenario

Name	Number Times Used	Avg Time per Usage(Min)	Avg Time Travel to Use (Min)	Avg Time Travel to Park(Min)	%Utilization	% In Use	% Travel To Use	%Travel To Park	% Idle	% Down
LGV1.1	23,689.00	4.15	1.07	1.32	95.53	75.92	19.61	0.32	0.16	4.00
LGV1.2	23,645.00	4.16	1.07	1.40	95.52	75.95	19.57	0.34	0.16	3.99
LGV1.3	23,606.00	4.17	1.08	1.49	95.52	75.88	19.64	0.36	0.17	3.96
LGV1.4	23,668.00	4.15	1.08	1.48	95.49	75.84	19.65	0.36	0.15	4.00
LGV1.5	23,558.00	4.18	1.08	1.40	95.55	75.98	19.57	0.33	0.15	3.97
LGV1.6	23,593.00	4.16	1.07	1.32	95.19	75.72	19.47	0.32	0.16	4.33
LGV1	**141,759.00**	**4.16**	**1.07**	**1.40**	**95.47**	**75.88**	**19.58**	**0.34**	**0.16**	**4.04**

Figure 4 presents a graphical illustration of some parameters from table 1. In this figure, the last column is the average for the six AGV.

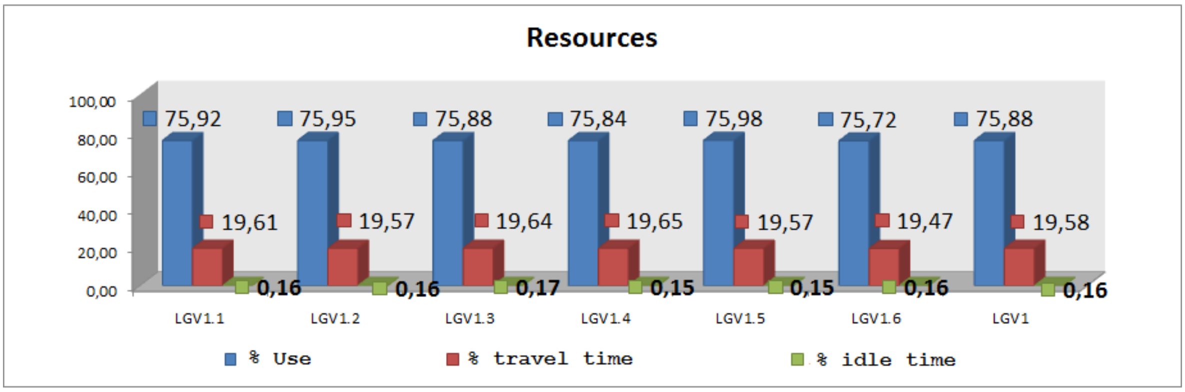

Figure 4: AGVs: Use, travel time and idle time

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

However, despite the high level of use, it can be seen in table 2 failures that occurred in the system.

Table 2- Entity Analysis to the first scenario

Entity Name	Total failed	Total Exists	Current Qty In System	Avg Time In System(Min)	Avg Time In Move Logic (Min)	Avg Time Waiting (Min)	Avg Time in Operation (Min)	Avg Time Blocked (Min)
PalletL1	2,638.00	6,424.00	0.00	23.16	3.18	16.49	1.00	2.49
PalletL2	796.00	15,202.00	2.00	10.92	2.94	4.29	1.00	2.69
PalletL3	1,002.00	14,611.00	1.00	11.30	2.74	4.58	1.00	2.98
PalletL4	1,151.00	15,463.00	1.00	11.21	2.55	4.61	1.00	3.06
PalletL5	1,824.00	9,250.00	2.00	15.58	2.07	9.05	1.00	3.46
PalletL6	1,047.00	10,421.00	1.00	13.10	1.91	6.60	1.00	3.59
PalletL7	1,075.00	11,1150.00	1.00	13.24	1.60	6.86	1.00	3.78
PalletL8	1,498.00	9,770.00	1.00	15.97	1.33	9.54	1.00	4.10
PalletL9	2,090.00	9,080.00	2.00	19.37	1.48	12.82	1.00	4.06
PalletL10	975.00	17,806.00	1.00	7.02	1.65	2.82	1.00	1.55
PalletL11	2,341.00	8,369.00	0.00	16.39	1.93	10.11	1.00	3.36
PalletL12	425.00	1,323.00	0.00	66.56	2.12	60.22	1.00	3.21

Figure 5: presents the graphical information from table 3.

In an attempt to solve the overload problem in the use of LGVs, it was added to the model 2 more unit of LGV, totaling 8 units. Table 3 presents the simulation results with the increased number of AGVs.

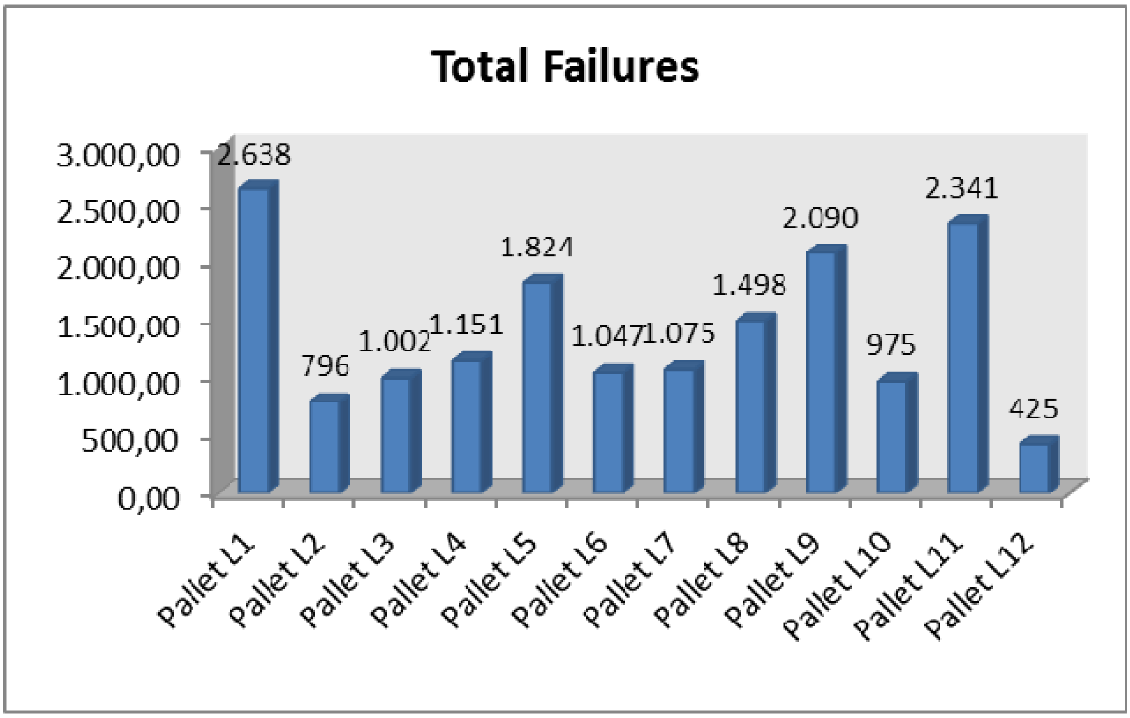

Figure 5: Total failures

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

Table 3- Resource analysis to the first scenario with 8 LGVs

Name	Number Times Used	Avg Time per Usage(Min)	Avg Time Travel to Use (Min)	Avg Time Travel to Park(Min)	%Utilization	% In Use	% Travel To Use	%Travel To Park	% Idle	% Down
LGV1.1	17,715.00	5.91	1.08	1.32	95.57	80.82	14.74	0.32	0.15	3.97
LGV1.2	17,724.00	5.90	1.08	1.39	95.56	80.75	14.82	0.33	0.16	3.95
LGV1.3	17,728.00	5.91	1.08	1.47	95.54	80.81	14.73	0.35	0.14	3.96
LGV1.4	17,708.00	5.91	1.09	1.47	95.53	80.69	14.84	0.35	0.15	3.97
LGV1.5	17,679.00	5.93	1.08	1.40	95.56	80.85	14.71	0.33	0.14	3.96
LGV1.6	17,827.00	5.88	1.07	1.32	95.63	80.87	14.75	0.31	0.15	3.91
LGV1.7	17,810.00	5.88	1.07	1.34	95.53	80.76	14.77	0.32	0.16	3.99
LGV1.8	17,699.00	5.92	1.08	1.34	95.55	80.86	14.69	0.32	0.15	3.98
LGVl	**141,890.00**	**5.90**	**1.08**	**1.38**	**95.56**	**80.80**	**14.76**	**0.33**	**0.15**	**3.96**

Due to the variation in the number of LGVs did not result in improvement to the system, the next step was to evaluate the local system. Table 4 presents the specific data of local single capacity (Single Location State), and the percentage of sites that feature lock (Blocked%) and may therefore be contributing to the failures of the system are the inputs of the stretch machine 1, 2 and 3.

The new strategy was the insertion of a buffer into the system. Thus a new simulation was performed to determining the minimum size of it. The result is presented in table 5 in the column “maximum contents”.

Table 4: Local single capacity to the first scenario

Name	Scheduled Time(HR)	% Operation	% Setup	% Idle	% Waiting	% Blocked	% Down
L1 In	2,160.00	0.00	0.00	44.54	55.46	0.00	0.00
L2 In	2,160.00	0.00	0.00	22.00	78.00	0.00	0.00
L3 In	2,160.00	0.00	0.00	22.80	77.20	0.00	0.00
L4 In	2,160.00	0.00	0.00	23.67	76.33	0.00	0.00
L5 In	2,160.00	0.00	0.00	33.02	66.98	0.00	0.00
L6 In	2,160.00	0.00	0.00	25.69	74.31	0.00	0.00
L7 In	2,160.00	0.00	0.00	24.15	75.85	0.00	0.00
L8 In	2,160.00	0.00	0.00	26.50	73.50	0.00	0.00
L9 In	2,160.00	0.00	0.00	25.83	74.17	0.00	0.00
L10 In	2,160.00	0.00	0.00	23.38	76.62	0.00	0.00
L11 In	2,160.00	0.00	0.00	38.01	61.99	0.00	0.00
L12 In	2,160.00	0.00	0.00	40.03	59.97	0.00	0.00
Pallet Center	2,160.00	0.00	0.00	0.00	99.06	0.94	0.00
Stretch 1	**2,160.00**	**0.00**	**0.00**	**70.95**	**0.00**	**29.05**	**0.00**
Stretch 2	**2,160.00**	**0.00**	**0.00**	**70.91**	**0.00**	**28.09**	**0.00**
Stretch 3	**2,160.00**	**0.00**	**0.00**	**70.10**	**0.00**	**28.90**	**0.00**
Stretch Maq	2,160.00	99.44	0.00	0.56	0.00	0.00	0.00

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

Table 5- Buffer analysis

Name	Scheduled Time (HR)	Capacity	Total Entries	Avg Time Per Entry(Min)	Avg Contents	Maximum Contents	Current Contents	%Utilization
Locl	2,16	999,999.00	145,739.00	7,179.69	8,073.77	16,150.00	16,148.00	0.81

Once increasing the buffer is not feasible in this case, another important point to be noted is the operation of the stretch machine itself. In accordance with table 4, this machine is in operation in 99.4% of the time, i.e., a potential system bottleneck. At the factory, it can be observed the fact that frequent queuing of LGVs to unload the pallets in the stretch machine.

Although this work has focused on the use of LGVs, during the analysis of this scenario and its variations, it was identified that an improvement with respect to the stretch machine can result in gains for the system. Therefore, as an additional contribution to the work, an additional scenario was developed exploiting the ability of this machine.

3.5.2. Second Scenario: improvement of the current production system

As found earlier, the stretch machine represents a possible bottleneck in the system. Therefore, it was decided to add a second stretch machine into the model. With this change, significant improvement was observed in the system as presented in table 6.

Table 6: Comparison between first and second scenario: resources

Name	*Avg Time per Usage(Min)*		*Avg Time Travel to Use (Min)*		*%Utilization*		*% Idle*		*% Down*	
	Scen1	Scen2	Scen1	Scen2	Scen1	Scen2	Scen1	Scen2	Scen1	Scen2
LGV1.1	4.15	2.16	1.07	1.03	95.53	69.29	0.16	27.12	4.00	3.26
LGV1.2	4.16	2.15	1.07	1.02	95.52	67.37	0.16	28.66	3.99	3.62
LGV1.3	4.17	2.15	1.08	1.02	95.52	66.28	0.17	29.72	3.96	3.63
LGV1.4	4.15	2.15	1.08	1.02	95.49	64.91	0.15	31.17	4.00	3.57
LGV1.5	4.18	2.15	1.08	1.01	95.55	63.18	0.15	33.26	3.97	3.23
LGV1.6	4.16	2.14	1.07	1.00	95.19	60.78	0.16	35.26	4.33	3.63
LGVl	**4.16**	**2.15**	**1.07**	**1.02**	**95.47**	**65.30**	**0.16**	**30.86**	**4.04**	**3.49**

Improvements can also be seen in relation to the entities and their indicators, as shown in table 7.

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

Table 7- Comparison between first and second scenario: entities

Entity Name	Total failed		Total Exists		Avg Time In System(Min)		Avg Time Waiting (Min)		Avg Time Blocked (Min)	
	Scen1	Scen2	Scen1	Scen2	Scen1	Scen2	Scen1	Scen2	Scen1	Scen2
PalletL1	2,638.00	0.00	6,424.00	9,062.00	23.16	6.30	16.49	2.01	2.49	0.11
PalletL2	796.00	0.00	15,202.00	15,999.00	10.92	5.86	4.29	1.83	2.69	0.10
PalletL3	1,002.00	0.00	14,611.00	15,613.00	11.30	5.50	4.58	1.66	2.98	0.11
PalletL4	1,151.00	0.00	15,463.00	16,614.00	11.21	5.12	4.61	1.46	3.06	0.12
PalletL5	1,824.00	0.00	9,250.00	11,076.00	15.58	4.22	9.05	1.07	3.46	0.10
PalletL6	1,047.00	0.00	10,421.00	11,468.00	13.10	3.93	6.60	0.91	3.59	0.12
PalletL7	1,075.00	0.00	11,1150.00	12,226.00	13.24	3.47	6.86	0.75	3.78	0.12
PalletL8	1,498.00	0.00	9,770.00	11,269.00	15.97	2.92	9.54	0.49	4.10	0.12
PalletL9	2,090.00	0.00	9,080.00	11,172.00	19.37	3.31	12.82	0.69	4.06	0.13
PalletL10	975.00	0.00	17,806.00	18,782.00	7.02	3.52	2.82	0.75	1.55	0.11
PalletL11	2,341.00	0.00	8,369.00	10,710.00	16.39	4.04	10.11	1.01	3.36	0.10
PalletL12	425.00	0.00	1,323.00	1,748.00	66.56	4.38	60.22	1.13	3.21	0.12

Figures 6 and 7 presents a comparison of the AGV use for scenarios 1 and 2 and the total failures for the pallets, respectively.

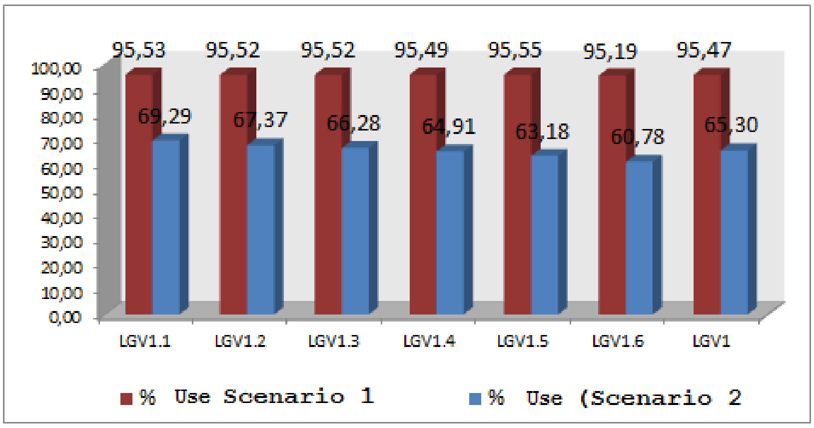

Figure 6: Comparing AGV use for scenarios 1 and 2

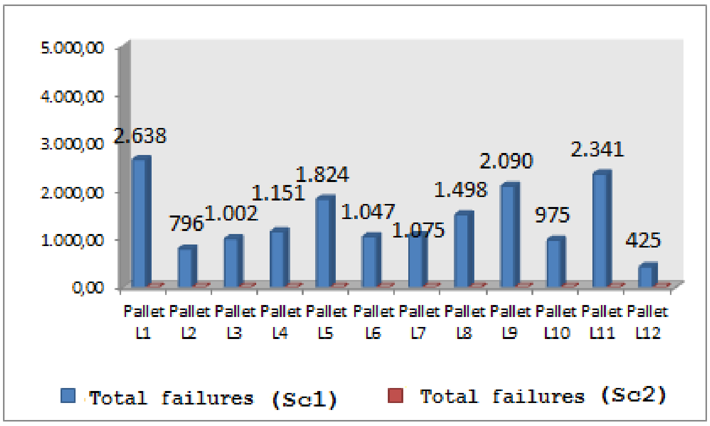

Figure 7: Comparing the pallets total failures for scenarios 1 and 2

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

4. RESULT ANALYSIS

By analyzing the resources, as shown in table 1, it can be observed that they are being used to its maximum capacity within the system by making use (utilization%) averaged 95% of the time, with an average idle (% idle) of while only 0.16% and not available for operation (down%) of 4%.

In table 2 the failures related to the first scenario was presented. These failures represent pallets that were released on the line, but there were no resources available to remove them, i.e., there is an overload of work for LGVs. Additionally, it is interesting to note that the line 10, which is currently the fastest one, is flawed, however at a lower level than the majority and the waiting time for resources is the smallest among all others. Therefore, it can be concluded that the actual existing prioritization of this line was correctly represented by the model.

This overload situation represented in the model validates the simulation because it can be verified in the current reality of the factory. Currently, the lines do not stop just because the production operators deviate from its main activity, which is monitoring the operation of the line, to make the removal of pallets when no LGV is available to accomplish the task. This deviation task ends up creating another problem because the operators eventually leave pallets (empty or not) blocking the route of LGVs. When the LGV is faced with an obstacle, even partially blocking the way, it stops (as your security configuration) and only return to work when the obstacle is removed. Consequently, the operation that is already overloaded is penalized again by these delays.

Trying to solve the overload problem of the LGVs a new simulation was carried out considering the insertion of two more AGVs. However, as shown in table 3, it was observed that even with the increased number of LGVs, they remain overloaded and arrival failure continue to occur in the system.

From the results presented in table 4, a change in simulation with the addition of a buffer (Loc1) with the aim of eliminating this block has been made. Initially, the ability of this new buffer was purposely set to infinity to determine what would be your ideal size. In table 5, the report shows that the local buffer should be sized for 16,150 pallet positions, which was the maximum amount of entities in this location so that

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

system failures do not occur, or 8,073 positions that would meet the average and reduce failures arrival, but did not solve it. However, this design is impractical.

By comparison of the results between the first scenario with the second (Table 6), it can be seen how the improvements impact the reduction in the average usage time of LGVs (almost 50%) and reduction in utilization (30%). This means that the LGV do not lose more time in a row to release the pallet, awaiting availability of the stretch machine. Improvements related to the entities are also achieved. The principal was the absence of arrival failures to any entities. Moreover, the average waiting times for resource and lock were drastically reduced. Therefore, the LGVs are available to meet all demands and as a consequence there was an increase in the output system entities, or increase of production at the same time interval. Finally, regarding the use of the additional stretch machine, the operating percentage was changed from 99.4% to 56.2%, lightening the whole system.

5. CONCLUSIONS

To operate in a global market without barriers and increasingly competitive it is essential to be ready to reduce costs and ensure quality. In this scenario, process automation is becoming a decisive factor for the success of businesses. Thus, this study contributes to assess the benefits and impacts to the automation of material handling integrated manufacturing lines and propose improvements for the case study through the use of simulation as originally defined in the objectives of this research.

To develop this work, factory visits, interviews with some of the engineers involved in the development and implementation of the project and the current leader of maintenance, responsible for the operation of LGVs, were performed as well as a survey of production data. It was finally dedicated a large portion of time to develop a model for computer simulation to represent satisfactorily the reality.

The use of simulation proved to be an effective tool to support decision making. Through it, it can be evaluated different scenarios and possibilities, helping to define what decision can actually bring more benefits and should be analyzed more deeply. Finally, through the simulation applied to this case study it was possible to identify an improvement in the system by adding a second stretch film machine.

http://www.ijmp.jor.br v. 6, n. 2, April - June 2015
ISSN: 2236-269X
DOI: 10.14807/ijmp.v6i2.257

REFERENCES

BERMAN, S.; SCHECHTMAN, E.; EDAN, Y. (2009) Evaluation of automatic vehicle systems. **Robotics and Computer-Integrated Manufacturing**, v. 25, p. 522-528.

EL-TAMIMI, A. M.; ABIDI, M. H.; MIAN, S. H.; AALAM, J. (2012) Analysis of performance measures of flexible manufacturing systems. **Journal of King Saud University – Engineering Sciences**, v.24, p. 115-129.

FERRARA, A.; GEBENNINI, E.; GRASSI, A. (2014) Fleet sizing of laser guided vehicles and pallet shuttles in automated warehouses. **International Journal Production Economics**, http://dx.doi.org/10.1016/j.ijpe.2014.06.008.

GELENBE, E.; GUENNOUNI, H. (1991) Flexism: A flexible manufacturing system simulator. **European Journal of Operational Research**, v. 53, p. 149-165.

JAHANGIRIAN, M.; ELDABI, T.; NASEER, A.; STERGIOULAS, L. K.; YOUNG, T. (2010) Simulation in manufacturing and business: A review. **European Journal of Operational Research**, v. 203, p. 1-13.

JI, M.; XIA, J. (2010) Analysis of vehicle requirements in a general automated guided vehicle system based transportation system. **Computers & Industrial Engineering**, v. 59, p. 544-551.

JOSHI, S. B.; SMITH J. S. (1994) ***Computer Control of Flexible Manufacturing Systems – Research and Developmen*****t**, Chapman&Hall.

JUNG, K.; KIM, J.; KIM, J.; JUNG, E.; KIM, S. (2014) Positioning accuracy improvement of laser navigation using UKF and FIS. **Robotics and Autonomous Systems**, v. 62, p. 1241-1247.

KESEN, S. E.; BAYKOÇ, Ö. F. (2007) Simulation of automated guided vehicle (AGV) systems based on just-in-time (JIT) philosophy in a job-shop environment. **Simulation Modelling Practice and Theory**, v. 15, p. 272-284.

KRISHNAMURTHY, N. N.; BATTA, R.; KARWAN, M. H. (1993) Developing conflict-free routes to automated guided vehicles. **Operation Research Society of America**, v. 41, **n.** 6, p. 1077.

NEGAHBAN, A.; SMITH, J. S. (2014) Simulation for manufacturing system design and operation: Literature review and analysis. **Journal of Manufacturing Systems**, v. 33, p. 241-261.

NISHI, T.; ANDO, M.; KONISHI, M. (2006) Experimental studies on a local rescheduling procedure for dynamic routing of autonomous decentralized AGV systems. **Robotics and Computer-Integrated-Manufacturing**, v. 22, p. 154-165.

RAJ, T.; SHANKAR, R.; SUHAIB, M. (2007) A review of some issues and identification of some barriers in the implementation of FMS. **International Journal of Flexible Manufacturing Systems**, v. 19, p. 1-40.

UM, I.; CHEON, H.; LEE, H. (2009) The simulation design and analysis of a flexible manufacturing system with automated guided vehicle system. **Journal of Manufacturing Systems**, v. 28, p. 115-122.

VIS, I. F. A. (2006) Survey of research in the design and control of automated guided vehicle systems. **European Journal of Operational Research**, v. 170, p. 677-709.