Planning and analysis of materials handling processes in production company using modelling and simulations

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Abstract: *In this paper is presented the method of planning and analysis of the materials handling line in one production company. The method consists of design, simulations, and analysis with the support of Arena simulation software. The design of the line is accomplished using modular modelling with interconnected modules and blocks, and simulations will be carried out to view the flow of boxes with materials and the functionality of main units and processes. The modelled line contains all the necessary units of the input processes, production and output processes, warehouses, materials handling vehicles, and the process flow of packages. Analysis will investigate key performance parameters and evaluate the functionality of the line. Production and logistics companies are implementing various software to plan and design their materials handling line, internal transports and production processes prior to the implementation and development of their plant. This enables them to plan the work, determine influential parameters and identify problems in the functionality. Results will be given in the graphical and tabular forms, which will represent the analysis of performance parameters and line efficiency.*

***Keywords**: MATERIALS HANDLING, WAREHOUSE, FACTORY, BOXES, PALLETS, MODULAR MODELING, SIMULATIONS, PROCESS CONTROL, PERFORMANCE ANALYSIS*

1. Introduction

The material handling systems and warehouse management are complex processes with many operations and devices that require adequate planning, proper design of infrastructure and deep analysis for good performance and functionality. Many logistics and production companies' deal with these issues, and search for the best solutions in order to increase production parameters. These processes can be planned before the development of materials handling and production lines and after them, if there are problems identified.

In order to support the companies for planning and analysis of materials handling lines, advancements are made towards the Industry 4.0 technologies using specialized software that help the modelling of these lines and apply simulations of working processes. In these software's, the model designed is a schematic representation of materials handling line.

The methodology in this paper is modeling and simulations of materials handling line for design and analysis. I took an example of materials handling company in Kosovo that produces canned food and has an input and output warehouses and production facilities. The line comprises of main structural units, vehicles like trucks, forklifts, conveyors, then warehouses, production units, stations and travel routes. The units are connected with transfer lines that define the entity flows, direction of movement and the interaction between main units. Main operations of the processes in the model must be exactly defined. Simulations should be carefully planned and tested to represent the correct behavior of the line and its units [1], [2]. Results will be acquired for Key Performance Parameters [3]. Analysis will identify the performance of the line and problems that require correction.

Design of the Materials handling line and simulations will be implemented using Arena Simulation software [4]. The software is developed from the Company Rockwell Automation, Inc. In the Fig. 1 is the view of the Software's User Interface and its main parts. Model design is carried by dragging and dropping modules in the Model window. These modules or blocks defines the process and are interconnected with connector lines, which represent the flow and direction of the entity [5], [6]. An entity is the product or package, or both, flowing in the process. Modules in this software can be *Flowchart Modules* and *Data Modules*.

Flowchart modules have various shapes depending on the functionality or operation. They are placed in the model window and interconnected between each other to form a flowchart, depending on the logic of the process [4], [5]. Data *modules* are defined in the spreadsheet interface of the Properties window and are not placed in the model window.

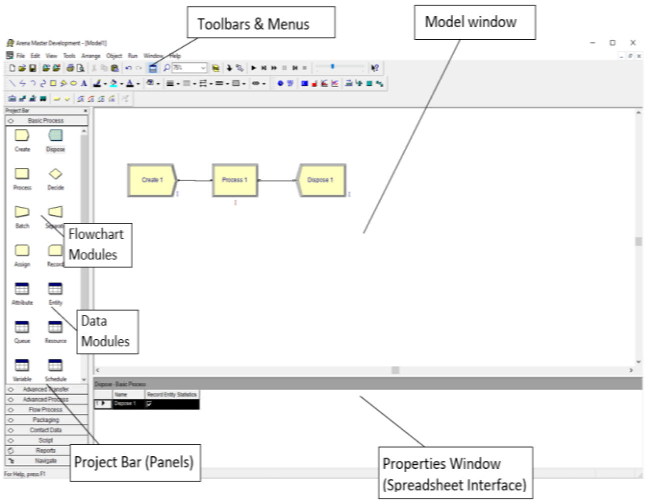

Fig.1. *Arena Simulation software - User interface with main design and simulation parts [4]*

Regarding the Literature review, several authors have published papers in the topic of modelling and simulation of materials handling and processing lines using Arena Simulation or other similar software.

S. Abedinzadeh et al. [1] in their paper present the simulation of a warehouse of an automotive company. They created a model and simulated it with ARENA software. The results presented bottle-necks in parts of the warehouse which lead to long waiting time for personnel. They presented strategies to reduce the average waiting time and improve the performance of the warehouse. Said M. et al. [3] identified Key performance indicators which were evaluated using Arena software. They developed a new improved production line layout a compared with real production line layout. Then analyzed the improvement of indicator values of new model compared to real model. Ch.Y. Liong et al. [10] in their paper presented ARENA simulation models for the loading and unloading systems in a warehouse. They analyzed for utilization of workers and waiting times at the various processes to identify the bottleneck in the system. They identified that the inter-arrival time of customers' trucks, number of forklifts, waiting time at the order picking, sealing, and loading process are the contributing factors towards the performance of the loading system. A.H. Abdul Rasib et al. [11] analyzed a real case study in food industry to construct simulation model in ARENA. Based on the issues found, they suggested improvements to the smoothness of the manufacturing system.

E. Pekel et al. [12] created a warehouse storage simulation model by using Arena Simulation Software of a hypothetical

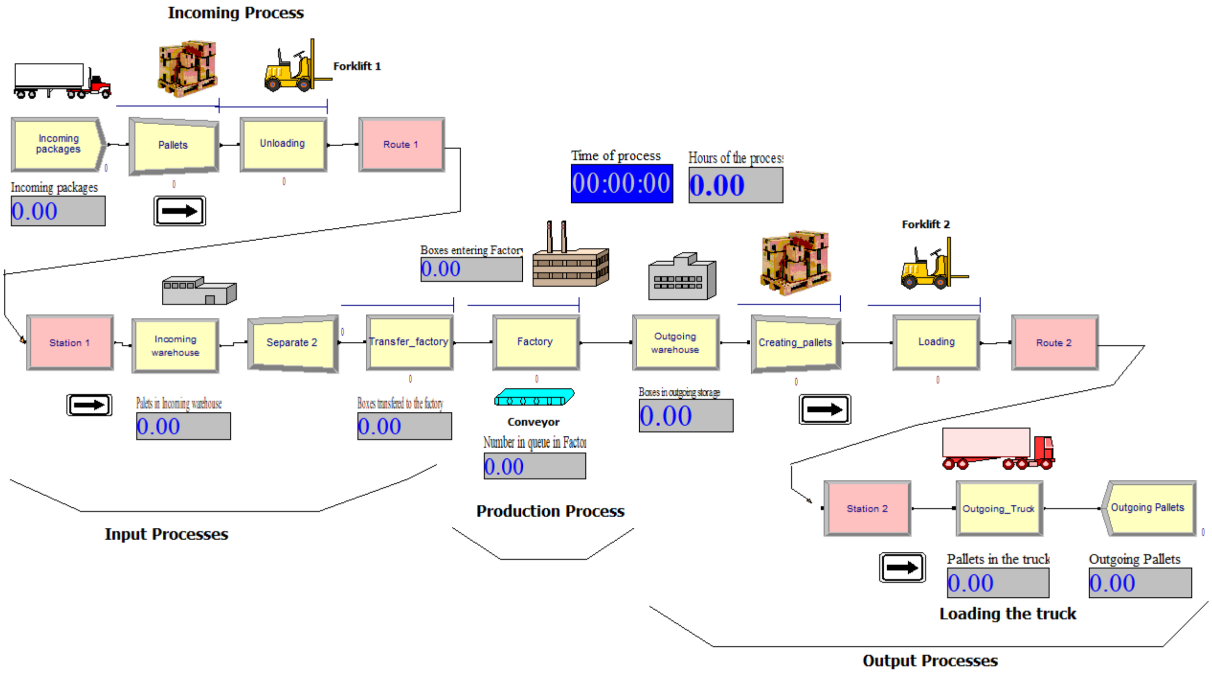

Fig.2. *Model of the Materials handling Line*

company. The aim was how to obtain the best possible result by fixing the departure time of the transporter and to determine how many pallets will be required monthly with the minimum and maximum bounds. Ch. M. L. Rahman et al. [13] created simulation model to a batch manufacturing system for process flow improvement. The model is an ARENA software of a UPS manufacturing line. They determined that the transformer making section was the main system bottleneck while other sections were running without delay. Changing the level of resources, adding extra workers and facilities re-layout have been suggested to improve the system performance. J. Saderova et al. [14] created simulation model for the receipt of goods into the warehouse. They observed and measured the forklift's work cycle, which unloaded pallets from the trucks. To create a simulation model they used EXTENDSIM8 software. They analyzed results of 3 experiments performed. Th. Wasusri et al. [15] analyzed case study in Arena Simulation in footwear warehouses. A. N. A. Ahmad et al. [16] present the method to increase the production output by improving conveyor layout, based on analysis using ARENA simulation.

2. *The Materials Handling Line Model*

Configuration of the Materials handling line is presented in Fig.2. The model of the Line consists of interconnected modules which represents an object, facility, resource or operation, and have their corresponding symbols. Modules are connected with wires. The model is designed in two rows, starts at the left and flows to the right, in one direction.

Other objects, like numerical results of key parameters are presented in gray color squares. There are textual boxes as a description of processes, and image description of facilities, loads, devices and vehicles. At upper part of the model are two important objects: *Time of the process* which shows the runtime of the simulation (Blue squared object), and *Hours of the process* which shows the hours of the line work (Grey color object).

The line is organized in three main parts: *Input processes, Production process and Output processes* (Fig.2) [2], [10], [12].

Units in the Input processes are:

1. *Incoming packages* – This is the name of the first module in the line, type *Create*. This module defines the startup processes and initiation of the operations (Fig.3). In this module is defined the *Entity Type* that flows in the line. It is named *Box.*

Boxes are packages with raw metarial that are brought with the truck, and carry it for manufacturing in the factory. One box has dimensions 40 cm width, 50 cm length and 30 cm height (Fig.4). *Max Arrivals* = 780 is the number of boxes that can fit in a trailer truck and will be unloaded [7], [8]. The boxes arrive every 0.1 minutes each for discharge from the truck, in *Random* distribution. But boxes are not single handled. They are part of the standard pallet to be unloaded, defined in the next module.

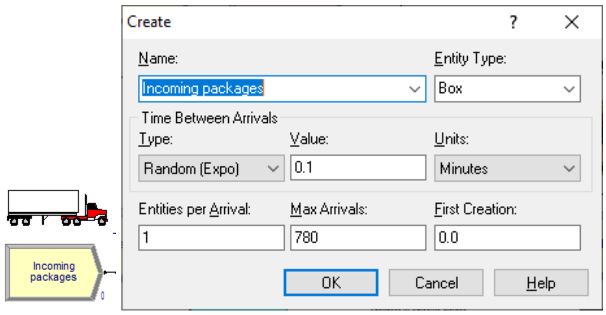

Fig.3. Create module symbol and properties

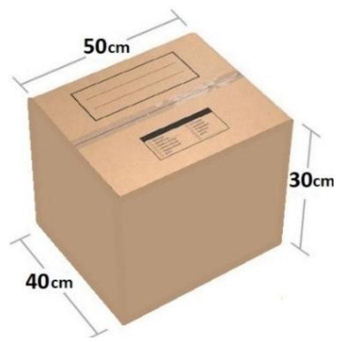

Fig.4. *Example of the standard Box with its dimensions, as a sample in the model analysis*

2. Second module is *Pallets*, type *Batch*. This is a grouping module of entities, in this case boxes. The boxes are grouped in one standard EURO2 pallet with dimensions 120x100 cm, and height

165 cm [9]. This is the most appropriate format of boxes which utilizes up to 99% the filling of the EURO2 pallet. One pallet consists of 30 boxes (Fig.5).

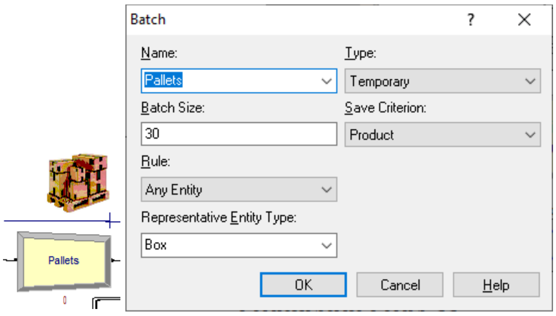

Fig.5. *Batch module symbol and Properties*

3. Third module in line is a process type, named *Unloading*. With this module is defined a process, in this case unloading of pallets from the truck. Unloading is done with one *Forklift*, which is defined as a *Recource*, named *Forklift1*. *Delay Type*, is the time required for the forklift to unload one pallet from the truck, and is defined by Uniform dispersion in minutes, between 2 and 3 minutes [4], [17] (Fig.6).

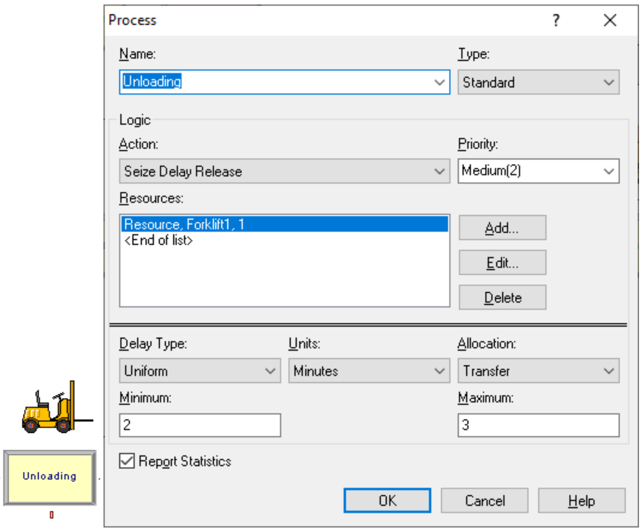

Fig.6. *Symbol and Input parameters of the Unloading process*

4. Next module is *Route 1* of type *Route*. The module represents the time the pallets are transfered by the forklift to the next station, in this case *Station1*. The route time of forklift travel is estimated 2 minutes (Fig.7).

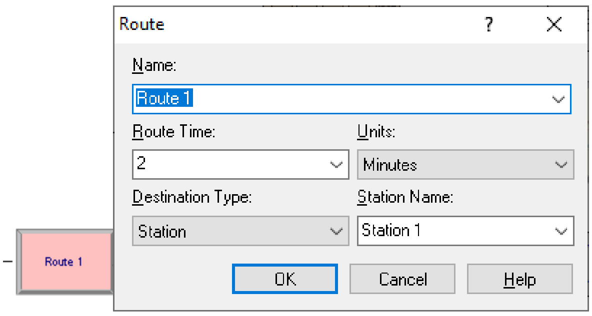

Fig.7. *Symbol and Input parameters of the Route module*

5. *Station* module, named *Station 1* defines a physical location, in this case the entry to the *Incoming warehouse* (Fig.7).

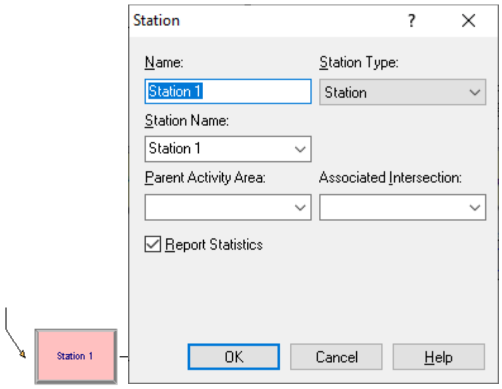

Fig.8. *Symbol and Input parameters of the Station module*

6. *Store* module, is used to add boxes to the storage, in this case *Incoming warehouse*. (Fig.8)

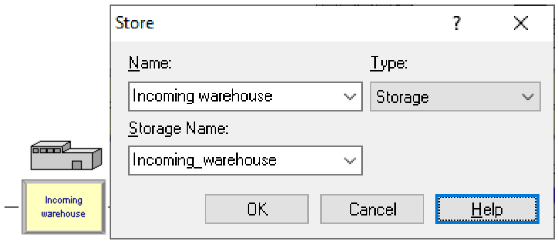

Fig.8. *Symbol and Input parameters of the Store module*

7. *Separate_boxes* is the name of the module type *Separate*, used to separate boxes from the previous batch created. In this case it means separating boxes from the pallets and sending them to the *Factory* for processing. (Fig.9)

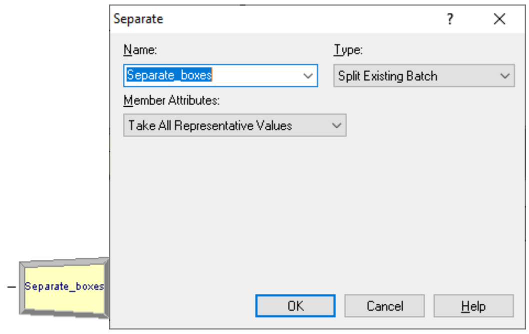

Fig.9. *Symbol and Input parameters of the Separate module*

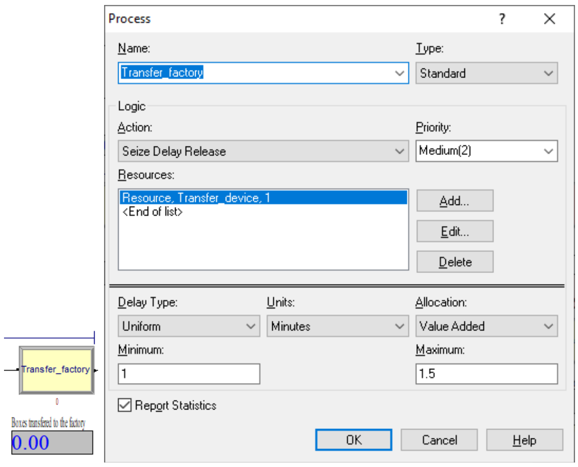

Fig.10. *Symbol and Input parameters of the Transfer_factory module*

8. *Transfer_factory* is the name of the process module that represents the time the input boxes will be transfered from the *Incoming warehouse* to the *Factory*, after being separated in the *Separate_boxes* module (Fig.10). Resource in this process is named *Transfer_device*. It is not defined exactlly, while it can be a forklift, cart or jack handled by workers, or even conveyor. *Transfer_device* is the resource that will transfer one box unit in Uniform dispersion in time 1 to 1.5 minutes (defined in *Delay Type).* This is an aproximated time, while *Transfer_device* can carry more than one box. For example, if a cart carries 5 boxes, it will require 6 to 9 minutes to transfer them to the *Factory*.

9. Next module in the line is a process module named *Factory* (Fig.11). This is the main module of the *Production process*. Here, raw material is discharged from the input boxes, products are created in the factory, and output boxes are filled with final products for output. Conveyor is the main recource as an internal transportation device for transfering products from the *Factory* to the *Outgoing warehouse*. One conveyor is planned for the process. There can be more than one conveyors, depending on the manufacturing processes. Also, other recources as vehicles can be used, like forklifts, cranes and carriages.

Delay Type means the time spent for filling one box with ready made products, sealing the box and transfering it with conveyor to the *Outgoing warehouse*. This time is a function of triangluar dispersion, and is estimated to be 10 to 14 minutes (Fig.11). This timeframe can vary, depending on the number and dimensions of the products (canns, jars, bottles, bags, etc.), format of the box they will fill in and velocity of the conveyor.

In this case, the manufacturing time starting from the raw materials processing to the final product is not included, while it can vary heavily on the type of products processed, number of machines, time between machines, packaging process, etc. If required, the manufacturing time can be added to the already estimated time.

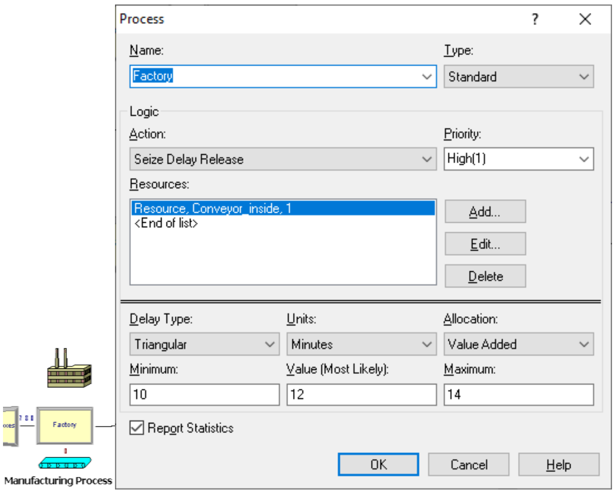

Fig.11. *Symbol and Input parameters of the Factory module*

Next modules in the line are units of the Output *processes*. The modules are:

10. *Outgoing warehouse* – The module is of type *Store*, which represents the warehouse where the output boxes come from the *Factory*.

11. *Creating pallets* – The module is the type *Batch*, where the outgoing boxes are grouped in 30 in one standard pallet EURO2. The number of outgoing boxes has the same box format as the incoming boxes for the purpose of pallet utilization (Fig.4).

12. *Loading* - The module is of type *Process*, which represents the loading of pallets from the *Outgoing warehouse*. Loading is done with one *Forklift*, which is defined as a *Recource*, named *Forklift2*. *Delay Type*, which is the work of Forklift is defined by Uniform dispersion in minutes, between 2 and 4 minutes. During this time it is estimated the forklift will take one pallet from *Outgoing warehouse* and load it on the truck.

13. Next module is *Route 2* of type *Route*. The module represents the time the pallets are transfered by the forklift to the next station, in this case *Station2*. The route time of forklift travel is 2 minutes.

14. *Station* module - named *Station 2* defines a physical location, in this case the entry of pallets to the *Outgoing truck.*

15. *Outgoing truck* – The module is of type *Store*, which represents the truck loaded with pallets.

16. *Outgoing Pallets* **– is** the last module in the line, type *Dispose.* This is the ending point of the model, in this case for the materials handling line (Fig.12).

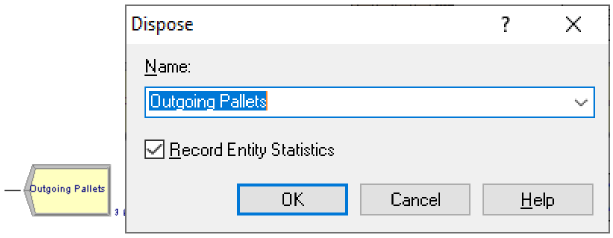

Fig.12. *Symbol and Input parameters of the Dispose module*

3. Simulation planning of the process flow in the line

After the model is designed and modules are connected, next step is planning the simulation scenario for the process flow.

The simulation is planned to run until all the boxes and pallets of raw materials as the input process are sent to the *Factory*, and all the boxes and pallets of outgoing process are loaded in the *Truck*. The main measuring parameter is the time of the main processes. The two timing boxes, first one in blue named *Time of process* shows the actual time of the process flow, and second one in gray named *Hours of process* shows the total hours of the process (Fig.13).

Results of boxes and pallets flow will be shown in the gray boxes around the corresponding modules during the simulation run. After the simulation, the software will generate report of results.

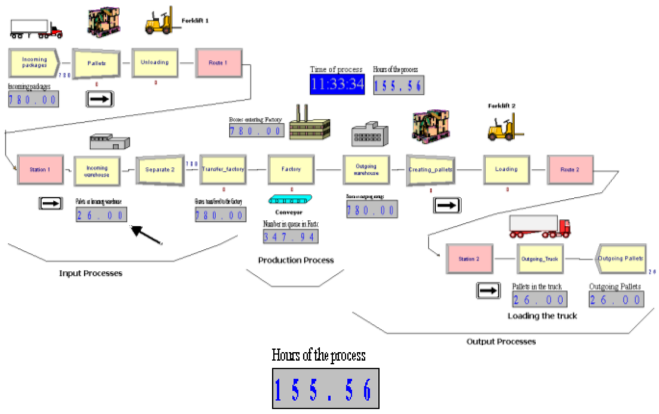

Fig.13. *Model after the simulations and results in boxes close to the modules. Below are shown hours of the process*

4. Results, analysis, and discussions

After the simulation, results are generated in the form of numerical results and can be viewed in the gray boxes of the model (Fig.13).

In the first unit of the Input processes, *Incoming packages*, is the truck carrying 780 boxes of raw materials, grouped in pallets that can carry 30 boxes each. There are 26 pallets with boxes in the truck to be unloaded.

The main parameter to analyze is the hours of the entire process duration or simulation in this case. The number of hours of the entire process is 155.56 hours. If we consider that one working day has two working shifts, or 16 working hours, the process will last 9.72 days.

The time the first pallet is unloaded from the truck with *Forklift1* lasts 3 minutes and 32 seconds (0.06 hours) (Fig.14).

All 780 boxes (26 pallets) carried by the *Forklift1* arrived in the *Incoming_warehouse* for aproximatelly 1 hour and 24 minutes (1.40 hours, or 84 min) (Fig.15).

While this is a line with uninterrupted and continuous flow, the first box to enter the *Factory* is after 9 minutes and 36 seconds.

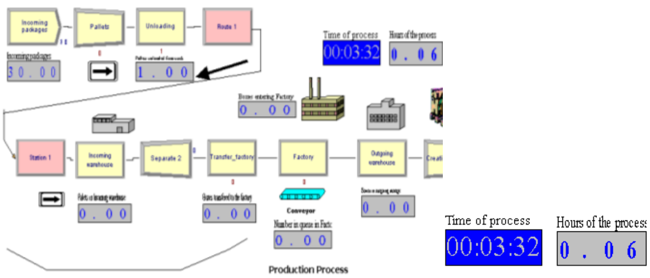

Fig.14. *The time of the first pallet is unloaded from the truck*

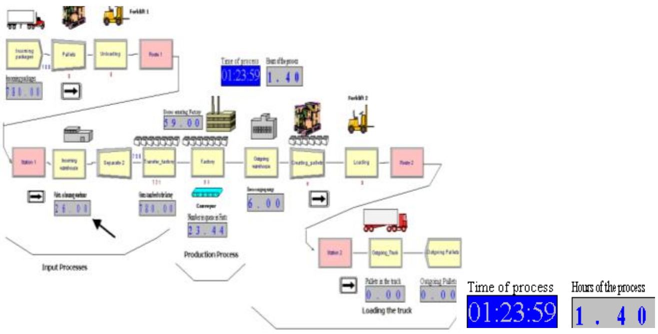

Fig.15. *The time all the pallets arrive in the Incoming warehouse*

The total time of the *Input processes* lasts around 16 hours 26 minutes or 16.44 hours (Fig.16). During this time, all the 780 boxes will exit the *Incoming warehouse*, are transfered and enter the *Factory*.

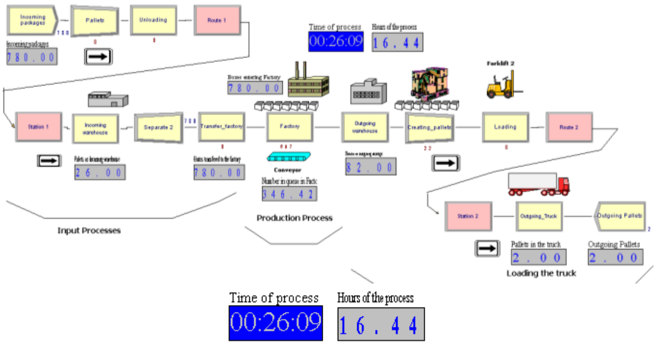

Fig.16. *The total work time of the Input processes*

Comparing the time all the pallets arrive in the *Incoming warehouse (*1.40 hours) and total work time of the *Input processes* (16.44 hours), difference is 16.44-1.40 = 15.04 hours. This is the time boxes spent in transfer between the *Incoming warehouse* and *Factory.* This is considered a bottleneck in the process.

The remaining total time of the process, 155.56- 16.44 =139,12 hours goes to the *Production process* and *Outgoing processes*.

By the end of *Input processes time*, 16.44 hours, in the *Factory* there will be in average 346 boxes in the queue for outgoing. There are only 82 boxes that exited the *Factory* and arrived in the *Outgoing warehouse* (Fig.16).

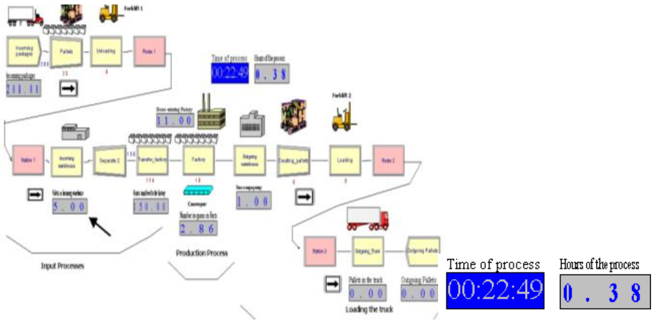

Fig. 17. *The time the first box exits the Factory and enters Outgoing warehouse*

The initial work in the *Outgoing processess* starts after 22 minutes and 49 seconds (0.38 hours) when the first box exits the *Factory* and enters the *Outgoing warehouse* (Fig.17). In this time 11 boxes entered the Factory, and an average of 2.86 are in the queue.

As shown in Fig. 18, pickup of prepared pallets in *Creating_pallets* module starts after 5 hours and 59 minutes (5.99 hours), when the first pallet with 30 boxes is assemblled and ready to be loaded with the *Forklift 2*.

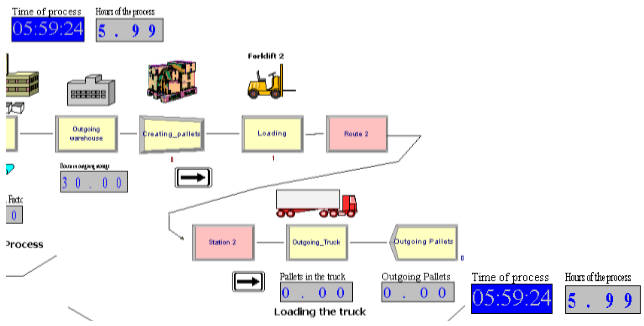

Fig.18. *The start of work in the Outgoing processes – after the first pallet is assembled with 30 boxes*

Based on last two figures, we can draw a conclusion that the time difference beetwen the first box exiting the factory and the first outgoing pallet assembled with 30 boxes is aproximatelly 5.99-0.38 = 5.61 hours (5 hours and 37 minutes). This is a long delay and the main drawback of the line, which identifies that transfer from the *Factory* to the *Outgoing warehouse* is the longest process and a bottleneck in the line.

Following the process flow after the *Factory*, the pickup of one assembled pallet with *Forklift 2* from the *Outgoing warehouse*, travell to the *Outgoing_Truck* and loading it in the truck will last aprox. 4.5 min.

4.1. Presentation and Discussion of reported results

After the simulations, the Report with results was generated by the software [4]. Results will be shown in tabular form.

Table.1. *Waiting times and Queues of boxes in the processes*

Process name and type	Average waiting time of boxes (hours)	Maximum waiting time of boxes (hours)	Average number of boxes in queue-	Max. number of boxes in queue-
Loading (Process)	0	0	0	0
Pallets (Batch)	0.0248	0.064	0.124	30
Transfer_factory (Process)	7.465	14.936	37.434	720
Factory (Process)	69.39	138.92	347.94	697
Creating_pallets (Batch)	2.888	5.882	14.84	30
Unloading (Process)	0.002	0.0174	0.0003	1

In Table 1, in the first two columns is given the waiting time of boxes in the main processes of the line. It can be concluded that the longest waiting times are in the *Factory*, then in the *Transfer_factory*, which proves previous conclusion that bottlenecks are present there. Other units show better performance. Best performance is in the *Loading* process.

In the columns 3 and 4 are given the number of boxes waiting in queues. The conclusion is similar; the highest number of queues are in the *Transfer_factory* and in the *Factory*. Maximum number of boxes in the *Pallets* and *Outgoing_pallets* is 30, but this is a scheduled number, while one pallet has 30 boxes.

Table.2. Time in hours the boxes spent in the line

Entity of the line	Average Total time	Average transfer time*	Average VA time**
Box	80.178	2.297	6.65

**Transfer Time*: It is the time when the box incurs a delay at a process whose allocation has been designated as transfer [4].

***VA Time*: Value added time is the time when a box incurs a delay at a value added process [4].

Based on the results in Table.2, one box spent in average 80.178 hours in the line. The time of transfer between units is 2.297 hours. This draws a conclusion that boxes spent much more time inside the units rather than in transfer between them.

Table.3. Usage of Resources

Name of Resource	Usage in %
Forklift 1	1.47
Transfer_device	10.4
Conveyor	99.80
Forklift 2	1.34

In Table 3 is given the usage of resources during the total time of the process (155.56 hours). It can be concluded that *Conveyor* was busy almost all the time of the process, 99.8% or 155.33 hours transferring boxes, *Transfer_device* was busy 10.4% or 16.17 hours, *Forklift 1* was busy 1.47% or 2.28 hours unloading 26 pallets, *Forklift 2* was busy 1.34% or 2.08 hours loading 26 pallets. Forklifts are low utilized compared to conveyor and transfer device.

For this line it is useful to shorten the delays in the transfer to the *Factory*, plan more than one conveyor, or shorten the delays in the *Factory*.

5. Conclusions

After the results and discussions, it can be concluded that using Arena Simulation software is useful to design materials handling line and analyze it after performing simulations. It is important to design the line, processes it adequately and plan the process flow accurately.

Most important parameter measured and analyzed is the number of boxes and pallets in the *Incoming processes, Production Process* and *Outgoing processes*. This division of processes in the line is better for study and analysis. The results gave us a view about the performance of the line and possible issues. The bottlenecks in the line were identified in the transfer from the *Incoming warehouse* to the *Factory*, and in the production process, in the *Factory*. The first one happens due to the slow transfer of boxes, and the second one mainly due to the long packaging of products, placing them in the box and transferring with conveyor to the *Outgoing warehouse*.

The *Incoming processes* and *Outgoing processes* of the line gave good results, while the time of the process flow is considerably short and there are no identified blockades.

With this model, it was possible to analyze also the performance of the *Resources* or vehicles like forklifts for loading and unloading, conveyor for transporting products inside the Factory and particular transfer devices. Conclusion is that the usage of conveyor was high, and Forklifts were used less compared to the conveyor in entire process.

The model design of the line can be further developed with addition of various production processes and testing various packages. That would increase the complexity of the analysis but also contribute to more research and investigation on this the topic.

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