SIMULATION MODEL TO ANALYZE TRANSPORT, HANDLING, TEMPORARY STORAGE AND SORTING ISSUES: A VALUABLE WAY TO SUPPORT LAYOUT, SYSTEM DEFINITION AND CONFIGURATION AND SCHEDULING DECISION

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ABSTRACT
The following paper describes the use of simulation models to analyze a common production scenario in manufacturing plants: many assembly lines producing specific families of items in a large variety of versions; following handling and transport system, evaluated to be effective, costless, with an adequate capacity to be not the bottleneck of the whole system, and integrated with a storage/sorting system to decoupling the assembly phase and the following ones as completion/test and expedition phase, included recovery and reform of the expedition lot.
To analyze a system like this, a simulation model has been developed with a flexible AGVs transport system, a Transit Point Warehouse acted by AS/RS, used also as sorting media. The size of the warehouse incoming bay, number of warehouse sub allocation zones or aisles, the capacity of all queues, all control logics for AGV's have been evaluated in a pre-modeling phase, and then evaluated by the model.

Keywords: AS/RS, Simulation Models, Handling and Transport Systems, AGV Systems, DSS.

1. INTRODUCTION

This paper focus on the evaluation among different solutions and layout configuration of the transfer and handling in a definite and already existing assembly system, and with the definition of many process parameters, with the aim to reach a better control on information about transferring process, an, moreover, an improved attitude to support productive contest evolution, that tends to an increase of levels of flexibility and mix and volumes variation.
Moreover, all operating logics have been evaluated, too.

Some results and related considerations have been outlined in previous papers, Gallo S. A., Melloni R. (2007), adopting as analysis tool a simulation model with a AGVs, diffuse and multi allocated storage system.

The original system we started from, is a production and assembly plant of engines, produced on demand, and in a large amount of versions. The part of the production/assembly system we considered start with some assembly lines each one configured to assembly just defined typologies of item families. Items travel in the system among distinct shops bringing on information, in the form of attributes, to define the sequence to follow and many process parameter.

Any item family is characterize by size, weight, relevant features, but, depending on customers specifications, national laws, final finishes or service to act, the number of item exploits to hundreds.

Furthermore, items have to be tested and finished in two other shops or areas, first one is at the end of the plant area for safety and noise problems, separated from the main area by a wall, instead, the finishing area is at the end of the assembling lines, back in the flow.

Each of the phases is decoupled with the others: we consider as time horizon of reference, a day, that is divided in single or double shift depending on the specific area of the process. In this time slot, labor rates for all systems, have to be equal, and the throughput must be those required by the Production Plan, PP.

The issue and proposal of the analysis is the definition of a new layout, new logics and new handling, storage, sorting systems. Furthermore, we had to respect some constrains, to define all configuration parameters, and maximize the system performance in terms of efficiency, cost, flexibility: problems of sizing of the specific parts of the systems, of defining the number and the capacity of vehicles, of dimensioning buffering areas and related means, emerge.

The issue addressed concerns the analysis of a possible alternative solution for the internal distribution of the engines from the assembly phase, through testing and finishing departments, up to the shipments area. The original distribution was carried out by a rigid transport system, a conveyor. This system performed its task, but it offered a high level of stiffness for production and distribution, as well as structural rigidity, preventing internal enhancement of the layout, such as the easy feeding of finishing materials.

We looked for a collecting, transport, storage and sorting system that present an high level of continuity, efficiency improvement, traceability and tracking of items. It should develop a system that allow continuous distribution and an increase in the current efficiency.

The previous research had focused on the overall analysis of the system, the quantification of flows of items, on the identification of the logical operation of the system, the definition of a model representing the as-is system in the real operating configuration. Successively, this was followed by a pre-analysis of the system, its constraints, and its need for the aspects related to the handling, to the interoperational storage, with the aim of the identification of one or more types of systems adequate to the replacement of the conveyor; after this preliminary analysis, we propose some interesting solution, a system that provided for an intermittent transport of groups of engines, loaded on racks, distributed as dynamic buffers at all operational phases, handled by automatic guided vehicles AGV (Towing Load).

In this work, as a replacement system, instead of the main collecting conveyor, it was considered an AGVs system, but with the presence of an automated warehouse, AS/RS, to decoupling the stages, that is the solution we refer to in the present work.

We can observe the representation of the structure of the model made in the simulation. You can see that the AS/RS stands along the entire area covered by the test brakes and the finishing department.

The need of the assessment of alternative systems lies in the difficulty that the existing system has to support the evolutionary scenario over time: the requests for supply of engines have been transformed by requests for large quantities of the same type and version to small lots with an high customization level. This made production planning and resource scheduling much more complex, as the line balancing, material flows management, production planning, and the system is increasingly required a high level of reconfigurability in terms of flexibility and elasticity.

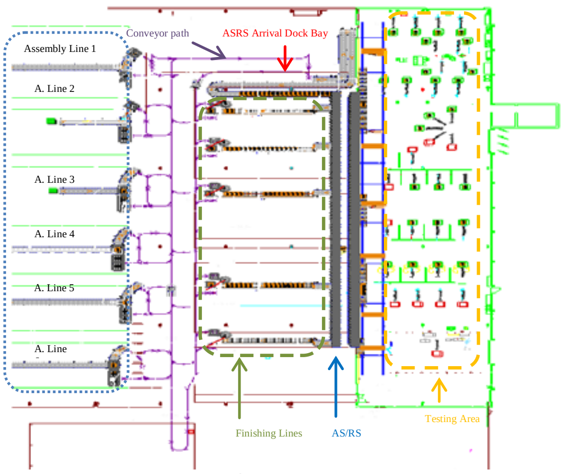

Figure 1: Snapshot of System layout in the present configuration.

Additionally, the main conveyor represents a fixed installation which limits the viability of the area and induced limitations to the realization of an efficient power supply system of the component parts, such as the feeding to the finishing lines.

The main conveyor also acts as a decoupling/storage system between the assembly stage and the other of testing and finishing, due to the different capacity which they present. This aspect, due to the lack of identification systems of the specific engine at a specific position of the main conveyor, makes engines traceability impossible, engines that, sometimes, for the space limitations may not be downloaded at their destinations, leaving many engines turning on the conveyor for many times, with break of sequence and need of reconstructing lots.

2. LITERATURE REVIEW

An important place in this work it will play the discrete event simulation, used to verify the goodness of the solutions, and to support decisions about system configurations, to evaluate obtained outputs, used in the comparison of the solutions.

One very interesting development of the simulation is to support operational simulation as a planning and control of short-term production and logistic systems, with the creation of simulation models detailed and updated as much as possible, that, in integration with enterprise information systems make possible to simulate in real time, in parallel to the real system, and evaluate the different decision alternatives.

The areas to which the operational simulation can benefit are design, scheduling, capacity planning and control. Cho, S. (2005).

Ceric and Hlupic (1993) present an approach to use simulation in evaluating different system configurations between the various alternatives. The conceptual model is made with active cyclic diagrams. The simulation result in a high level of complexity due to the wideness and dynamics of the system. They are useful when the real system to compare with, does not exist, the validation is made of independent type verification and validation based on face validity (expert consultation) and not on statistical analysis to measure and error checking.

Simulation models can be used to improve the performance of production systems, and in this case, the process of improving the performance tend to the evaluation of the system in terms of interactions and interdependencies of the elements of the system. An example is presented by Alan and Pritsker (1997), as regards the analysis of the performance of existing systems. The authors use simulation to analyze the performance improvement process, and focus on criticality of the system, interactions and dynamics.

Another example of performance evaluation of the system is presented by Ueno, Sotojima Takeda (1991). As in Alan and Pritsker (1997), simulation is used as a tool and a DSS to support the redesign of the production process, to identify dynamically bottlenecks or machines with the lower production rate. The aim of the simulation is to define a new configuration of the production line with the minimum cost.

The use of simulation for strategic decision making, presented by Kumar and Nottestad (2006), was aimed to redesign production system in order to improve the productive capacity. It has been developed a Discrete Events Simulation system, DES to configure a line semi-automated production as part of process to improve the existing production process capacity. The simulation is validated with Design Of Experiments (DOE), used to interpret the results and information on specific parameters. Surfaces of response were produced to evaluate system behavior depending by control factors, such as average cycle time machines, buffer capacity, MTTF of machines, number of parallel machines and the size of the lots.

An tactical level example of simulation models is provided by Watson, Medeiros and Sadowski (1997). The authors analyze the release schedule of orders for a make-to-order production. For these models MRP logic, with infinite capacity and lead time defined on historical data and past experience, is adopted. Often, schedules are obtained that are often unfeasible.

One particularly accurate use of simulation models to schedule flow shop systems has been proposed by Vaidyanathan, Miller and Park (1998). The system is divided in scheduling program, used to generate the daily schedule, and the simulation model, that uses the obtained scheduling to simulate the system and improve it.

To analyze job shop systems we find many approaches. The approach proposed by Selladurai, Aravindan, Ponnambalam and Gunasekaran (1995) tries to elaborate scheduling using the simulation directly, limited to rules of dispatching.

Systems have been created that allow allows to decompose NP-hard problems into sub problems, with the aim of solve problems of scheduling multi - objective with setup time variables.

Examples have been proposed by Yang and Chang (1998), based on a Pareto analysis in the field of production systems, for multi-objective optimization approach. The proposed methodology is compared with the traditional approach and several heuristic rules for dispatching based on numerical examples.

More recently, we can cite some study that use simulation models as cost effective means to evaluate checking and configuring the plant layout, considering both the process line features and the material handling features and carefully integrating them together toward best efficiency in Kolkka, Rajagopalan, and Suksi (2013). The study of configurations covers the layout, but also deals with the individual lines in-feeding and out-feeding systems with appropriate storage areas and system, along with the way the product is packed and handled before being shipped to the customer. The findings of study are checked by real-time simulation to arrive at the best capacity of the material handling equipment, like cranes, AGVs, transfer conveyors, building area, types of storage, cycle time.

In Malmborg (2001), is presented a model for configuring storage racks in an AS/RS systems with multi-shuttle machines. The models goes on to extend consolidate rules for sizing storage racks based on defined performance levels of system utilization. The models forecast the relative proportion of different types of order picking cycles used in a system, with the use of stochastic, analytical model of system interleaving.

In Jane and Laih (2005), in a synchronized zone order picking system, all the zones process the same order simultaneously. This paper develops a heuristic algorithm to balance the workload among all pickers so that the utilization of the order picking system is improved and to reduce the time needed for fulfilling each requested order. With a similarity measurement, a natural cluster model, which is a relaxation of the well-studied NP-hard homogeneous cluster model, is constructed.

In Perry, Ronald, Hoover, Stewart, Freeman and David (1983), is showed the use of a simulation model as a design aid for an AS/RS, where the flow of bins from storage locations to work stations via conveyor and return to original storage locations, is controlled by heuristic acted on a computer. The initial model goes into a cost effective system for achieving desired performance goals through judicious use of a detailed, stochastic simulation model.

3. SYSTEM LAYOUT DESCRIPTION

Our analysis refers to a portion of the production, handling of engines produced between departments.

The current market needs tend more and more to the creation of small and customized lots. This means to produce engines of defined types, but with levels of "adaptation" and personalization which greatly vary in relation to the use of the engine, in relation to the market, that affect legal emission levels, etc., which means that product flows very vary, subject to change that define different product codes, and thus different sequences between the stations that perform the process.

3.1. Assembly lines

The assembly area shows six parallel assembly lines distinct by family and version of product. They work in a single daily shift.

In the original system, at the end of assembly phase, the operator retrieves the motor by an hoists and places it on the main conveyor, to be moved to its next phase, the testing phase. The original main conveyor is a trays conveyor.

The engines, in next phases of the process, will be again repositioned on the conveyor to be transported in the direction of the finishing department.

The speed of the conveyor is on about 1.8 m/s, to safely allow placement and removal of engines from the operators. Conveyor conformation is continuous, with a referable complex "U" shape, and allows the completion of the entire ride in about 4.5 h.

It works both as an handling mean, but also is used as a dynamic warehouse being composed of 450 trays. It was placed between the heads of the final part of the assembly lines, and the finishing ones, but another part served the testing area. It performed all its duties, however, problems growth related to viability, material handling, tracking and traceability of the items.

3.2. Testing room, testing department

The testing area, on the right of layout, consists of six areas in which there are dynamometric brakes grouped and allocated appropriately in relation to the tests characteristics, to the capacity requirements they can perform. This phase is bottleneck for the process, and works in a double daily shift.

Each group of brakes is provided with buffering rollers, sized in relation to ensure the feeding of brakes, on movement reliability and speed, space constrains, and to decouple this phase. On each roller conveyor, operators positioned motors to be tested, unloading them, via hoists, from the main conveyor. Once the test is complete, engines were repositioned on the conveyor.

3.3. Finishing Lines and Applications

Continuing along the path of the conveyor, the tested engines were taken, by the operators of the finishing department, to be positioned above rollers, used as buffering docks, placed to the side of the specific lines. Here, operators perform a first composition of the batch of shipment, using visual recognition and information with the engines.

Originally, finishing department had five lines, and works in a single daily shift.

3.4. Shipping Area

In the left lower side of the layout there is the shipping area that follow the Finishing phase. Handlings are made by forklifts. Load Unit, LU, stored to be shipped, are reassembled to definitely constitute lots of shipment, if this activity is not done before. Identical motors of an order lot are scheduled in repeated sequences defined to achieve a good balance of the single assembly lines, and to balance the load in the referable time unit (shift - hour), feeding next steps based on available capacity offered by these. All this causes a break in the FIFO sequence and integrity of the lots, in such a condition impossible to recover.

4. DEVELOPMENT OF THE ANALYSIS

The original system of handling effectively responds to the characteristics and requirements as:

1. Handling of LU between assembly and testing area, and between testing and finishing.
2. Handling continuous LU.
3. Possibility of an intermediate buffering to decoupling all phases because of the different timing of the departments.

The solution we consider, since the preliminary assessment, and confirmed by the results of the simulations, showed better performances compared to the initial situation with regard to the opportunity of having the tracking and tracing of engines, to support the ability to trace more easily shipping batch within the system; to the level of the occupation of the soil for the storage of working or finished engines; to the opportunity of having more finishing lines with better correspondence between the line and type engine; to the increasing of the capacity to configure specific finishing on more than one finishing lines corresponding to different outlets of the warehouse; to the ability to perform the secondary material feeding to the lines, especially finishing ones, more efficiently; to the reduction of transfer times between each stage; and, finally, to the reduction of throughput limitation due to the handling system.

To meet the identified needs, an AS/RS system has been considered. After the analysis of the path the original main conveyor, after the analysis of all flows and the area of interest in the plant, considering the limitation of space, a possible location of the warehouse is represented by area along the wall in front of the finishing department toward the testing department. This positioning, furthermore, would allow a direct distribution of the LU at all finishing and testing areas, and avoid the use of further transport systems to distribute engines to the various brakes, such as the AGV themselves, conveyors, reducing their number, capacity and with a limited need of human supervision, with an affordable investment and exercise cost, and, in addition, coping with the scarcity of space.

The system that appeared most appropriate and convenient, in terms of quick response and continuity of supply, in terms of flexibility and versatility, low operating costs and the absence of limitation to the practicability of the area, as distribution and handling system with a very high level in automation, was represented by AGVs.

Different systems of transport of Unit Loads of engines from the assembly lines are critical, as already seen in previous works, because they are rigid with fixe occupation of the area, as conveyors, because of danger problems and psychological impact, as with overhead chain conveyor. The forklifts handling of single items or LU by carried by human, imply high use of labor and related costs, subjective management of movement, or in the best case, supported by systems of flow analysis to be integrated to carriers. Instead, the system based on the use of AGV should meet the automation needs in the creation of LU and their delivery to the loading bay on the AS/RS, a relevant cost of investment, but a lower operating cost, big reliability, tracking and traceability of item flows, a level of continuity of flows to feeding all parts of the system, very easy to module.

The first issue to face with, is the one of the dimensioning of the LU, as number of items to group together, and as physical dimension of the LU, considering the different sizes of the items to collect. This issue affect both the handling interface and the relative automation level, both the opportunity of standardization of the LU, both the space consuming, the number of travel missions.

In the logistic principles, it is very important have an standard type of LU for all systems that participate in the definition of the logistic system and for the entire chain to use standard equipment along all the system, to define warehouse loading bays, and avoiding the need for adaptation in the future and a structural reconfiguration of the store.

Observing the size of the engines, Table 1, may be defined a basic type of handling pallet or rack, on which to mount each engine, that could be able to support the movement until the end of the finishing phase, where it will be separated and recovered, of dimensions 800 x 600 mm, which allows to support any size increase.

Table 1: Size and Weight features of items

Features of Engines								
Type	Assembly destination	1D (l)	2D (L) [mm]	3D (h)		Weight [kg]		Volume [dm^3]
9LD	Gruppo 9	559	633	600		110		212,308
11LD_522	Gruppo 11	500	656	558		153		183,024
11LD_626	Gruppo 11	484	770	586		170		218,390
LDW502	VETTURETTE	407	404	472		60		77,610
LGW523	VETTURETTE	406	420	420				71,618
LGW627	SARMAS	406	412	449				75,105
LDW702	SARMAS	412	421	515,5		66		89,415
LDW1003	SARMAS	412	513	515,5		85		108,954
LDW1204	SARMAS	440	593	515,5		96		134,504
LDW1204/T	SARMAS	480	593	556,5		101		158,402
LDW1404	SARMAS	412	596	515,5		98		126,582
LDW903	SARMAS	412	513	515,5				108,954
RD2	RD	559	633	600		110		212,308
MD2	MD	464	485	498		63		112,070
MD3	MD	500	666	558		153		185,814
Analysis Outlines								
Mean		456,867	553,867	525		105,417		143,341
MAX		559	770	600		170		218,390
MIN		406	404	420		60		71,618

Initially, it was considered, a trip for each item. This would have implied a number of trips, at least multiple by ***2n*** of the number of engines (a trip for each phase, with n phases, plus the return), and a number of vehicles too excessive (a high way traffic area..), so we considered to manage items movements in groups. Six is the maximum number of grouped items, based on size and weight of the LU, and on available space. But the real size for any LU was defined in attributes whose value is specific for each item. Engines are supported in wheeled racks.

Is possible consider the transfer of the engines from the assembly lines to this support mean, in an automated way, by defining a further conveyor section, transversal to assembly lines, with a size verified trough the simulation. The same is made when AGV have to download items on Arrival Dock Bays, ADB at the AS/RS.

Vehicles used for handling through the assembly departments and storage could have been used to distribute engines from the storage area to the testing department, using the space, freed by the removal of the conveyor, however really small. A second hypothesis for same aim, was to use a portion of the main conveyor.

The final hypothesis, the one we chosen, analyzed, modeled, has been to use the AS/RS as a engines sorter directly to the area of use.

This decision was based on the following considerations:

- the need to limit the number of LGV missions to timely supply items to specific brakes,
- considerations about the spaces of the testing area, too narrow,
- considerations about the presence at the test area of the bridge cranes, useful for transferring of engine on the brakes, in a very simple way,
- considerations about the capacity level for the Storage & Retrieval Machine (SRM), and about the opportunities raising from AS/RS availability to use this as a sorting mean, also.

This opportunity has been possible thanks to the size of the warehouse itself and its physical location, i.e. parallel to the areas of testing. With the substitution of the conveyor, and the freed space, it's possible place the structure of the warehouse in a way that can be used both as a storage system but both as a sort system, also: engines are brought to the areas of destination by gravity roller conveyors on different levels (input and output from the tests) and placed on trolleys or roller using the pre-existing system overhead crane. Once back in the AS/RS, from testing brakes, via different conveyor, the engines are repositioned within the AS/RS structure.

If carefully designed the warehouse allows us to reconstruct the lots of shipping, allowing the finishing process to only play the task required to them: to finish engines and place them in the appropriate structures of shipping (pallets or crates).

The distribution towards the finishing area is done with the same methodology of the distribution in testing. Moreover, it is possible to eliminate the phase times of both downloading the item from the conveyor to buffering rollers, and both from buffering rollers to finishing lines, directly connecting the downloading zone of AS/RS, with the finishing lines. To avoid that operators remain blocked among finishing lines, we supposed to have downloading bays at an high level of the AS/RS, that, with descending conveyors, could feed finishing lines. This create a passage used by operators to access the workstation, and allows to use this space to recharge materials kits to finishing lines, without crossing AGVs paths.

When the finishing phase is ended, the handling of lots of shipping will be carried out by the same AGVs, since the route is in part superimposed to the return path to the AS/RS. Vehicles, after each delivery mission, has to query for the next mission.

The extent of the AS/RS Arrival Dock Bay has been evaluated after many simulations, to absorb the peaks of engines, massively delivered at certain times, to free the head of the assembly lines. The delivered engines have to wait to be uploaded into the warehouse from the S&RM, that can be just one because just one aisle can exist, and whose capability is lower than the sum of all assembly rates.

4.1. Distribution between assembly and storage

The work of analysis, the logical definition, the modeling and programming of the logic, begins with the study of the first operation performed by the main conveyor, the engines transport from the assembly lines to testing area. To define the characteristics of the truck to use to design the LU to be handled, to evaluate the optimal amount of engines in the LU, and consequently how many vehicles use, we made many preliminary simulations carried out with the simulation software.

The first step was to emulate the production of engines made during the reporting period, in terms of quantity for each assembly line, with their defined characteristics such as type, version, reference times for the various stages, destinations, etc.., defined in attributes of representative engine load, to determine the need for transportation of AGV. We have used the data collected previously collected in tables sorted by line.

The model read production plan data supported on spread sheets in .csv format. In the data sheets is defined the Assembly Plan, AP, of the line of relevance. In this way is very easy processing many different data sets, and evaluate the model and logic sensitivity to the typology variation of items, their distribution among the versions.

Observe and describe what is collected in them:

- Date: scheduled work for that day.
- Customer: customer name.
- Type of engine: type of engine in production.
- Line Phase Time (distribution parameters): time required for the assembly of the engine.
- Version K: is the engine code, identifies type, customer, and lot release testing of the engine.
- Inspection Time (distribution parameters): time required to stay on dynamometers for testing.
- Finishing Time (distribution parameters): time required for finishing the motor.
- Type of test: possible types of tests to be performed.
- Q: amount of motors assembled in sequence, or the Order Quantity. Does not represent the amount of engines of a lot.
- Sorting Codes: codes to determine stations, phases and lines that have to cross the engine.

Table 2: Extract of Assembly Plan for engine family.

TABELLA DI CARICO DATI LINEA VETTURETTE

	CLIENTE	TIPO DI MOTORE	TEMPI DI FASE LINEA VETTURETTE						VERSIONE K	TEMPI DI COLLAUDO		TEMPI DI FINITURA (FASE DI IMBARCO)	TIPOLOGIA (CLASSE DI TEMPO) DI COLLAUDO	SET UP	Q	Convenzione per smistamento motori
			μ	σ	μ	σ	μ	σ		μ_{Coll}	σ_{Coll}					
05/09/2005	LIGIER JS28	502	5.54	1					3B2674	17		5.54			37	13
	R.C.M.	502	5.54	1					3B4380	35		5.54			10	14
	CHATENET P.FUSO	502	5.54	1					3A8619	17		5.54			37	13
06/09/2005	CHATENET P.FUSO	502	5.54	1					3A8619	17		5.54			45	13
	MICROCAR	502	5.54	1					3B0905	17		5.54			39	13
07/09/2005	MICROCAR	502	5.54	1					3B0905	17		5.54			84	13
08/09/2005	MICROCAR	502	5.54	1					3B0905	17		5.54			41	13
	VEXEL QUOVIS	523	5.54	1					3B3172	35		5.54			12	14
	MICROCAR	502	5.54	1					3B0905	17		5.54			31	13
09/09/2005	MICROCAR	502	5.54	1					3B0905	17		5.54			51	13
	MICROCAR MC1	523	5.54	1					3B2080	35		5.54			12	15
	LIGIER JS28	502	5.54	1					3B2674	17		5.54			19	13
12/09/2005	LIGIER JS28	502	5.54	1					3B2674	17		5.54			63	13
	GANSOW *	502	5.54	1					394558	35		5.54			6	14
	LIGIER PF40A	502	5.54	1					3A5745	17		5.54			10	13
	CASALINI	502	5.54	1					3B3003	17		5.54			5	13
13/09/2005	CASALINI	502	5.54	1					3B3003	17		5.54			55	13
	SECMA	523	5.54	1					3A8722	35		5.54			13	15
	CASALINI PIAGGIO	502	5.54	1					3B1363	17		5.54			16	13
14/09/2005	CASALINI PIAGGIO	502	5.54	1					3B1363	17		5.54			24	13
	SECMA	523	5.54	1					3A8722	35		5.54			12	15
	MICROCAR	502	5.54	1					3B0905	17		5.54			48	13
15/09/2005	MICROCAR	502	5.54	1					3B0905	17		5.54			34	13
	CHATENET P.FUSO	502	5.54	1					3A8619	17		5.54			50	13
16/09/2005	CHATENET P.FUSO	502	5.54	1					3A8619	17		5.54			32	13
	MICROCAR	502	5.54	1					3B0905	17		5.54			52	13
19/09/2005	MICROCAR	502	5.54	1					3B0905	17		5.54			84	13
20/09/2005	MICROCAR	502	5.54	1					3B0905	17		5.54			14	13
	CHATENET P.FUSO	502	5.54	1					3A8619	17		5.54			69	13
	LIGIER JS28	502	5.54	1					3B2674	17		5.54			1	13
21/09/2005	CHATENET P.FUSO	502	5.54	1					3A8619	17		5.54			13	13
	LOMB.MARINE	502	5.54	1					3B3191	35		5.54			10	14
	SECMA	523	5.54	1					3A8722	35		5.54			6	15
	CHATENET P.FUSO	502	5.54	1					3A8619	17		5.54			55	13
22/09/2005	CHATENET P.FUSO	502	5.54	1					3A8619	17		5.54			27	13
	LIGIER JS28	502	5.54	1					3B2674	17		5.54			57	13
23/09/2005	LIGIER JS28	502	5.54	1					3B2674	17		5.54			25	13
	AIXAM	523	5.54	1					3B3682	35		5.54			6	15
	LIGIER JS28	502	5.54	1					3B2674	17		5.54			53	13
26/09/2005	LIGIER JS28	502	5.54	1					3B2674	17		5.54			29	13
	MICROCAR	502	5.54	1					3B0905	17		5.54			45	13
27/09/2005	MICROCAR	502	5.54	1					3B0905	17		5.54			84	13
28/09/2005	MICROCAR	502	5.54	1					3B0905	17		5.54			84	13
30/09/2005	MICROCAR	502	5.54	1					3B0905	17		5.54			73	13
	DULEVO	502	5.54	1					389954	35		5.54			5	14
	TASSO PF 40A EST	502	5.54	1					3B0633	17		5.54			6	13

The correct attributes permit to generate the correct types of engines, to create the correct sorting, AGVs request, testing typology, and make possible the correct grouping in the LU at the end of the line.

Furthermore, those items with higher production rate must have of the highest levels of priority in the request of AGVs, and this last consideration would imply the block of AGVs to serve just more produced items, putting in infinite queue the entire list of the other missions of the trolley, including those related to the track feeding where necessary. This has been a very interesting issue in the definition of the control rules of missions of AGVs. In fact, the logic to place an AGVs request based on the filling level of the rack/LU at any station has been one of the solution to manage fluently AGVs missions.

Another requirement is the reduction of the number of trips, and then the question of how many engines send for each mission.

To thoroughly have some determinations for many logic and configuration choices, many initial simulations were ran concerning the modeling of the process of movement between engine assembly and loading bay to the warehouse, only, in order to define the size of LU and their consequent numbers, and the space required for the accumulation of LUs at assembly lines, parameterized to the number and speed of available vehicles (1, 2) in each test simulation.

We summarize obtained results in the next table showing not only the importance of the number of motors to be sent to the warehouse, but also the intrinsic link between the speed of AGVs, and the speed of the used Storage & Retrieval Machine, S&RM.

Table 3: Rack Quantity required at each line end for each AGVs speed.

n° vehicles	Items for each rack	velocità AGV	max number of racks waiting to be transported					
			line 1	line 2	line 3	line 4	line 5	line 6
1	2	0,7	3	3	3	3	3	3
		1	3	3	3	2	3	3
		1,3	3	3	2	2	3	3
	3	0,7	3	3	2	2	3	3
		1	3	3	2	1	2	3
		1,3	3	3	1	1	2	2
	4	0,7	3	3	1	1	2	2
		1	3	2	1	1	1	1
		1,3	3	2	1	1	1	1
2	2	0,7	3	3	1	1	2	2
		1	3	2	1	1	1	1
		1,3	2	2	1	1	1	1
	3	0,7	2	2	1	1	1	1
		1	2	1	1	1	1	1
		1,3	2	1	1	1	1	1
	4	0,7	1	1	1	1	1	1
		1	1	1	1	1	1	1
		1,3	1	1	1	1	1	1

We can see that the solution of a single AGV, is acceptable with the exception just in the case of groups of four items. The limitation arise from the need to place in line 1, the one dedicated to the most intensive production of engine n°1, more than 3 racks, given that peak quantity of them.

It is noted, instead, the easiness of response, to the assembly lines, with two vehicles. This will be the solution that will be accepted, also verified when considering handling requests from the finishing shop, when AGVs will also play new missions, thus increasing the whole number of them.

Validated the solution on two vehicles, we started to evaluate the amount of motors to transport that will form the LU. As we can see in the table, the best responses occur by increasing the amount of motors transported per trip. Looking just at the missions required to serve assembly line, the reduction of the grouping value, lower the peak at the ASRS Arrival

Dock Bay, ADB, since the S&RM has more time to store the engine, and consequently reduces the maximum length of the conveyor used as ADB. On the other side, such definition of the LU, more continuous and fluid, however, affect missions number, and or the vehicles number, both much larger.

Under these opposing effects, it is much more preferable promptly to dispose and route assembled engines at the end of assembly lines, that cannot accumulate to much, due to space in that area, and size a greater loading bay, so there is a tendency towards larger LU.

To transport any of known engines in groups of three, the rack structure we evaluate be larger than 1800 x 800 mm instead, to transport items of any size in groups of four, will be of 1200 x 1600 mm. The structure dimension for the transportation of four of the motors is largely acceptable, and is, then, validated, the choice to move more motors is discarded for the excessive size of the structures suitable to their handling. Obviously, these handling facilities never should miss at the end of assembly lines, otherwise you would have halted all production, which is unacceptable. To assure their availability where required, during the simulation, a cyclic control of the availability of LU racks within their bays, is performed. This task of feeding racks, is the first in the priority list of the AGV. The maximum acceptable number for each zone is equal to three because, otherwise, it would be necessary too much space just to host structures.

The evaluation of response capacity of the S&RM at the ADS Bay of warehouse has been particularly complex in the quantification of the racks and LU size.

If the S&RM should work exclusively for storing engines of the LU coming from the assembly, with normal levels of performance, it would be able to cope with, just with an adequate dimensioning of the loading bay: despite the speed of examined S&RM, anyway, it results a peak which determines the need for the incoming roller of a length that is enough to constitute a decoupling buffer between assembly/transport and storage. In particular, the maximum accumulation will be achieved in the hours close to break time, when assembly line, that work on a single shift, have produced all the items of the day, testing brakes are not able to equal the ratio, and when the whole system requires the maximum services of S&RM. To overcome this problem, it should be considered the possibility of offset of few hours shifts of shops, anticipating or delaying the time at which the stock will have difficulty.

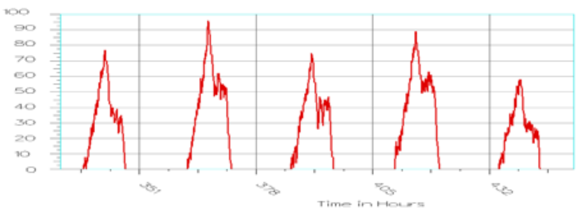

Figure 2: Cyclicality of waiting items amount Waiting at ADS Bay.

4.2. Distribution between storage and testing shop

Once in the AS/RS, items must wait until it is free the next phase, the testing one, to be moved again.

No changes have been done with respect to the initial structure, except for the replacing of the main conveyor with new rollers available at the benches of dynamometric brakes, capable of supporting a couple of motors, just those to be mounted on brake testing as soon as the previous one is released at the end of testing. Such substitution reduce the buffer protection of the resource bottleneck to a minimum, comforted by the performances of the AS/RS used also as sorter.

Initially, it was thought to use as a Downloading Bays toward brakes, from the AS/RS, a portion of the main conveyor that occupied or the entire length of the longer side of the testing shop, but we considered the space limitation and the need that it should would have to be a closed loop, not suitable to sort appropriately items to their destinations.

In a second step, it was decided to use the AGV to delivery engines to each dynamometric brakes, which made the request, an hypothesis also discarded because of limited space and the resulting chaotic traffic, and the potential lack of responsiveness offered by a discontinuous handling system. It appeared interesting, instead, the idea of using the AS/RS as sorting mean, assigning it sorting tasks to the testing department.

The distribution is found to be simple because it was sufficient to use the rollers at the side of the wall corresponding to the AS/RS, where previously there was the conveyor, and using the overhead cranes to handle items toward serving trolleys in the vicinity of brakes, shorter than previous and original ones.

The engines, after test, had to return inside the AS/RS, also placed on a roller conveyor along the same wall of the AS/RS, as those direct to the testing phase. The solution was then to position the rollers on two levels, with appropriate gradients to have a movement flexibility handling by operators, always comfortable.

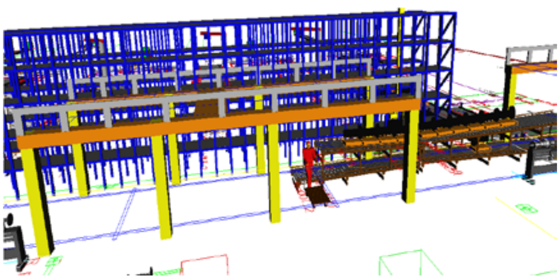

Figure 3: A snapshot from the testing area toward the AS/RS and the rollers at overlapped levels.

The length of the rollers are proportional to the needs: capacity and space are balanced to both the AS/RS maximum delay, and both the delay of the bridge crane in the sorting stage of the testing.

Motors, to access the testing shop have to be requested and ordered directly from the brakes buffers, as soon as they have ran a test. The order arrives at the AS/RS, that interrogates its inventory and observe if there are engines for the request, if there are, they are taken and routed on the conveyor outlet, vice versa is there aren’t, no mission is done, but the request remains stored in the logic infinite queue, the order lists.

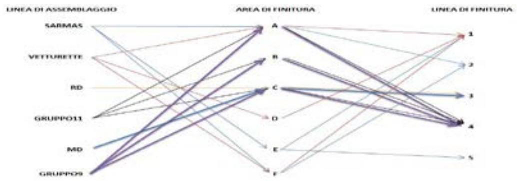

Figure 4: From To Chart in the observed configuration.

The assignment of the zone of the AS/RS, whose allocation rule is a Class Based Storage Policy, is made on the base of the testing destination of each engine, and, consequently, is made as soon as the engine is taken from S&RM from ADS Bay. Warehouse shelving is divided into dedicated zones.

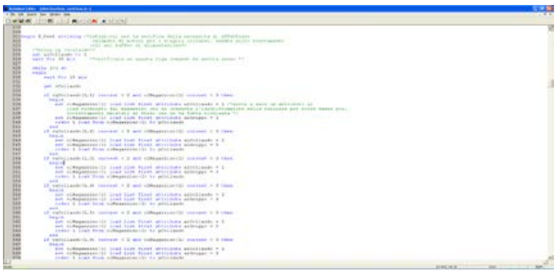

Figure 5: A snapshot of the logic code to advance items toward testing destinations.

Each buffering area manage an internal fictitious queue (OrderList), containing any of the useful attribute values, as the engine typology and version, the Order Line that generates that item, the entry time in the buffer, that when questioned from the brake banks, will answer on the availability of engines defined features. For the distribution was considered the FIFO logic.

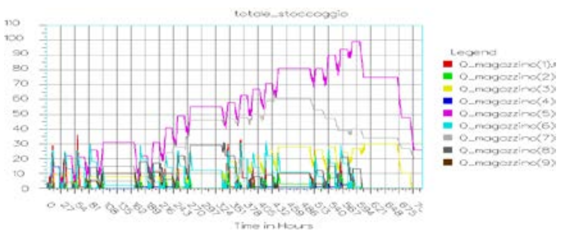

Figure 6: A snapshot of the variability of levels of engines in AS/RS waiting to be moved to test brakes.

The available capacity offered by the testing brakes, considering that is a high time consuming phase, has been highlighted in preliminary simulations. This phase is the only one that requires a daily double shift to accomplish the Assembly Plan.

In the graph it is represented the stock level for each area of the AS/RS, each one devoted to feed brakes for specific test typologies, and shows the difference reported by two zones of warehouse:

First, zone 7 is not too much critical for the low number of engines produced, but should be assessed more accurately if production level should reach higher values. In this case, is possible evaluate the opportunity to re configure, with appropriate setup of 4.5 hours, alternative brakes. Second, is critical, instead, the curve number 5, the zone devoted to store items with the higher intensive flow, which tends to rise, and when it happens, is possible use a jolly brake, in the same area, at the expense of the engines of other typologies, that are usually served by that brake.

4.3. Distribution between testing and finishing

The engines, then, travel from the exit of the tests in the direction of the corresponding finishing lines. As previously occurred, even in this case is the S&RM that reads and defines the exact destination that should have the motor. For the destination pre-assigned attibutes are read. The engine is, then, taken from the testing brakes and placed on the rollers to be routed through AS/RS to the corresponding finishing lines.

Since the opportunity of using the AS/RS as sorter too, instead of buffering conveyor, it is thought to achieve better results routing engines on as many rollers, as the finishing lines, adjacent to the wall of the warehouse, to be taken by operators with the use of gantry cranes, avoiding the engine search and by providing a more robust and defined routing.

Moreover, we decided to use the AS/RS as a sorter to automatically deliver directly to the finishing lines, enabling operators to always be in the possession of the motors to work avoiding the transshipment between the two rollers.

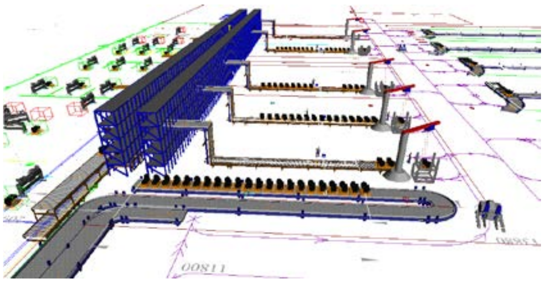

Figure 7: A snapshot of the finishing area with the engine distribution from the top.

Furthermore, the solution we propose, avoids to close operators inside finishing lines, preventing them to have escaping routes or easiness of walking, and makes possible using this corridor to the supply finishing materials or kits. The items comes out from the AS/RS not at the ground level, but at a higher aerial level, at about five/six meters, and brought to fair quote by from automatic descenders.

To compensate for the excess distribution that would reach to the finishing lines, it was considered a double criteria control logic based both on the AS/RS residual storage capacity, and both on the free space on the service rollers at the finishing lines.

It has been defined a logic activated by the engines after the testing phase that evaluate the amount of motors present in the finishing line of destination, and, in case of availability of space, place an handling order to the S&RM that move the item in appropriate roller, as soon as possible, otherwise ask for a moving mission to the bays of wait, close to the dedicated opening areas, at destination descenders, one for each outlet.

From the graph it is possible to note the necessity of engine storage capacity, especially in the early hours of the morning, in correspondence of the activity of testing, that starts two hours before assemblies, while this possibility decreases in the course of the day.

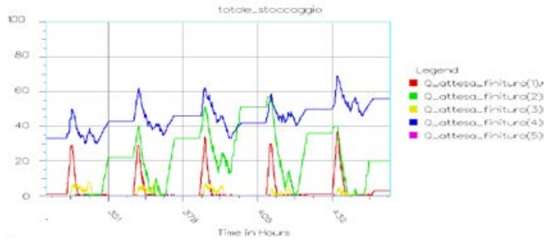

Figure 8: Trends of the engines number waiting to be moved to finishing Area.

It should be noted that the lines of destination, as configured in the real situation, would lead to an excessive load handling for S&RM, therefore was more appropriate, without losing adherence to the real system, reallocate finishing lines in correspondence of the testing areas of the same items, but on the opposite side with respect of the AS/RS.

We arrived at the end of the process, the engines must now be placed in transport units to be shipped. In original situation, movements of these units were done by trans pallet driven by operators. It is natural consider of using AGVs for this last transportation. The motors are placed at the end of the finish using hoists or cranes in pallet or boxes suitable for shipping and then are picked up by the AGV toward the expedition area.

We provided to use another item attribute to be used to define an exact quantity of engines that it was appropriate to recompose lots of shipment. This information, anyway was not available at the time of our work, and we considered the blind hypothesis a generic quantity of five engines per lot.

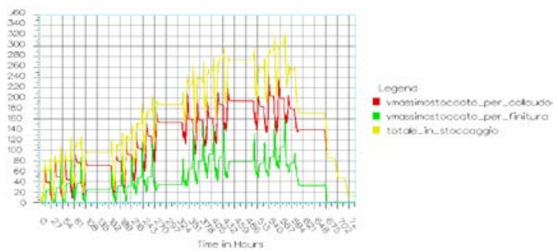

Figure 9: Amount of whole items at testing area (red), finishing area (green), and in all the system (yellow).

Engine attributes, read at the initial phase of the simulation, presents not only the destination of finishing information, but also identify the type of contract and customer. The shipment logic can keep an item in the AS/RS before complete the finishing phase and the shipment too, case for shipment to finishing, till the last item of the shipping lot is not already tested: any engine taken from the testing will check if is the last of its shipment order, that ask for the release to the finishing area, from the AS/RS of all other items to be shipped, allowing operators to have motors in the correct order.

In the following lines an extract of lines of code responsible for the activation of the logic model for the selection and identification of lots and handling.

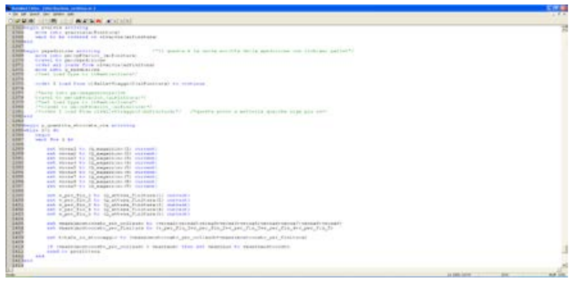

Figure 10: Snapshot of the logic to activate selection and identification of lots relative handling

CONCLUSIONS

The analysis of a new handling and transport system that could replace the conveyor has been completed according to the solutions, that in the preliminary analysis, resulted most adequate among those remaining solutions not yet verified, through simulation models.

The models and analysis of the produced results have supported both the definition and validation of the general structure, of features to consider, the definition of configuration parameters to be used, such as speed and acceleration of AGV and S&RMs, number of vehicles, items number to be aggregated in LU, management rules of the system, layout definition, locations, buffer sizing, warehouse sizing, and so on.

A comparison of the tested system with those previously assessed, not presented here, can show the important differences, relating to occupation of space, economic investment, interoperational buffer level, reconstitution of lots control. The current solution shows prevalence in space occupation, lower incidence of human activity due to the increased level of automation, a greater rigidity in accompanying the flow variations, with a trend towards greater initial investment cost.

The initial obtained results led to the definition of an AS/RS, used not only for its most obvious function, but also the possibility to be used to distribute motors to the finishing lines and to the areas of testing, allowing to reduce the levels of motors in interoperational buffer, obtaining a greater availability of space within the dimensions already departments themselves. This, in the perspective of improvement and increase of production, is transformed into the possibility of developing its departments through the introduction of new machinery or new lines, or, as seems appropriate, in the definition of finishing lines in greater numbers than at present, each dedicated to specific codes, perhaps replicated more than one times in case of request of capacity increase for a specific code in the finishing activities, and to achieve more flexibility.

The use of the simulation tool has allowed us to light on aspects of detail in the definition of some characteristics of the assumed system: the number of vehicles needed, interoperational buffer sizing, performance parameters of LGV and S&RM, level of aggregation of the LU, up to highlight the limits of efficiency of the model configurations assumed, and suggest the characteristics of structurally different solutions, as in the case of the use of two S&RMs.

The proposed system and related models have been defined to have the highest possible degree of flexibility, resilience and reconfigurability (also made with many configuration value supported on data sheet , on reading files, external to the application, easy to reconfigure, as well as in the definition of the structural characteristics of the system.

Under these considerations, it could be nice continue to evaluate results with different configuration, and different production data, both in terms of quantity and mix.

The model can support any item information to enforce item recognition and traceability and tracking, but it isn't based on very intensive automation level. Order lots integrity in guaranteed as FIFO policies accordingly with lean production principles, also if it is applied in a smooth and tolerant way: because the randomness of the system and the simulation model too, sometimes one previously introduced item can be over passed by another one of same family, version and client order.

AS/RS has been concept as a transit point and sorting system, combining the storage feature with the skill of manage the sorting need of items in an automated way.

But not all the system is been thought adopting automated means, just where considered more effective.

The control logic to manage final assembly area fulfilment, and the consequent need to be freed, and the coupled logic to pick items as the last process phases are going in shortage represents a satisfying mix of push pull logic: the main activation impulse is a production plan already processed based on Due Date respect, but the advancing logic of prepared lots of items, especially the transport system is phased on a hierarchical control logic that mixes buffers area limitation constrains and shortages for buffers feeding lasts of processing phases, or bottleneck machines, as the testing machines that represent the ones to be operative and working because they have the longest processing time.

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