Scenario Analysis based on simulation models to determine the efficency of an Aircraft Industry

Daniela Chiocca, Teresa Murino, Liberatina C. Santillo, and Elpidio Romano

Abstract-The aim of this paper is to set up a simulation model of the production process of an aircraft company in order to obtain a tool for process analysis and decision support. To achieve this object has been used ProModel as simulation software. The advantages of all tools used in a correct and efficient internal movement, the different layouts and the possible usable materials handling system.

Keywords— discrete event simulation, salesman problem, routing, production process simulation.

I. INTRDOUCTION

Logistics is an integrated collection of all activities, related to the handling and storage of materials and materials handling represents a phase of the logistics cycle that must be closely related and integrated with all other stages of production and service. Because the transportation doesn't increase products value, but increases the costs, a good accommodation in the production areas should always conduct a minimum of inventory stock and transfers of materials, avoiding congestion, delays and unnecessary handling. These systems are closely related to different type of production, or rather weight, volume and production of parts and the choice of plant layout that best meets production requirements. Handling systems are classified according to their degree of automation: mechanized, semi-automatic, automatic and automatic control.The beginning cost of an automatic system is greater than the mechanized one, so the investment in equipment will be greater. The ROI of automation is resulting in lower operating cost. An automatic system, if properly designed and controlled, should be more efficient than a mechanical system interms of labour, damage, accuracy, product protection and stock rotation. In mechanized systems is used a combination of labour and handling equipment in order to facilitate the receipt, manipulation and /or shipping. Typically, the labour is still high a percentage of the overall cost of mechanized handling. These systems employ a wide variety of handling equipment, such as: transpallets, forklifts, dragging systems, carriages trucks and trailers, continuous conveyors.

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Transpallets are trolleys, wheeled platforms for manual handling of pieces, of unit loads and various materials, with limited possibility of lifting (about 13), which are then usedfor horizontal transfer of pallets in closed environments (frequent movements and short distances).Forklift trucks are used for moving pallets and holders both horizontally and vertically. The trucks are economic for travelling over long distances due to the high vehicle costs to the operator and to the small payload.

Dragging systems consist of ropes or chains in constant motion, mounted in the floor or suspended for pulling trucks. The main advantage of a dragging system is automatic movement, but these systems on the other hand do not have the forklift flexibility.

A tractor and trailer system is constituted by a driving unit that drives more carriers. The carriers are typically dimensioned for two pallets transfer. This system has the advantage of flexibility path, but it's less economical than dragging systems, because it requires a human presence.

Continuous conveyors are widely used in operations of shipping and receiving and constitute the means of handling for many types of sorting systems. The continuous conveyors may be motor or gravity, roller or belt. They are flexible, since the changes of location are relatively easy.

The semiautomatic system integrates a mechanized handling system automating some operations. It has a semiautomatic system when only some operations are automated, while others are manual or mechanized. The typical used equipment is: AGVS and monorails, automatic sorting systems and robot.

The Automatic Guided Vehicles make the same type of movement of a forklift truck. The main differences are driverless and bound path at predetermined lanes. AGV Systems use three o four wheeled carriages, which move in an automatic way within an establishment. These are systems that arise from the need to overcome the constraints in terms of management by the rigidity of classical industrial trucks (sixe, manoeuvrability, balance, energy costs, presence of an operator for each machine). The guidance systems are divided in two categories: a fixed path (require an installation of a track on the floor) and variable path (require a map of the area in which carriages operate and some fixed points of reference which are detected by carriages).

The AGV control system is usually hierarchical levels. At the lowest level is positioned the "machine control" or the single AGV, realized by a microprocessor installed on board the truck. This processor receives the information from the higher hierarchical level and controls vehicle's functions, such as direction, speed, stops, for example due to obstacles. At a higher hierarchical it's a "control unit" of the entire fleet of AGVs, which tasks of managing trucks' fleet are assigned, such as allocation of jobs and routes, maintenance management, etc. finally, at the highest hierarchical level, “general supervisory control” of handling system of the plant is present, which has the tasks to coordinate between themselves and with production system, different systems of handling, to pursuit an objective function. The problem about management of AGV system has features typical of operations and is therefore managed by systems such as queuing theory, numerical simulation: rules must be established to utilizing AGV park to serve a number of operative stations, taking into account any constraints (path, production plans to be respected, technological priorities, maintenance, downtime, etc.) and functions to be optimized (minimized paths, expectations, maximum saturation of machines, uniform using tracks, etc.).

Automated systems, unlike those mechanized, seek to minimize the labour replacing it with equipment. Any type of movement can be automated. The most common application, however, are realized by automating the storage function (ASRS-Automated High Rise Storage and Retriva System). The automation interest lies in the fact that it replaces labour to capital investment in machinery. In addition to a lower use of labour, usually an automatic system operates faster and with greater precision of a mechanized system. The disadvantages are the high level of investment and the complex nature of maintenance.The concept of optimized handling by automating management is relatively new and is still experimental. The principle is interesting because it combines the possibilities of control of an automatic system to the operational flexibility of normal mechanical means.

II. THE INTERNAL TRASPORT

The industry subject of this work has a discrete production that distinguished production systems of manufacturing industry i.e. those “product”, usually characterized by two phases: “manufacture” and components “assembly”.

With regards to its management production policy, the firm is a company that puts itself at intermediate levels between a PTO and ETO system. PTO (purchase to order) is a policy adopted only if the customer is ready to wait sufficient time. The feature of this policy is, therefore, that companies are allowed to handle the purchases of raw materials on the basis of received orders. ETO (engineering to order) is a management policy according to which the time allowed by customer is enough to cover the design phase. It’s a philosophy adoptable by companies that base their business on providing excellent personal service made “ad hoc” for its client.

The choice between these two levels depends on design stage preceding the production and which is realized on the basis of client’s requirements, but not with the same frequency with which it’s produced. Once the design of a landing device is made and organized production for that property, it will proceed to receive and process orders of production which, for the same device, will arrive in time. The design phase will take place, therefore, only when the request for a device not belong yet to the production mix or when an existing device should have reached the terms ofobsolescence. When fully operational, weproduce according to PTO policy.

Plant layout is structured according to Job Shop system. The need of this configuration is dictated by the characteristics of production: in fact, works on commission and production is small and medium series, that is characterized by reduced production volumes with great cycle variability.

It is simultaneously about managing a backlog with different cycles and low repeatability. More suitable type of production is thus for “process” with a job shop layout characterized by groups of machines performing similar work. In each shop item are simultaneously processed, that require operations carried on the same type of resource.

The product mix is extensive but production volumes are generally higher (in fact, the low production volumes are a feature of the aviation industry, at whatever level it operates as the complexity, size, quality and accuracy required for these types of products permits no alternative).

The departments of the studied plant are following:

1. Materials Warehouse: it’s place where activities of receipt, storage and retrieval of raw materials, semi finished products, and outputs that are bound to perform external works, take place;
2. Oven Department and Treatment for Plastic Deformation Shop: the first is characterized by ovens used for manufacturing of thermal treatments, ageing, cementation and nitrogen-hardening. The second is one in which treatments are performed sandblasting and shot peening. It is surface treatment that exploit the principle of the plastic deformation of metals to be able to confer their special properties;
3. Mechanical Shop: is self-sufficient department for machining of special aluminium alloy, titanium, medium and high strength steels. It is equipped with: CNC lathes, conventional lathes, machining centres;
4. Electro Discharge Shop: is equipped with EDM (Electro Discharge Machining) and WEDM (Wire Electro Discharge Machining);
5. Paint Shop: is used for production of partial or total paint;
6. Assembly and Finishing Shop: is the place where assembly of particular products takes place;
7. Quality Control Shop: hardness tests, dimensional checks and functional tests, metallographic, penetrant test, acid etching are made, in order to ensure the quality of its products;
8. Finished pieces Warehouse and Shipping Shop: is the place where all products are collected and put in stock waiting to be sold.

The products follow almost all their own processing cycle within company, since most of processing phases is “home made”. If it is thought, then, the multiplicity and variety of made items (considering pieces, sub assemblies and assemblies it get to about 1500 products) and the large number of workings that each requires, it is evident the importance and weight that a correct handling has within the company itself.

In this regard, our work is aimed at optimizing internal handling:since there is no a real system of handling, transporting parts from one machine to another of the same shop is made by a worker who has finished the last operation, whereas for the materials handling from one machine to another belonging to a different shop, is used to handling manpower. These are two and no criterion of scheduling requirements, optimization of trips they load a lot of pieces to pick up a machine in a shop and bring them to a machine of another shop.

It happens that when a worker finishes a process on a lot of pieces, that must be transferred to another shop to continue the cycle, he informs one of the handling manpower that lot must be transferred from the source to a particular destination. The officer, after completing the journey that was performing and after fulfilling all the requests that has accumulated prior to that, shall transfer the lot in question.

The movement means adopted are nothing more that the simple trolleys that are pushed manually and only in the case where the load is too heavy or complicated to handle, fork trucks, instead, are used but this solution is adopted especially for the cart is assembled, which must only be shipped to the customer. The operation schedules have been prepared in such a way taking into account of this inefficiency: studying them, in fact, are evident queue times present for all operations and for all products.

Obviously, a situation like this entails delays in delivery (which generates, consequently, customer dissatisfaction) and a limited use of production capability. We have conducted this study analysing all processed pieces by 4 machines, subassemblies and finally 5 types of assemblies. The choice is not entirely accidental, but justified by the fact that these pieces as well as being the most frequently produced in the plant, are also those most eventful.

If it's assumed to produce at least one batch of each type per month, the total meters are represented in table 1:

Table 1: Walked Meters

		WFL	***Kitamura***	***Mandelli 6***	***Mandelli 8***
Pieces		9792,4	3912,7	25366,3	4060,8
Sub-assemblies		3311,1	1853,2	17483,5	2809,4
Assemblies	3429,98				

Considering only these pieces, their respective sub-assemblies and 5 assemblies, during a month two handling staff run through a minimum number of 72.02 km. It's therefore evident incidence that internal handling has actually.The Company intends to pursue that the goal is reduction of flow-time, and consequently a production increase, pieces through a rationalization of internal efficiency. After highlighting how current management of flows of shares involves a significant impact on the shipping time internal throughput time of the products within the plant, it will move to rationalize the internal handling of company, showing how it can drastically reduce this performance indicator by acting appropriately on it.

III. CURRENT SCENARIO SIMULATION AND MODEL CONSTRUCTION

Speakingaboutsimulationmeansreplicate by means of suitablemodels a reality alreadyexisting or to be designed, in order to study, in the first case, the effects of possibleactions or events in some way predictable, or, in the second, to evaluateseveralpossible design choicesalternatives.
Thesemodelshave a fundamentaldifferencecompared to analyticalmodels to use the computer notonlyas a computationaltool, butalsoas a way of representation of the elementsthatconstitutethe reality under study and the relationships among them.

In thisstudy the simulator thatwehavechosenisProModel: it's a simulation and animationtool, easy to use, employed to model alltypes of manufacturing systems (from job shop to production systems for large lots) quickly and accurately. The SimulationProcessbegins with the definition of allelements of model, an animatedrepresentationallows to view on the screen the processduringitsexecution. At the end of the simulation, the performance indicators, suchasresourceutilization, the level of stocks and productivity can be measured and plotted. To define a model, it'snecessary to specifytwotypes of elements: System Objects and System Operations. Objects are Locations, resources, Entities and Path Networks; Operations, instead, are Arrivals and Processes.

Entities are anythingthat model processes /rawmaterials, semi finishedproducts, assemblies, loads, etc.). They are elementsanalyzed by the process.

The locations are fixedcomponents of the system, in which the Entities are moved in order to be processed, stored or intended to othertasks.A resource can be a person, a mean of handling or anyotherthingused for Entities transfer, for the locationsmaintenance or otherresources and to assist entities processing onlocations.Paths Networks are optional and are nothing more thanpaths made by entities and resourceswithin a plant. Thereis the possibility to defineseveral networks and to associate each with itsresources and entitiesthatrunthrough.An arrival (Arrivals) occursevery time that an entityisintroducedinto the system.The Processes (Processes) defineentitiesroutinginto the system and operationsoccurred in any location wheretheyenter.
Processesspecifyeverythingthathappenstoentitiessincetheyenter the systemuntilleaving.Thanksto Merge Function, made available by ProModel, every shop wasrepresented with a specific model and allmodelsthuscreatedwill be used in the general model: eachdepartmenthasbeencreatedasifitwas a new model and onlyafterthatall sub-modelswerejoined, i.e. after the construction of global model, allentitieshavebeenthencreated and processeshavebeendefined.

Sub-models use is due to 3reasons:

1. Model creation is not a simplification of reality, but it is an accurate reproduction, so it follows that it's able to act on a single sub-model if it was necessary to make changes;
2. Concept of modularity allows an immediate reusability of sub-models and a major control during simulation (and, therefore, it allows an increased monitoring and especially targeted performance).
3. Several proposed scenarios will be different for external handling and so, considering a special lock

for everything that happens outside, it's been enough to act on this sub-model to make desired changes to the system.

Therefore, the created sub-models are:

- Raw Materials Warehouse (Fig 1);
- Shipping Arrivals Warehouse (f Fig 2);
- Finished Goods Warehouse (Fig 3);
- Mechanical-Adjustment Department (Fig 4);
- Mechanical CN Department (Fig 5);
- Painting Department (Fig 6);
- Shot peeing Department (Fig 7);
- Evidence Room Department (Fig8);
- Control Department (Fig 9);
- Assembly and Finishing Department (Fig 10);
- External Department (Fig 11).

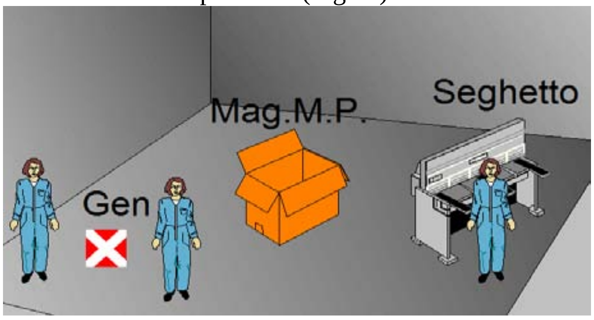

Fig 1: RowMaterialsdepartment

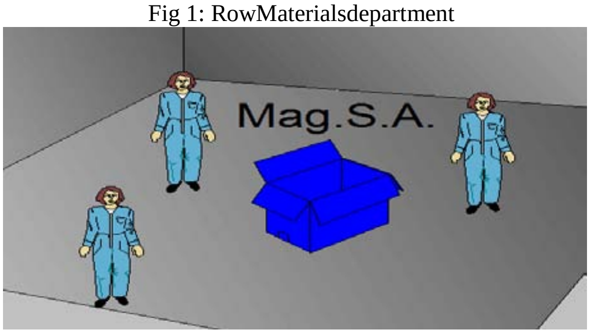

Fig 2: ShippingArrivalsWarehouse

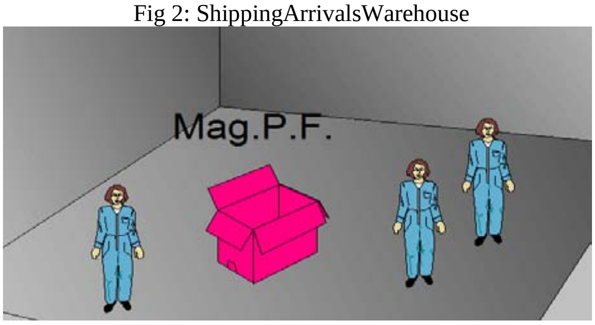

Fig 3: FinishedGoodsWarehouse

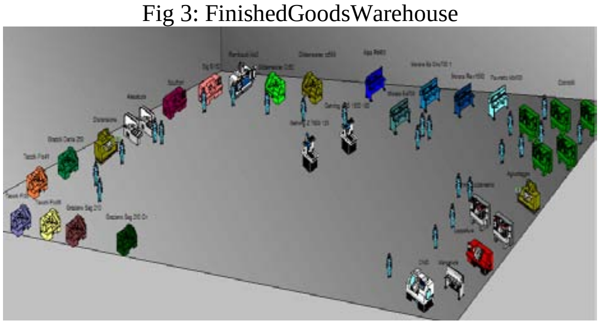

Fig 4: Mechanical-AdjustmentDepartment

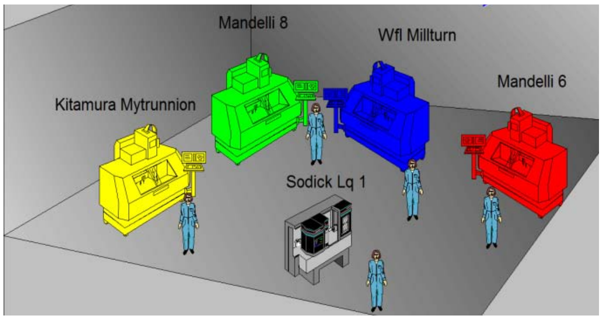

Fig 5: Mechanical CN Departemnt

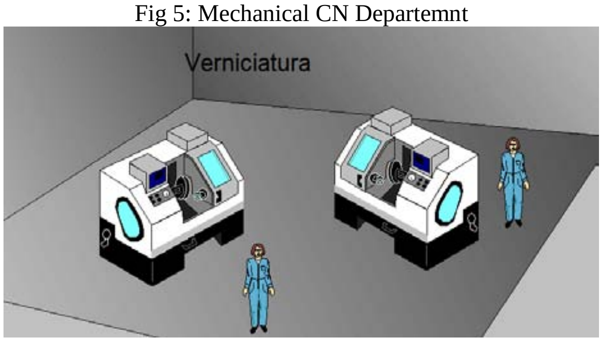

Fig 6: painting Department

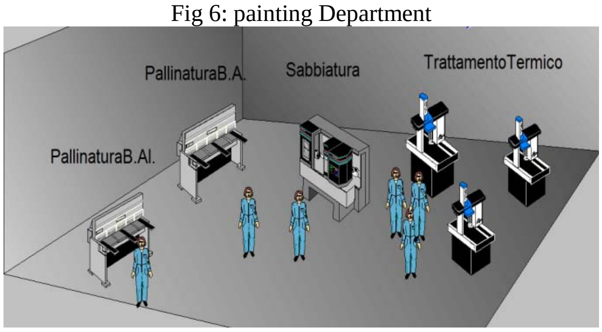

Fig 7: ShotPeeingDepartment

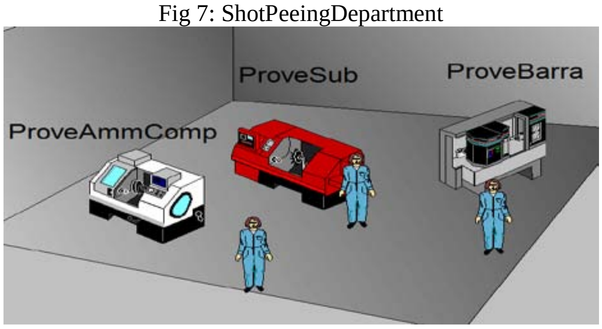

Fig 8: EvidenceRoomDepartment

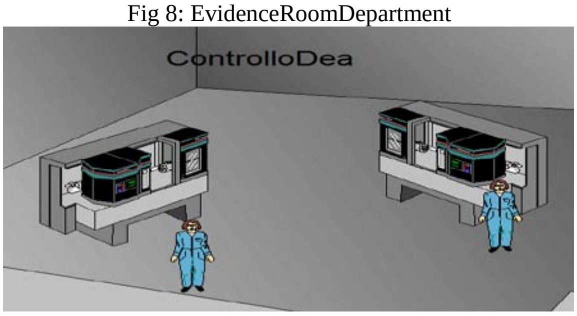

Fig 9: Dea Control department

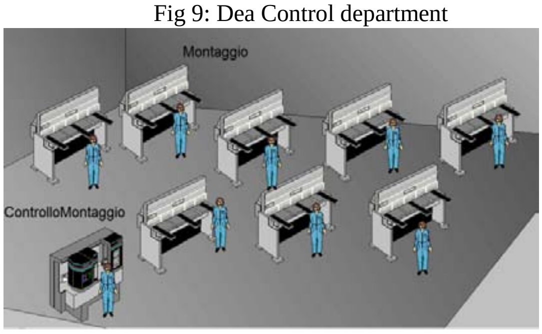

Fig 10: Assembly and FinishingDepartment

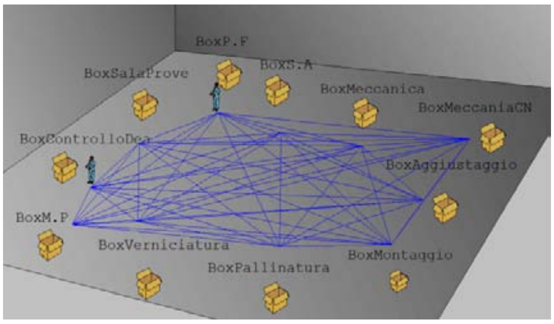

Fig11: External Department

In any sub-model there are a number of Locations and Resources and there is a Path Network only in one of them. Since the built model does not provide simplifications, but it plays exactly the reality, in order to not complicate the graphics, lots have been considered as entities instead of individual items.

Entities, all known as "e" followed by a growing number from 1 to 63, are then 63 manufactured batches, represented in figure 12.

For items and sub-assemblies, these batches are constituted by 20 units (from "e1" to "e62"), while number for assemblies is considerably lower. In fact, the shock absorber batch (e63) and gas compressor batch (e64) of ATR42 is constituted by two units, the shock absorber batch (e65) and gas compressor batch (e66) of ATR72 is constituted by four units, lot of telescopic bar (e67) of ATR72 is 10 units.

As regards locations, these are all machines on which sixty seven pieces are processed (including raw materials warehouse, shipping/arrivals and finished parts warehouses). Internal resources shops, which in our case are represented by workers, in addition to moving lots within the same shop, transferring them from one machine to another or to shop box, workers also must follow the process.

Path Network considered is unique and it represents the network that links the different shops. Therefore, the only sub-model in which a Path Network will be represented is the external environment to shops. This network is formed by eleven nodes (representing eleven shops) and all possible links with, of course, the respective distances.

As regard workforce shift, it's important to make a difference between workers in the Mechanical Department at NC and all other workers more two handling ones. In fact, the first work from Monday to Friday, scheduling three shifts, with three breaks (6:30-7.00, 12:20-13:00, 22:30-23:00), while on Saturday they work on two shifts, from 06:00 to 22:00, with two breaks (12:20 to 13:00 and 20:30 to 21:00). The scheduling of these workers is shown in figure 13.

Workers of all other departments and handling staff have shift from Monday to Friday, from 07:50 to 16:30, with a break from 12:20 to 13:00, as shown in figure 14.

After calculating frequency of each batch orders, we have calculated its cumulative distribution that will be then to determine arrivals sequences. It will use, for this purpose, Monte Carlo Method.

This aspect has been simulated, creating a new entity: "piece", that is the only one appears in the block of arrivals (arrival Location is "gen"). Its arrival logic provides, for each arrival, an extraction of a pseudo-random number between 0 and 1, depending on the extracted number it proceeds to processing of item that has, as frequency range, that in which the number in question falls.

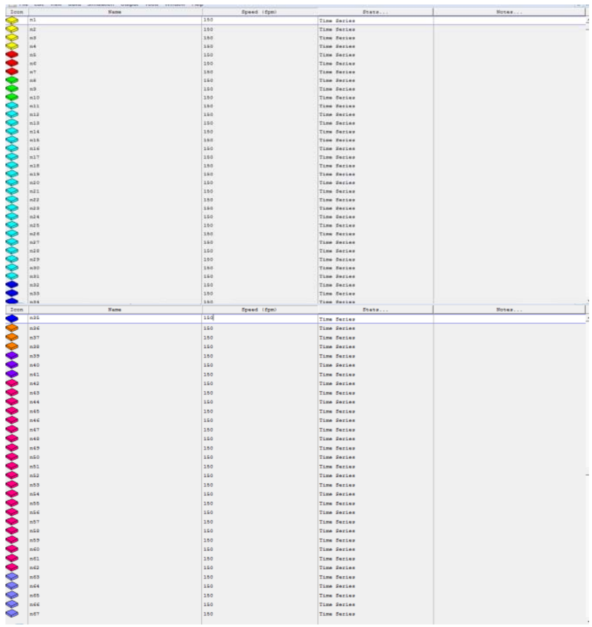

Fig12: Entities

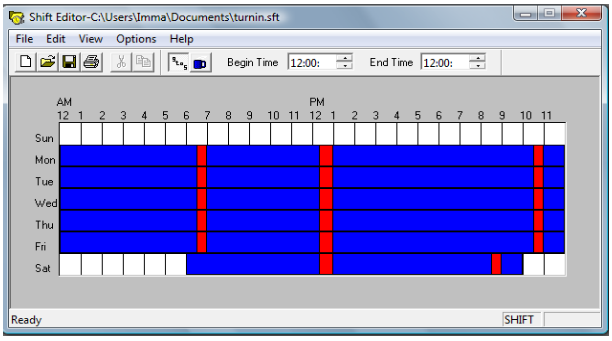

Fig13: Workers Mechanical CN Shifts

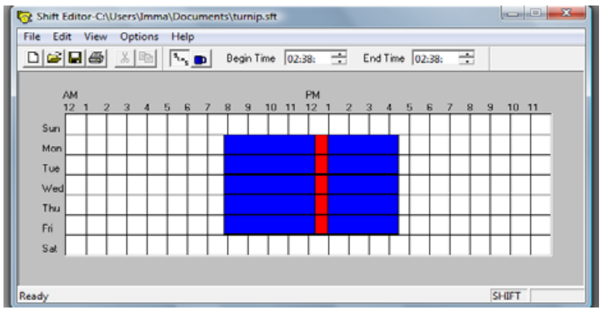

Fig14: Workers and handling staff shift

For the "piece" entity, process is established with a conditional instruction IF-THEN-ELSE: IF number is inside the first range, THEN Route1 (i.e. it realizes "e1" entity), IF number is inside the second range, THENRoute2, and so on.

As regards all other entities, processes refer to WAIT a certain time command (which will refer to the code on processing cycle), USE command (holds one or more resources for a certain time and the releases them), and MOVE WITH command (it moves the piece by an operator, who is in charge of handling, and then it releases when he has finished).

In this scenario, the only used attribute is "number", that is real and is joined entities. We define, now, parameters that mostly affect the obtained results and validation model.

We suppose to estimate average of steady-state v= E(Y), that generally is defined as:

$$v = \lim_{i \to \infty} E(Y_i) \tag{1}$$

So, transitional converges at steady state. The most serious consequence of the problem about transient is that probability is:

$$E[\bar{Y}(m)] \neq v \tag{2}$$

for each m (where m is replication number)

The technique, mainly used to overcome this problem, is called "warming up the model" or "initial-data deletion". The idea is to delete a number of observations at the beginning of a new replication and to use onlythe others to estimate v .for example, given the observations $Y_1, Y_2, \ldots, Y_m$, is often recommended to use as an estimator of v:

$$\bar{Y}(m,l) = \frac{\sum_{i=l+1}^{m} Y_i}{m-l} \tag{3}$$

Now, the problem is to choose l. This parameter must be chosen in such a way that:

$$E[\bar{Y}(m,l)] \approx v \tag{4}$$

If l and m are chosen too small, $E[\bar{Y}(m,l)]$ could be very different from v. On the other side, if l is chose n larger than necessary most likely y will have a high variance $\bar{Y}(m,l)$ will have a high variance. In literature, different methods in order to make the choice of l are present. Kelton and Law (1983) have developed an algorithm for the choose of l and m well built for a large variety of stochastic models. However, this algorithm has a limit: it is based on the assumption that $E(Y_i)$ is a monotone function of i.

The simplest and general technique for $l$determination is a graphic procedure carried out by Welch (1981.1983). This technique has a specific objective: to determine a time l index such that $E(Y_i) \approx v$for i> l, where l is the warm up time. In general, it is very difficult to determine l for a single replication since the process variability Y1, Y2,…,Ym. The Welch procedure is to do n independent simulation replications and to develop the following four steps:

- To carry out n simulation replications ($n \geq 5$), each of$m$ lenght.
- To determine $\bar{Y}_i = \frac{\sum_{j=1}^{n} Y_{ji}}{n}$ for$i$=1, 2,…,m, that are the process averages..
- To smooththe high frequency oscillations in $\bar{Y}_1$, $\bar{Y}_2$, $\bar{Y}_m$, a moving average $\bar{Y}_i(w)$ is defined:

$$\bar{Y}_i(w) = \begin{cases} \dfrac{\sum_{s=-w}^{w} \bar{Y}_{i+s}}{2w+1} & if\ i = w+1, \ldots, m-w \\ \dfrac{\sum_{s=-(i-1)}^{i-1} \bar{Y}_{i+s}}{2i-1} & if\ i = 1, \ldots, w \end{cases} \tag{5}$$

wherew is the *window*, and it is entire type and it has values: ; it is called moving average since it moves with time.

- To diagram $\bar{Y}_i(w)$ for i=1, 2,…,m – w and to choose$l$, that it is the value after the one the $\bar{Y}_i(w)$ seem to be convergent.

Consider the proposed model that replicates the current firm scenario. A simulation time large enough, for example four years, ie 34560, has to be chosen. Our m is equal to sixteen as will carry out simulations at intervals of three months (ie. three months, six months, up to forty-eight months). The chosen number of replications is five since our system stochasticity concerns only the random numbers generation (in fact, the obtaining results, repeating this procedure with a larger number of replications are close to these). The evaluated output will be:

$$P = \frac{number\ of\ produced\ pieces}{number\ of\ scheduled\ hours} \tag{6}$$

The results that are obtained with(2) are shown in Figure 15:

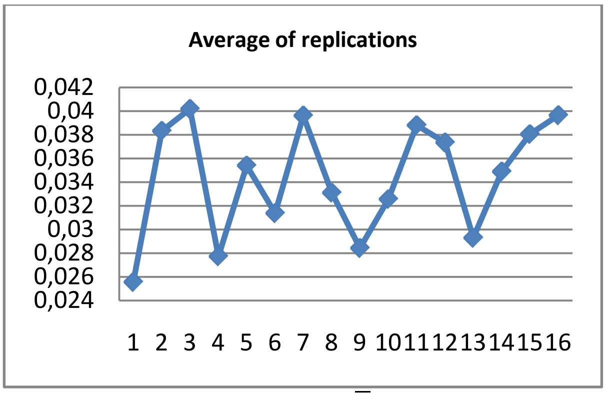

Fig 15: Values of $\bar{Y}_i$

The formula results of steps three are depicted in Figure 16:

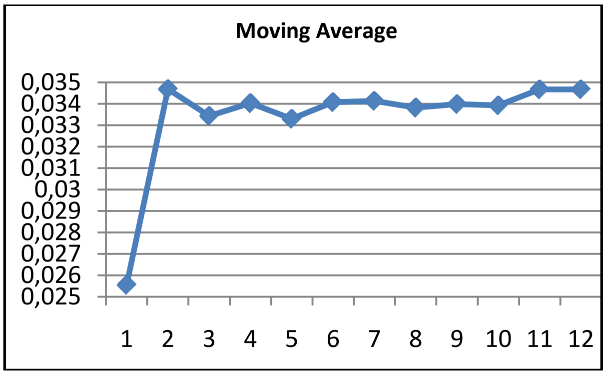

Fig16: $\bar{Y}_i(w)$Values

It is evident starting from the value of six, ie from the eighteenth month later, the system reaches the stationary. Therefore, the value of l to consider is six and the expected value to be considered will be:

$$\bar{Y}(m,l) = \frac{\sum_{i=l+1}^{m} Y_i}{m-l} = 0{,}035171602 \tag{7}$$

In carrying out the simulation again, it is necessary to insert in the proper field a warm-up period of eighteen months (12,960 hours).

The system automatically will generate a simulation of 12,960 + 34,560 hours and the results shown are only those for the past four years, i.e. those are obtained during transition phase will not be displayed and considered.

Four years are simulated and the number of produced lots in this period of time is 2959.

The Figure 17 highlights how the materials handling engraves deeply onflow time pieces. With the color blue has been reported as the percentage of time required for transfer from one department to another, with yellow color as the percentage of time that the lots are waiting on the machine (the worker is engaged in another process), while with the green color are indicated the percentages of time required to perform the operations provided by the cycle.

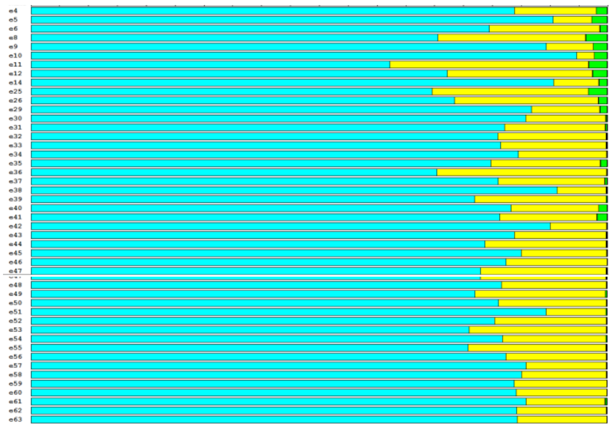

Fig17: Entities state

Clearly, therefore, the influence of time of materials handling, especially if related to the time really needed, namely those necessary to accomplish the operation process.

In Figure 18 is, instead, shows a graph that highlights the resources status of resources, of the workers.

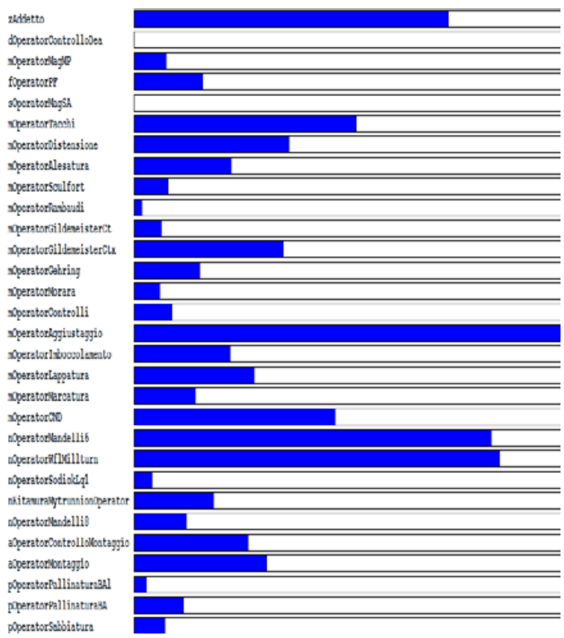

Fig. 18:resources and manpower status

Finally, Figure 19 shows the quantity of pieces that currently wait daily at each box. Also in this case that parameter will be analyzed and compared with that obtainable in an evaluative scenario.

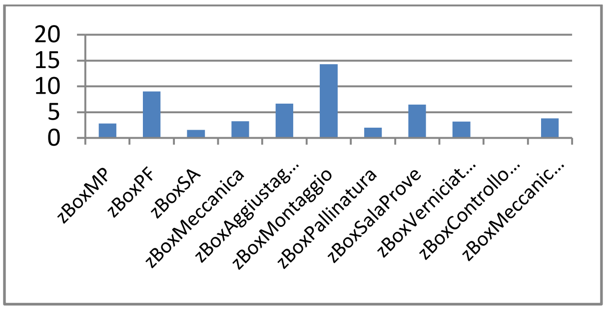

Figure 19: Lots number in the box every day

IV. VALIDATION MODEL

In this step, it is necessary that proposed model provides valuable results for the system under construction. In particular, it must examine if the performance measures of the real system are well approximated by measures generated by simulation model.

To do this one, a comparison is made between flow time, obtained by simulation, and actual measurements. This comparison makes sense, because in writing all pieces processes, operations times are considered as constant (effective those that piece is worked of on each machine).

Doing this comparison between planned lead time and those obtained, it’s possible to see that thesystem is able to model reality correctly.In addition afurther comparison between company and reality reproduced by simulator was carried out: in both cases using the number of achievable lots.

ProModel is estimated that in four years the number of lots is 2959 and analysing fulfilled orders in years before it notes that this indicator is close to which evaluated in the real system. This step is very important because, if the model approximates reality correctly, as it actually happens, it is reasonable to think that the future results will be the one that real system will provide. In summary, this phase allows to understand if results will be shown later are representative of the impact that the proposed solutions will be or not in the real system.

The tools to optimize the inner handling are: optimization of routes and the choice of handling system which would increase the speed of handling and which, above all, would allow to carry more batches simultaneously. After defining the possible combinations of points, it will go on the application of *Travelling Salesman Algorithm* and, finally, the choice of possible suitable means to handle within the plant and to carry the desired load.The choice of pick-up points and delivery service is important because, according to their number, it possible to pass from possibility of finding, in a short time, a solution of global optimum to that having to settle for a local optimum, because of computational complexity. We’ll repeatedly apply Travelling Salesman Problem: we will consider different routes, depending on different points of pickup and delivery, and at the end we’ll evaluate how the solution changes in the different analysed scenarios.

In the first TPS application, it will consider 11 collection points: Raw Materials Warehouse, Shipping and Arrivals Warehouse, Assembly and Finish at top floor and another below to traditional mechanical department, a single point will be allocated for non-destructive testing, dimensional inspection and adjustment, a point will need for DEA control and five points for coating, NC mechanical department, Shot Peening, Testing Room and Finished Parts Warehouse.

As a consequence of choice of collection and delivery points, distance matrix which will serve in the application of the TSP Algorithm turns out to be that shown in table 2.

During a second TPS application, it will consider a single point of collection and delivery to the General Store (which will obviously be divided into two areas): Raw Materials Storage and Shipping-Arrivals Storage will share the same pickup point instead of having one each (Distances with 10 nodes). It may prove to be logical to consider a single point of pickup regarding the Shot Peening Department and that in which non-destructive testing are made, dimensional control, marking, deburring and rounding (distances with 9 nodes).

Table 2: Distances with 11 nodes

	1	2	3	4	5	6	7	8	9	10	11
1	/	19,7	193,8	193,8	182,145	128,415	122,72	148,15	159,915	68,645	61,245
2	19,7	/	188,82	188,2	177,165	123,435	117,77	143,17	154,935	63,665	56,265
3	193,8	188,82	/	0	65,585	245,11	239,445	264,885	42,885	132,995	198,415
4	193,8	188,2	0	/	65,585	245,11	239,445	264,885	42,885	132,995	198,415
5	182,145	177,165	65,585	65,585	/	206,24	192,23	217,66	31,2	121,34	186,76
6	128,41	123,43	245,11	245,11	206,24	/	15,085	21,875	184,01	92,74	138,16
7	122,72	117,77	239,445	239,445	192,23	15,085	/	34,86	178,345	87,075	132,495
8	148,15	143,17	264,885	264,885	217,66	21,875	34,86	/	203,77	112,505	157,925
9	159,915	154,935	42,885	42,885	31,2	184,01	178,345	203,77	/	99,11	164,53
10	68,645	63,665	132,995	132,995	121,34	92,74	87,075	112,505	99,11	/	73,26
11	61,245	56,265	198,415	198,415	186,76	138,16	132,495	157,925	164,53	73,26	/

Using Lingo Software, it has come TPS Problem is resolved, in reference to 3 distance matrices, respectively, with 11 nodes, 10 nodes and 9 nodes. After analyzing processing cycles for each product, their production lots, the weight of materials that must be moved from one shop (including warehouse) to another, the lung-storages to be provided, it switches to choice mean by taken in the final solution. In our case two decisive characteristics were considered essentially, which are those then affect the productivity: speed (with and without load) and capacity, as also shown in table 3:

Table 3: Key features of handling

	Model 1	Model 2
Capability	3000 kg	5000 kg
Speed with load	8,5	5,0
Speed without load	12,5 km/h	8,0 km/h

The proposed scenarios are six, as also shown in table 4:

Table 4: Scenarios to be implemented

	Model 1	Model 2
11 nodes	Scenario 1	Scenario 2
10 nodes	Scenario 3	Scenario 4
9 nodes	Scenario 5	Scenario 6

We will see at the beginning as handling mean introduction has been handled and then the change of pickup and delivery points (Fig 20)

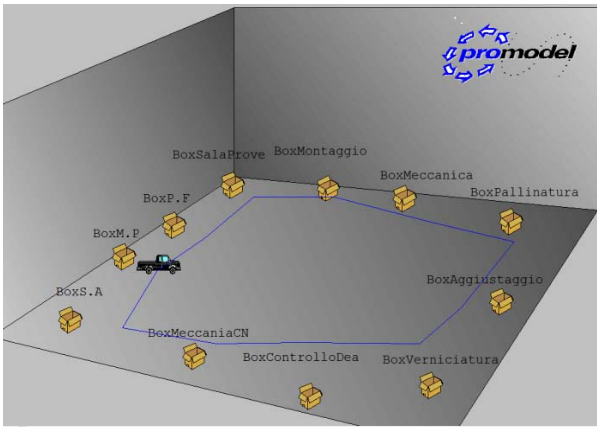

Fig 20: Traveling Salesman network

Some made changes to the vehicle are made on sub-model representing the outside of departments and, instead, others are made globally with appropriate variables, subroutines and external queue.

Regarding the first changes, the two handling operators have been replaced with a single resource. Since this is a resource, it has been possible to assign the speed with which it travels when has a load and not (which are precisely the mean's characteristics). Furthermore, it has been assigned a network path on which to move, that has been obtained by solving the TPS algorithm, and that, aswe'll see, changes from time to time. "Capacity" variable has been introduced, which represents mean capacity. It is a real type and its beginning value will be 3000 or 5000, depending on the simulated scenario. Regarding scenario's variation due to routing changes, is sufficient to operate on path network, modifying distances.

After the simulation of six proposed scenarios, in table 5 are shown the values of quantity of pieces made at the end of three scheduled years. This is the index of productivity.

Table 5: Made Entities results

	Made Entities
Current scenario	2959
Scenario 1	8700
Scenario 2	8701
Scenario 3	8738
Scenario 4	8732
Scenario 5	8735
Scenario 6	8752

From theseinitialresults, the importance of an improvement, that can be obtained by applyingone of proposedsolutions, isevident. In particular, the last scenario isthatpresentslargervalues of the amount of achievablelots.

Let's look at another parameter: Flow Time (FTM), i.e. the crossing time of a lot within the plant. Now, in fact, we consider its average value, that is:

$$FTM = \sum_{i=1}^{63} t_i / n \qquad (8)$$

where:

$t_i$is flow time relative to i-th entity, thatis the time thisentitytakes to be realized (it's the sum of threealiquots. Working time, time for transportation and time lost on the machine).

$n$is the number of completedlots, i.e. thosehaveleft the system.

The obtainedvalues for differentscenarios are shown in table6:

Table 6: results of mean flow time

	FTM(hr)
Current scenario	516,68
Scenario 1	156,98
Scenario 2	157,29
Scenario 3	156,41
Scenario 4	156,08
Scenario 5	166,20
Scenario 6	165,65

Thisparameter, evaluated in sixscenarios, isdrasticallyreducedcompared to current situation and thisalsoexplainshow the number of achievablelots in proposedscenariosisworththatmuchcompared to presenttoday. Beingveryinsignificantdifference of crossing time in differentscenarios and consideringincreasedproductivity of company, itchoosesasproposing scenario, the sixth. Fig 21 and 22 show twoindicesconsideredpreviously, for the sixscenarios.

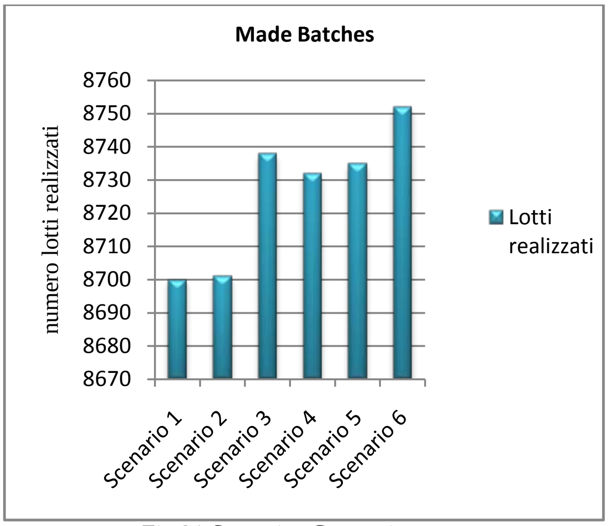

Fig 21:Scenarios Comparison

In Fig 23 is,however, illustrates the greatdifferencethatoccursbetween the current and future results:

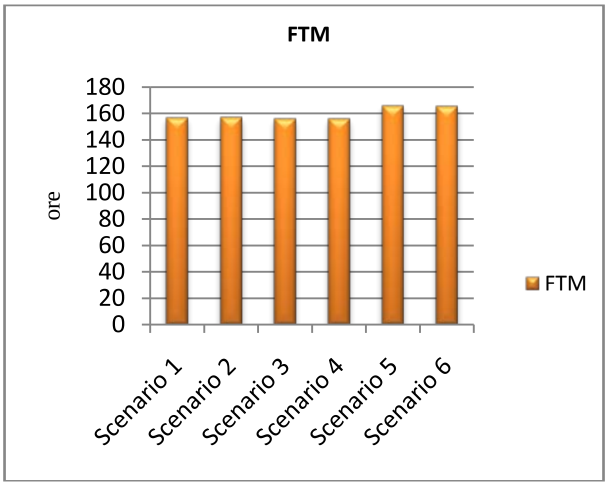

Fig22: Scenarios Comparison

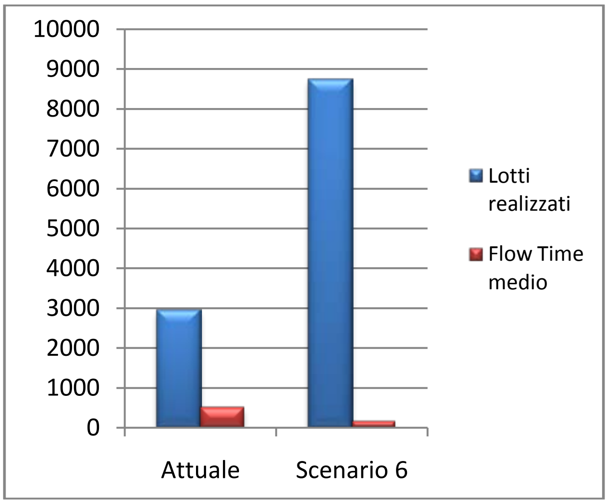

Fig23: Comparison with actual situation

V. CONCLUSIONS AND FEATURE DEVELOPMENTS

Wehaveshownthrough the development of simulationmodels, that alternative layouts and logisticssolutions and can be compared performance are evaluated. The proposedsolutionwouldallowthe company to significantlyincreaseitsproductivity and, simultaneously, to save human resources. The average production flow timeisreduceddrastically by encouraging on-time deliveries and therebyresulting in greatercustomersatisfaction.

In addition, this new handlingsystemwouldincrease the componentswithin the plant turnover index, with the consequent WIP decrease. Reducing the lotsnumberstationingatpointscollectionpointsiteliminates the possibility of damage to the lotsthemselves, and all the otherdisadvantagesassociated with warehousesaturation (deterioration, slow in handling, delays in pickupoperations, etc). Theseresultswerereachedonlyworkingon internalmaterialshandling, thatis, given the layout, changing the number of involvedpeople, the equipment of handlingused, the nodes to be visited, the optimalpath to track and the visitfrequency. However, in the future otherissuescould be consideredthatwouldallowtofurtherimprove the results just obtained. In case of transfer to a new plantitmight be cheaper to redesign the layout: keepingunchangedits job shop typology, whichaswehaveseenis the onemostsuited to an industrylikethis. Itispossible to think of a better and more convenientmachines layout location. Another goal of thisstudyis the optimization of time lost on the machine. In essence, itwould solve a resourcesschedulingproblem, so with the intent to reduce the other rate impactingseverely on lead time: the time due to "wait for resources". The obtainablesolution can be implemented in conjunction with the oneproposed in this work.

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