On the Travelling Salesman Algorithm: An Application

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Abstract:- Logistics is an integrated collection of all activities, related to the handling and storage of materials. Materials handling represents a phase of the logistics cycle and 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. 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.

Key words: problem solving, salesman problem, routing, production process simulation.

1. Introduction

Handling 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 in terms 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.

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.

2. The internal transport in Magnaghi Aeronautica S.p.A

The *Magnaghi Aeronautica S.p.A.* has a discrete production that distinguished production systems of manufacturing industry i.e. those “product”, usually characterized by two phases: “manufacture” and “assembly” of components.

Plant layout is structured according to Job Shop system. The need of this configuration is dictated by the characteristics of production: in *Magnaghi*, in fact, works on commission and production is small and medium series, that is characterized by reduced production volumes with great cycle variability. 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;
2. Oven Department and Treatment for Plastic Deformation Shop;
3. Mechanical Shop;
4. Electro Discharge Shop;
5. Paint Shop;.
6. Assembly and Finishing Shop;
7. Quality Control Shop
8. Finished pieces Warehouse and Shipping Shop.

In this regard, our work is aimed at optimizing internal handling. 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	3912,74	25366,36	4060,82
Sub-assemblies		3311,11	1853,24	17483,56	2809,475
Assemblies	3429,975				

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.

3. Current Scenario Simulation and the Model Construction

Speaking about simulation means replicate by means of suitable models a reality already existing or to be designed, in order to study, in the first case, the effects of possible actions or events in some way predictable, or, in the second, to evaluate several possible design choices alternatives.

In this study the simulator that we have chosen is ProModel: it’s a simulation and animation tool, easy to use, employed to model all types of manufacturing systems (from job shop to production systems for large lots) quickly and accurately. The Simulation Process begins with the definition of all elements of model, an animated representation allows to view on the screen the process during its execution. At the end of the simulation, the performance indicators, such as resource utilization, the level of stocks and productivity can be measured and plotted. To define a model, it’s necessary to specify two types of elements: System Objects and System Operations. Objects are Locations, resources, Entities and Path Networks; Operations, instead, are Arrivals and Processes.

Thanks to Merge Function, made available by ProModel, every shop was represented with a specific model and all models thus created will be used in the general model: each department has been created as if it was a new model and only after that all sub-models were joined, i.e. after the construction of global model, all entities have been then created and processes have been defined. Therefore, the created sub-models are:

- Raw Materials Warehouse;
- Shipping Arrivals Warehouse;
- Finished Goods Warehouse;
- Mechanical-Adjustment Department;
- Mechanical CN Department;
- Painting Department;
- Shot peeing Department;
- Evidence Room Department;
- Control Department;
- Assembly and Finishing Department;
- External Department.

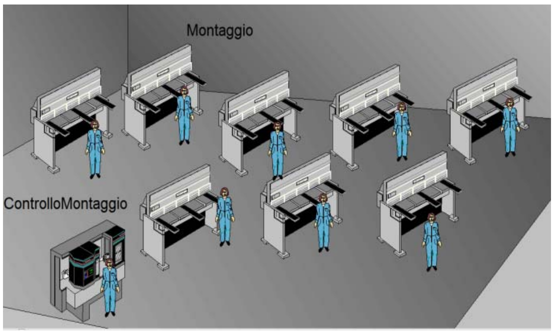

Figure 1: Assembly and Finishing Department

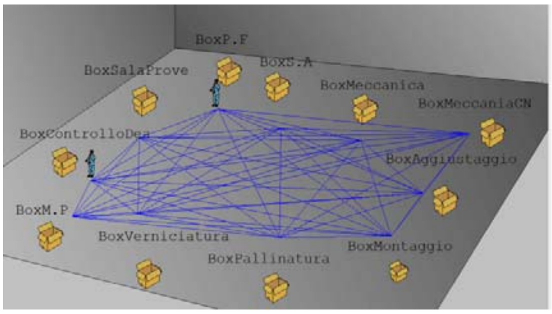

Figure 2: External Department

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.

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

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:

(1)

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

(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 only the others to estimate v . for example, given the observations $Y_1, Y_2, \dots, Y_m$, is often recommended to use as an estimator of v:

(3)

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

(4)

d m are chosen too small, $E[\overline{Y}(m,l)]$ 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 $\overline{Y}(m,l)$ 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 $\overline{Y}_i = \frac{\sum_{j=1}^{n} Y_{ji}}{n}$ for i=1, 2,…, m, that are the process averages..
- To smooth the high frequency oscillations in $\overline{Y}_1$, $\overline{Y}_2$, $\overline{Y}_m$, a moving average $\overline{Y}_i(w)$ is defined:

$$\overline{Y}_i(w)=\begin{cases}\dfrac{\sum_{s=-w}^{w}\overline{Y}_{i+s}}{2w+1} & se\ i=w+1,\dots,m-w\\[2mm] \dfrac{\sum_{s=-(i-1)}^{i-1}\overline{Y}_{i+s}}{2i-1} & se\ i=1,\dots,w\end{cases} \quad (6)$$

where w is the *window*, and it is entire type and it has values: $w \leq \lfloor m/4 \rfloor$; it is called moving average since it moves with time.

- To diagram $\overline{Y}_i(w)$ for i=1, 2,…, $m - w$ and to choose l, that it is the value after the one the $\overline{Y}_i(w)$ 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:

$$P = \frac{number\ of\ produced\ pieces}{number\ of\ scheduled\ hours} \quad (7)$$

The results that are obtained with relation (2) are shown in Figure 3:

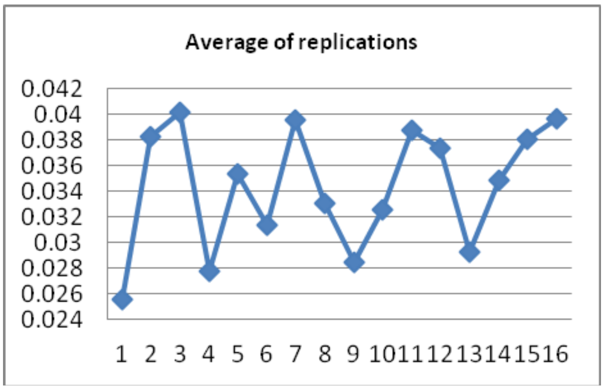

Figure 3: Values of $\overline{Y}_i$

The formula results of steps three are depicted in Figure 4:

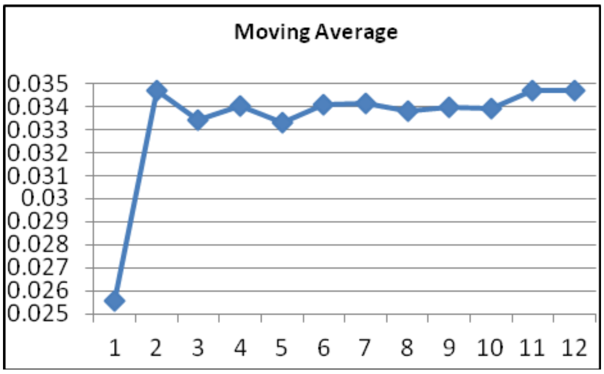

Figure 4: $\overline{Y}_i(w)$ Values

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:

(8)

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.

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.

Finally, Figure 5 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 evolutive scenario.

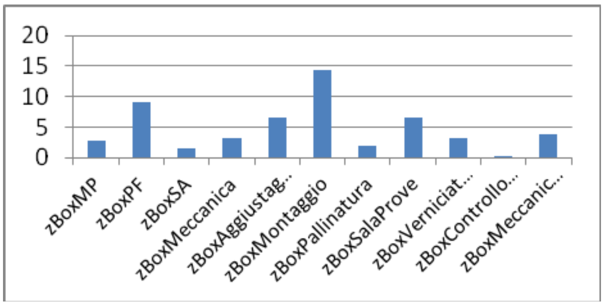

Figure 5: Lots number in the box every day

4. Validation Model

In this step, it is necessary that made 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 has sense, because writing all pieces processes, operations times were considered as constant (they are effective those that piece takes on each machine).

Doing this comparison between planned lead time and those obtained, it's possible notice system is able to model reality correctly. A further 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 which 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 have on the real system or not.

The tools to optimize the inner handling are: optimization of routes and the choice of moving 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. 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).

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 department (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 2:

Table 2: 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 3:

Table 3: 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

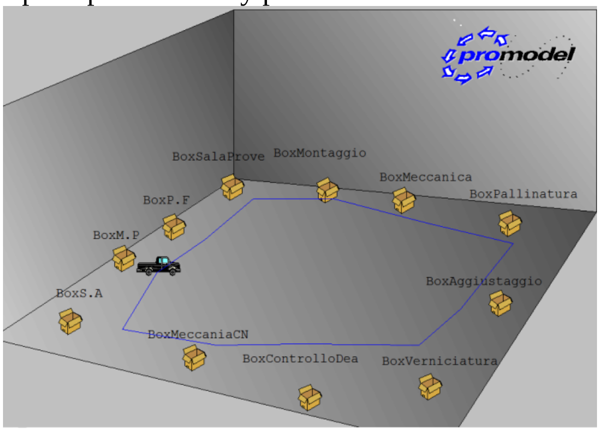

Figure 6: Traveling Salesman network

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, as we'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 4 are shown the values of quantity of pieces made at the end of three scheduled years. This is the index of productivity.

Table 4: 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 these initial results, the importance of an improvement, that can be obtained by applying one of proposed solutions, is evident. In particular, the last scenario is that presents larger values of the amount of achievable lots.

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:

$$FTM = \sum_{i=1}^{n} t_i / n \qquad (9)$$

where:

t_i is flow time relative to i-th entity, that is the time this entity takes to be realized (it's the sum of three aliquots. Working time, time for transportation and time lost on the machine).

n is the number of completed lots, i.e. those have left the system.

The obtained values for different scenarios are shown in table 5:

Table 5: 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

This parameter, evaluated in six scenarios, is drastically reduced compared to current situation and this also explains how the number of achievable lots in proposed scenarios is worth that much compared to present today. Being very insignificant difference of crossing time in different scenarios and considering increased productivity of company, it chooses as proposing scenario, the sixth.

5. Conclusions and feature developments

We have shown through the development of simulation models, we can compare alternative layouts and logistics solutions and evaluate performance. The proposed solution would allow the company to significantly increase its productivity and, simultaneously, to save a human resource. The average production flow time is reduced drastically by encouraging on-time deliveries and thereby resulting in greater customer satisfaction.

In addition, this new handling system would increase the components within the plant turnover index, with the consequent WIP decrease. Reducing the lots number stationing at points collection points it eliminates the possibility of damage to the lots themselves, and all the other disadvantages associated with warehouse saturation (deterioration, slow in handling, delays in pickup operations, etc). These results were reached only working on internal materials handling, that is, given the layout, changing the number of involved people, the equipment of handling used, the nodes to be visited, the optimal path to track and the visit frequency. However, in the future other issues could be considered that would allow to further improve the results just obtained. In case of transfer to a new plant it might be cheaper to redesign the layout: keeping unchanged its job shop typology, which as we have seen is the one most suited to an industry like this. It is possible to think of a better and more convenient machines layout location. Another goal of this study could be the optimization of time lost on the machine. In essence, it would solve a resources scheduling problem, so with the intent to reduce the other rate impacting severely on lead time: the time due to "wait for resources". The obtainable solution can be implemented in conjunction with the one proposed in this work.

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