Warehouse visual simulation applied to a practical layout (Brasil)

António E. S. Carvalho Brito
J. M. Feliz Teixeira

LASSIP – Simulation Laboratory for Production Systems
GEIN – Section of Management and Industrial Engineering
Department of Mechanic Engineering and Industrial Management.
Faculty of Engineering of University of Porto
PORTUGAL

July 1998

ABSTRACT

This paper presents a simulation study made on the project of a warehouse layout, designed by the Portuguese company EFACEC with the purpose of installing it in Brasil. The case have been analysed using *Visual and Interactive Modelling*, conceiving the elements and processes in the warehouse with the same base philosophy of management and control systems this Portuguese enterprise uses in building automated warehouses.

The results presented here where achieved by developing an *object oriented simulator*[i] where one could look to the warehouse by a hierarchic decision level point of view, which allowed a more realistic separation of the responsibilities on the system. It was a modular approach, where each entity was responsible for its own integrity and functionality, and where the decision rules were separated on three fundamental levels: *element level*, *control level* and *management level*. In this perspective the other components of the simulation were reduced to methods of material handling between *elements* and to some decision rules implemented in some more or less complex algorithms. The chosen operating system was the *Windows95/NT* and the programming language the *Microsoft Visual C++*.

The present results, achieved by the usage of such a simulator, had the intention of characterising the behaviour of the warehouse, mainly its maximum rates of throughput material and the expected delay times for the most relevant processes.

1. Introduction

Warehouse automated systems are nowadays fundamental equipment to ensure the modernisation of production and distribution centres[ii]. That is a rule for improving their flexibility and also to rise their processing capabilities in order to answer with more efficiency to the actual market demands.

The importance of simulation modelling in this field of industry is from all recognised[iii], anyhow, as the commercial software modellers seem to be or too simple to allow a reasonable modelling of the real system, or too complex to build it in a proper time. For these two main reasons only few Portuguese companies are making efforts in the field of simulation.

Nevertheless, with the strong evolution of *Object Oriented* programming languages, given its decrease of price and its improving flexibility, and also due to the excellent tools to build the user interface, simulation is becoming practicable even in those cases which imply the development of a particular solution. This case study is an example of such a facility to quickly build a model with this kind of approach.

2. Objectives

The main objective of this work was to characterise a warehouse, mainly its maximum rates of throughput material and the expected delay times for its most relevant processes. Nevertheless, this work also have contributed for improving the warehouse simulator modeller early developed on this laboratory, acting as a good practical case to test its modelling capabilities.

The maximum material processing rates proposed by the client were the following:

Single warehouse input rate = 165 palettes/hour
Single warehouse output rate = 165 palettes/hour
Warehouse working input+output rate = 100 + 100 palettes/hour

3. Method

The simulation computer program developed for this case have acted over a scale representation of the layout designed and proposed by the firm EFACEC with the file format DWG (AutoCAD). Every element in the warehouse was previously defined following the client specifications and the original dimensions presented in the warehouse AutoCAD drawing. The layout had the following characteristics:

- Warehouse rectangular dimensions = 150x80 m2
- Racking area = 15 ways of two side access racking.
- Input conveyor zone = 5 reception points + 1 manual.
- Distribution conveyors serving the 15 racking ways.
- 2 transfer tables per each way of racking.
- Output conveyor zone = 1 despatch point.
- Rotating table to access the despatch point.
- 4 *Racking vehicles* serving the 15 raking aisles.
- 1 *Transfer vehicle* serving the racking vehicle group.

The study was made in four distinct phases with which we pretended to characterise the overall response profile of the warehouse layout:

- Single input material simulation mode.
- Single output material simulation mode.
- Grouped input + output material simulation mode.
- Estimation of the rate dependency on the number of *racking vehicles* aisle exchanges per time unit.

For each of the first three phases it have been imposed on the model a input (output) rate of palettes a bit higher than the required by the client in order to make it possible to force the system to its maximal performances, and then the simulation was made to run for time enough to reach stabilised results.

Concerning the last phase, the estimation of rates dependency on the number of aisle exchanges per unit time, we have decided to consider the system working in output palette mode, as we expected this dependence to be maintained in the other working modes. This was achieved by including in the simulator a new parameter that was responsible to impose the maximum action radius for each *racking vehicle* movement, which indirectly leaded to variations on the number of aisle exchanges per unit time. This number, however, have always been calculated by the simulation computer program in the end of each running, and not by any kind of direct action of the user.

4. The layout and its elements

The following layout parameters and elements characteristics were considered in the simulation modelling:

Model: layout Brasil	
Nº of racking palette cells:	18900
Nº of *Racking vehicles*:	4
Nº of *Transfer vehicles*:	1
Nº of reception points:	5 + 1
Nº of despatch points:	1
Nº double racking ways:	15
Conveyors characteristics:	
Width (m)	1.2
Average speed (m/s)	0.2
Unload time (s)	0.5
Transfer table characteristics:	
Width (m)	1.2
Action time (s)	3.0
Rotating table characteristics:	
Width (m)	1.2
Action time (s)	5.0
Racking vehicle characteristics:	
Initial acceleration (m/s2)	0.4
Average speed (m/s)	3.8
Break acceleration (m/s2)	0.4
Average time for loading (s)	10.0
Average time for unloading (s)	10.0
Transfer vehicle characteristics:	
Initial acceleration (m/s2)	0.4
Average speed (m/s)	1.0
Break acceleration (m/s2)	0.4
Average time for loading (s)	10.0
Average time for unloading (s)	10.0

Next figure represents a small view on the layout's reception zone served by conveyors, the kind of conveyors distribution zone to access the racking zones and three out of the fifteen raking aisles where *racking vehicles* move.

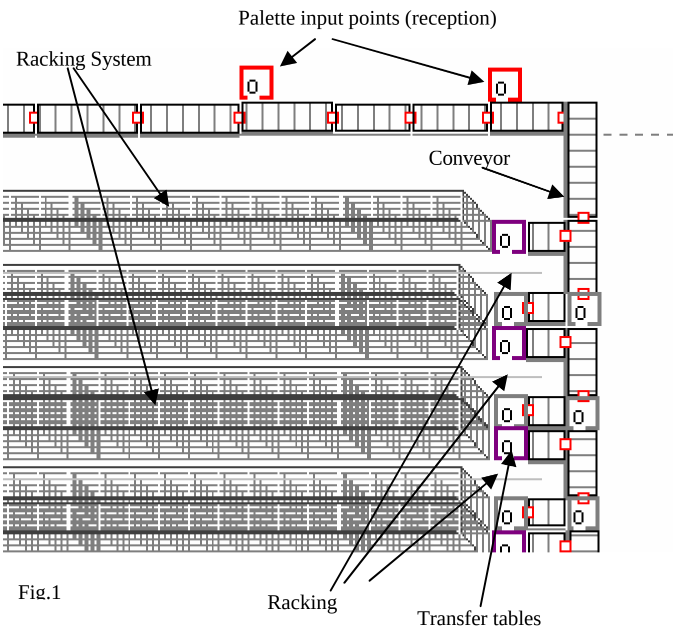

Fig.1

In the next figure the output (despatch) zone of the layout is shown, also served by conveyors and with only one output palette point. Also in this figure the racking modules are represented and some racking aisles, as well as the transfer tables used to interface the conveyors distribution zone with the *racking vehicle* access points. These vehicles receive the material in palettes coming from the reception zone by a transfer table interface point, and the same holds for the process of outputting material to the despatch point.

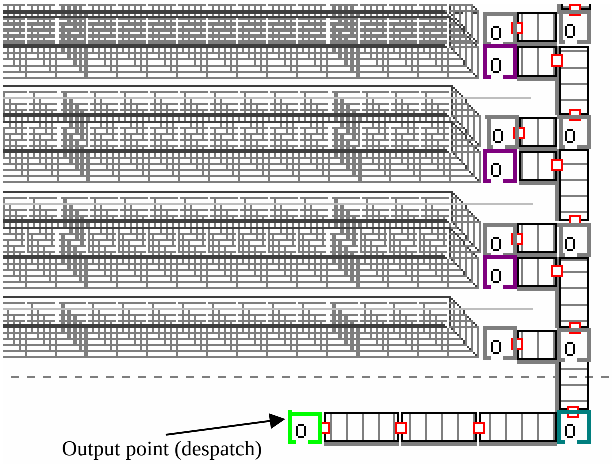

Fig.2

Finally, in the next figure is presented two out of the four *racking vehicles* as well as the *transfer vehicle*. This last vehicle is responsible for changing of aisle the *racking vehicles*, by first moving to the vehicle when necessary, and then loading it and transferring it to the next aisle. In this figure is also visible some of the racking modules where the palettes are stored in the warehouse and five racking aisles used by the racking vehicles to access the storage.

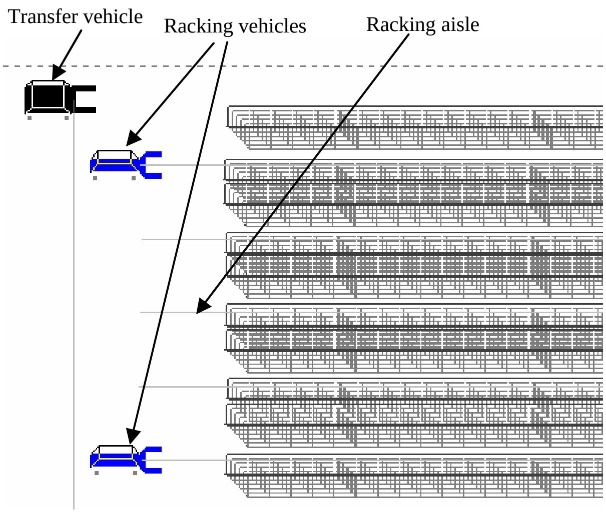

Fig.3

5. Results and analysis

Due to the four different phases on testing the layout, the results will be presented in the following sequence: *input response*, *output response*, *input+output response* and *output rate variation* with the racking aisle exchanges per time unit.

Row data first collected from the simulator was moved to a spread sheet program where histograms have been chosen to store the main results. In this section each case will be described by means of its boundary conditions as well as discussed while presenting the results.

5.1 Single input response

The single input palette rate was simulated imposing to the group of 5 input points an overall input of 200 palette/hour, reducing the output demand to 2 palette/hour and then observing the system evolution in time. It have been considered two different situations concerning the action radius of each *racking vehicle*: first imposing a minimum number of racking aisle exchanging, (what leaded to a calculated value of 2.04 exch/hour/vehicle), situation which could be compared to a sever politic on choosing the racking places to store the material, and in the second case considering this choose to be random.

In the first case an 11.58 hours continuous period of activity was simulated, while for the second case the results were observed to stabilised after 6.96 hours of simulation time. Each of these results is resumed in the following histogram:

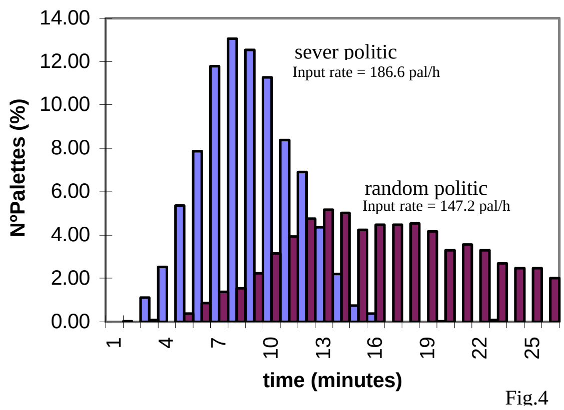

Fig.4

- In the case of using "sever politic" for choosing the racking places to store the material, which leaded to 2.04 exch/hour/vehicle, the average input rate observed after 11.58 hours of continuous activity simulation was **186.6 pal/h**. Due to the extreme conditions of input demands this can be considered the <u>maximum input rate the layout allows</u>. In the histogram the time distribution for palette processing is plotted, in terms of percentage of overall number of palettes processed, and the results for this case shows an average value near 9 minutes for the layout to process a palette, in which one can expect a variation of ±7 minutes depending on the system's input oscillation. This distribution shows a good symmetry around the average value, as can bee seen from the plotted points in the histogram, mainly because the "severe politic" condition implied a similar *racking vehicle* time consuming for almost all the input cases, as these vehicles most of the time stand in the same racking aisle. This fact also leaded to a low average time for processing the inputs.

- In the case of a "random politic" for choosing the palettes destiny the observed an average input rate after the 6.96 hours of simulated activity was **147.2 pal/h**. This situation leaded to a spread on the time processing distribution (same histogram), rising the average value to 16 minutes and the variation to ±11 minutes. Also this distribution shows less symmetry compared with the previous case, due to the natural broadening of time processing for each *racking vehicle* required by the "random politic" choosing for palette destination. The observed broadening was also due to the excessive input rate required, what caused some situations of congestion in the palette flow through the layout's conveyor network. In fact, the actual design of this layout's conveyor's distribution network let us suspect of this kind of problems when in excessive input conditions, as in some case the palettes have to wait too much time in the interface tables for the *racking vehicle* to pick them, thus producing a break in the material flow in the main distribution conveyors line.

5.2 Single output response

The single output palette rate was simulated imposing in the output point (despatch) a demanding rate near 200 palette/hour and minimising the inputs to around 2 palette/hour, and then observing the layout's behaviour in time. As in the previous case of single input rate, we have considered again the same two extreme situations on choosing the palette's origin racking cell, what leaded to two different situations for each *racking vehicle* working radius. For the "sever politic" it was observed a minimum in the racking aisle changing equal to 2.47 exch/hour/vehicle and a continuous activity time of 13.89 hours have been simulated. In the case of "random politic" the same working time have been considered (13.89 hours). The results are presented in the following histogram:

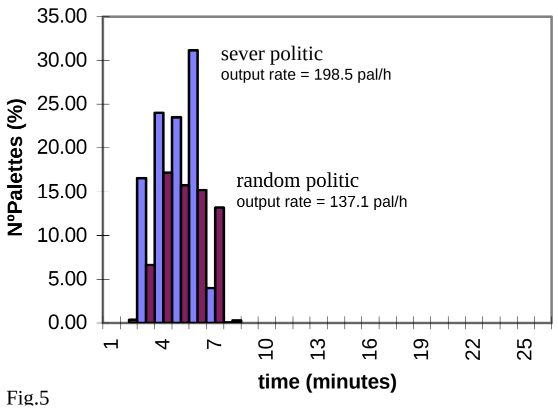

Fig.5

- Using a "sever politic" on choosing the palette origin inside the storage zone, which leaded to a racking aisle exchange rate of 2.47 exch/hour/vehicle, it was observed an average output rate of palettes of **198.5 pal/h**. This can be considered the <u>maximum admissible output rate for this layout</u>. In the histogram is presented the distribution for output palette time processing (fig. 5), which shows that the output process is faster than the input process. In fact, one can expect the output processing time to be between 4 and 6 minutes within a variation of ±3 minutes. This results show that the conveyor system has a good efficiency for outputting material, as in this case the interference of stopped distribution conveyors don't affect the flow to the output point as much as in the previous case of inputting material.

- In the case of "random politic" the output rate observed was reduced to **137.1 pal/h**, even if the output palette processing time remained very near to that observed in the case of "sever politic".

5.3 Grouped input+output response

In most practical situations in a warehouse the input processes stand together with output processes, that is, while some material is flowing into the warehouse storage, other material is flowing out to the output points. Therefore it was necessary to simulate the layout's behaviour in this case. The last two working modes were important to estimate the maximum rates for input and output in order to characterise the working limits of the layout, anyhow, only simulating the grouped input+output response could lead to more realistic data concerning the stand alone day by day processes.

In this case the input+output rate was simulated imposing in the input points group an overall input rate of 100 palettes/hour and defining in the output point a rate of 100 palettes/hour, then observing and registering the system's evolution with the time. Also in this case there was considered two extreme modes for palette choosing within the layout storage zone: "sever politic" and "random politic".

The "sever politic" working mode leaded to an observed rack aisle exchanging rate of 2.6 exch/hour/vehicle during the 8.34 hours of simulation time. In the "random politic" mode the layout running for 8.41 hours of simulator time. The results are presented in the following histograms.

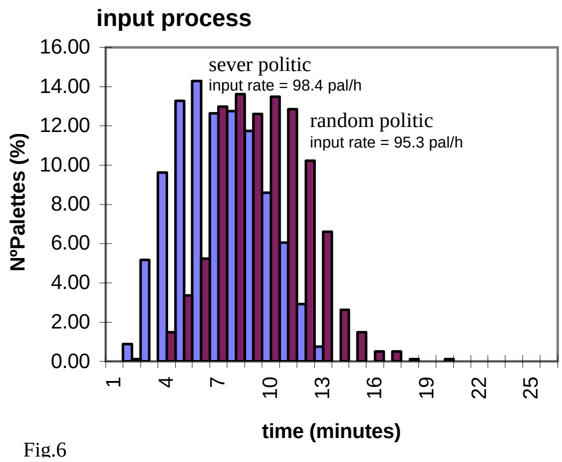

Fig.6

- For input processes and in "sever politic" working mode the observed input rate was **94.8 pal/h**. The output palette processing time distribution (fig. 6) showed the same tendencies as for single input response, although with a small performance increase due to the reduction of material processing times between 2 and 13 minutes. The average processing time was also reduced from about 9 to 7 minutes. This modest increase of performance is mainly due to the reduction on the overall input rate imposed on the layout's input points. This rate was 200 pal/h during the single input processing working mode and only 100 pal/h in the present case, what could reduce the system resources usage rate. It was also observed the output 100 pal/h process did not interfere significantly in the input process, what means the system was working in a "relaxed" mode.

- In the “random politic” mode it was observed a significant reduction on the input palette processing time (from 16 minutes with 200 pal/h to 9 minutes with 100 pal/h) what could rise the input processing rate to **95.3 pal/h**. Also the processing time distribution became less spread than in the previous case, approaching to the “sever politic” behaviour. These results show the conveyor distribution net plays an important rule on the system’s performance when working with high input requirements.

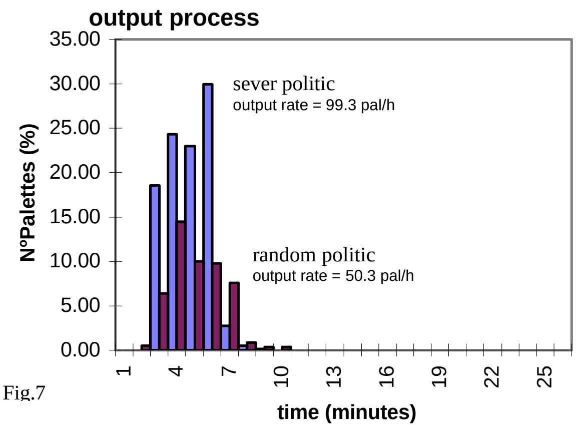

Fig.7

- For output processes in “sever politic” working mode (fig. 7) the layout behaved as if it would be working in single output mode, meaning that the input process does not interfere significantly on the output process at the actual 100 pal/h required level. Thus, the observed output palette processing rate was **99.3 pal/h** during the 8.34 hours of simulation time.

- In the “random politic” working mode it was also observed an output performance similar to the case of single output mode. Anyhow, it was detected a small increase of 3 minutes during the output processing of some few palettes. The observed output processing rate was **50.3 pal/h** during the 8.41 hours of simulated activity.

The previous results will be presented in the next two graphs by means of separated palette choosing “politic”, what will let the reader understand better the system’s behaviour on this two separated material processing modes. The graph of figure 8 represents the system response in “sever politic” mode, related with a racking aisle exchange rate of 2.5 exch/hour/vehicle, while the one of figure 9 represents the response observed in during “random politic” working mode, which leaded to an observed value of 26 exch/hour/vehicle for the racking way exchange rate.

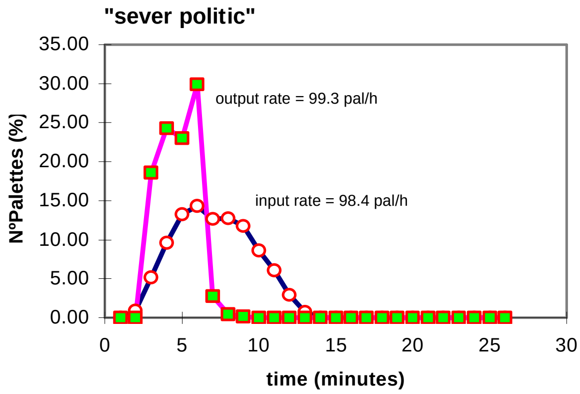

Fig.8

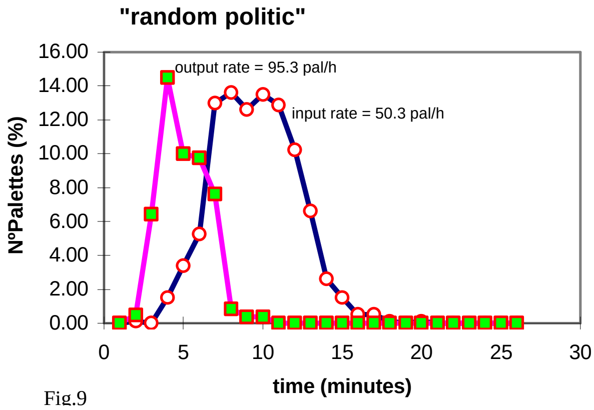

Fig.9

5.4 **Output rate variation with the racking way exchange number**

The previous results were referred to the two extreme working situations named “sever politic” and “random politic”. The “sever politic” let us characterise the system’s behaviour in its maximum processing capacity, while the “random politic” let us observe its performance in less demand situations. Anyhow, it seemed interesting to try to predict how the system would behave between these extreme working modes, what leaded us to study the layout’s output rate variation with the racking aisle exchange rate variation. With this results we pretended to quantify the expected layout’s response by means of different choosing palette’s position criteria, thus leading to different storage material management criteria. One can say a “moderate sever politic” will correspond to 4 exch/hour/vehicle racking aisle exchange rate (or number), while in a practical “moderate politic” this value could be between 8 and 10 exch/hour/vehicle.

Thus, the system was sampled 15 times in single output material mode while in different situations of racking vehicles action radius, a parameter early introduced in the simulation program. Each time this parameter was changed the system have been simulated during a continuous working activity of about 14 hours of simulation time, and the number of racking way exchanges was calculated by the program at the end of each simulation run.

The results of this testes are presented in the next graph (fig.10) where 2.47 exch/hour/vehicle corresponds to the “sever politic” and 25.58 exch/hour/vehicle to the “random politic”.

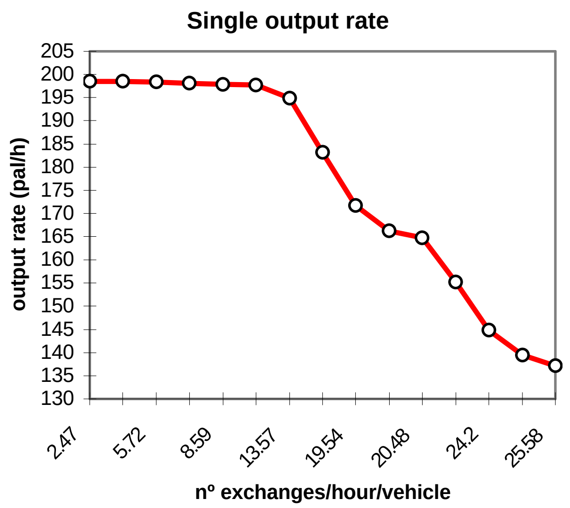

Fig.10

As it can be understood by the data plotted on this graph, the output rate stays more or less stable around its maximum value till 10 exch/hour/vehicle, meaning the system is expected to maintain its performance independent of working in a “sever politic” mode or even in a “moderate politic” mode. Thus, the management criteria for choosing the palettes on the storage zone will not interfere significantly to the system’s performance on these sort of conditions. This first result was expected as in this situation the *Transfer* usage time would be diluted on the usage time of the group of *racking vehicles*. Indirectly this is due to the long extension of each racking way as well as to the high processing level asked to the system. The significant decrease of output processing rate observed around 10 exch/hour/vehicle was due to the obvious increasing on *Transfer* usage when the palettes start to spread around more than two racking aisles, implying a substantial increasing on the *racking vehicle* displacement length, thus increasing the time for processing an output palette.

6. Conclusions

From the point of view of the client requirements this study could let us conclude the layout proposed is able to guarantee the requirements, at least within an expected deviation of ±3 pal/hour rate. Anyway, it was observed a certain responsibility on the conveyor network for the spreading and increasing of the input palette processing time, mainly during high input requirement rates. However this interference was yet very reduced when the input requirements are made low, what means the layout is expected to work properly within the conditions proposed by the client.

References:

[i] J. M. Feliz Teixeira, António E. S. Carvalho Brito, “*Introduction to a warehouse visual simulator*”, LASSIP, Faculty of Engineering of University of Porto, PORTUGAL, November 1997.

[ii] António E.S. Carvalho Brito,"*The Use of CAD Techniques in Configuring Visual Interactive Simulation Models: A New Approach for Warehouse Design*", Ph.D. Thesis, Cranfield Institute of Technology, U.K., 1992.

[iii] António E.S. Carvalho Brito,"*The Use of Computer Aided Design Techniques in Configuring Visual Interactive Simulation Models for Warehouse Design*", Journal of Decision Systems, Volume 1 - nº 2-3, Hermès, Paris, 1992.