Warehouse visual simulation applied to a practical layout (Iran)

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

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ABSTRACT

In this paper we present the results of a case study made on warehouse characterisation by means of computer simulation techniques. In this study three different layout solutions were considered, one proposed by the ultimate Iranian client, and the other two designed and proposed by the Portuguese company EFACEC with the intention of achieving better performance and price than those on the Iranian's proposal. Each case have been analysed independently using as the base modeller a *visual and interactive warehouse simulator* early developed on this laboratory. This simulator uses an *object oriented approach*[i] and looks to the warehouse by an hierarchic decision level point of view, which permits an interesting separation of the responsibilities on the system. It is a modular approach, where each entity is responsible for its own integrity and functionality, and where the decision rules are separated on three fundamental levels: *element level*, *control level* and *management level*. The *simulator* was running on *Windows95/NT* operating system and have been developed using *Microsoft Visual C++*.

The present group of results are intended to characterise and compare the behaviour of the three different layouts in study, mainly their maximum rates of inputting and outputting material and the delay times expected in the most relevant processes.

1. Introduction

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

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 permit a reasonable modelling of the real system, or too complex to consent to build it in a proper time, for these two main reasons only few Portuguese enterprises stand making some efforts in the field of simulation.

Nevertheless, with the strong evolution of programming languages in the direction of *Object Oriented Paradigm*, given its decrease of price and its improving flexibility, and also due to the excellent tools to build the user interface, simulation starts to become practicable even in those cases which imply the development of a particular solution, and this case of study showed the facility to built such models based on some basic simulation tools early developed.

2. Objectives

The main objective of this work was to characterise the three layouts in study, named *Layout1*, *Layout2* and *Layout3*, later presented on this paper, mainly their maximum rates of inputting and outputting material and the delay times expected in the most relevant processes. Nevertheless, this work also have been a new test for the warehouse simulator modeller early developed on this laboratory, acting as a good practical case for evaluating its capabilities of modelling. Each layout had two different levels for material movement, as the racking system could also be accessed by two distinct floors on the warehouse, what implied the adaptation of the simulator software to include this new feature on future usage.

The performance tests made on each layout were bounded to the following maximum rates imposed by the ultimate Iranian client:

- Maximum input+output rate = 60 + 60 palettes/hour including 20 palettes/hour of manual input picking and 20 palettes/hour of manual output picking.

3. Method

For each layout, there have been a scaled representation on the modeller's interactive view using the appropriate drawing tools included on it. This representation followed the warehouse dimensions and all the element's parameters proposed by the company EFACEC and the Iranian client. The basic warehouse layout structure was presented by EFACEC in a scaled AutoCAD drawing.

The study was made analyzing the “grouped input+output” response of each layout in order to characterise its overall response profile. The input palettes rates on the system, as well as the output rates, were established to be a bit higher than the client request, what could let us observe the system working even under more charge than what was required. In each case, simulation was made to run during time enough to reach stabilised results.

In some cases the response of the layout was analysed in two different situations for the material positioning on the racking storage: *maximum* concentration, and *random* spread. This was achieved by including in the simulator a new parameter who was responsible for to impose the maximum action radius for each *racking vehicle* movement, what indirectly leaded to variations on the number of way exchanges per unit time, and so influencing the layout’s input and output processing rates.

4. The basic layout and its elements

The basic characteristics common to the three layouts in study was the following:

- Warehouse rectangular dimensions = 140x80 m2
- Racking area = 20 ways of two side access racking.
- 1 fixed rate reception point + 1 manual reception point.
- Input conveyors zone serving the reception points.
- 1 fixed rate despatch point + 1 manual despatch point.
- 4 *Chariot vehicles* distributing along 20 raking ways.
- Input/Output access conveyors for each raking way.

Over this basic characteristics some changes were considered in each of the layouts, mainly the number *of raking vehicles* and *transfers* and the type of transference of palettes between the distribution *chariot* zone and the *racking* storage. Nevertheless all the layouts presented the following basis:

Model: layout Iran(1,2,3)	
Nº of reception points:	1 + 1
Nº of despatch points:	1 + 1
Nº double racking ways:	20

Conveyors characteristics:	
Width (m)	1.2
Mean speed (m/s)	0.2
Unload time (s)	0.5

Transfer table characteristics:	
Width (m)	1.2
Action time (s)	3.0

Chariot vehicle characteristics:	
Initial acceleration (m/s2)	0.4
Mean speed (m/s)	2.0
Break acceleration (m/s2)	0.4
Mean time for loading (s)	3.0
Mean time for unloading (s)	3.0

Racking vehicle characteristics:	
Initial acceleration (m/s2)	0.4
Mean speed (m/s)	3.0
Break acceleration (m/s2)	0.4
Mean time for loading (s)	10.0
Mean time for unloading (s)	10.0

Transfer vehicle characteristics:	
Initial acceleration (m/s2)	0.4
Mean speed (m/s)	0.5
Break acceleration (m/s2)	0.4
Mean time for loading (s)	10.0
Mean time for unloading (s)	10.0

Next figure represents a narrow view on one of the layout’s reception zones served by conveyors, the kind of conveyors distribution zone to access the *chariots* zones and height out of the twenty raking ways where *racking vehicles* move. As one can see, there are two levels for the material flow, one closed to the layout’s ground (level 0) and another in a “second” floor (level 1).

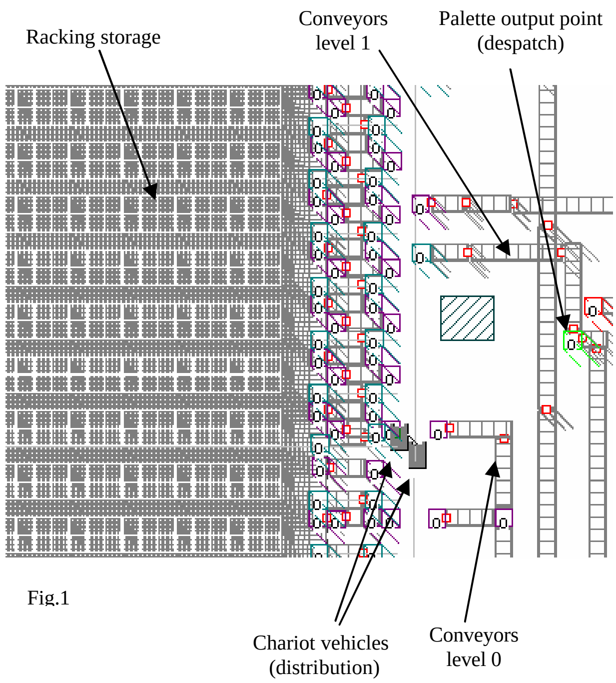

Fig.1

In the next figure (fig.2) one can see with more detail the two levels for material flow and the superposition of various conveyors on the access to the racking storage. Also is represented a pair of *chariots*, one responsible for the level 0 distribution and the other responsible for the same job at the level 1. Once in the racking storage areas, the material will be handled by *racking vehicles* (not represented on the figure).

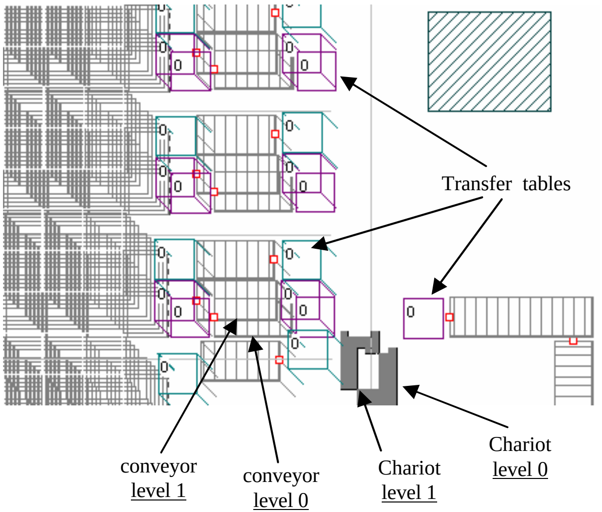

Fig.2

Finally, in the next figure is represented the back part of the warehouse, where one can see two *racking vehicles* as well as a *transfer vehicle*. This last vehicle is responsible for the *racking vehicle* exchanging of racking way, by first moving to the vehicle when necessary and then loading it and transferring it to the destiny way. In this figure is also visible some of the racking modules where the palettes are stored in the warehouse and five racking ways used by the *racking vehicles* to access the storage.

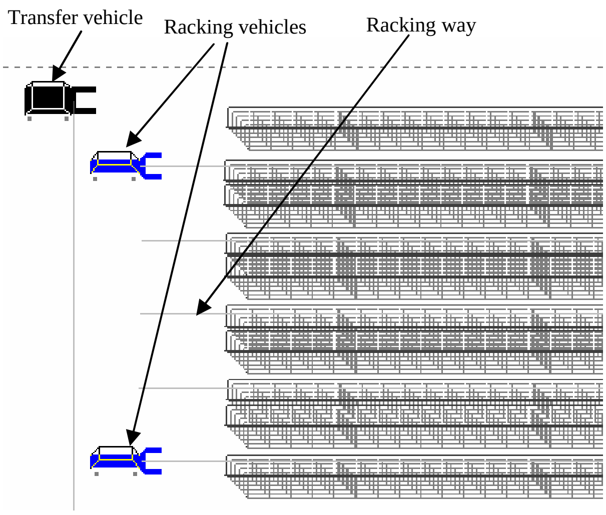

Fig.3

5. Results and discussion for separated layouts

Each of the four layouts proposed have been analysed separated and then the results compared between each other. Therefore in this section we present a more specific view on each layout followed by its correspondent discussion and results. Each layout was tested in *input+output response* mode, that is, while receiving orders for input and output material. Nevertheless, two different politics for conditioning the palettes on the storage have been considered, which indirectly was related with the rate variation on the *racking vehicle way exchanges per unit time*: *random politic* and *sever politic.*

In the *random politic* approach the palettes were picked or putted on the storage in a chosen random racking cell, while in the case of *severe politic* the chosen cell was conditioned by a “management” number (between 0 and 1) early introduced in the simulator. This number acted as a filter to choose the cell position on the storage.

Row data was first collected from the simulator results and then moved to a spread sheet program where histograms have been chosen to store the main results.

5.1 Results of *Layout1* (proposed by the Iranian client)

This layout was early proposed by the ultimate Iranian client and has the following characteristics over the basic ones presented in the last section of this paper:

- Two-level conveyors zone between *racking vehicles* and the *chariot* lines.
- 6 *racking vehicles* serving the 20 ways two-side access racking.
- 6 *transfers*, one for each *racking vehicle.*

The elements of this configuration have already been presented in the previous figures, where one can see the two-level conveyor zones for palette transference between the *chariot* lines and *racking vehicles* (fig.1 and fig.2), and the kind of *racking vehicles* used associated to a *transfer* (fig.3). However, in this layout there was one *transfer* for each *racking vehicle*, which is not the same condition as that represented in the figure 3.

As this layout (*Layout1*) presented a large number of *racking vehicles*, as well as one *transfer* for each of them, it have been tested with rates of palette input/output higher than those required by the client. This way we expected to estimate the deviation between the required performance and the effective capacity of that configuration.

So, it was imposed an input rate of 100 pal/hour, including manual inputs, and an output rate of 140 pal/hour also including manual output requests.

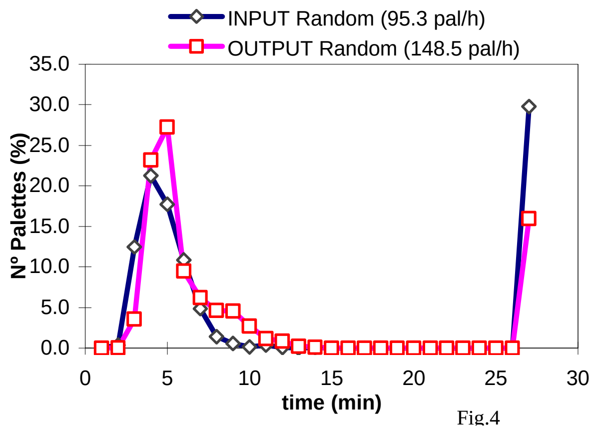

Fig.4

The layout was then simulated and its response observed and recorded (fig.4) during the time necessary for the stabilisation of the results. The "management" number used on the simulation was 0.5, what leaded to a case closed to the *random politic* approach.

The results obtained by simulation (fig.4) have shown the expected good performance of the system, as it have not been observed any kind of flow problems during the 10 hours of simulated activity. It have been detected, however, a large concentration of palettes waiting for processing either on the input and in the output points. Nevertheless, this was observed to be related with the extreme high rates imposed on the system, what have interfered with the capacity of delivery of the input/output conveyors group. This effect is can bee observed in the previous histogram as a large number of palettes with a processing time higher than 25 minutes.

The mean time for processing an input order stayed around 4 minutes with a spread variation between 3 and 8 minutes for most of the cases, for an input maximum rate of 95.3 pal/hour. For output processing the mean time was around 5 minutes with a variation between 3 and 10 minutes, for an output maximum rate of around 150 pal/hour.

By this results it became obvious that *Layout1* shows a significant higher capacity of processing that the 60+60 pal/hour required by the client, mainly due to the large number of *racking vehicles* and *transfers* used, what leaded to a fast response on processing input and output orders.

5.2 **Results of *Layout2*** (EFACEC's option A)

Layout2 was the first layout proposed by the company EFACEC to the ultimate Iranian client. This option has the following characteristics over the basic ones for all the layouts:

- Two-level conveyors zone between *racking vehicles* and the *chariot* lines.
- 3 *racking vehicles* serving the 20 ways two-side access racking.
- 1 *transfer* serving all the *racking vehicles*.

As one can see, the difference between this configuration and the previous one is the number of *racking vehicle* elements considered as well as the number of *transfers* used. So, the configuration of this layout (*Layout2*) stays very similar to that presented on the previous figures (fig.1, fig.2 and fig.3).

As in this case the layout is expected to show a performance closer to the client demands, due to the reduction on the number of vehicles, it have been simulated within small rates of input/output than the previous case. For the same reasons this case was simulated in the two different conditions of management: *random politic* and *severe politic*. However, in the two cases have been imposed a rate of 60 pal/hour in the group of input points (40 pal/hour normal + 20 pal/hour manual), and the same rate imposed on the output points group.

The number of *racking vehicles* was reduced to 3, and there was only one *transfer* to serve all these *racking vehicles*.

The results for the *random politic* approach, which have been simulated during 10 hours of simulator time, are condensed on the following histogram:

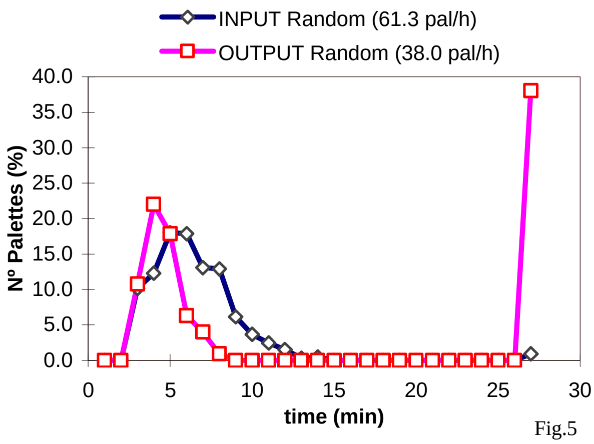

Fig.5

By these results one can conclude this layout was not enough fast to process all the required output orders at the imposed rate of 60 pal/hour. In fact, even if in the case of input processing the rate observed (61.3 pal/hour) in simulation was near the requirements, the output showed only a possible maximum processing rate of 38.0 pal/hour. As one can see from the same histogram, the system was even not able to start to process a large number of output palettes (time>25 min).

Anyway, in this *random politic* case the observed racking exchange way rate was 14.7 exch/hour/vehicle, which is far from the "management" levels considered normal in EFACEC company, what could mean the requirements maybe would be satisfied considering a higher level "management" politic.

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In fact, simulating the same layout with a more *sever politic*, which in the case leaded to 5.8 exch/hour/vehicle, the observed rates have almost reached the client requirements, stabilising at 61.6 pal/hour for inputs and 60.0 pal/hour for outputs after 14 hours of continuous simulation time. These results are resumed in the next histogram.

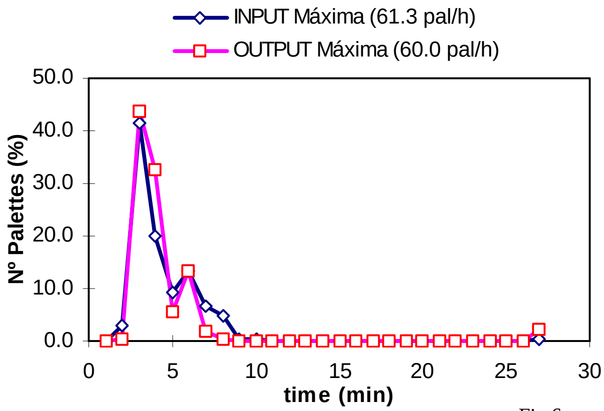


Fig.6

From these results is evident that in the conditions of a *sever politic* of the order of 5.8 exch/hour/vehicle the mean time for processing input and output requests are reduced and no palettes will be waiting for processing. This means that in such a condition one can expect this layout to work properly fulfilling the required client rates.

As the unique disadvantage of this layout we would say it is the fact that these results only could be obtained using a *severe politic* on managing the storage cells choice, what means the system will not be used in a "relaxed" condition.

5.3 **Results of *Layout3*** (EFACEC's option B)

Layout3 was the second layout proposed by the company EFACEC to the ultimate Iranian client. In this option the two-level conveyors between the *chariot* lines and the *racking vehicles* was replaced by *transfers* equipped with conveyors. The new characteristics are the following:

- 3 *transfers* with conveyors between *racking vehicles* and the *chariot* lines.
- 3 *racking vehicles* serving the 20 ways two-side access racking.

In this configuration the *transfers* play two different roles: to transfer the palettes from the *chariot* distribution zone to the *racking vehicles* zone, and at the same time to ensure the transference of the *racking vehicles* when they need to change to a different racking way. This fact implied new developments on the simulator software with the intent of adapting it to this new *transfer* interface case.

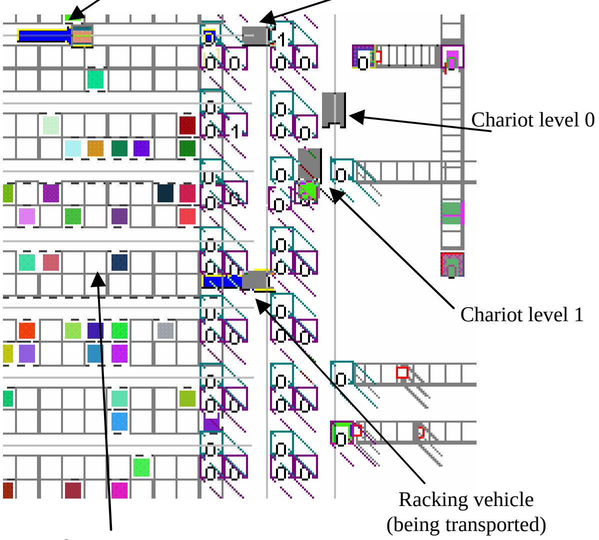
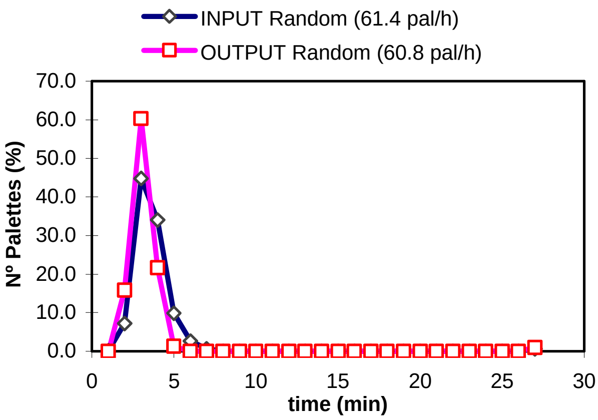


Fig.7

As one can see on the previous figure (fig.7), this layout is significantly different from the other two, and the main idea was to concentrate the work on the transfers to increase the overall processing layout's speed.

As this configuration early seemed faster that the previous EFACEC's option, the layout was simulated using only the random politic approach, as this approach represents the worst case for layout response.

The correspondent result are shown in the histogram:



After 10 hours of simulated continuous activity this layout showed that could process all the input and output orders, leading to an observed 61.4 pal/hour input processing rate and to 60.8 pal/hour output rate. This values were obtained with a random politic to which corresponded 22.4 exch/hour/vehicle, what means that even better performances would be achieved considering a more sever politic.

The mean time for processing input or output orders of around 3.5 minutes showed that this layout was the faster of all the considered ones, and at the same time it is a "relaxed" configuration for the client proposes.

6. **Conclusions**

From comparing the three proposed layouts one can conclude that the last option (*Layout3*) is far the most interesting configuration, as it will guarantee the performances required by the ultimate client within a good security margin of values. Also this solution is preferable, at least to the one proposed by the Iranian client, due to the reduction on the number of vehicles used. At the same time, around 60 conveyors could be eliminated from the layout.

What concerns the EFACEC's option A (*Layout2*), one can say this layout would also meet the requirements if used within *sever politic* of warehouse management, anyhow, some problems could arise on using it high demand situations.

Concerning the original layout (*Layout1*) this study have shown an excessive usage of vehicle resources, what means that is a super-dimensioned solution.

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.