Comparing a Standard and a Naïve Stock Refill Policies by Means of Simulation

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ABSTRACT

In this paper will be compared, by means of a next event dynamic simulation, two different stock refill policies applied to the same in-lined one-product Supply Chain. The first method is the Japanese method usually known as KANBAN[1] (similar to the "*Two Bins*" method, in terms of dynamics), and the second is a naïve method named by the authors the "*BanKan*" for the reasons that will be explained later in this text. The surprising results obtained show an obvious operational advantage of the naïve method, at least under the conditions of the present Supply Chain design and configuration. This method does not make use of any criteria dependent on the actual stock level at the facility, and it was also observed that the materials flow through the Supply Chain as in a "river without dams", and with extremely low local inventory, as it was defended by Taiichi Ohno, the father of *just-in-time* (JIT) systems, in the 1980s.

1. Introduction

This article is the result of a curiosity: the curiosity of taking to confrontation the sophisticated and the obvious. The idea was first coming out as an example to help to test and verify the consistence of a Supply Chain Simulator conceived by Feliz-Teixeira in his Ph.D. studies (Feliz-Teixeira & Brito, 2003) and inspired by the vision of materials flow presented by Mr. Taiichi Ohno for the Toyota Production System (Ohno, 1988), which have resulted in the KANBAN system to implement JIT. Contrary to the occidental believes of those times, which were based on demand forecasts and have leaded to *just-in-case* (JIC) systems using a *push*-into-stock philosophy, the KANBAN method had changed the sophisticated forecasts by the simpler idea of producing the smallest possible quantities of material triggered by the real demand, thus *pulling* the materials from the stock. Systems of this kind let the Japanese automotive industry overcome its American counterpart already in the turn of 1980s, for example, and since then have started to be applied in many other industrial areas all over the world, whenever is possible. We have chosen this method as the standard method because of its simplicity and for its excellent performances. Nevertheless, the KANBAN system is still using Bins of material, and decides the moment to ask for the next Bins based on the quantity that rests in the stock after each stock operation. This method will be carefully explained in the next section. By the contrary, the naïve method does not need any information about material levels in the Bins to order the new material. Thus, it is completely independent on the inventory state.

It is also important to notice that the simplicity of KANBAN systems could help reduce dramatically the inventories as well as improve the throughputs, and in fact the materials flow close to the flow of a river, but, as we will see, the naïve method is even more effective in inventory reduction and, unlike the KANBAN that flows like a river by impulses, the naïve *BanKan* will simply flow continuously.

2. Overview on the KANBAN (*Two Bins*) method

Originally, the KANBAN method was used to ensure the perfect availability of materials at the input of a work-station in a production system, but later it started to be used also as a material reordering policy between facilities in certain Supply Chains. *Volkswagen*, for example, is today applying JIT concepts in the supply network for the production of its new *Beetle* model, between Martorell, Spain, and Puebla, Mexico. But a better understanding of the KANBAN method can be achieved with the help of the next figure (Fig.1).

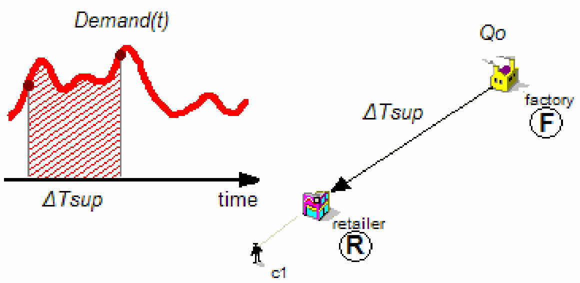

Fig. 1 Factory serving a retailer

Let us consider a factory (F) producing a previously optimized lot size (*Qo*) of a certain product, and needing a time ΔT_{sup} to supply the retailer (R), in which there is a time dependent demand *Demand(t)*. Following the simple idea of the "*Two Bins*" method,

[1] In fact, the KANBAN is a signal to authorize the production of the next Bin of material, and it is many times associated with a card.

the minimal quantity the retailer (R) must order to the factory to avoid *stockouts* is the total demand during $\Delta T_{\sup}$, that is, the total demand during the time the new material will need to arrive from the factory. As one can see from the figure, this quantity can simply be given by the integration:

$$\int_{to}^{to+\Delta T \sup} Demand(t).dt \qquad (1)$$

As this quantity is in most of the cases dependent on both *to* and $\Delta T_{\sup}$, this integral is usually approached in practice by an estimation of its value calculated from historical data, known as the *Demand During Lead-Time* (*DLT*), plus a safety-stock quantity (*SS*) which is expected to protect the system against variations in the real *Demand(t)*. Thus, the minimal quantity to order to the factory will be:

$$DLT + SS \qquad (2)$$

Or, expressed in terms of factory lot sizes (*Qo*):

$$Ko = \frac{DLT + SS}{Qo} \qquad (3)$$

Ko is therefore the minimum number of lots to order to the factory, is usually known as the KANBAN, and can in practice be signalled by a card located at the appropriate position of the stock, as figure 2 suggests. Each time the inventory level reaches the KANBAN there must be a new order of material.

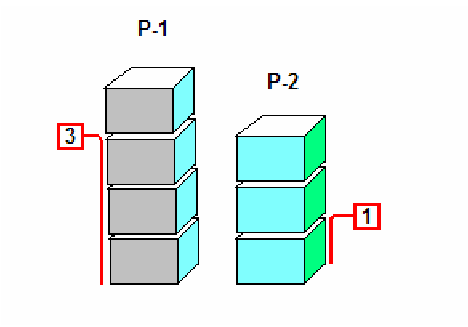

Fig. 2 Using KANBANs to signal reorder points in a stock of two products

Notice that if the factory lot size (*Qo*) would match the *Demand During Lead-Time* (*DLT*), then *Ko* = 1, and this case would automatically transform in the widely known "*Two Bins*" method, which uses two Bins of material and decides the moment to ask for the next Bin based on the quantity that rests in the present Bin. The full Bin quantity is established to represent the *Demand During Lead-Time* (*DLT*), and a new Bin of material is ordered whenever the present Bin gets empty (or almost).

3. The in-line one-product Supply Chain

Imagine now that the factory and the retailer become simply too distant for that the KANBAN quantity at the retailer can be maintained within acceptable values – for instance, in accordance with the *Economical Order Quantity* (EOQ) of Ford W. Harris (1913) –, and thus there is the need to order the material to an intermediate warehouse. For academic purposes, let us consider this new warehouse located precisely at a Lead-Time distance of $\Delta T_{\sup}$, and that it will order the material to a second warehouse distant of $2\,\Delta T_{\sup}$, and finally that this second warehouse will order the material to the factory distant of $3\,\Delta T_{\sup}$, as it is depicted in the figure 3. It is considered only one product. This kind of lineal Supply Chains is many times used for didactic or academic purposes, as it is, for example, the case of the so called "*Beer Game*" developed at MIT in the 1960s (Sterman, 1989).

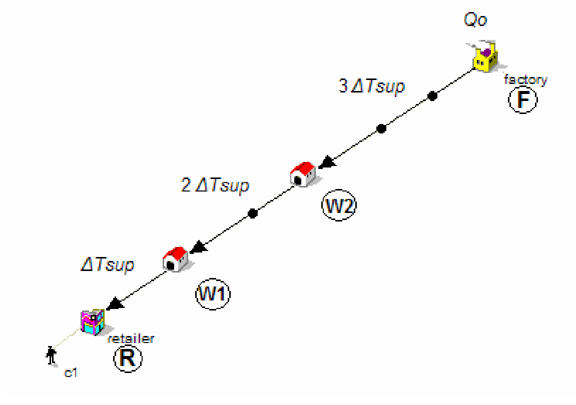

Fig. 3 In-line Supply Chain to compare the KANBAN and the *BanKan*

In this case, the objective is to compare the KANBAN method with the naïve method that soon will be presented. With such intents and for simplicity, let us consider the lot size (*Qo*) matching the *Demand During Lead-Time* (*DLT*) on the retailer. Then, it comes out from the examination of last figure that *Ko* = 1 for the retailer, meaning the retailer must order a Bin = *Qo* to the first warehouse (W1) each time the actual Bin gets empty (or near empty). Then, this warehouse will order to the second warehouse (W2) a quantity *2Qo* each time its stock reaches the KANBAN *Ko* = 2, and this facility will finally order to the factory a quantity *3Qo* whenever its inventory level reaches the KANBAN *Ko* = 3. Notice that this differences result from different *Demand During Lead-Time* (*DLT*) values observed along the Supply Chain.

4. Simulating the case

This Supply Chain have been modelled using a Supply Chain Simulator created by Feliz-Teixeira during his Ph.D. studies (Feliz-Teixeira & Brito, 2003), and the results have been achieved with the same simulation tool.

In the case under study, the customer's demand have been defined as *d* = 1 product units per day, with a standard deviation of 0.3 days. This let us choose *Qo* = 10. On the other hand, the *Time for Full Satisfaction (TFS)* of the customer was established to be 0.3 days, what means any order arriving from the retailer within this delay will be considered 100% satisfaction[2]. Orders with longer delays will contribute to the decline of the customer's satisfaction.

Concerning the retailer (R), whose reordering policy and configuration was kept the same in the two simulated approaches, the initial stock was 12 units, the stock refill policy was the KANBAN (*Ko* = 1), and it was allowed *no-backorders*. On all the other facilities *backorders* were allowed. All the other facilities used in the first approach the KANBAN method for reordering material, as it was explicitly referred in the last section, and only in the second approach they used the *naïve method*. The retailer, as we have noticed, kept using the KANBAN in the two cases.

Finally, it have been assumed $\Delta T_{\sup}$ = 10 days. So, the first warehouse (W1) will be distant from the retailer 10 days, as well

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[2] We use this measure to retrieve a quantitative idea on the clients "satisfaction", and we apply this concept not only to last customers but also to any facility in the supply chain.

as 20 days from the second warehouse (W2), which will be 30 days distant from the factory (F). The factory is served by an ideal supplier distant 40 days.

The final results were obtained applying statistics to the data acquired after 5 simulation replications of the same model, with each run representing one year of operations. The measures of interest for each facility were the *inventory state*, the *accumulated variable costs*, the "*satisfaction*" as defined above, and finally a group of standard metrics usually applied in Supply Chain facilities[3], like the *total costs*, *variable costs*, *incomes*, *turnover*, *service level*, and *stockout ratio*. It was based on this measures that the two refill policies have been compared.

4.1 *Results with the KANBAN policy*

As we have noticed before, in any case the retailer was operating with the KANBAN method and for that reason some of the results related with this facility will be very similar in the two cases in study. An example is the *inventory state*, which is shown in the next figure (Fig. 4). As one can see, the inventory starts from the initial condition of 12 units and swings as expected between 0 – 12 units.

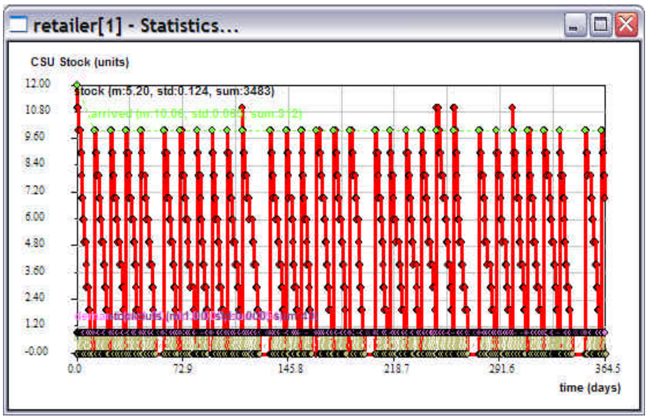

Fig. 4 Retailer inventory state during a year of simulated operations

Another similarity of the two systems is the customer "satisfaction", depicted in the figure 5, which runs oscillating between 50% and near 100%. Remember this holds for a *Time for Full Satisfaction (TFS)* in the customer of 0.3 days. Notice also that there is some orders "*not served*", which correspond to *stockouts* at the retailer.

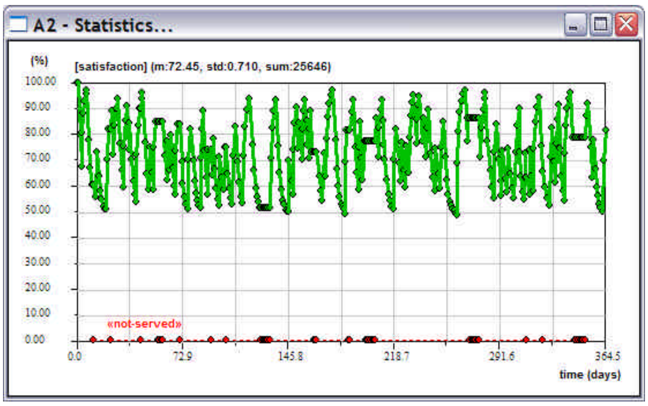

Fig. 5 Customer's "*satisfaction*" and "*not served*" orders

As we will see later, the big differences will be noticed on the other measures and more dramatically at the upper facilities on the Supply Chain. For the purpose to compare with next results, we show in the figure 6 the inventory state of the second warehouse (W2). By inspecting this figure is easy to detect that the KANBAN was $Ko = 3$, once it always orders 30 units of material. The inventory level swings between 0 – 40 units.

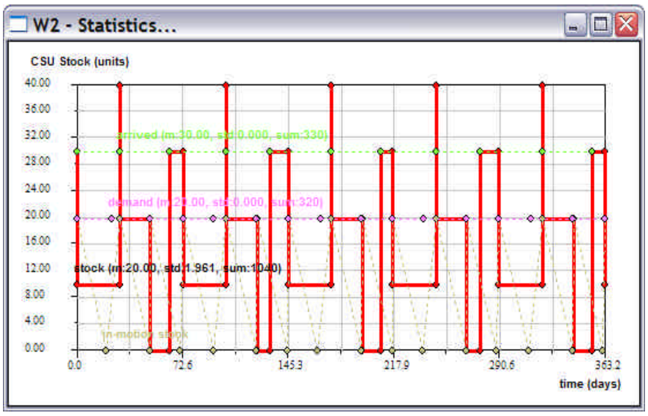

Fig. 6 Warehouse (W2) inventory state during the simulation

It have been observed that the first warehouse (W1) and the factory exhibit this same kind of swing, the first between 0 – 20 units and the last between 0 – 60 units.

Finally, on the next figure (Fig. 7) is represented the final characterization of the retailer (R) performance in terms of some standard logistic measures, considering also their variability along the 5 simulation runs.

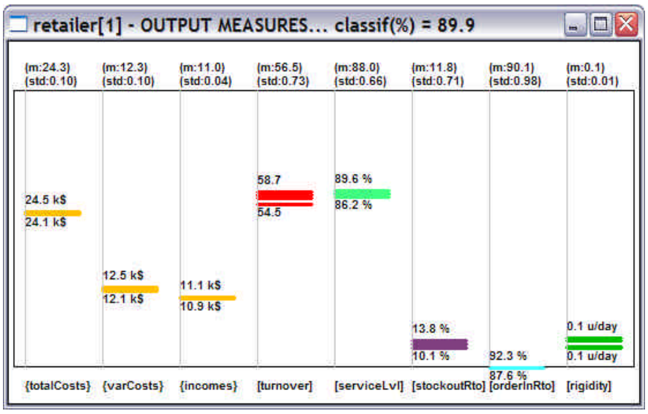

Fig. 7 Retailer final characterization

Notice that the *turnover* was around 56, the *service level* around 88% and the *stockout ratio* of the order of 12%. The last measure is not standard, is still in study, but it is expected to make possible the measure of "*rigidity*" at the facility, which is thought as the inverse of "*flexibility*" (Feliz-Teixeira & Brito, 2004). These results seem plausible to be expected on a JIT system.

4.2 *The naïve BanKan and its results*

It is now time to break the secrecy and talk about the naïve *BanKan* method. It is always difficult to start talking of a naïve solution, but we hope most of this strange impression will vanish after the presentation of the results achieved with such a scheme.

If we imagine a river, it is easy to understand that the material is moving by the influence of vacuum. That is, as long as a certain quantity of material leaves a certain space, the same amount of material is automatically moved to that space in order to fulfil

[3] Even if some efforts are being made to establish Supply Chain metrics (Lambert & Pohlen, 2001), meaningful metrics that look to the network structure of a Supply Chain are not yet precisely defined. Most of the times people still talking about and apply standard logistics measures.

such vacuum. Obviously, this process does not have anything to do with the quantity of material in motion, but only with an action that is triggered by another action. If in a certain moment 10 litres of water are moving forward, it automatically will be moved 10 litres of water to that same place in order to maintain the coherence of the fluid. If, in another situation, de quantity that leaves is 23, for example, then the quantity that enters must be the same 23. There is, in fact, no need of any other reasoning or calculation. On the other hand, if the water stops in one place, all the other "places" will stop as long as they are completed of water. To better visualize this process in a Supply Chain helps consider the water having a very high viscosity, thus moving very slow each time it has to fulfil a certain "emptied" space. Also, it can help to think on a chain of men unloading rice bags from a truck. Each man passes a bag to the next man as long as there is a "vacuum" in the next man and material enough to fulfil such "vacuum".

From these considerations the naive policy comes out as saying: "*I will order whenever someone orders me, and exactly the same quantity*".

Let us make a pause for laugh, but also to look once more at the Supply Chain in study, which is presented again in the next figure (Fig. 8).

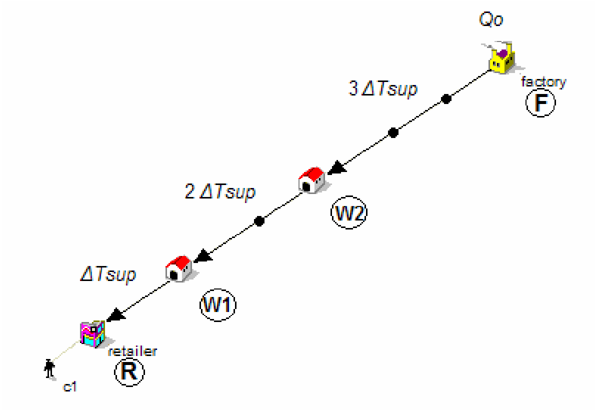

Fig. 8 In-line Supply Chain to compare the KANBAN and the *BanKan*

Taking in account that the retailer must always use the KANBAN, it will order *Qo* to W1. If now all the other facilities use the naïve method, in that precise moment W1 orders *Qo* to W2, and this the same quantity to the factory, and the factory to its supplier. At the same time, a quantity *Qo* is served to each client facility if there is stock available. As it is now easier to visualize, the quantity of material that will flow between any of the facilities in the Supply Chain is always *Qo*, the lot size produced at the factory which matches the *Demand During Lead-Time* (*DLT*) at the retailer, as previously considered in the section 3. The result is a continuous flow of material from the factory to the retailer, precisely like in a river free of dams. Of course, to ensure there will be no *stockouts* during the start and any restarts of this process one must ensure a certain minimum inventory at the beginning at each facility. And this minimum inventory is precisely the previous value of the KANBAN at the facility. That is, the first warehouse (W1) must have an initial stock of *2Qo*, the second warehouse (W2) an initial stock of *3Qo*, and the factory (F) an initial stock of *4Qo*.

Let us now present some results obtained with this method. The next figure (Fig. 9) represents the *inventory state* again at the retailer (R), and, as we have predicted, it is very similar to that of the last case. The initial stock is again 12 units, and during one year of simulated operation it was swinging between 0 – 12 units. It is observed, anyhow, that the retailer incurred in less *stockouts* than in the previous case, as we will see soon.

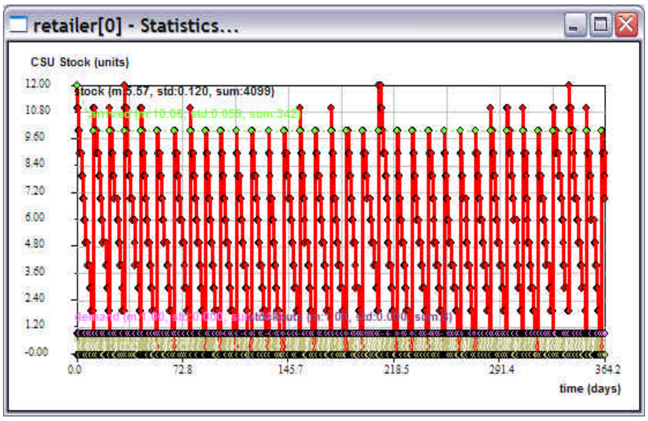

Fig. 9 Retailer inventory during a year of simulated operation

Depicted in the figure 10, it is the customer "*satisfaction*" which again oscillates between 50% and near 100%, as in the previous case. Nevertheless, it can also be observed from this figure that there was much less cases of material "*not served*" to the customer, which obviously means less *stockouts* at the retailer.

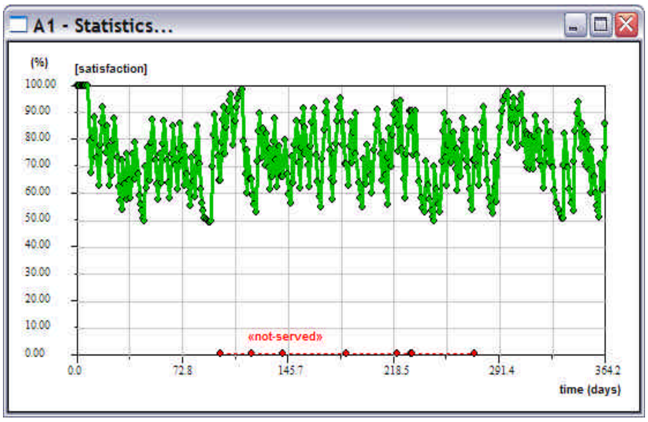

Fig. 10 Customer's "*satisfaction*" and "*not served*" orders

The figure 11 shows the inventory at the second warehouse (W2), which must be compared with the previously shown in figure 6. The initial state is *3Qo* = 30 units, but then the level goes fast down to the range 0 – 10 units. This is because the naïve method tends to turn the inventory practically all into motion.

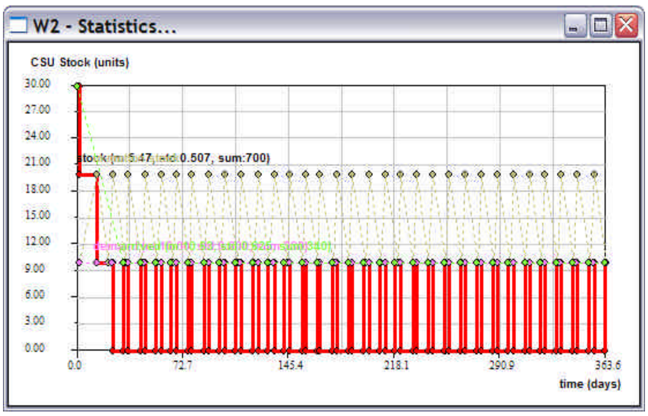

Fig. 11 Warehouse (W2) inventory during the simulation

This same behaviour have been observed at the other facilities (except the retailer), and the next figure (Fig. 12) shows the inventory state at the factory (F). Once again the initial stock of 40 units was fast going down to the range 0 – 10 units, which is precisely the range observed at any of the warehouses.

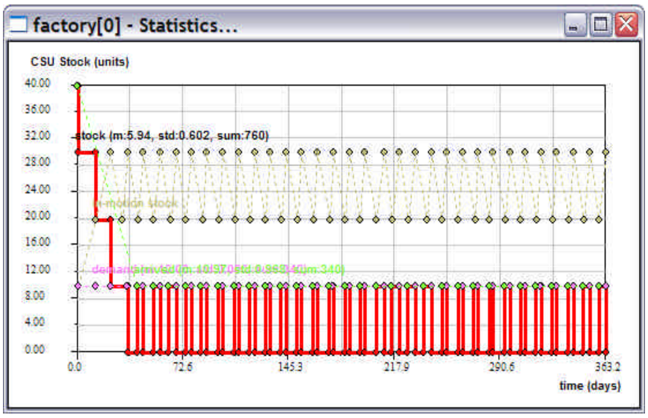

Fig. 12 Factory (F) inventory during the simulation

Finally, on the next figure (Fig. 13) is presented the final characterization of the performance of the retailer (R) in terms of the same standard logistic measures as before, considering also their variability along the 5 simulation runs.

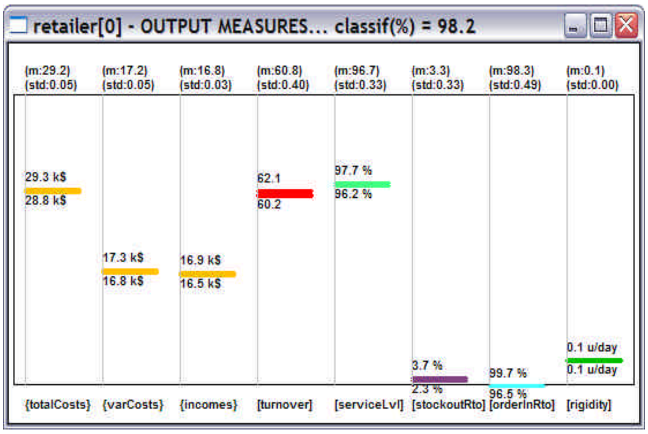

Fig. 13 Final characterization of the retailer

From these measures, which must be compared with those of figure 7, one can already conclude about the superior operational performance achieved with the naïve *BanKan* method. In fact, not only the ratio between *incomes* and *costs* is higher, but also higher are the *turnover* and the *service level*, and clearly smaller the *stockout ratio*. About this last measure, it is interesting to notice that it was reduced from 12%, on the KANBAN method, to 3%, when using the *BanKan*. A more attentive inspection of these results would lead us to conclude the naïve method reveals superior in almost every aspects.

We can now explain the reasons to choose the name *BanKan* for the naïve method. The first idea was to keep the "Japanese" phonetics as a tribute to the sense of simplicity and perfection with which the Japanese conquest our sympathy, as well as made possible the popularisation of technologies, mainly informatics and digital, which before seem to be given to the public only in small doses by monopolist enterprises. The second reason has to do with the fact that the *BanKan* is somehow the inverse of the KANBAN, once the stock "operator" is much more interested on dispatching the material from its stock than on the calculation of when and how much to order. The KANBAN was thought to make the stock available for a certain operation in a Production System, while the *BanKan* is thought to make the stock not available at all in the facility, while keeping the system running. Because of its Japanese phonetics the *BanKan* can also be a tribute to Taiichi Ohno, the father of JIT, and at the same time expresses the inverse reasoning of KANBAN and other standard methods of inventory control. In one sentence, the KANBAN controls, while the *BanKan* does not.

5. Comparing the KANBAN and the *BanKan*

To compare with more accuracy the performances of these two policies, the results from the simulation were later organized by facility and presented graphically. In figure 14, for example, it is represented the *average inventory* held at each facility during one year of operations, where from we can obviously conclude that it grows from the retailer to the factory while using the KANBAN, but stands constant and minimal when using the *BanKan*, as this method tends to set all the inventory in motion.

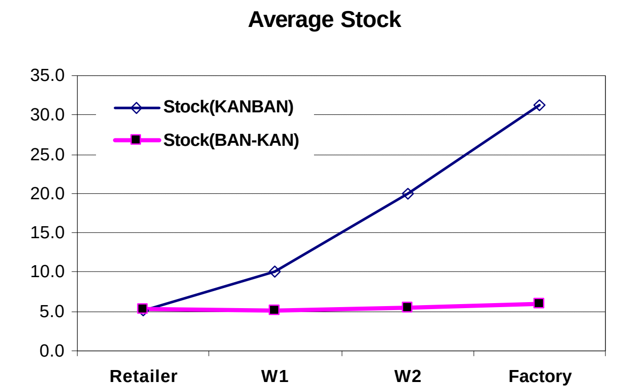

Fig. 14 Comparing the *average inventory* along the Supply Chain

What concerns the *turnover* and the *service level*, both represented in the figure 15, the results show that the *BanKan* solution is obviously preferable at any level of the Supply Chain. With the KANBAN these measures show a tendency to decline as one approach the factory, while they are kept practically constant with the *BanKan*.

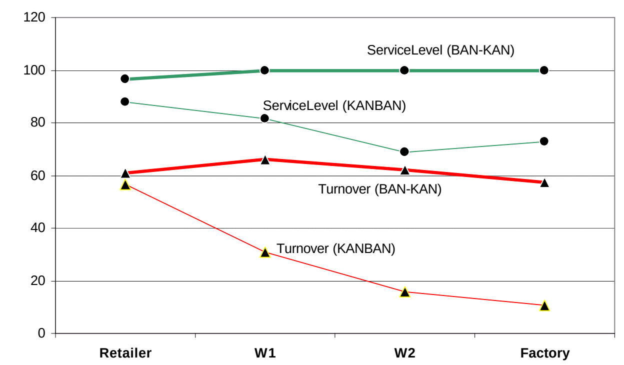

Fig. 15 Comparing the *turnover* and the *service level*

The last comparison concerns the *costs* and the *incomes*, which are very important measures for realistic Supply Chains. And even in this case the results appear surprising. One could expect the *costs* to be higher with the naïve method due to the more frequent transportation of material, and that is what simulation have shown, anyhow, as it is represented in figure 16, the *ratio* between *incomes* and *total costs* continues higher in all facilities when using the naïve method. *Holding costs* were obviously also included and considered even with the inventory in motion.

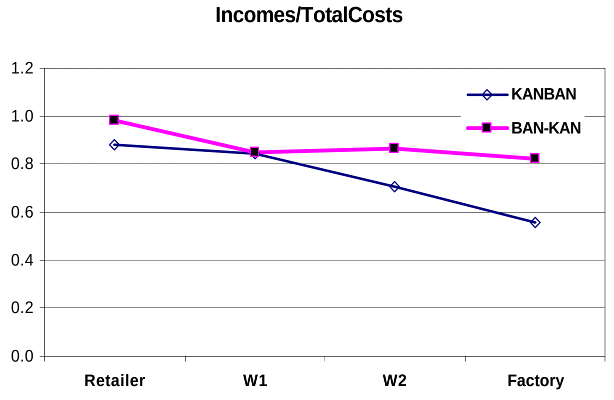

Fig. 16 Comparing the *incomes/totalCosts*

There is, however, in this *naïve* process a negative aspect, which probably is the reason why managers do not use it in practice: the final cost of the product. As the figure 17 shows, the cost of the product rises when it approaches the retailer, as expected, and this implies an obvious increase on the price of the product at the last customer, once the transportation costs have been made to reflect in product price at each facility. In this particular case, in which was considered a null *business margin* in each facility (thus the price increase was only due to the transportation effect), it was observed a product cost at the retailer of about 60% higher that in the KANBAN case. So, at least this difference would have to be projected to the last customer.

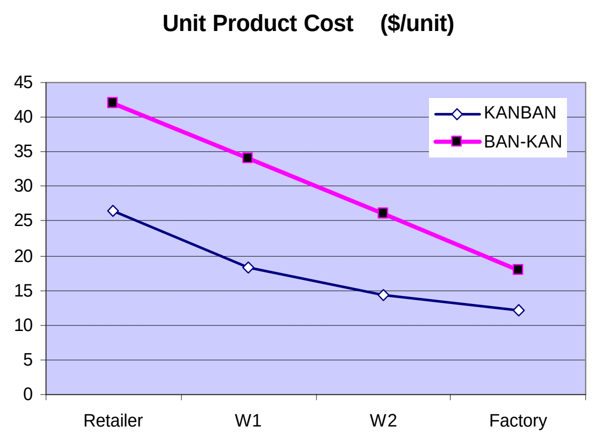

Fig. 17 Comparing the unit product costs

It is also important to refer that the transport costs in this simulation were made dependent on the level of occupation on the delivering vehicle, as usually happens in real cases. It was, therefore, considered discounts of quantity. Anyhow, in all the facilities these discounts were the same. Such discounts are also responsible for the higher costs in the *BanKan* case, as the facilities order much less material quantity in each order than in the other case, turning the product prices higher.

6. CONCLUSIONS

The surprising results obtained by simulation on comparing these two reorder methods let us conclude that at least it could be interesting to study the effects of the naïve *BanKan* method in other kinds of Supply Chain, as well as under diverse demand patterns and with more than one product. At least, for the demand variability considered in the present case, the results have shown a superior operational performance while using the naïve *BanKan* method, where also it was observed much less *stockouts* at the retailer level than when using the KANBAN. This, for sure, must have a meaning, even apart from the fact this was an academic case study (Hewitt, 2001).

Another interesting conclusion coming out from this study is the fact that using the naïve *BanKan* method one does not have to care too much about speed in the delivery, but instead about its exactness. Actually, as the *BanKan* method is mainly regulated by time, and not quantity, this can take away from the managers and suppliers the constant stress of delivering faster and faster, and, instead of that, to let them plan their jobs with more precision and tranquillity in the time domain. If a supplier is able to delivery in two hours running as a crazy, for sure it will also be able to deliver in five hours spending less energy, running slower or, perhaps, serving more facilities than before. The only difference is that the quantity *Qo* will have to be a bit higher that in the previous situation. Extremely important is that the supplier will be at the client facility at the scheduled time in order that the synchronism with the demand at the retailer can be maintained high. Of course, this kind of behaviour would imply a sense of cooperation between all the Supply Chain operators, what again reveals the importance of *trust*.

Apart from this, using the *BanKan* at the "inner" facilities of the Supply Chain could probably also mean less space needed for inventory, less complex software for processing orders, less expensive stocking processes, which obviously would result in less expensive warehouses. Perhaps then the final price of the product could be enough reduced at the customer level.

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