MANUFACTURING STRATEGIC PLANNING: THE INTEGRATION OF LOGISTICS AND TECHNOLOGY STRATEGY (APPLICATION TO JIT)

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Abstract

The paper presents an experimented model to cope with the problem of manufacturing systems design in high competitive-dynamic markets, the main challenge being to simultaneously manage short product and process life cycles, high productivity, flexibility and low inventory, some of them contradictory.

The paper goes along with the criteria of machines and systems flexibility and short product and process life cycles, but actively seeking high productivity standards in terms of as much automation as possible and, which is more crucial, of a very smart advanced organisational practices set.

Keywords

Technology, product life cycle, process life cycle, strategic-planning, product added value, process added value.

1. INTRODUCTION AND BACKGROUND

Surpresive markets proliferate everywhere. A surpresive market is that shooting extremely short product and/or process life cycles. In other words, more or less revolutionary product-applied technology and advanced new processes are permanently on their way. Never minded if dealing with own or customer's products, a trend is certified to spread simultaneously changes in both product and process technology.

Most companies are, in some way, immersed in this dynamic environment, and surviving there requires from them to be in a leading position (what means creating at least one product/process technological leaps), or alternatively contend in a place where the sucking effect from the leaders innovation is significative enough. That last means not at all to "copy ok and fast", but crafting self-innovation around.

Basically, companies in this last situation - the majority - have to demonstrate:

- An operative model for continuously re-aiming and deploying the technology strategy.

- A technology strategy which is sounded and flexible enough, requiring only stepped gradual changes.

What follows represents the model applied to redesign a multinational subsidiary basque country company based facility for attending the world-wide portable air conditioned market, being a newcomer regarding this particular high-competitive far-eastern coped activity.

It is important to highlight the core assumptions used:

* Identify product and process added value aspects and their influence in business profitability.

* Create as much as possible "potential energy" and eliminate any significative drag in the organization for systematically doing the fastest innovation in product and process technology.

* Make clear along that effective and faster innovation requires a well established permanent removal of manufacturing process non-added value activities: "Be fit to be able to leap".

* To use a "smart logistics model" as the input for manufacturing strategy, thus giving a reference to be self-benchmarked in process added value and technology.

* Identify strategies for marketing the technology strategies, as additional sinergistic effect.

Let's go to examine all them separately.

2. PRODUCT ADDED VALUE

Matrix in FIG. 1 represents competitive barriers of product and process added value. In a mature product and market any significative innovation means a competitive barrier, but sooner or later patents pending are -if sense- easily violated, thus converting innovation in no more than current "value analysis" practices. We decided to create "potential energy" for innovation rather than trying to differentiate in product technology from the starting point. This is supposed to give us more opportunities to make continuous relatively market appreciable innovation leaps, and also concentrate in very effective value analysis activities oriented to increase the ratio "function value/function cost".

	Size of competitive barrier	Duration of competitive advantage
PDAV (product-added-value)	High	Small
PRAV (process-added-value)	Low	Large

FIG. 1. PRODUCT AND PROCESS ADDED VALUE MATRIX

The mentioned “potential energy” creation is based on technology strategy and convenient suppliers development. The FIG. 2. is the supplier matrix, where they are classified attending product and process critical parts, a critical part being one that is related to the potential of differentiation in product function/cost or process cost/reliability in the future.

Two kinds of suppliers where selected to be developed in terms of technology; the product and the process technology related ones, but simultaneously protecting as the own core that areas where both product and process technology are considered critical. This aggressive approach is made taking care enough to the sort of suppliers dealing with, in all cases SME's with long-term agreements in terms of price-volume, price-time, number of technology suggestions from them, technology support from ours, and no concurrence with competitors. The suppliers are supposed to provide us with a contribution to a faster innovation and consequent release of own overhead costs.

Examples are (see FIG. 2):

- Reserved to company; final assembly, functional on-line tests, performance tests, condensation systems.
- Product oriented suppliers; copper piping, protecting handling and surface contamination.
- Process oriented suppliers; stampings and plastics related to external design.
- Price-based purchasing; sheet bending, small machined parts.

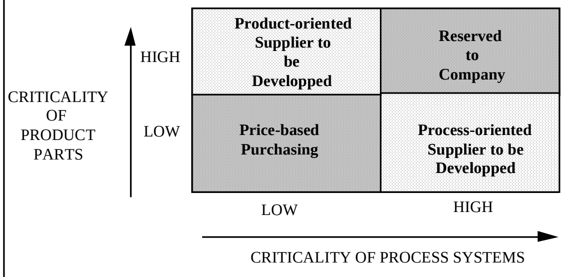

FIG. 2. THE SUPPLIERS MATRIX

The R+D department organisation with two assignments in both product and process technology innovation is another important issue. A commercial-oriented manager was got in charge, with a short polivalent product/process technology team able to manage own innovations and suppliers R+D contribution activities. Value analysis practices set as part of their tasks gives degree of more practical and sounded innovation decision as well as more frequent cost reduction results and team morale.

Finally, another significative product-added value oriented action was creating an innovative after sales technical service - AST - approach. AST commitment ranges from current customer orders and specifications reception and processing, to product installation and typical after sales field service. In this way, the AST department is first concernig with the product in engineering adaptations, reliability of solutions, and field originated value analysis suggestions, and in second term the customer has only one and consistent window of communication with the company along product contract and utilization cycle.

3. PROCESS-ADDED VALUE

How we create process added-value oriented potential energy?. We used three main commitments; eliminate non added-value cost pools activities, create added value to the customer by process differentiation, and finally increase the Sales/Assets (S/A) ratio with as less as possible direct and indirect labour.

These were key processes, represented in form of table in FIG. 3. Now we will follow deeping on the logistic previous model, the manufacturing strategy components and the advanced organizational practices.

	Objective	Approach
Elimination of non added-value proccess activities	• Sistematic cost and manufacturing lead-time reduction	• Smart logistic model is an input to a sounded defined manufacturing strategy. • Process-Management oriented staff organisation (PDM and work flow software) • Minifactories oriented shop-floor lay-out.
Add value by process differentiation	• Reduce delivery time. • Reduce time for industrialisation of product modifications. (Think and done)	• Flexibility and polivalence of machinery. • An integrated process reliability program.
Increase S/A with low involved manpower	• Contribution to the shareholders value through assets profitability.	• Flexibility and polivalence of machinery. • Soft-low cost manufacturing process integration. • An integrated process reliability program.

FIG. 3. HOW THE PROCESS ADDED VALUE IS CREATED

4. RELATED ASSETS PROFITABILITY

Assets profitability, given by the quotient AP (assets profitability) = NP (net profit) / NA (net-assets) is the most significative business and shareholders value contributor. Linking it with managerial practices is an interesting and practical issue for helping business-policy deployment along the organisation. One way to do that is factoring AP in Margin as NP/S (Sales) and Rotation as S(Sales)/NA, and relating them with strategies. In the case of the high-competitive matured markets a close relation does between Margin and product added-value activities, given that otherwise market prices' trend-to-decrease velocity is greater than the sole effect of continuous-improvement practices cost reduction results.

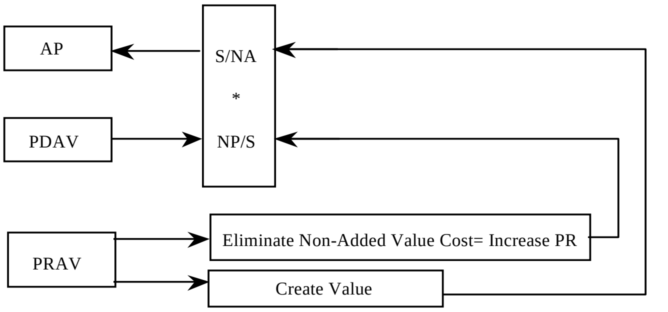

FIG. 4. ASSETS PROFITABILITY AND PRODUCT-PROCESS ADDED VALUE ACTIVITIES MODEL

On the other hand, Rotation figures (supposing competitive direct manufacturing costs are well performed) are clearly influenced by process added-value activities.

The elimination of non-added value cost is symbolised by the productivity ratio (PR).

$$PR = \frac{US * FTOT}{CT}$$

, where

US = unites sold

FTOP = future technical optimal process time
(a constant with no technology changes)

CT = consumed time

This is the way in which Assets profitability and Technology strategy are clearly identified and related, giving a continuous-channel for communication and innovation-management along the organisation.

5. ELIMINATE NON-ADDED VALUE COSTS: SMART LOGISTICS FIRST, AND A SOUNDED MANUFACTURING STRATEGY

A smart logistic model and a correspondent manufacturing strategy are previous steps to successful elimination of non-added value cost, otherwise efforts becoming worthless. Current examples are found in programs for reducing machines set-up times beyond a convenient point, or trying to make a survivor of product changes of an extensive automated expensive machine, or the elimination of continuous-little breakdowns for another one high integrated asset piece.

By "logistic first" we understand that the manufacturing strategy is coupled with a smart-realistic logistic model which implicit manages all type of very small scraps and inefficiencies.

The logistic model is established on the following items:

5.1. Regarding a seasonal demand pattern (typical from air-conditioned products), balance and optimize the monthly production:

- near the demand: low inventory cost
- near the constant: low manufacturing direct cost

The solution is approximated by a combination of both by a very simple electronic-sheet simulation model given, in general, a result of "stepped production model" (Number of steps and production quantity) as seen in FIG. 5. for each item.

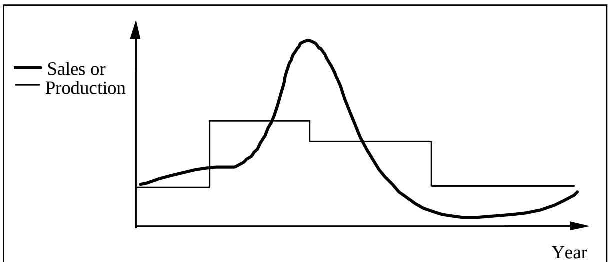

FIG. 5. SEASONAL PATTERN AND STEPPED PRODUCTION MODEL (THREE STEPS)

5.2. Decide from where in the process you are going to make ATO (assemble to order), thus confining the MTS (manufacturing to stock) area.

5.3. Define the lead and auxiliary lines (see FIG. 6.) considering critical product and process technology and the possibility of minifactories based organisation model.

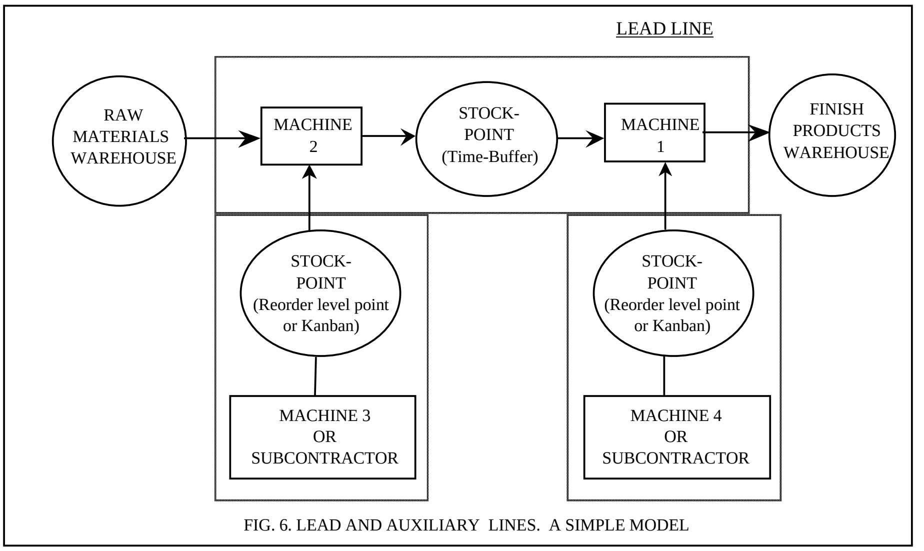

FIG. 6. LEAD AND AUXILIARY LINES. A SIMPLE MODEL

The lead-line to be identified will have precise features:

- The stock points (between machine M2 and M1) in the example must be safety lead-times (time buffers), thus synchronizing both machines.
- Contains the MRP inverse calendar and the critical-path of the product, and in consequence the normal bottlenecks and the more technological processes.
- The flexibility of the manufacturing system is conditioned by this lead time.

Lead lines are going to be the scopes of the manufacturing strategies, containing on them all the product and process critical parts, and where the approaches deployed in FIG. 4, have priority to be fully implemented.

In the practical development, the lead-line is composed by the assembly of product base, tubing, welding, test and packaging, and auxiliary lines are sub-assemblies of tubing (welding) and electrical sub-assemblies.

5.4. Make production lot size equal to transfer lot size.

The transfer lot-size (the convenient quantity of product to transport or manipulate) is study with independece of the machines. Generally speaking, transfer lot size is smaller than production lot size, and overlapping of this last is normally used as a way of reducing lead-times. But overlapping just concerns one lot once it is in process, and does not manage the time of waiting in front of a machine. Then, policy is to make the machines at least as flexible as the transport process is making production lot size equal to transfer lot-size, and being this a crucial point in relation to the "machine-selection-triangle" given in FIG. 7.

6. A SOUNDED MANUFACTURING STRATEGY AND ORGANISATIONAL AGRESSIVE PRACTICES

First, we have the mentioned "machine-selection-triangle" as seen in FIG. 7. There is a compatibility between flexible (low set-up-time) and polivalent (product-changes surviving) machines and systems, and no-compatibility with high automated internally integrated ones, which are clearly rigid and become easily obsolete with product evolution. Clearly, we have to select flexibility and polivalence, what means to couple with the factors of add value by process differentiation that are reflected in FIG. 3.. This policy also protects from process obsolescence, and it is coherent with keeping Rotation high (S/NA). The point is how to do all that with the seen PR-productivity-ratio also keeping high. Policies and tactics are as follows:

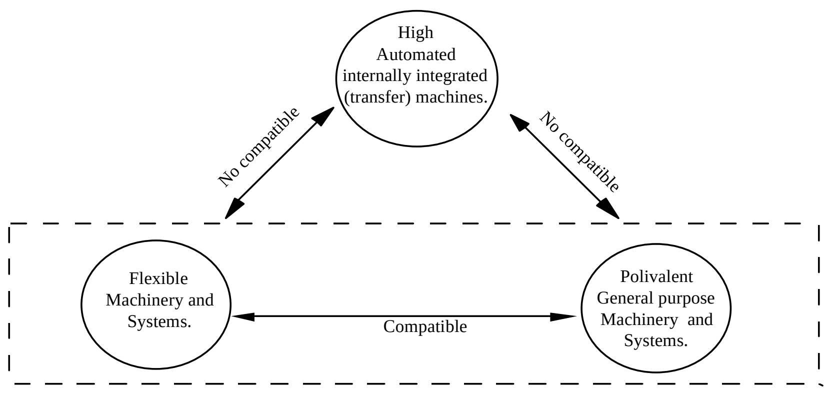

FIG. 7. THE MACHINE-SELECTION-TRIANGLE

* Perform R+D process capabilities, designing proprietary solutions based on well tested commercial machinery parts.

* Don't integrate operations internally in machines (transfers); instead of that do external low-cost-general-purpose-components based specifically engineered integration between also general-purpose machines, and then give automation enough for the most significative external handling.

* Allow “by-passes” for manual operation along the integrated process. Frequently, that is only a matter of only a light-over in assigned floorspace.

* Reduce all the elements of set-up time that are not concerned with the physical conception of machines and tools (they will be reduced by machine selection strategy). Process-tuning adjustments are in this category of items.

* Adjust process off-machines, and if on, have the on-line monitoring facilities and computer-aided decision support systems to make "first part good".

* Process technology domain is critical. Integrate management and capabilities concerned along with an organizational model that has a full-time integrated team for:

  - Some process innovation staff.
  - Maintenance and condition monitoring.
  - Quality engineering.

We call this the "process engineering team".

* Apply I.T. (information technology) in the process in terms of on-line automated SPC integrate with on-line condition monitoring predictive maintenance systems. This is the information system by excellence for the mentioned process engineering team.

* The number of breakdowns, and particularly small breakdowns in critical machines, are a symptom of the quality of process engineering work. Use the SPC-Predictive Integrated I.T. system to deep in root causes of failure. The proper rule is putting machines working as fast as possible, no matter if they are in a very high automated environment or not.

* Design installations and aground systems carefully to allow a reliable yearly (every August) lay-out change. In practice, with the exception of very few critical machines, restrictions to the move are more concerned with installations and other stuff.

7. THE PRACTICAL LIMITS FOR J.I.T.

Car component makers are particularly forced to continuous improvements in lead-times and costs reduction. The FIG. 8 represents a very attractive interaction in which cleverly focused lead-time reduction leads to dramatically reduce costs improving simultaneously quality and service. But is this an absolute linear non-ending model, then showing us Z.I. (Zero Inventories) as the panacea for best manufacturing practices?. The answer is no; the multiplying links of the figure works out only from an initial manufacturing system given situation to another in which the maximum limit achievable manufacturing flexibility is a function of the involved machines technology.

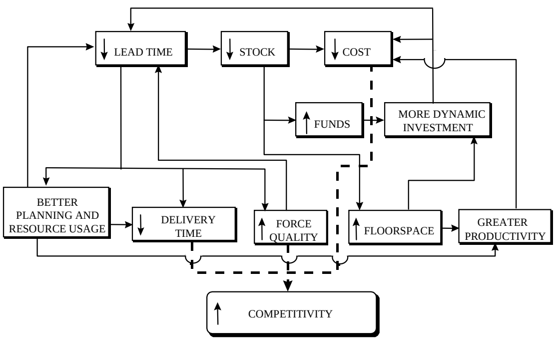

FIG. 8: LEAD TIME, ITS REDUCTION AND COMPETIVITY IMPROVEMENT
Note the “multiplying” characteristics of the links.

Going on beyond this point reducing set-up times is just a waste of precious time and money. Therefore, the minimum level of inventory you can have depends only on the Technology Strategy you are practicing. The confusion stands because the problem in real life is identification of the inventory sources. But take that into account; if you deduce the level of the inventory related to a lot-sizing practice (roughly ½ EOQ), and you compare the figure with plant obtained samples, the surprise is that theoretical inventory is only one third (or less) than the sampled. Where is the difference?. Very easy; on things that must be dramatically eradicated; machine breakdowns, inadequate and suppressive CPK´s, scrap and rework, under controlled process adjustments of setting up with loss of expensive material, or inadequate or very slow operating planning and scheduling systems. Z.I. that must be pursued most is the inventory you have because all these things more or less randomly occur. This is the limit of linear behaviour of the model showed in FIG. 8, and what we call P.Z.I. (practical zero inventories).

Proper identification and removal of these all scraps requires a previous setting of a logistics model and a coupled technology strategy for involved machines and plant physical systems.

8. THE LOGISTIC MODEL AND THE MANUFACTURING DECISION TRIANGLE

Supposed defined if you are a ATO (assemble to order), MTO (manufacturing to order) or MTS (manufacturing to stock), the identification of main and auxiliary lines is the key to issue. The FIG. 6 represents the lay-out of M&A lines.

The main line is synchronized, time buffered inventory, contains the most added value product parts and process technology, and sets the manufacturing lead-times. Main lines contents the reserved capacity of differentiation on product inventory, quality, flexibility and service, and cost reduction for the future. The auxiliary lines (machines or subcontractors) are just opposite decoupled systems likely producing any of the rest of the areas represented in FIG. 1, and performing JIT or reorder-level-point operating practices.

Main lines are the places to perform PZI, and doing this hierarchy through the logistic model is extremely useful, given that it channels to there product and process innovation and more intensive continuous improvement management efforts.

Which is the most convenient practical lot-size in the main-line?. If you can manufacture as small as you can rationally move you get the following:

- If the customer fix order’s window is small (and in fact is decreasing continuously), there is a clear trend to order what is reasonable to move and deliver if you do transfer and manufacturing lots equal the main line remains syncronized along process stages.

- Operative integration of production and material handling personnel decreasing labour costs through polivalence and self-balancing.

- Extremely simple and straight planning, scheduling and control system, complemented by easy work in progress visual traceability.

- Everything that is on the plant must be moving (with exception of safety time-buffer-stock) and assigned to a customer order.

- Safety time-buffer stock size, convenience and lead-time added is clearly and continuously visually identified so decisions about definitive or occasional removal of safety are very easy to take.

– With the exception of some given scheduling conveniences (grouping for saving in set-up times) customer orders priorities or changes affects not very much to productivity.

So, it is clear that in the main line manufacturing technology must be coupled with the idea of doing manufacturing lot size equal to transfer lot size. The level of the transfer lot-size is selected with the criteria of minimizing handling costs, and depends on the product morphology, distances, and transport devices design (selected for minimum handling costs).

With these conditions, we have to select the manufacturing technology for the main line. Minimum theoretical set-up times have to be reasonable for producing transfer lot sizes, and are calculated reversing the well known “Wilson” or “Coverage” formula (Coverage analysis is more appropriated for a family of products produced in expensive main lines). With deduced convenient set-up times, maximum admitted direct and labour costs, and product life cycle, we move to the FIG. 7; the machine decision triangle.

Looking at the figure, and if needed flexibility is given by the transfer-lot, what we have to do is move as much as possible to automation but keeping the ability of necessary rapidity in changeovers. This contradictory trade-off can be alter in own favour with good integrated product and process engineering practices. The Table 1 represents how to decide on the different alternatives, and FIG. 9 situates them on an interline flow-chart.

TABLE 1

HOW TO BALANCE THE “MACHINE TRIANGLE” OR THE “DECISION´S CUBE”
IN PRACTICE (for the key-machines of the lead syncronized line)

F = Flexibility H = Human
P = Polivalence C = Economic comparison
I = Investment

	(1) Current Alternative		(2) Transfer Line		(3) Flexible Manufacturing system		(4) Flexible Transfer-line		(5) Flexible Manufacturing Cell	
	Value	Technical Comments	Value	Technical Comments	Value	Technical Comments	Value	Technical Comments	Value	Technical Comments
F										
▪ Set-up time										
▪ Material cost in set up times										
▪ Optimum manufacturing batches										
▪ Set-ups/year										
▪ Transfer batch										
▪ Theoretical lead-times: Tp+tu.L										
▪ Lead-time or terms (adjusted with (6))										
▪ Stocks’s level (1)										
▪ Set-up total cost (mat+MO)										
AI										
▪ Typical optimum frequent limit (Tf)										
▪ Material scrap/hour										
▪ Variable operation cost/hour (without amortization)										
▪ Variable maintenance cost and stocks/hour										
▪ MOD cost/hour (4)										
▪ MOI cost of supporting/hour										
▪ MTBF										
▪ MTTR										
▪ Aviability.% $\frac{MTBF}{MTBF+MTTR}$ (6)										
▪ Operation total cost/hour										
▪ Number of hours/year										
P										
▪ Target process cycle life without changes										
▪ (2) Investment in process in period 1, 2, 3, 4 Until target										
H										
▪ Differential cost/hour (4)										
▪ Training cost (5)										
▪ Improvement capacity (A,M,B).										
▪ Investments according to current situation										
I										
▪ Net investment (3)-(1) $\lessgtr$ (2) + (5)										
C										
▪ Comparison of alternatives: VAN/TIR in marginal target of costs										

HOW TO BALANCE THE "MACHINE TRIANGLE" OR THE "DECISION´S CUBE" IN PRACTICE (for the key-machines of the lead syncronized line)

F = Flexibility H = Human
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I = Investment

Criteria	⑥ Cell including general purpose		⑦ Manipulate orientated cell including general purpose		⑧ Disminish set up oriented cell including general purpose machines		⑨ Set up oriented cell including general purpose machines	
	Value	Technical Comments	Value	Technical Comments	Value	Technical Comments	Value	Technical Comments
(F) ▪ Set-up time ▪ Material cost in set up times ▪ Optimum manufacturing batches ▪ Set-ups/year ▪ Transfer batch ▪ Theoretical lead-times: Tp+tu.L ▪ Lead-time or terms (adjusted with (6)) ▪ Stocks's level (1) ▪ Set-up total cost (mat+MO)								
(AI) ▪ Typical optimum frequent limit (Tf) ▪ Material scrap/hour ▪ Variable operation cost/hour (without amortization) ▪ Variable maintenance cost and stocks/hour ▪ MOD cost/hour (4) ▪ MOI cost of supporting/hour ▪ MTBF ▪ MTTR ▪ Aviability.% $\frac{MTBF}{MTBF+MTTR}$ (6) ▪ Operation total cost/hour ▪ Number of hours/year								
(P) ▪ Target process cycle life without changes ▪ (2) Investment in process in periods 1, 2, 3, 4 (Until target)								
(H) ▪ Differential cost/hour (4) ▪ Training cost (5) ▪ Improvement capacity (A,M,B). ▪ Investments according to current situation								
(I) ▪ Net investment (3)-(1) ≶ (2) + (5)								
(C) ▪ Comparison of alternatives: VAN/TIR in marginal target of costs								

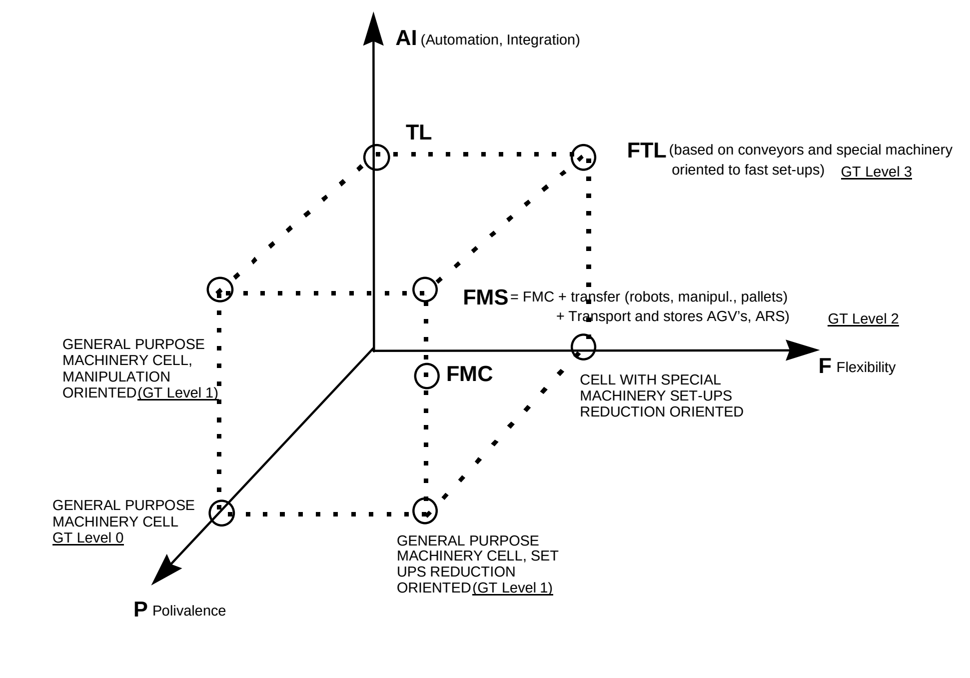

FIG. 9. THE DECISION CUBE

TL = transfer-line
FTL = flexible transfer - line
FMS = flexible manufacturing system
FMC = flexible manufacturing cell

9. DEDUCTION OF PZI AND RELATED M.I.S (management information system)

The size of PZI can be calculated in a roughly way (formula-based) or by simulation of optimal sequences in scheduling systems software that has the input of the MPS (master-plan) for the main-line (FIG. 10). The difference is that in the first, products are independently pipe-lined along the main line, and that with simulation grouping and changeover savings-and then some finish product inventory excess-arises. Depending on real cases, both are valid tactics, and their results are the ideal limits for plant management performance indicators.

The formula for deducting PZI for one part in terms of time is:

PZI = Σ (Set up time+Transfer lot*Production-time+Transport-time+Minimum Safety lead-time)

(time) (process stages)

$$PZI = PZI * \frac{\text{unit cost * Annual Demand (units)}}{365}$$

(money) (time)

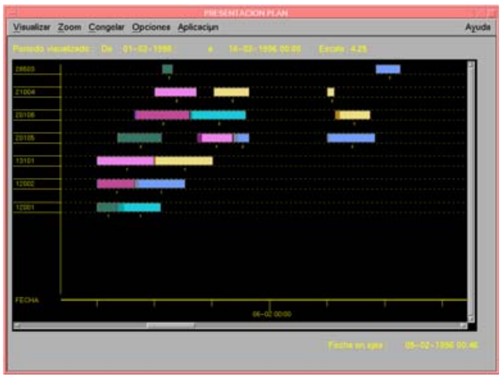

FIG. 10. Gantt chart of an scheduling system software

Finally, a convenient M.I.S. for managing ZPI could be as follows:

- PZI excess (see FIG. 11) =
- +● Time EDI - Time dispatching.
- +● Time breakdowns and shortages - Time scheduled for buffering.
- +● Time scrap+rework - Time scheduled for buffering.
- +● Non-identified .

This non-identified piece of excess must also be continuously traced for deducting not so obvious problems.

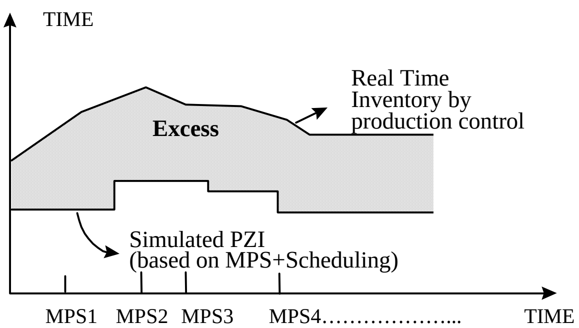

FIG. 11: INVENTORY EXCESS FROM PZI

10. CONCLUSIONS

In high competitive-surpresive markets we need to make compatible continuous improvement managerial techniques with leaps in both product and process innovations, given that the former are not capable by themselves to compensate price reduction pressures. Creating "potential energy" in a fit organisation for facilitating product innovation leaps, and deploy a logistic based flexibility and polivalence-oriented manufacturing strategy are the points to exploit.

Finally and closing the loop we need some strategies to marketing the adopted technology strategies. Is that possible?. We need to be realistic and the profitability of that kind of actions is not always enough. But when your customer values future, it is possible to get effects (more in sales, and never in price) giving perspective of facts he is interested in. Those facts that precisely create value in the product/process technology strategy: for example delivery time reduction.

The perspective for customer has to be marketed as follows:

- What have we done in the past.
- What is different from our competitors right now.
- What are we going to do in the future.
- How can technology strategies contribute.

The paper concludes saying that Z.I. is not, general speaking, a consistent strategy, but very interesting approach is arised if you fight Z.I. only for these all elements that are not part of the manufacturing system decision triangle strategy, and that push to you to have, sometimes, much more inventory than optimized correspondent set-up times EOQ would.

BIOGRAPHY

Prof. Dr. Javier Borda Elejabarrieta has been working as plant Engineer and Production Manager staff for 7 years, and from 1984 he is the managing director and C.E.O. of DATALDE, S.A., a spanish 35 people industrial engineering company, sited in the Basque Country. He read in 1989 the Doctoral Mechanical Engineering dissertation on "CIM for plastic injection workshops". He is also Professor of Production and Engineering Management in the University of Deusto, Bilbao, and the author of several international papers and a book titled: "Advanced Maintenance Techniques" (1990). He has become recently an IFIP WG 5.7 member.

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