COMPUTERIZED BENCHMARKING AS A DEDUCTION OF PRACTICAL INDUSTRIAL PROJECT

G. Halevi
Technion – Israel Institute of Technology
Dobnov St. 20a Tel-Aviv 64369 ISRAEL
Fax. + 972 3 696 2833
Tel. + 972 3 696 2833
E-mail merhlev@techunix.technion.ac.il

Abstract

A company should continuously adjust its objectives, activities and organization to the changing customer needs. The adjustment process may be done by a continuous process of comparing ones' products, services and practice either with the strongest competitor or with those companies that are regarded as the industrial leaders. i.e. a relative measurement.
With the conviction that an ATO - Absolute Theoretical Optimum exists, It is proposed to use it as an absolute measurement yard stick instead of the relative yard stick.

This paper will present the basic concepts of a system that construct and use the ATO concept. It will concentrate only on two, out of many, stages and methods: The setting of company level of competitiveness and computerized product definition and design.

A report on a project, that was carried on along the basic concepts, in electronic company will be given. It proved that savings of $11 million could have been made in a project of $15 Million. Product specifications that used to take several month, of negotiation with customers, can be made within a few days. Product design time was reduced to a few weeks.

Keywords

Manufacturing systems, product specification, product design, process planning, production management, benchmarking

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1 INTRODUCTION

The competitive market of today imposes new demands and objectives on the manufacturing process. Demands such as: Short time to market; Product diversity and options, Quality products; customer satisfaction and customer seductiveness and naturally competitive price. The traditional methods do not supply solutions to the new demands, and therefore new methods and solutions are being proposed. Most of the proposed new methods are good ones, however, they aim to solve some aspects of the manufacturing process, while ignoring others.

The product specification has to seduce the customer, with its options and appearance. To arrive at such specifications many disciplines of the manufacturing cycle should be involved, and a comparison to similar products, produced all over the world, must be made (Benchmarking, One of a Kind, World Class Manufacturing, etc.).

To arrive at a product design that will result in low cost, ease of manufacturing and ease of assembly must be considered. (DFM, DFA, Concurrent Engineering etc.).

The manufacturing process must consider the points of view of many disciplines in order to arrive at good performance. Each discipline considers a problem at hand from a different angle For example :-

- The product designer will evaluate methods of achieving product functions
- Marketing will evaluate its seductiveness to the customers
- Finance will evaluate the required investment
- Manpower will consider the work force demands
- The manufacturing engineer will consider floor space and material handling
- Purchasing and shipping will consider how to store the product
- and so on.

A good balanced and unbiased decision will be arrived at by considering the view points of all disciplines and finding a compromise between them all. The need for such a compromise is also commonly accepted. The problem is: How to arrive at such a compromise. The easy solution, and not an imaginative one, is to set committees and group discussions.

The structure of the manufacturing process is a result of evolution over many years. Evolution that utilized the available resources of that time to the outmost. However, the situation, working tools, conditions and objectives have since changed, and there is now no reason to keep the old faithful solutions to problems that do not exist any more. New problems needs new solutions. Computers introduce new capabilities to the manufacturing process and may be the basic element for new solutions.

In our studies we arrived at the conclusion that the most critical drawbacks of present day manufacturing philosophy and methods are that:

1. Decisions are being made too early.
   Therefore they must ignore market fluctuations and demands and shop floor on-line situation. Thereby fictitious constraints, such as: limited product options, bottlenecks, machine overload and underload, failure of meeting due dates, etc. occur.
2. Decisions are being made by managers that are not always experts in the decision matter involved They do not always know the implication of their decision on the overall plant strategy.

Data transfer between stages is of decisions only and does not reflect the decision maker intentions, alternative, methodologies, new ideas, etc.,

To overcome these drawbacks re-structuring the manufacturing process is proposed.

This paper will describe the basic concepts of the proposed system and concentrate on only two stages and methods. The setting of company level of competitiveness and product definition and design.

A report on a project, that was carried on along the basic concepts, in electronic company will be given. It proved that savings of $11 million could have been made in a project of $15 Million Testing equipment that used to be non-recurring becomes useable. Dead stock was reduced by $2500,000. Product specifications that used to take several month, of negotiation with customers, can be made within a few days. Product design time was reduced to a few weeks.

2 BASIC CONCEPTS

The basic concepts of the proposed system are:

a. The manufacturing process is composed of many disciplines that their point of view must be considered. The personal in each discipline is trained and is an expert in the specific subject matter. In many cases a decision taken by one discipline, on matters that are not crucial to them, might affect drastically the performance of another discipline. Therefore:
   Each stage in the manufacturing process must consider other stages interest, but make decisions only in its area of expertise and to product functionality.

b. The manufacturing environment is very dynamic. The decisions should consider the conditions at the time of decision making. If decisions are being made too early they must ignore market fluctuations and demands and shop floor on-line situation. Optimum decision that were taken at a certain point in time might not be good at another time. The manufacturing process is basically very flexible and this flexibility should be utilized. Therefore:
   Decisions will be made at the latest moment possible, i.e. at the execution time.

c. The manufacturing process is composed of a series of decisions, where each decision depends on the decisions taken in the previous stage. If a decision maker would know the reasons that led to the acceptance of a decision he will have additional degree of freedom in the decisions that he has to make. Therefore:
   Data and decisions transfer between stages will include intentions, alternatives, ideas, reasons etc. and not merely decisions.

d. Each stage of the manufacturing process have its own objectives and criteria of optimization. Optimization of a single criteria does not necessary result in overall optimization. Advancement from operation - part - product mix optimization should continue to manufacturing optimization. This task may be achieved in the computerized era. Therefore:
   The manufacturing process will be carried out by appropriate computer programs and aimed at Total Manufacturing Operations optimization

To imply the above concepts the many disciplines involved are divided into three groups, which are:

Group A -- Includes those disciplines that make the decisions.

Group B -- include all disciplines that are affected by the decision taken.

C -- Includes the technical disciplines whose decisions are based upon mathematical computations.

The disciplines in each group are listed in the Table 1.

Table 1 Arrangement of disciplines in groups

GROUP C	GROUP B	GROUP A
BILL OF MATERIAL	MARKETING	
	SALES	PRODUCT
ORDERS	COSTING	DEFINITION
	ECONOMICS	
MATERIAL	SHAPE	PRODUCT
REQUIREMENT	COLOR	DESIGN
PLANNING	STORAGE	
	COLOR	PROCESS
PRODUCTION	MATERIAL HANDLING	PLANNING
SCHEDULING	PACKING	
	SHIPPING	PRODUCTION
	PURCHASING	MANAGEMENT
	BOOKKEEPING	
	CUSTOMER RELATION	

A brief description of the product definition stage will be presented following by a practical project made along those lines. The product design will be referred only to its role in the project. Production management should serve two main purposes:

1. Supply data to management business decisions
2. Released orders to shop floor and to purchasing.

In this paper only an example of setting of company level of competitiveness will be discussed. In the discussion a short explanation of the process planning stage will be given.

Group C is an extenuation of the production management second purpose. A single combined program runs: Master production schedule; Material Requirement (Resource) Planning; Capacity Planning. However, this stage will not be discussed in this paper.

3 PRODUCT DEFINITION

The activities in the product definition field might be of three types:-

1. The company may manufacture to order. In such cases the product is defined by the customer. However, it will be a good idea to consult with the manufacturer on the design of the production order to reduce manufacturing costs.
2. The company manufactures a line of existing products. In such cases it is a good idea to keep track of possible design changes that might reduce manufacturing costs, increase product appeal to customers, and introduce options and new models of the same product.
3. The company would like to enter a new field of activities.

It is a natural tendency for the one who specifies product characteristics to aim for the best, and rightfully so. However, he is not always aware of the costs and manufacturing implications. In many cases, reducing the specified values by as little as 5% may result in cost reduction of more than 60%. We assume that the product specifier may change the specifications when he is aware on this effect.
Let us take, for example, a bathroom scale. The accuracy of the scale has to be specified. It is nice to have a scale with an accuracy of +/- 1 gram. It can be done. However, it calls for more costly accurate sensors and support circuits. If the accuracy will be specified as +/- 100 grams, a simple sensor and a low cost product will result.

Any product is used to fill a certain need. To perform these objectives, certain functions must be available, and have to be specified accordingly. However, there are many features that do not contribute to the main objectives of the product but come to serve as supporters. Following the previous example, the display is essential for the product's performance, but the method by which it is held, and shaped is irrelevant to the product performance. We suggest to call such features "fillers." Research has indicated, that in many cases, the product specifier does not pay much attention when specifying fillers even though, the fillers cost is not negligible. Marketing (group B) must be consulted in this decision.

The objective of the product definition module is to assist the product specifier in defining a product that will meet all product objectives, with a minimum cost and lead time. The philosophy behind this proposal is that product definition is an innovation process and, as such must leave freedom and judgment to the individual that performs this task. The role of the computer will be to draw the attention of the user to the meaning of his decisions and, in some cases, to propose alternatives. However, the final decision is left to the user.

It has been realized that a computer system that assists in defining new product may be used for budget control, and suggest options and alternatives in cases of changes in market demand and technology. Moreover, the computer program may be used by managers to follow up the progress of the projects in the sense of time keeping, and more important in the sense of assuring that all relevant factors and procedures has been considered.

This study proved that within a few days an optimum product definition that gets the approval of all disciplines has been specified. The difference between this approach and that of Value Engineering, or the TQM is that this methodology handles the initial design, and not the post-Morton improvements.

4 COMPUTERIZED PRODUCT DEFINITION - Project report

The basic concept behind this system is that each manufacturing company is in a specific line of products or business. A line of products usually has many common features. For example:
A Radar system, have a basis, electronics, servo system, power supplies etc.
A communication products have a power supply, cabins, printed boards, antennas etc.
Optical products have lens, lens holder, polishing technique, electronics etc.
Rocket engine have nozzles, isolation, propellants, Guides systems have sensors, electronics etc.

As one may notice, even in different line of products there are several common sub-assemblies, not to mention different models of the same product. Each one have its own characteristics and requirements, yet there is something in common. The proposal is to study the products in order to come up with a "MASTER DESIGN". A "master design" is defined as schematic block diagram of the product, where each block of the diagram represents its objective and includes alternatives, availability and cost information together with technical specifications. The purpose of this "master design" is to guide the product specifier in decisions that has to be made, and draw his attention to the effect of the decision on the product cost and lead time.

A dialog computer program that includes the "master design" and a "NOTE file" that contains group B disciplines remarks and demands; market research of competitive products; database of suppliers of off the shelf products; test equipment; tooling , is used to guide the product specifier in his task.

The concept was implemented in an electronic plant on developing monitors. The main problem was that it took over 4 month of negotiations with the customer to define the specifications of the required monitor, and agreeing on cost and time table.

A study the line of monitors shows that a one block diagram may represents all types of monitors. Studying the different block diagram indicates that a typical block diagram may be form, including

- CRT
- High Voltage Power Supply (HVPS)
- Low Voltage Power Supply (LVPS)
- Vertical & horizontal deflection assembly
- Vertical & horizontal sweep generators
- Video amplifiers
- Brightness control
- RGB output stage
- Digital control
- Sync timing & blank circuits
- Protection circuits
- Picture correction circuit
- Bit & filters

Moreover, the main video amplifiers, deflection assemblies, Synchronization and protection circuits may be designs in such a method that they will fit, with minor adaptations, any monitor .

The decision tree computer program is a very large, and calls for a detailed technical and professional study. In the following a sample portion of the computer program will be presented.

The user is asked to specify the purpose of the session, such as:

- New product
- Improvement of existing product
- Incorporating new technologies.
- Market data: who are the potential market, expected quantities.

Monitors basic classification are according to their intended use. Therefore the session initial inquiry is:

- Is it a monitor for civilian or military use

- Is the monitor for airborne, marine or land usage.

The next inquiry is the size of the monitor. An help function will display the standard available commercial monitors. If the user selects a non-standard size, the system will display a note stating: "The specified monitor size is not a standard one. Please be aware that in this case the cost of the product will might be 1000 higher the a standard size, and the developing and delivery time might be several months, as compare to a day or so, for a standard size". " Please reconsider and confirm your choice"

Next inquiry is " A color or a monochrome monitor ". The cost difference will be display as help.

The display may be a CRT, LCD, LEDS or Plasma screen. The user is asked to specify his choice. An help screen will display the operation difference and the associated circuits, and any other information that will assist the user in making his choice.

The following example will concentrate on CRT screen. CRT screen may operate in a raster scan mode or a stroke on raster. To understand the difference between these two option, An help screen may be called and will look like:

> "Usually Raster scan display a video picture while stroke display alpha-numeric text and special symbols. The difference lies with the yoke drivers, the deflection circuits. The response of the stoke mode is faster. Therefore the deflection model and the amplifiers are more complicated. The cost of a deflection model for stroke/raster mode might be twice as much as raster mode, $500 compare to $1000."

Depending on the decisions the program will present inquiries regarding the speed (25,000 or 50,000 for stroke ; 525 or 875 for raster) following by selection of brightness, contrast etc.

The decision made dictates the specifications for the required circuits.

The environmental requirements such as: temperature and altitude, sand and dust, humidity, vibration, mechanical shock, acceleration etc. specified by the user will consult with the group B Note file. The user might pass and let the auxiliary files set the required value.

To get cost estimation the system will attempt to do part of the design at the specification stage. Keeping on with the CRT example, the system will call the suppliers database in search for the specified CRT - by size, color, brightness resolution etc. It will compare prices for the available products. If exact requirements are not found, it will propose changes, if economic, that will not effect the performance but rather reduce product cost. If no one of the suppliers can meet the desired CRT specifications, the system will call a routine that guide the user in specifying the required parameters, such as (in case of CRT) :- Line width, warm-up time, x-ray radiation, stray emission etc. The group B Note file will be used to set parameters or to compare the specified ones.

It is quit an extensive job to form such a computer program. The main effort is not in programming but rather in technological studies of the products, the controlling factors, the effect of the parameters on product performance. Yet, for a line of products, it is a one time job.

A project that was carried on in electronic company that developed monitors, has indicated the by using the proposed method it takes only a few days to specify a new product, that gets the approval of all disciplines and customers.

This project was extended, using similar approach to the design stage.

When ever a module is needed, such as a HVPS, first priority is given to in plant inventory. In case that such item is not found, a search for similar item is made. Check is made if the specifications may be changed and use the replacement item. If not, an estimate is made as to the modification cost of the available item. In parallel a search in the suppliers database is made and availability and costs are compared. In case that there is no standard, off the shelf item, a request for quotation is issue. A decision of comparing the in house modification cost and the external suppliers item cost is made, and a decision is taken of where and how to supply the required item. Consideration is given to dead stock item, Preferred Part List (the computer will enforce the use of company standards) , available testing equipment (usually it is a non-recurring equipment, and it cost is not negligible).

An estimated cost comparison of the last four monitors developed with a total cost of $15,130K indicates that by employing proposed system the total cost could have been $3,810K. Dead stock reduced by $2500,000. Product specifications that took several month, of negotiation with customers, can be made within a few days. Product design time was reduced to a few weeks.

5 SETTING COMPANY LEVEL OF COMPETITIVENESS

Machining efficiency is defined as the suitability of the resources to the product mix. It establishes plant level of performance and thus the ability to compete on the market. The machining efficiency is not the only parameter that effects the competitive ability, however, in this paper we will treat only this aspect. Machine efficiency varies in time, as product mix might change and new machines are introduced possessing more and better capabilities. Therefore, a continuous evaluation of the fitness of the machines to the product mix must be made. This is a huge task, and due to lack of efficient tools it is seldom done. A computerized method that may be used to perform the evaluation task and establish the level of competitiveness in an honest, justice, and free from improper influence is presented. The method employs the matrix concept.

5.1 The matrix concept

The proposed system philosophy is that each decision should be made by the most qualified person and at the latest moment possible, i.e. at the point where work is being performed. Therefore, process planning is divided into three stages.

The first stage is the ATO - Absolute Theoretical Optimum , it is a fixed universal reference point. Its value is based on actual available technology. It considers real strength and technical constraints. It assumes an imaginary machine, that is, no machine constraints are considered. Thus the ATO process plan is practical from the engineering standpoint and theoretical from a specific shop standpoint.

The second stage builds an operation-resources matrix, where the operations are those that were specified into ATO stage, and the resources are those available at a specific shop. The PTO -Practical Theoretical Optimum , represents the minimum time or cost to machine an operation. It is practical, as the machines are available at the specific shop. It is theoretical as the required machine might be occupied (overloaded).

The third stage is solving the matrix. The PTO total value gives the optimum machining time by performing individual operation optimization i.e. using the best machine for each operation. However, individual operation optimization must not result in part optimization. To arrive at part optimization, the expenses of setup, inspection, transfer time between machines, machine rates etc. must be considered Notice that these expenses are for a batch, and therefore depends on the quantity to be produced. The optimum process must be a compromise between all expenses and the individual operation cost. The part optimum process will be given by a path that, comprises all the operations and, results in a minimum sum of machining time (or cost) values registered in the matrix, with a sequence constrained by the priority number and with addition of a penalty for changing machines. For solving this matrix problem a special technique has been devised, and it can be done within seconds.

An example of a matrix containing operation cost and time for part #1 is shown in the following table.

Table 2 Machine - Operation Matrix (T = Time : C = Cost)

Oper-ation	ATO	#1	Mach. #2	#3	#4	#5	#6	PTO	Prio-rity
010 T	0.47	0.57	0.62	1.28	99	1.62	1.18	0.57	0
C		2.28	1.86	1.79	99	1.62 *	2.36	1.62	
020 T	0.17	0.27	0.32	0.88	99	1.22	0.59	0.27	010
C		1.08	0.96 *	1.23	99	1.22	1.18	0.96	
030 T	0.31	0.41	0.46	0.97	99	99	0.56	0.41	020
C		1.64	1.38	1.36	99	99	1.12 *	1.12	
040 T	1.89	1.99	2.04	2.55	99	99	2.14	1.99	030
C		7.96	6.12	3.57 *	99	99	4.28	3.57	
050 T	0.24	0.34	0.39	0.99	99	1.35	0.74	0.34	010
C		1.36	1.17 *	1.39	99	1.35	1.48	1.17	
060 T	4.16	4.26	4.31	4.82	99	99	4.41	4.26	050
C		17.04	12.93	6.75 *	99	99	8.82	6.75	
070 T	0.03	0.13	0.18	0.69	0.69	1.03	0.28	0.13	020
C		0.52 *	0.54	0.97	0.69	1.03	0.56	0.52	
080 T	0.22	0.32	0.37	0.89	0.86	1.22	0.47	0.32	070
C		1.28	1.11	1.25	0.88	1.22	0.94 *	0.94	
090 T	0.20	0.30	0.35	0.86	0.86	99	0.45	0.30	080
C		1.20	1.05	1.20	0.86	99	0.90 *	0.90	
	7.69	8.59	9.04	13.93			10.82	8.59	TIME
Total	7.69	34.36	27.12	19.51			21.64	17.55	COST

5.2 Machine level of competitiveness

The definition of machine level of competitiveness might have three forms:
a. Competitiveness ratio of machining time - MRT
b. Competitiveness ratio of machining cost - MRC
c. Competitiveness ratio of machine utilization - MRU
The decision of which rating to use, is up to the user (management).
The definition of the ratio of machining time (or cost), is set to the average ratio of the Practical Theoretical Optimum (PTO) to the Absolute Theoretical Optimum (ATO) of all products forming the product mix. These two values are given by the matrix format as shown in tables #2.
By definition, the closest the ratio is to the value of one (1) the shop is in a better competition position. These definitions are presented by the following equations:

$$MR = \frac{1}{P}\sum_{i=1}^{P}\frac{PTOi}{ATOi} \qquad [1]$$

Where: MR - Machinability Rating
P - Number of parts
PTOi - Practical Theoretical Optimum of machining part i
ATOi - Absolute Theoretical Optimum of machining part i

Note that the ratio of PTO/ATO for a single part is the specific part machining ratio.
The MR - Machining Rating may have one of the four forms:
MRTT - Machining Time in case of maximum production criteria of optimization
MRCT - Machining Time in case of minimum cost criteria of optimization
MRTC - Machining Cost in case of maximum production criteria of optimization
MRCC - Machining Cost in case of minimum cost criteria of optimization
For each on of the following cases the appropriate PTO and ATO value will be inserted in the machining rating equation.

The definition of machine utilization - MRU is the ratio of the individual machine occupation time for a single part to the machine with the maximum occupation divided by the number of machines. This definition can be expressed by equation #2.

$$MRU = \frac{1}{M}\sum_{j=1}^{M}\frac{\sum_{i=1}^{P} MTi}{MAX\sum_{i=1}^{P} MTi} \qquad [2]$$

Where : MRU - Machining Rating for machine Utilization
M - Number of machines
P - Number of parts
MTi - Total machining time of part i machine m
MAX - The maximum value of machining time on a single machine

By definition, the closest the ratio is to the value of one (1) the shop facilities are fully utilized. Zero means a machine that no part is using it.
The above definitions are based on manufacturing a single part, or the same quantity of all the parts. If one wishes to consider a different quantity of each individual part equation #1, may be modified to have the form of equation #3.

$$MRQ = \frac{1}{\sum_{i=1}^{P} Qi} \sum_{i=1}^{P} \frac{PTOi}{ATOi} \times (Qi) \qquad [3]$$

Where:
MRQ - Machinability Rating with quantity effect
P - Number of parts
PTOi - Practical Theoretical Optimum of machining part i
ATOi - Absolute Theoretical Optimum of machining part i
Qi - Quantity of part I

and the machine utilization be modified to have the form of equation #4.

$$MRUQ = \frac{1}{M} \sum_{j=1}^{M} \frac{\sum_{i=1}^{P} MTiQi}{MAX \sum_{i=1}^{P} MTiQi} \qquad [4]$$

Where : MRUQ - Machining Rating for machine Utilization with quantity effect
M - Number of machines
P - Number of parts
Qi - Quantity to produce of part i
MTi - Total machining time of part i machine m with quantity Qi
MAX - The maximum value of machining time on a single machine, or the number of minutes that the quantity has to be manufactured.

The above machining rating result with the competitiveness rating of the product mix. The following examples will demonstrate the use of the rating system.

5.3 Machine level of competitiveness - example

Assume that six parts has to be manufactured on the available seven machines. The procedure of the matrix format was followed and the routing of each one of the parts is as shown in table #3. (data of part #1 are taken from tha matrix shown in table #2). The numbers in the machine raw indicates the machining relative hourly rate,(e.g. hourly rate of Mac#1 is 4.00). The numbers in the ATO column indicates ATO machining time and cost (relative hourly rate is one) and below it the quantity required for each part. For each part there are four raw in the table.

The first raw indicates the Cost of operations on the machine for minimum cost criteria.
The second raw indicates the Time of operations on the machine for minimum cost criteria
The third raw indicates the Cost for maximum production criteria.
The forth raw indicates the Time for maximum production criteria.

The MRT and MRC columns indicates the machining rating for time and cost for each raw.

At the bottom part of the table totals and rating are given. Using equation #1 the four machining rating for the data given in the example are:

For case of maximum production criteria of optimization :

MRTT = 1.35 MRTC =3.73

MRUT = 0.355

For case of minimum cost criteria of optimization :

MRCT = 2.03 MRCC = 2.91 MRUC = 0.564

Table 3 Data for the example

t No.	ATO	Mac#1	Mac#2	Mac#3	Mac#4	Mac#5	Mac#6	Mac#7	PTO	MRT	MRC
		4.00	3.00	1.40	1.0	1.0	2.00	1.70			
1	7.69		2.13	10.32		1.62	3.52		17.59	0	2.287
			0.71	7.37		1.62	1.76		11.46	1.49	0
		34.36							34.36	0	4.468
	1000	8.59							8.59	1.117	0
2	12.33		6.85	13.17	5.93	4.78	11.19		41.92	0	3.40
			2.28	9.4	5.93	4.78	5.6		27.99	2.27	0
		62.4							62.4	0	5.06
	2000	15.6							15.6	1.265	0
3	4.8			4.5	2.83	3.15	2.48		12.96	0	2.7
				3.21	2.83	3.15	1.24		10.43	2.173	0
							13.92		13.92	0	2.9
	3000						6.96		6.96	1.45	0
4	17.48		18.74	12.11	9.64	6.38		21.3	68.17	0	3.9
			6.25	8.65	9.64	6.38		12.53	43.45	2.486	0
		57.88						12.55	70.43	0	4.03
	1500	14.47						7.38	21.85	1.25	0
5	13.5			5.64	7.84	4.38		2.57	20.43	0	1.51
				4.03	7.83	4.38		1.51	17.75	1.31	0
					6.9			15.81	22.71	0	1.68
	2500				6.9			9.3	16.2	1.2	0
6	14.9		11.68		11.12	8.76	9.15	13.68	54.39	0	3.65
			3.89		11.12	8.76	4.58	8.05	36.4	2.44	0
			42.9	3.04		2.77	7.8	6.32	62.83	0	4.22
	2000		14.3	2.17		2.77	3.9	3.72	26. 86	1.80	0
	MTTop	38.66	14.3	2.17	6.9	2.77	10.86	20.4	$\sum$Topt	8.08	22.36
	MTCop	0	13.13	32.66	37.35	29.07	13.18	22.09	$\sum$Copt	12.17	17.45
	$MRUT_i$	1.0	0.37	0.056	0.178	0.071	0.281	0.528	0.355	1.35	3.73
	$MRUC_i$	0.0	0.351	0.874	1.0	0.778	0.353	0.591	0.564	2.03	2.91

The results clearly indictate, that the available machines are in a good competitive standing, in case that the competition is on fast deliveries, however, it results in a penalty of excessive production cost, and idle machines. It is up to management to decide on the compromise that is most profitable for plant operation. The matrix method may be used in deciding on such compromise.
The quantity effect may be checked using similar method but with the appropriate equations.

5.4 Improvement competitiveness level

The Machinability Rating indicates the plant total of the plant product mix. However, in order to evaluate, and search ways to improve the competitiveness level, additional information is needed. Such information is available through the matrix method.

The machining rating for machining time is 1.35 for maximum production and 2.03 for minimum cost criteria of optimization. However, there are quit large variations between individual parts.

Figure 1 shows these variations. It is clearly seen that while the chosen machines are in good correlation with the requirement of part #1 & #5, they do not result with good rating for part #4. The chosen machine where based on purely mathematical basis and local optimization. As can be seen from table #2 a minute change in machining time may result with a substantial reduction of cost.

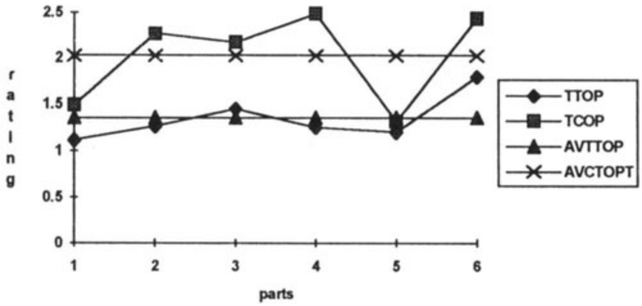

Figure 1 machinability rating for machining time.

The rating gives a good indication of the fitness of the available machines to the product mix. The machining utilization ratio indicates the average level of machine utilization. However, it does not indicates the load capacity of each individual machine, this is shown in figure 2. Examining this figure it is clearly seen that there is a significant difference in individual machine utilization as a function of the criteria of optimization. The extreme is that machine #1.

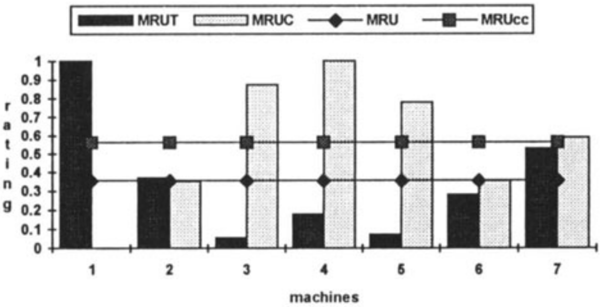

Figure 2 : Machine utilization vs. machine rating

For each part there exist a matrix as shown in table 2. For the case of simplicity the following example will relate only to this data. Table 2 reveals that if in case of maximum production machine #2 will be employed instead machine #1, which is the optimum machine, the increase in machining time will be 5.2% (from 8.59 to 9.04) while the decrease in cost will be 20% (from 34.36 to 27.12). Other modifications might be to move operation 040 from machine #2 to machine #6 (increase time from 2.04 to 2.14; decrease in cost from 6.12 to 4.28) and operation 060 to machine #3 (increase time from 4.31 to 4.82 ; decrease in cost from 12.93 to 6.75) and making similar changes in parts #1 #2 and #4 the utilization rating will increase to 0.7. See figure 3.

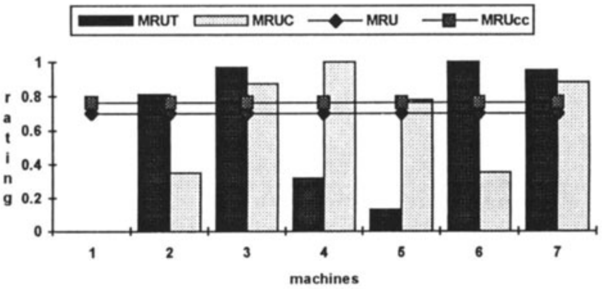

Figure 3 Machine utilization vs. machine rating (improved)

Notice that the balance between the two criteria of optimization, which means that the set of machines may serve both criteria. Further improvement may be made. This load balancing have effect on the machinability rating . The effect of the above modifications are seen in figure 3. It is clearly seen that while the changes caused a slight increase in the machining time rating, they reduced substantially the machining cost rating. The adjustment and improvement can be realized only because the data transferred is by the matrix format and not as a fix routing.

6. CONCLUSIONS

The manufacturing process is very flexible by nature. However, the structure of the manufacturing process employed today makes it rigid. Therefore, re-structuring of the manufacturing process is proposed. The basic concepts of the proposed system are:

a. Each stage in the manufacturing process must consider other stages interest, but make decisions only in its area of expertise and to product functionality.
b. Decisions will be made at the latest moment possible, i.e. at the execution time.
c. Data and decisions transfer between stages will include intentions, alternatives, ideas, reasons etc. and not merely decisions.
d. The manufacturing process will be carried out by appropriate computer programs and aimed at Total Manufacturing Operations optimization

The system encompasses several stages. In this paper the product definition stage and the supplying data to management are detailed.

The objective of the product definition module is to assist the product specifier in defining a product that will meet all product objectives, with a minimum cost and lead time. The philosophy behind this proposal is that product definition is an innovation process and, as such must leave freedom and judgment to the individual that performs this task. The role of the computer will be to draw the attention of the user to the meaning of his decisions and, in some cases, to propose alternatives. However, the final decision is left to the user.

It has been realized that the computer system that assists in defining a new product may be used for budget control, and suggest options and alternatives in cases of changes in market demand and technology. Moreover, the computer program may be used by managers to follow up the progress of the projects in the sense of time table, and more important in the sense of assuring that all relevant factors and procedures has been considered.

A report on a project, that was carried on along the basic concepts, in electronic company was presented. It proved that savings of $11 million could have been made in a project of $15 Million. Product specifications that used to take several month, of negotiation with customers, can be made within a few days. Product design time was reduced to a few weeks.

A company should continuously adjust its objectives, activities and organization to the changing customer needs. The adjustment process may be done by a continuous process of comparing one's products, services and practice either with the strongest competitor or with those companies which are regarded as the industrial leaders. i.e. a relative measurement.

One parameter that should be continuously under control is the machining efficiency. It establishes plant level of performance and thus the ability to compete on the market. Machine efficiency varies in time, as product mix might change and new machines are introduced possessing more and better capabilities. Therefore, a continuous evaluation of the fitness of the machines to the product mix must be made. This is a huge task, and due to lack of efficient tools it is seldom done. A computerized method that may be used to perform the evaluation task and establish the level of competitiveness in an honest, justice, and free from improper influence is presented. The method employs the ATO - Absolute Theoretical Optimum and the matrix concept.

With the conviction that an ATO exists, It is proposed to use it as an absolute measurement yard stick instead of the relative yard stick. A method how to do it was described.

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8. BIOGRAPHY

Gideon Halevi received his M. Sc in Mechanical Engineering from the University of Pennsylvania (1959) and his Doctor of Science in Technology from the Technion (1973). He is as adjunct professor at the Technion (1981), teaching mostly at the graduate school on CAD/CAM and CAPP. For more than 30 years he has been active in industry in production development, Combine Technical Operations, heading the corporate computing center and as manager and director of the CAD/CAM Research and Development Center. He has developed the All Embracing Technology, which was published in his book "The Role of Computers in Manufacturing Processes (Wiley 1980). He is an active member of the CIRP, Israeli representative to IFIP TC5, a member of IFIP WG5.3 and WG5.7, past chairman of SME chapter 319 and chairman of IPICS.