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Production Process and Inventory Management for Machine Tool Companies: Analysis and Development of Optimisation Models

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EMCO MECOF (formerly MECOF)

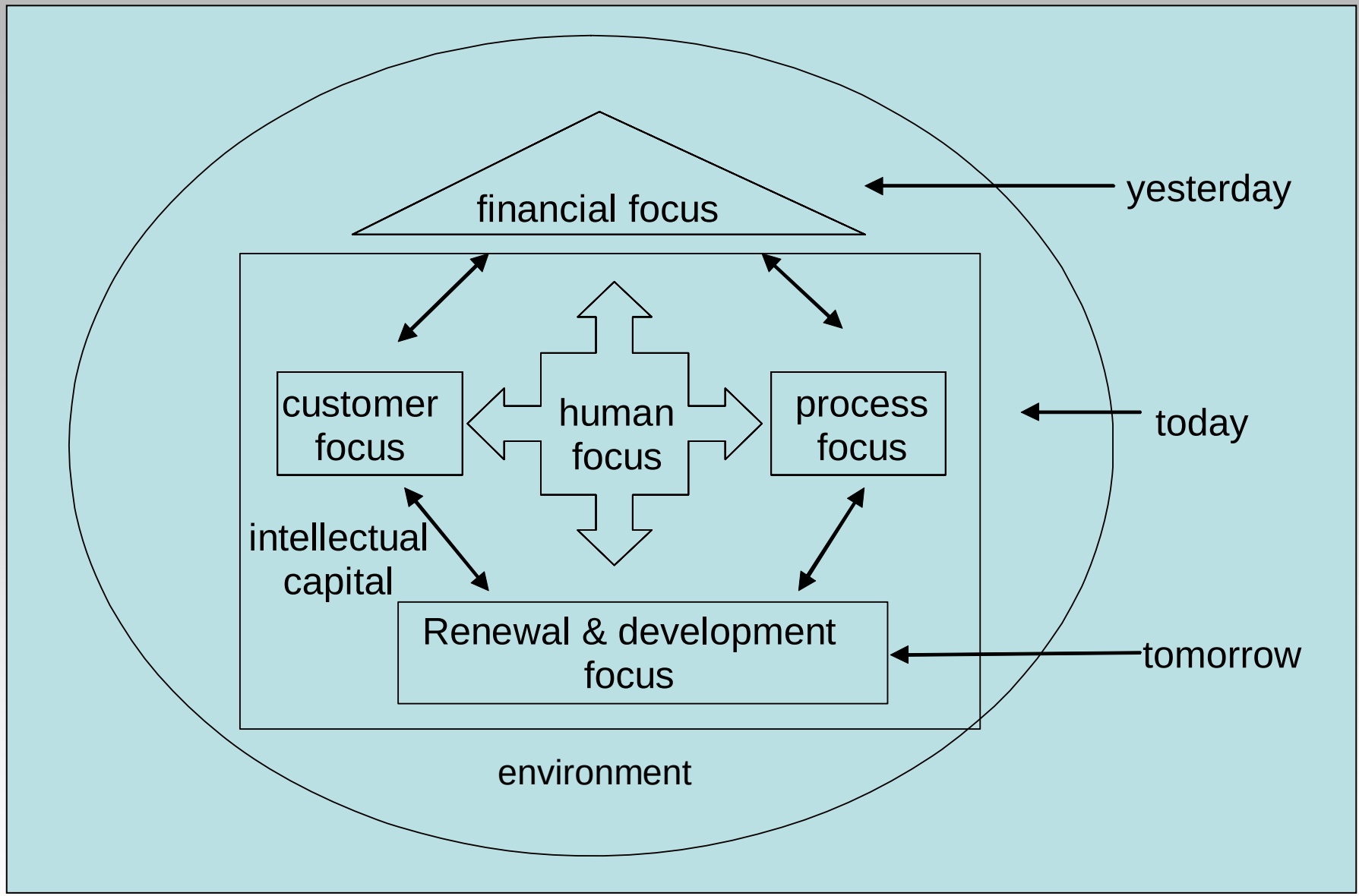
Milling machines
working volume (max): 14000 x 1250 x 2000 mm^3
2000 components:
50 parts hold 80% cost
80 parts represent 15% cost

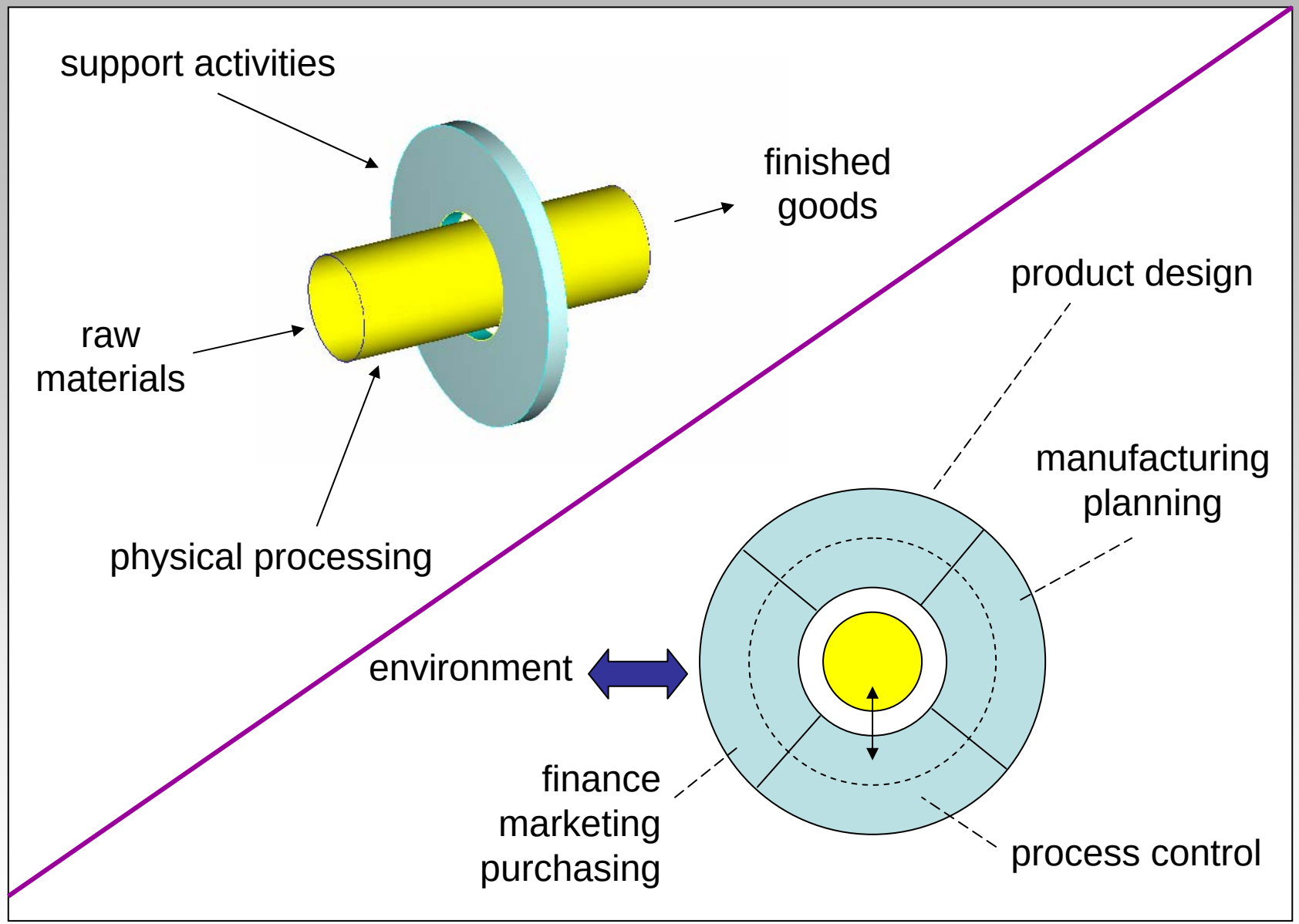
Agile CS 500
Precisa CSX
Precisa MX
Linea PERFORMA
Linea PRIMA
Linea Agile M
Linea Dynamill
The Machine
AirOne 165-220

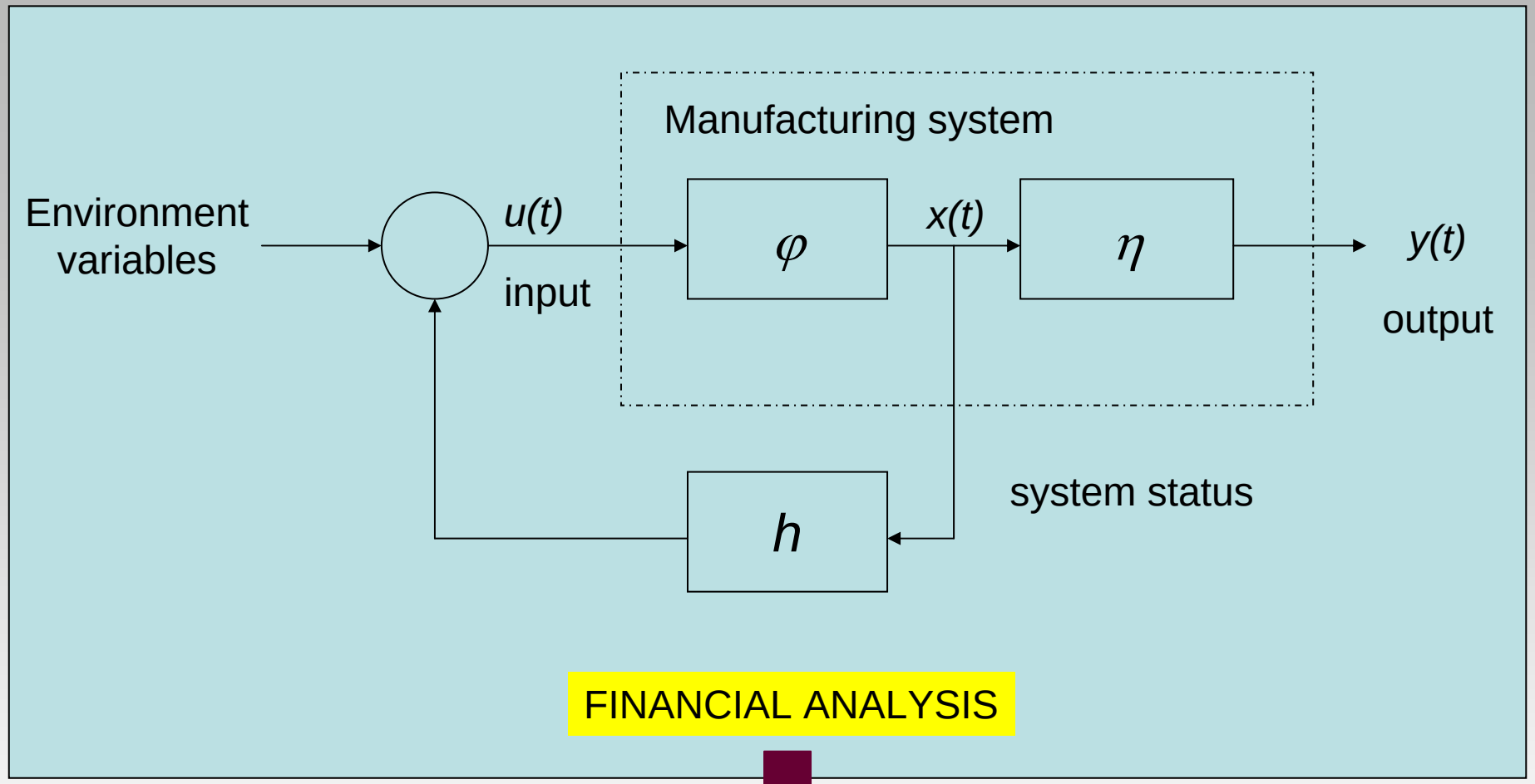
year 2000

Workforce: 500
Sales: 58 M€

1852 milling machines (since 1946)
1096 customers (since 1946)


financial focus
yesterday
customer focus
human focus
process focus
today
intellectual capital
Renewal & development focus
tomorrow
environment


support activities
finished goods
raw materials
physical processing
product design
manufacturing planning
environment
finance
marketing
purchasing
process control

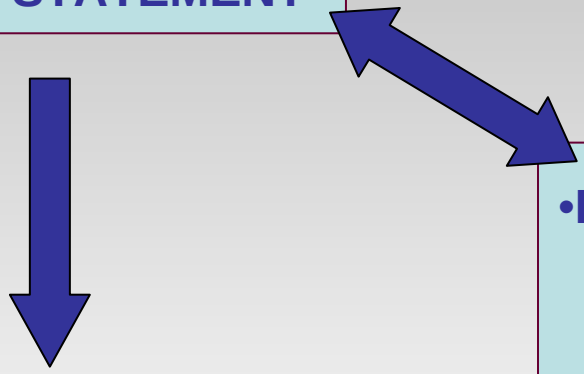


FINANCIAL ANALYSIS

STRUCTURAL / TECHNICAL IMPROVEMENTS

FINANCIAL ANALYSIS

- **BALANCE SHEET**
- **INCOME STATEMENT**



ANALYSIS RATIOS

- **HOMOGENEITY**
  - **SUBJECTIVITY**
  - **ACCOUNTING PRICIPLES**
- **NATIONAL LAWS HARMONIZATION**
- **TERMINOLOGY**
- **REFERENCE PERIODS**

ANALYSIS RATIOS

Profitability ratios	
Return On Equity (ROE)	Net profit after taxes (= net income) / stockholders' equity
Return On Investment (ROI)	Net profit after taxes / total assets
Return On Sales (ROS)	Income before taxes / net sales
Return on Capital Employed (ROCE)	Pre-tax operating profit / Capital employed

Activity ratios	
Inventory Turnover (IT)	Cost of goods sold/Average inventory value
Accounts Receivable Turnover (ART)	Net sales / Average Account Receivables for the Period
Average Collection Period (ACP)	Average Accounts Receivable / (Net sales / Number of days in the period)
Accounts Payable Period (APP)	Accounts payable / (purchases on credit/ period of accounting statements)

INVENTORY TURNOVER (IT)

Company	Inventory Turnover (IT)		
	1997	1998	1999
MECOF	2.23	2.61	2.81
MCM	3.12	2.96	2.91
FPT	4.62	3.82	3.15
PARPAS	4.16	5.2	4.51
FOREST LINE	3.55	5.22	10.35
DROOP & REIN	3.63	3.77	5.16

DECISION EFFICIENCY

IT ⟺ WIP

IT ⇓ ROCE

$$WIP = \frac{PC \cdot U}{S_W \cdot H} \cdot MLT = W \cdot R_p \cdot U \cdot MLT$$

ROI = ROS x ROCE

$$TC_{pc} = C_m + C_1 + \int_0^{MLT} \left[C_m + \frac{C_1 \cdot t}{MLT} \right] \cdot h \cdot dt$$

ROI = Return On Investment
ROS = Return On Sales
ROCE = Return On Capital Employed

AVERAGE COLLECTION PERIOD (days)

Company	Average Collection Period		
	1997	1998	1999
MECOF	67	60	68
MCM	125	104	77
FPT	124	109	93
PARPAS	188	172	180
FOREST LINE	180	163	179
DROOP & REIN	42	65	55

ACCOUNT PAYABLE PERIOD (days)

Company	Accounts Payable Period		
	1997	1998	1999
MECOF	106	89	100
MCM	133	131	120
FPT	160	128	129
PARPAS	162	137	145
FOREST LINE	131	130	130
DROOP & REIN	25	34	33

MECOF PRODUCTION PROCESS

PRP – Project Required Planning

MRP – Material Requirements Planning

SIC – Statistical inventory Control

Production fired by → Customers' order OR Internal Order

CUSTOMERS' ORDERS

Model	N	Mean delay	delay / lead time	Mean lead time
		months	%	months
CR 15/SPEED	4	1,7	18,7 %	9,1
CS 50	3	0,9	14,8 %	6,1
CS 500	15	0,5	7,5 %	6,7
DYN. 2000/L	1	1,0	6,5 %	15,4
DYN. 3000/L	4	1,1	8,9 %	12,4
M 3	3	1,9	15,4 %	12,3
M 5.3	1	5,2	24,6 %	21,1
MILLER M1	1	0,6	5,2 %	11,6
Total	32	1,1	11,7 %	9,1

INTERNAL ORDERS

Model	N	Mean lead time
		months
CR 15/SPEED	8	0,9
CS 50	6	0
CS 500	15	0,5
DYN. 3000/L	2	1,3
M 3	4	0,7
PERFORMA	1	-1,0
Total	36	0,5

PC = 68 - WIP = 25

IMPROVEMENT OF MANUFACTURING ORGANIZATION

MRP + JIT

→ SHOP FLOOR SCHEDULING & CONTROL
(PRODUCTION CONTROL)

→ LONG RANGE PLANNING, SCHEDULING,
MATERIALS PLANNING & COORDINATION
(INTEGRATION PLANNING TOOL)

SCHEDULE INSTABILITY ⟺

FREEZING TECHNIQUES:
1. PLANNING HORIZON
2. FREEZING PROPORTION
3. RE-PLANNING PERIODICITY
4. FREZING METHOD

IMPROVEMENT STRATEGY

DEFINITION OF A NEW BOM STRUCTURE

1. **family**: similar products developed cooperatively by the design, purchasing, marketing and production departments;
2. **basic**: products designed to facilitate production, forecasting and planning;
3. **function**: similar products to improve production, forecasting and planning;
4. **module**: products characterized by efficient engineering and forecasting;
5. **model**: the end product;
6. **kit**: parts with specific functions;
7. **manufacturing assembly**: sub-assembly: used for production.

IMPROVEMENT STRATEGY

MULTI-STAGE APPROACH FOR PLANNING & SCHEDULING:

- sales forecasting governs inventory, annual production volume and capacity requirement plans
- orders for components and production facilities set accordingly to their delivery time in order to avoid any delay
- schedule horizon for the machine tool final assembly programs three weeks providing daily plans for each production line
- plans of the first two weeks are frozen

MRP & JIT INTEGRATION
(EARLINESS-TARDINESS PRODUCTION SCHEDULING AND PROGRAMMING)

earliness: difference between the delivery date and the due-date of the considered product

tardiness considers only the positive values of this difference otherwise it assumes the nil value

N types of products manufactured to satisfy market requirements in a time horizon $[1,T]$

M assembly or processing steps

$d_i(k)$ product *i* required in period *k*

$c_j(k)$ available capacity of process *j* in period *k*

w_{ij} unit capacity required by product *i* for process *j*

I_i initial inventory of product *i*

s_i lot size of product *i*

$p_i(k)$ planning production quantity of product *i* in period *k*

MRP & JIT INTEGRATION
(EARLINESS-TARDINESS PRODUCTION SCHEDULING AND PROGRAMMING)

$$\min_{P} = \sum_{i=1}^{N}\sum_{k=1}^{T}\left\{\alpha_i\left[I_i + \sum_{t=1}^{k} p_i(t) - \sum_{t=1}^{k} d_i(t)\right]^{+} + \beta_i\left[\sum_{t=1}^{k} d_i(t) - \sum_{t=1}^{k} p_i(t) - I_i\right]^{+}\right\}$$

CONSTRAINTS

$$\sum_{i=1}^{N} w_{ij} \cdot p_i(k) \le c_j(k) \qquad j = 1,2,\cdots,M; k = 1,2,\cdots T$$

$$0 \le p_i(k) \in S_i \qquad (i = 1,2,\cdots,N; k = 1,2,\cdots T)$$

$$S_i = \{r \cdot s_i, r = 0,1,2\cdots\}$$

$\alpha_i \quad \beta_i \quad (i = 1,2,\cdots,N)$ are the unit time earliness and tardiness penalty of product *i*

ETPSP FOR EFFICIENCY EVALUATION

P computation for actual and improved manufacturing organization

time horizon T = 1 year
classes of milling machines N = 6
machines produced di = 12, 9, 30, 6, 7, 4 (in yr 2000)
planned quantities pi = 16, 9, 33, 7, 7, 4
lot sizes si = 5, 1, 4, 2, 1, 1
production stages M = 4:

1. mechanical sub-assembly,
2. final mechanical assembly,
3. no mechanical parts assembly
4. final assembly

production capacity cj = 68 equal for all the production stages
unit capacity requirement wij of product i for process j:
wij = production capacity cj / produced quantities di
inventories level $Ii = 0$
$\alpha i = \beta i$ = mean delays for the make-to-order and the make-to-stock production

EFFICIENCY EVALUATION

Machine tools typology		s_i	$\alpha_i = \beta_i$
1	CR 15/SPEED	4	0,65
2	CS 50	1	0,23
3	CS 500	3	0,25
4	DYN 3000/L	1	0,60
5	M3	1	0,65
6	Other milling machines	1	1,45

Lot sizes and penalties (proposed model)

actual production: $P_0 = 7,9$
proposed approach: $P_{new} = 2,45$

EFFECTS OF MRP & JIT INTEGRATION

Model	Mean delay	Mean MLT
	months	months
CR 15/SPEED	0,85	8,3
CS 50	0,45	5,7
CS 500	0,25	6,5
DYN. 3000/L	0,55	11,9
M 3	0,95	11,4
Others milling machines	1,32	14,9
Total	0,53	8,5

CONCLUSIONS

- Procedure for inefficiencies audit
- Financial analysis
- MRP/JIT integration
- ETPSP for efficiency evaluation