Bertil N. Colding

MANUFACTURING AND ENTERPRISE ECONOMETRICS

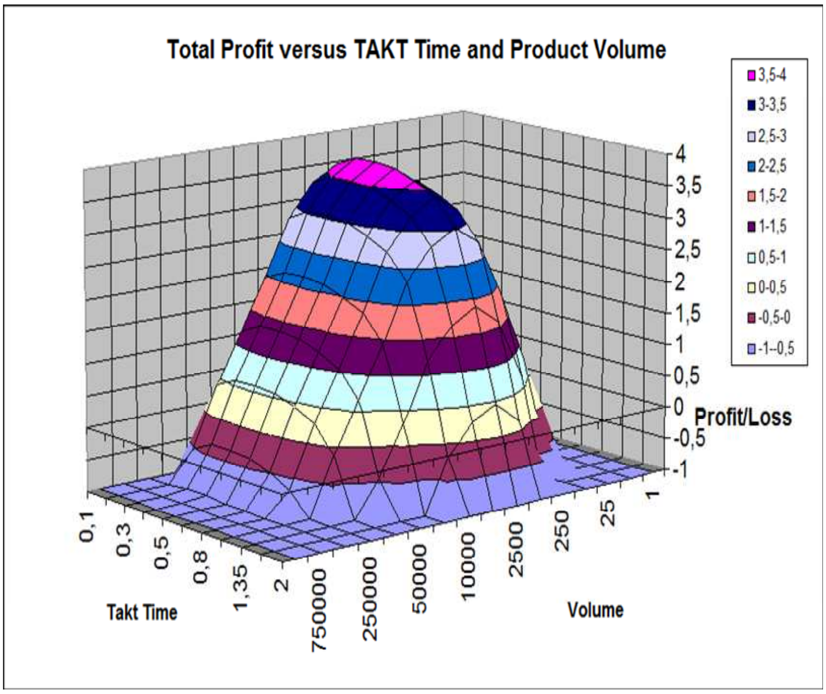
Part I. MANUFACTURING ECONOMETRICS –

Production Planning, Scheduling, Takt time. Weeks and Cost to complete Order

Part II. MANUFACTURING ECONOMETRICS –

Theory, Performance and Applications of Manufacturing Econometrics

Part III. ENTERPRISE ECONOMETRICS - Econometric Models and Forecasting



Textbook and handbook

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MANUFACTURING AND ENTERPRISE ECONOMETRICS

By Professor Bertil Colding

Bertil , born 23 August, 1927, became professor Mechanical Technology , KTH, appointed in 1967 after a seven years stay with ASEA (later ABB). He succeeded Ragnar Woxén , then Rector of KTH, who also was the prime examiner at the presentation of his doctor's theses:

Colding, B.N., 1959, A Wear Relationship for Turning, Milling and Grinding -Machining Economics, *Dissertation Teknologie Doktor, KTH.*

The Nomenclature Econometrics is concerned with the tasks of developing and applying quantitative or statistical methods to the study and elucidation of economic principles. Econometrics combines economic theory with statistics to analyze and test economic relationships.

In the CV Jubeldoktor Nils Bertil Colding on the last page you will find a description on one page of his academic and industrial backgrounds

Part I. MANUFACTURING ECONOMETRICS –

Production Planning, Scheduling, Takt time. Weeks and Cost to complete Order

Foreword

This Section describes an interactive process and production plan described in the two papers Plant Master and Takted Production. This involves procedures, calculation methods and results given in the Project work/ Industrial case Machining, a module this author as a committee member presented to the ***European Production Engineering Committee****, chaired by professor Mihai Nicolescu, KTH, Stockholm.*

There are approximately 15 necessary parameters required to perform a reasonably accurate cost assessment for a manufacturing system. In machining operations, we have to deal with an additional great number of parameters.

Formulas are given so that the users can program these into their own software programs.

The influence of asynchronous and synchronous product flow including the production layout on the feasibility are shown with examples focused on time/cost calculations, which are applicable to all manufacturing processes including the impact of planning lead time.

In almost all instances we have to consider "Granular Metrics", in order to do things right, which is described in Part III, Section 3.

The consensus regarding best practices is not only trying to reduce slack time (Non Value Added Time) as well as the Value Added Time, but the necessity for the manufacturing engineers to enhance the knowledge level, i.e. the great impact of Intellectual Capital, described in Part III, Section 7.

Table of Contents

1. INTRODUCTION

This Section describes an interactive process and production plan described in the two papers Plant Master and Takted Production. This involves procedures, calculation methods and results given in the Project work/ Industrial case Machining, a module this author as a committee member presented to the **European Production Engineering Committee**, chaired by professor Mihai Nicolescu, KTH, Stockholm.

There are approximately 15 necessary parameters required to perform a reasonably accurate cost assessment for a manufacturing system. In machining operations, we have to deal with an additional great number of parameters. Formulas are given so that the users can program these into their own software programs.

- *The influence of asynchronous and synchronous product flow including the production layout on the feasibility are shown with examples focused on time/cost calculations, which are applicable to all manufacturing processes including the impact of planning lead time.*
- *In almost all instances we have to consider "Granular Metrics", in order to do things right, which is described in Section* ENTERPRISE ECONOMETRICS.
- *The consensus regarding best practices is not only trying to reduce slack time (Non Value Added Time) as well as the Value Added Time, but the necessity for the manufacturing engineers to enhance the knowledge level, i.e. the great impact of Intellectual Capital, described in Section 1.*

- ***Very few firms use economic algorithms and results from well known and established economists in order to assess feasibility and budget problems but rely on averages or rough experienced data. This method is often subjected to erroneous results and decisions detrimental to the business, compare with Chapter***

3"Granular Metrics" in Part III.
Granular segmentation of cost elements into functional quantities allows a company to focus, to measure, to learn a to innovate. A.L.Hax-D.L. Wilde (Sloan Management Revie Winter, 1999) have extensively studied various companies ar found astounding discrepancies between actual and calculat costs when comparing the granular approach with the conventional using averages: for example individual order c varied up to 10:1. This book employs granular methods and appropriate weighted time and cost parameters in order to achieve good results.

2. Process and Production Planning

- An interactive plan is made up and described in the two papers Production Plannir and Scheduling and Takted Production, including the procedures, calculation methoc and results that are given in the XLS-files "Sections 0-7".s, found in: Module Colding
  Project work/ Industrial case Machining, a module this author as a committee memb presented to the **European Production Engineering Committee**, called
- **Excellence in Production Engineering**
- **Module 2 EPR202 COLDING Process and Productio Planning**

- eprode© European Production Engineer

The project work is here selected and worked out as Machining Technology. It can be applied as well to the other Manufacturing Technology such as forming, stamping, welding and assembly working methods by using cycle time as the primary variable. Calculations of lead times and manufacturing costs are accomplished using the same methods and techniques described for Machining Technology, see the book by Colding,B.N., (2008), (Adobe format), **Machining Data Selection for Lean Manufacturing, Formulas and Machinability Relationships** including algorithms for determining the five constants.

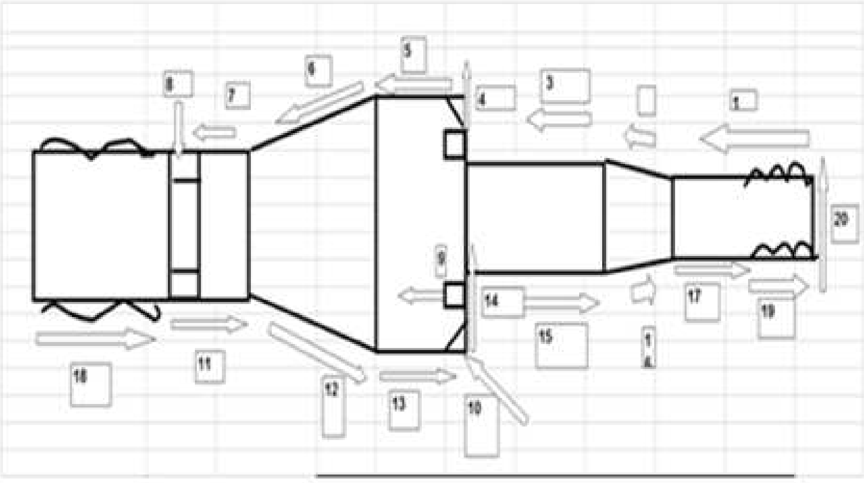
In the following pages we will describe in succession the many parameters to be determined in order to make a production plan including corresponding product times and costs.

3. Description of the procedures making a Machined Part,

see 3 EPR II 03 Process-Production Planning and Scheduling

Typical Turned Part

Figure 2.

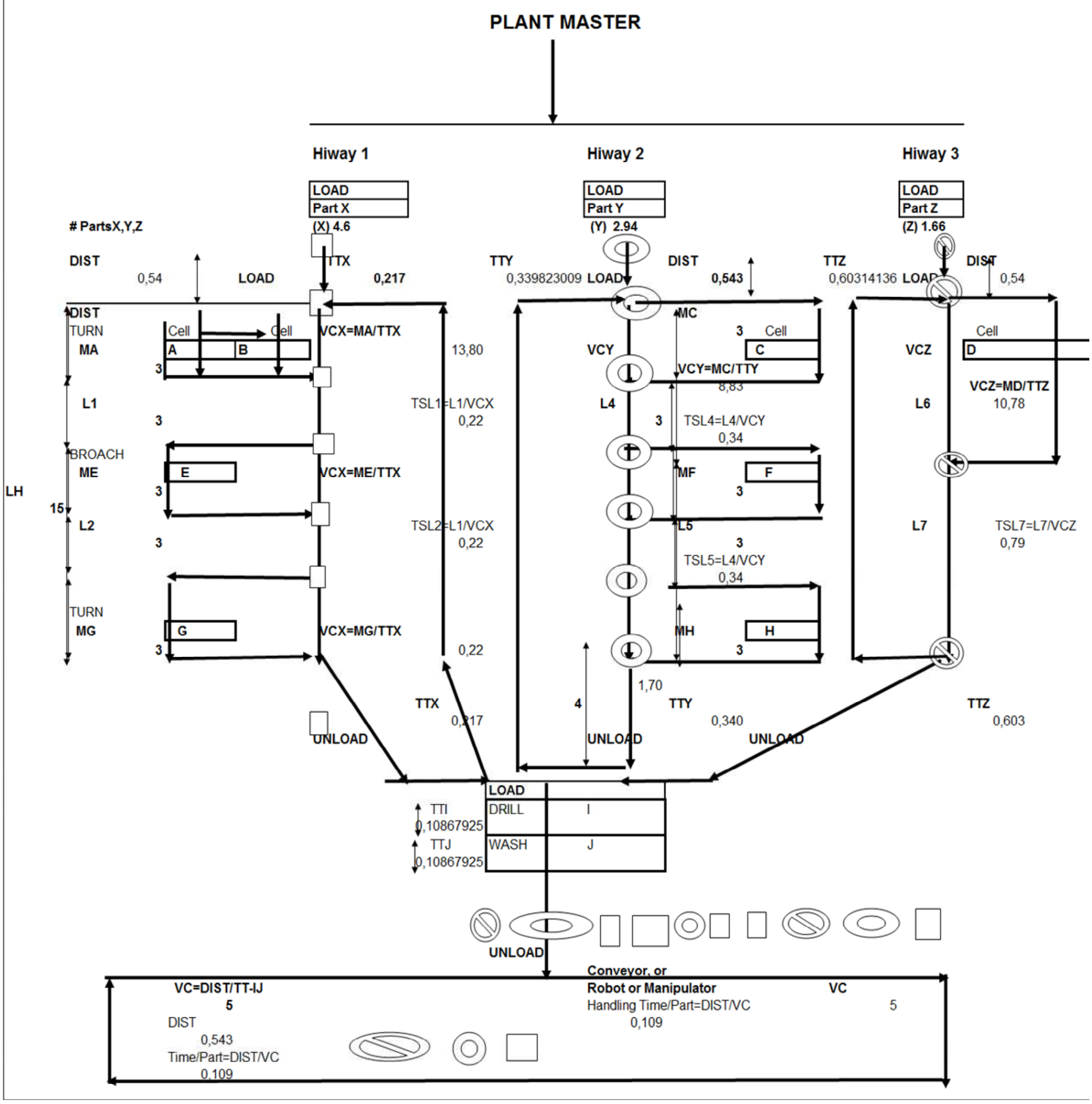


Typical Process Plan

OP #	Type of Operation		Tool ID	Tool Grade	OP #	Type of Operation		Tool ID	Tool Grade
1	Longitud	Rough	L-001	ABC	11	Longit	Finish	LF-001	ABC
2	Taper Out	Rough	T-001	ABC	12	Facing	Finish	TF-001	ABC
3	Longitud	Round in	L-002	ABC	13	Longit	Finish	LF-002	ABC
4	Facing Ou	Rough	F-001	ABC	14	Facing	Finish	F-002	ABC
5	Longitud	Rough	L-003	ABC	15	Longit	Finish	LF-003	ABC
6	Taper In	Rough	T-002	ABC	16	Taper I	Finish	TF-002	ABC
7	Longitud	Rough	L-004	ABC	17	Longit	Finish	LF-004	ABC
8	Grooving		G-001	BCD	18	Thread	Radial	TH-001	CDE
9	Face Groove		FG-001	BCD	19	Thread	Flank	TH-002	CDE
10	Chamferin	Axial	CH-001	ABC	20	Parting		P-001	DEF

Advanced Production Plan

Example: 3 Hiways including Satellites from and to Machine tools A,B,C,D,E,F,G,H.
All 3 products X,Y,Z produced in above machines at different rates at 100% Capacity Utilization:
Average production time 0. 327minutes.
All 3 products X,Y,Z delievered, after drilling and washing in one set of machines I,J,
at production time 0.109 minutes (1/3 of time in Hiways 1,2,3) at 100% Capacity Utilization.



4. Reading and Exercising

- *Proficiency in Process and Production Planning Machining is obtained by solving assigned problems in EPR2-05*

Section 0 describes:

- Databases: DBG Constants Turning-Milling-Drilling and Grinding

- Build up of Machinability Constants programmes

- First,Select Material from Material Groups Table and cutting speed and force correction factors are automatically evaluated.

- Second, Select Tool Grade and Tool-life & Surface finish Constants including Force Sensitivity Constants (LF/L)

  Third, Select Economic Tool-life, or desired tool-life

- ECT = Equivalent Chip Thickness

- Geometry Figure 1. ECT and Calculation of Chip Flow Angle (CFA) to Determine Axial (FA) and Radial (FR) Forces from Resultant Force FH

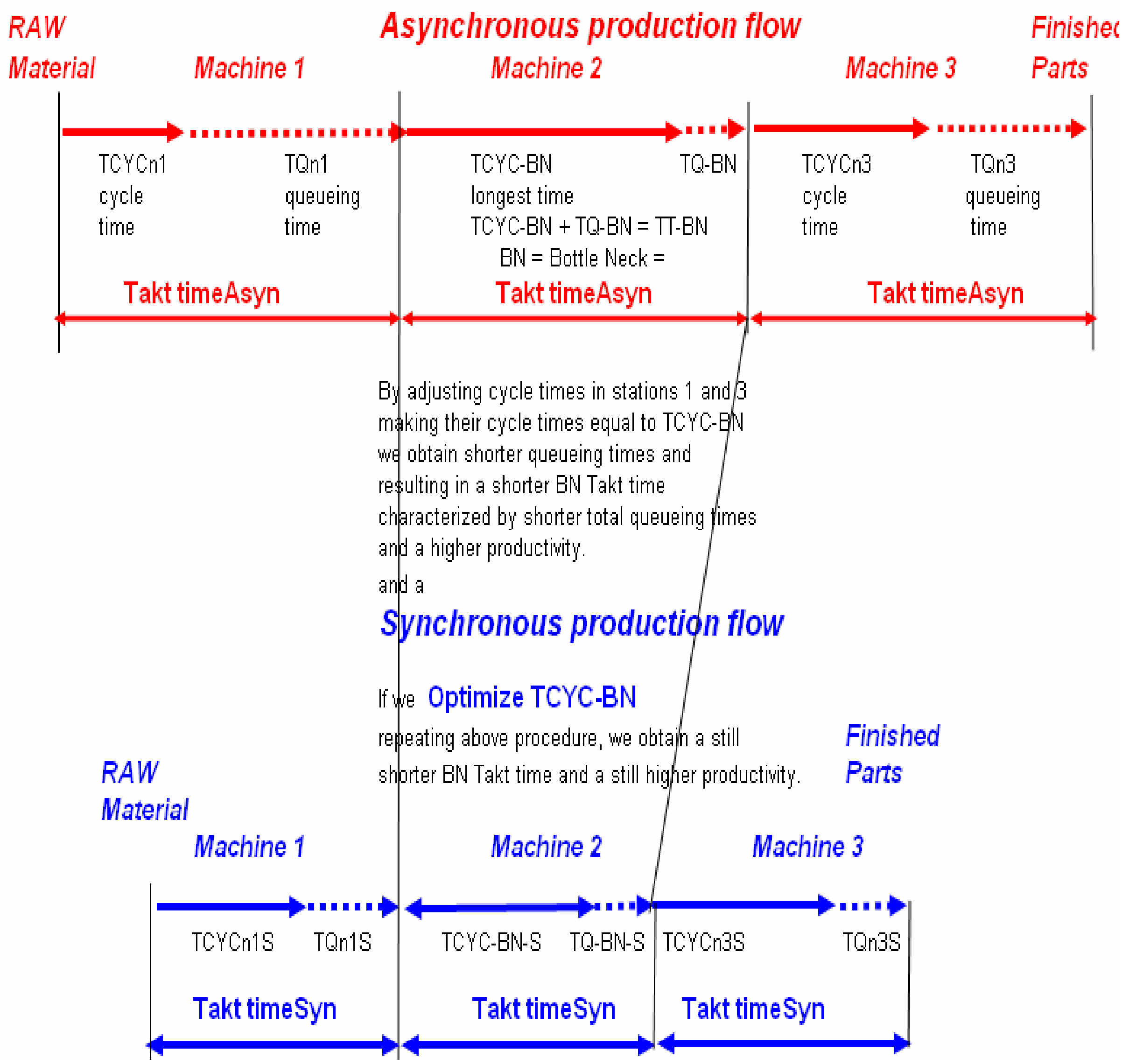
  Shopdata and its calibration coefficient

5. Section 1. Interactive e-Learning Machining – Longitudinal Turning Running Instructions:

to calculate fundamental data CEL,AREA,ECT,CFA, including

Machine Settings, Machine and Fixture Requirements, Tool Change Schedules, Batch Times and Costs ***(Ideal times and costs, as well as real values depend on disturbances)***

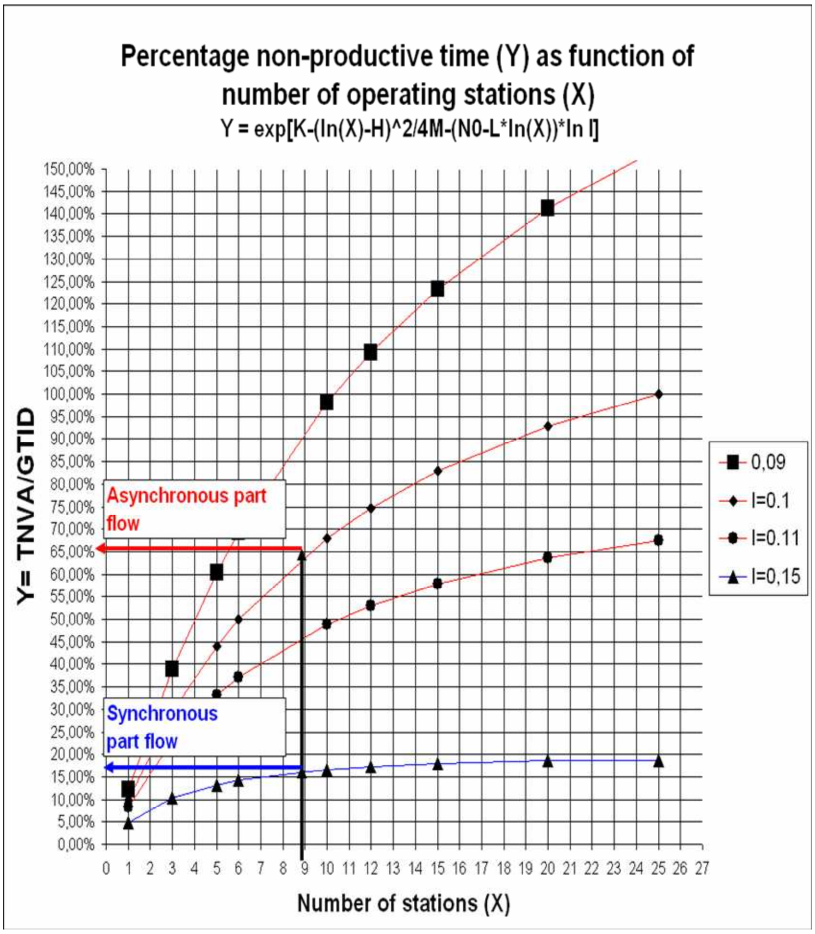
6. Section 2. Going from Asynchronous to Synchronous Product Flow



7. Disturbance Percentage Going from Asynchronous to Synchronous roduct Flow

- *Section 2: Disturbance percentage (Y) vs # Operating Stations (X) for Asynchronous and Flow*

Section 2: Going from asynchronous to synchronous part flow



The 6 Exercise Modules of which the learning tasks, calculation methods and results are given:

- Exercise Module #1 Calculation of Cutting Time and Surface Finish
- Exercise Module #2 Calculation of 3 Cutting Forces, Torque and Power
- Exercise Module #3 Calculation of Time and Number
- Tool Changes per Batch, Cycle Time per Part, Tooling
- Cost/Batch and Cycle Cost/Batch
- Exercise Module #4 TOOL CHANGE SCHEDULES
- PART TIMES AND COSTS Turn, Broach, Drill
- Exercise Module #5 Time (hours), Cost ($) per Batch for Batch Sizes 5000, 5889, 1060000
- Exercise Module #6 Distribution of and Factory Cost for Synchronous versus Asynchronous part flow

The Sections 0 – 7 and the 6 Exercise Modules are included as Excel formats retrieved as sepatate attachments:

- Section 0 Interactive e-Learning Machining- Database (DBS) Constants
- Section 1 Interactive e-Learning Machining-Longitudinal Turning
- Section 2 Interactive e-Learning Machining-Synchronous Flow
- Section 3 Interactive e-Learning Machining-Threading Radial
- Section 4 Interactive e-Learning Machining-Short Hole Drilling
- Section 5 Interactive e-Learning Machining-Face Milling
- Section 6 Interactive e-Learning Machining-High Speed End Milling
- Section 7 Interactive e-Learning Machining-Grinding Cylindrical External

Tool-life is the Key Variable

- A given Tool-life (T) determines the machinability, or the productivity, of a tool-work system: the magnitude of speeds and feeds.
- The productivity of any metal cutting operation is governed by the magnitude of T).
- (T) is, besides cutting geometry, the primary variable determining cutting forces (FC, Fa, Fr) and surface finish (Ra),
- Colding, B.N., 2004, A Predictive Relationship between Forces, Surface Finish and Tool-life". CIRP Annals, 53/1/2004, p.85.

Exercise Module #1 Calculation of Cutting Time and Surface Finish

MACHINE SETTINGS					
Tool-life	Cutting speed	RPM	Feed Rate	Surf Finish Bottom	Cutting time per piece
T	V		FR	Ra	tc
min	m/min	RPM	mm/min	µm	seconds
60	355	1129	113	?	?
15	?				
15	?				
5,8	?		?	?	?

Exercise Module #2 Calculation of 3 Cutting Forces, Torque and Power

MACHINE AND FIXTURE REQUIREMENTS							
SHARP TOOLS						WORN TOOLS	
Cutting Force FC	Result FA $ FR FH	Axial Force FA	Radial Force FR	POWER	TORQUE Newto	POWER	TORQUE Newton
Newton		Newton	Newton	KW	meter	KW	meter
631	520	435	286	3,7	32	4,4	37,9
?							?
							?
							?

Module #3 Calculation of Time and Number Tool Changes per Batch, Cycle Time per Part, Tooling Cost/Batch and Cycle Cost/Batch

		Setup				
		time				
ctool/p	c-cycle/p	minutes	TIME/b	NO.Tch	Ctool/b	Ccyc/b
$	$	30	hours	batch	$	$
0,04	?		?	?	?	?
ctool/p=(tc*Hourly Rate/3600)*Rapid traverse rate/tcyc						
c-cycle/p=(tc*Hourly Rate/3600)*(1+Rapid traverse rate/tcyc+						
			(tindex/p+t-wpiece/p)/tc)			
	TIME/b=(tcyc*Batch Size/60+NO.Tch*ctool/b)/60					
		NO.Tch=Batch Size*tc/T/60				
			Ctool/b=Batch Size*ctool/b			
			Ccyc/b=Batch Size*c-cyc/b+			
			Hourly Rate*Set-up Time760			

Exercise Module #4 TOOL CHANGE SCHEDULES PART TIMES AND COSTS Turn, Broach, Drill Exercise

	MA #	OP #				
	1001	1003	Batch size		5000	
Operation	MC	Feed	Cutting	Time	Time	Cycle
data selections	2.1	per	Time	Indexi	changin	Time
		rev.		tool	work	per part
	Tool		per part	per pa	piece/p	
	Grade	f	tc	tindex	t-wpiece	tcyc
	GC4030	mm	seconds	secon	seconds	seconds
Operation type						
TURN	AB,G	0,10	3,55	4,94	4,55	**13,04**
BROACH	E	0,18	6,61	3,93	2,5	**13,04**
TURN	C,F,H	?				**?**
TURN	D	?				
DRILL	I	?				**?**
WASH	J	?				**?**

8. EPR 203 Factory and Company Costs

The following items are to be calculated:

Running Instructions to calculate fundamental data:
Calculation of Synchronous Times
Calculation of Takt Time. Machining Time and Efficiency.
Calculation of Daily and Weekly Delivery of
Number of Parts, and Weeks to Complete
Number Parts/Week versus Disturbance Percentage
Delivery Weeks versus Disturbance Percentage
Factory Cost Synchronous versus asynchronous part flow
Cost per day
Total Cost per order
Ideal costs at given batch size transferred from table:
TOOL CHANGE SCHEDULES PART & TIMES AND COSTS
are put into cells CM, Manufacturing Cost and Tooling Cost,CT in
module Factory Cost.

Exercise Module #5

Machine	BATCH TIMES AND COSTS										
	Batch size		Hourly Rate $/h		Batch size				Batch size		
	5000		100		5889				1060000		
	Time	Tooling	Total		Time	Tooling	Total		Time	Tooling	Total
		Cost	Cost			Cost	Cost			Cost	Cost
	per	per	per		per	per	per		per	per	per
	Batch	Batch	Batch		Batch	Batch	Batch		Batch	Batch	Batch
	hours	$	$		hours	$	$		hours	$	$
AB	18,11212097	97,94	1909,15		21,33	115,35	2249		3840	20763	404740
E	?				?				?		
G			?		?				?		
C	28,32173749	26,31	2858,49		33,36	30,9896	3367		6004	5578	605999
F	?				?				?		
H			?			?			?		?
D	?				?				?		?
I	?								?		
J	?						?		?		?
Sum	**46**	**124**	**4768**								

Exercise Module #6 Distribution of and Factory Cost for Synchronous versus Asynchronous part flow

Factory Cost			
Synchronous versus asynchronous part flow			
Days/year	**Days/ week**	**# Shifts for X,Y.Z**	**Hours/ shift**
180	5	2	8
Hours/ day	**Hours/ week**	**Hours/ year/Order**	**Order size**
16	80	2880	1060000
Pieces/ day	**Synchronous part flow**	**Asynchronous part flow**	**Asynchronous part flow**
5889	Disturbance percentage (Y):	Disturbance percentage (Y):	Disturbance percentage (Y):
	20,0%	*50,0%*	*100,0%*
CMTRL, Material, $ /order	$983 333	$983 333	$983 333
PPC, Production Planning $/ord	900 000 kr	900 000 kr	900 000 kr
OK, Order Cost, $/order	1 450 000 kr	1 450 000 kr	1 450 000 kr
	Parts X+Y+Z	**Parts X+Y+Z**	**Parts X+Y+Z**
	20,0%	*50,0%*	*100,0%*
***Cost* per day**	***Cost* per day**	***Cost* per day**	***Cost* per day**
i = Policyränta perår, %			
20			
CM, Manufacturing Cost	$25 202	$25 202	$25 202
(From Total Cost per batch (Ccyc/b)*(Pieces/day)/(Batch Size)			
CMY, Disturbed Manufacturing			
Cost (Tooling not affected)	$30 116	$30 116	$30 116
CMTRL,Cost material	$5 463	$5 463	$5 463
PPC, Cost Production Planning	$5 000	$5 000	$5 000
OC, Order Cost	$8 056	$8 056	$8 056
PLK = PPC + OC	$13 056	$13 056	$13 056
CMY+CMTRL+PLK	$48 634	$48 634	$48 634
WIP, Work-In-Process	$7 147	$7 147	$7 147
FC, Factory Cost	**$61 245**	**$61 245**	**$61 245**
Tooling Cost,CT	**$630**	**$630**	**$630**
Tooling/CM %	**2,50%**		
Tooling/FC%	**1,03%**		
Tooling/piece	**$0,00**	?	?
FC, Factory Cost/piece	**$10,40**	?	?

9. References

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Part II. MANUFACTURING ECONOMETRICS –

Theory, Performance and Applications of Manufacturing Econometrics

Foreword

Chapters 1 and 2 review the influence of several factors including the production layout on the feasibility including examples. Chapter 3 presents methods of Scheduling including of a product mix. Chapter 4 deals with MANUFACTURING TIME/COST RELATIONSHIPS, an expansion of the text given in Part I including an in-depth description of the use of time/cost algorithms. Time and Cost Formulas for any Lot Size, Setup Time, TAKT Time and Hourly Rate, Times and Costs are defined. When we deal with machining refer to the time and cost calculations including tooling costs described in Part I. ***The text depicts the advantages of the employment of Colding's Equation and how to develop your own software.***

Since Dr. Merchant introduced CIM and Professors Peklenik and his colleagues Spur, Sata and Colding initiated the CIRP yearly Seminars on Manufacturing Systems 30 years ago [2] an enormous amount of research activities on Flexible Manufacturing Systems (FMS) started all around the world. These activities were primarily directed towards Computer Aided Process Planning (CAPP) and Adaptive Control (AC) of machining processes. A variety of manufacturing computer systems have emerged, under different names: Merchant's Computer Integrated Manufacturing (CIM), Flexible Manufacturing Systems (FMS), Agile Systems and many other names [2]. The expectations were early very optimistic as shown by the Delphi forecasts on Material Removal, Manufacturing Systems and Manufacturing Management, conducted by Smith, Colwell and Colding in 1977-78 [3]. It was predicted with 90 % probability that in 1988 30% of all manufacturing would use computers, automatically generating process plans, but 11% of the participating experts predicted "Never".

On the other hand other authors reveal good reasons why Flexible Manufacturing Systems (FMS) and MRP Systems have not met expectations. *According to the book by R.Harmon [6], based on the opinions of hundreds of experienced professionals, the manufacturing benefit potential lies overwhelmingly in process improvements. Today 80-90 % are achieved by continuos operation or process improvements, while only 10 - 20 % can be achieved based on improved manufacturing computer systems. Harmon says that the wrong sort of "Integration" is applied to manufacturing systems and suggests that CIM should be defined as "Computer Disintegrated Manufacturing", meaning simpler and less intertwined systems. Professor Colding has advocated for a long time that the* ***Cycle Time in any manufacturing system is the crucial parameter to increase performance.***

Company managers are urged to employ this Econometrics in order to ascertain realistic results. Only a simple internal program can be introduced and all the many determinations will be made quickly.

Table of Contents

1. INTRODUCTION

- *This Section starts with a brief review of the reasons why Flexible Manufacturing Systems (FMS) and MRP Systems have not met expectations rules, new trends and recommendations regarding layouts, product flow and synchronous manufacturing follow. The influence of several factors including the production layout on the feasibility are shown with examples in Chapter 2. Chapter 3. Presents a method of Scheduling a product mix. Chapter 4 is focused on time/cost calculations, which are applicable to all manufacturing processes including the impact of planning and scheduling.*
- *There are approximately 15 necessary parameters required to perform a reasonably accurate cost assessment for a manufacturing system. In machining operations, Section 3, we have to deal with an additional great number of parameters. Formulas are given so that the users can program these into their own software programs.*
- *In almost all instances we have to consider "Granular Metrics", in order to do things right, which is described in Part III.*
- *The consensus regarding best practices is not only trying to reduce slack time (Non Value Added Time) as well as the Value Added Time, but the necessity for the manufacturing engineers to enhance the knowledge level, e.i. the great impact of Intellectual Capital, described in Section 1.*

Cost Effectiveness of FMS and MRP Systems

Since Dr. Merchant introduced CIM and Professors Peklenik and his colleagues Spur, Sata and Colding initiated the CIRP yearly Seminars on Manufacturing Systems 30 years ago [2] an enormous amount of research activities on Flexible Manufacturing Systems (FMS) started all around the world. These activities were primarily directed towards Computer Aided Process Planning (CAPP) and Adaptive Control (AC) of machining processes. A variety of manufacturing computer systems have emerged, under different names: Merchant's Computer Integrated Manufacturing (CIM), Flexible Manufacturing Systems (FMS), Agile Systems and many other names [2]. The expectations were early very optimistic as shown by the Delphi forecasts on Material Removal, Manufacturing Systems and Manufacturing Management, conducted by Smith, Colwell and Colding in 1977-78 [3]. It was predicted with 90 % probability that in 1988 30% of all manufacturing would use computers, automatically generating process plans, but 11% of the participating experts predicted "Never".

The Reasons for poor System Performance

The reasons for poor System Performance may be summarized as follows. Inadequate process planning methods, Inability to fully Utilize and Optimize the Cutting Process to Increase Productivity, Lack of efficient methods to handle constraints in the cutting process itself and Lack of efficient process planning methods to predict the magnitude of part tolerances. Other reasons include inaccurate Materials Requirement Planning (MRP) systems, Lack of efficient methods to balance product flow, lack of accurate Scheduling functions to accommodated changes in scheduling of production, and Mistakes and errors generated in offices and on the shop floor. Human mistakes and errors made in process planning and execution on the shop floor contribute to poor performance

Process Improvements

- *Parallel with the advancements in manufacturing systems by CIRP, NIST and other research organizations, the industrial community has followed another much more applied route. According to the book by R.Harmon [6], based on the opinions of hundreds of experienced professionals, the manufacturing benefit potential lies overwhelmingly in process improvements. Today 80-90 % are achieved by continuos operation or process improvements, while only 10 - 20 % can be achieved based on improved manufacturing computer systems. Harmon says that the wrong sort of "Integration" is applied to manufacturing systems and suggests that CIM should be defined as "Computer Disintegrated Manufacturing", meaning simpler and less intertwined systems.*

Lean Systems

Yet another productivity improvement approach is associated with the term “Lean”. This is a pull system, usually thought of as the Japanese system whose basis is the Toyota Production System (TPS). This is a market driven system within the factory, with the purpose of reducing flow time and the creation of a flexible system that responds to customer needs, and to eliminate waste, such as: Overproduction, Waiting during production flow, Conveyance inessential to direct work flow, Over-processing, Useless motion, Inventory excess and Defect correction. Lean has become the “buzz” word for eliminating any kind of time that does not create Value Added Time (VAT). but the definition is also used to account for improvements in processing methods (VAT). Another important issue of utmost importance is improving the utilization of calendar time by continuous production. An example is the comparatively long lead times in production of dies for automotive panels.

Team Work

Finally, maybe the greatest factors leading to inefficiency is found in the performance of the human being and in organizational structures. A major task is How to improve the relationship between CEO–Executive Management-Middle Management and operators in order to secure that the firm operates as a team. Product, customer, production and 1st, 2nd.3rd tier suppliers must be increasingly networked.

Information Technology (IT) and CIM

In the manufacturing sector the term Information Technology is a new word for the terms CIM (Computer Integrated Manufacturing) and FMS (Flexible Manufacturing Systems) which were introduced in the 1960's. It is a tool meant for achieving future manufacturing success. The ultimate vision in this roadmap is the achievement of totally integrated and interconnected manufacturing enterprises where every function of the enterprise has real-time access to all the information it needs. In the future, IT is forecasted to transform the meaning of "manufacturing" with fast and cost-effective transition from concept to production, instantaneous availability of all manufacturing knowledge and innovative products that are 100% accurate and reliable.

Product cost, lead time and productivity in existing plants can be substantially improved by implementing systems located between the factory floor and the corporate level, for example, MES (Manufacturing Execution Systems), ERP (Enterprise Resource Planning), including machine specific software such as CAD/CAM including optimized machining data, product tracking and logistics programs.

Manufacturing Execution Systems (MES) are used as the primary shop floor module in Enterprise Resource Planning (ERP) systems. MES include suh software as Process Planning,, CNC and CAD/CAM control systems, machining and grinding optimization programs such as COMP and the Plant Master (PLM) for scheduling parts in a synchronous flow. The rquirements of these IT.Systems include Adaptive Operator Interfaces (AOI) and Human Machine Interfaces (HMI).
ERP is often a confusing terminology but to put it in simple terms: ERP is an acronoym meaning Enterprise Resource Planning. It is a software package/solution most often used within the manufacturing environment. ERP is a business tool that management uses to operate the business day-in and day-out. It is usually comprised of several modules such as a financial module, a distribution module, or a production module. Each of these modules share information that is housed within the database structures on which the ERP system was coded. ERP helps to break down barriers between departments within a company.
Currently the great potential of aforemmentioned systems has not yet been realized.

2. Plant Layouts – Product Flow

The System Strategy
Optimal layouts and optimal processes are the backbones for meeting customer demands, low inventory and high productivity. These criteria often go hand in hand with high quality. In other words efficient Quality Control is achieved by checking the process, not the final product, Dr. Deming [13] .

"Takt" Time
The term means using a constant takt time across machines in a cell or line, where the Bottle Neck Machine determines TAKT Time.
An economic solution depends on the entire system flow: "Takt" time is a new word (German) for constant pace between resources, and the borttle-neck operation dictates the duration of the takt time.

means using a constant takt time across machines in a cell or line, where the Bottle Neck Machine determines TAKT Time.

Balancing

Figs. 1 and 2 describe 2 different systems for balancing individual machines in order to obtain a constant takt time, one cell configuration and one line-type with conveyors.

In a cell-type system with robots seen in Fig. 1. the queuing and waiting times are essentially eliminated by balancing across cells by an optimization of the bottle-neck (BN) cell, and then adjusting the cycle times of the other cells to get the same takt time and zero waiting and queuing. An efficient method of obtaining balancing is to use the machine tool power train to first optimize speeds and feeds for all machines, sometimes using data for maximum production rate in the bottleneck machine (BN). Usually cycle time can be changed by altering feeds and speeds by a factor of 2 per machine.

When it is impossible to balance and completely eliminate Non Value Added (NVA) time we may yet increase the production rate. This is illustrated in the simple example in adjacent Table 1 consisting of 4 machines. The (NVA) times are automatically reduced by applying maximum production rates in Machine 1004, and modifying and increasing rates in machines 1001,1002,1003. Hence, TAKT Time is Reduced from TT1 to TT2, where TT = VA + NVA.

Table 1. Alternate Production Rates-Example

VA = Value Added time (machine produces)

NVA = Non-Value Added time (queuing and waiting)

Machine ID		**Alt.1 TAKT Time TT1=8 minutes**		**Alt.2 TAKT Time TT2=3 minutes**
1001	VA	2	VA	2
	NVA	6	NVA	1
1002	VA	4	VA	2
	NVA	4	NVA	1
1003	VA	3	VA	2
	NVA	5	NVA	1
1004,BN	VA	5	VA	2
	NVA	3	NVA	1

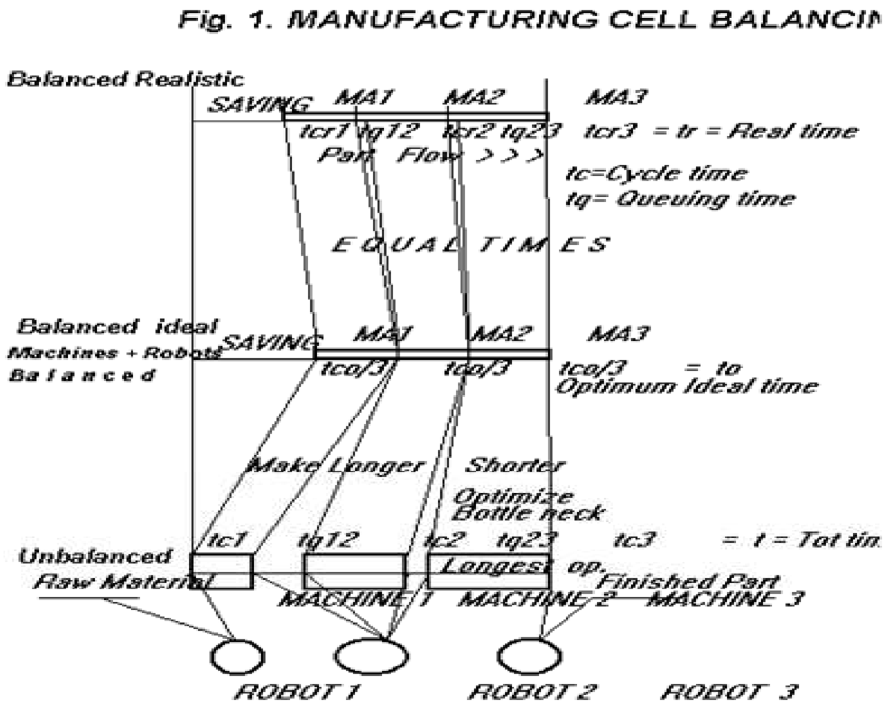

Fig. 1

vith robots seen in Fig. 1. the queuing and waiting times are essentially eliminated ells by an optimization of the bottle-neck (BN) cell, and then adjusting the cycle s to get the same takt time and zero waiting and queuing. An efficient method of to use the machine tool power train to first optimize speeds and feeds for all using data for maximum production rate in the bottleneck machine (BN). Usually ged by altering feeds and speeds by a factor of 2 per machine.

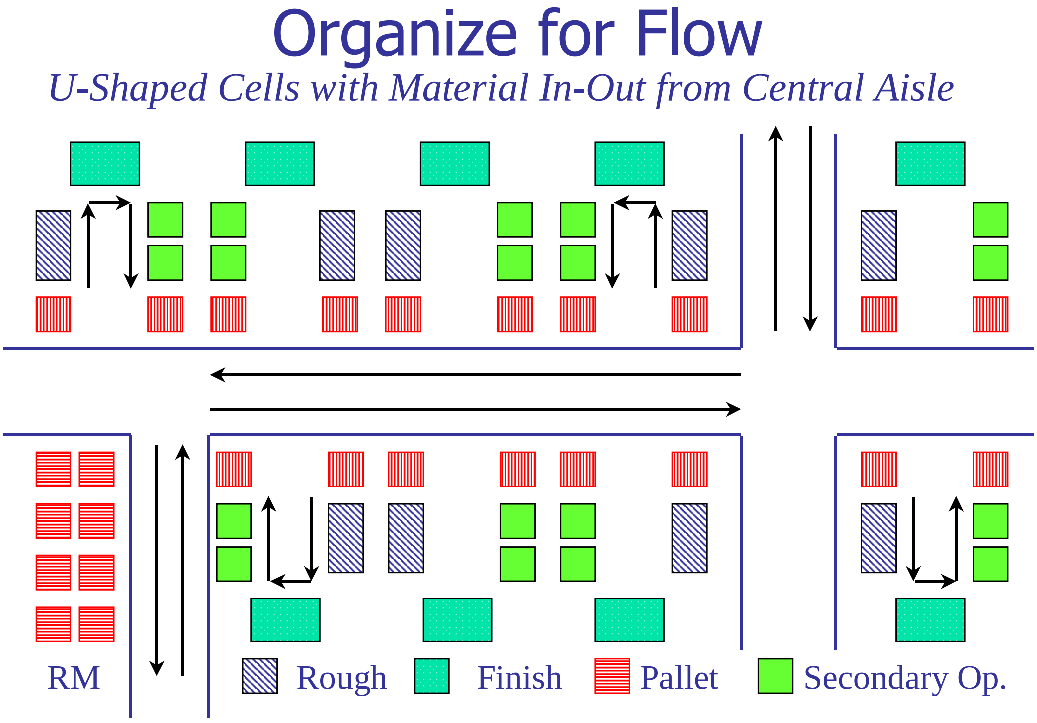

Figure 2

The principle of a U-Shaped production system is shown in Figure 2.

In a line-type (U-Shaped) system**,** Fig.4**,** described in detail in chapter 3, consisting of the three lines of machines, conveyors and satellites, the ideal solution is obtained when parts flow without necessitating buffers. The task is to balance the flow of the 3 different parts under the requirements shown in the adjacent Table, and their simultaneous delivery on the conveyor belt seen at the bottom of Fig.4.

Assuming 3 designs produced during 1 shift/day:50%X, 32%Y,18%Z.
All 3 designs made simultaneously except for Drill-Wash (schedule)

Days/y	Hours/ day	Design	# Ops	# Parts year	Per cent	# Parts day	# Parts hour PH	Parts/ min
240	8							
		X:Front h	6	530000	50	2208,3	**276,04**	4,6007
		Y:Rear h	5	339000	31,9811	1412,5	**176,56**	2,9427
		Z:Rear h	3	191000	18,0189	795,83	**99,479**	1,658
		Total	14	1060000	100	4416,7	552,08	

Balancing is accomplished by varying the speeds of highways and satellites as well as the machine cycle times, simultaneously accomodating demand changes and changes in distribution of product volumes.

In this example this is accomplished, including cost calculations, by the Excel software program, called the PLANT MASTER, described in detail in chapters 3 – 5**.** This Manufacturing Execution System (MES) is based on the principle of volume continuity and constant takt time within each processing or assembly unit. It determines optimum synchronous flow of parts through any configuration of plant design, or for a new plant configuration, operating at minimum cost and optimal utilization of plant capacity, theoretically avoiding the necessity of buffers. The program determines order quantities in terms of parts per day/week, number of shifts and number of weeks to complete the order. When several customers for the different products the program provides each customer with desired deliveries per day of week.

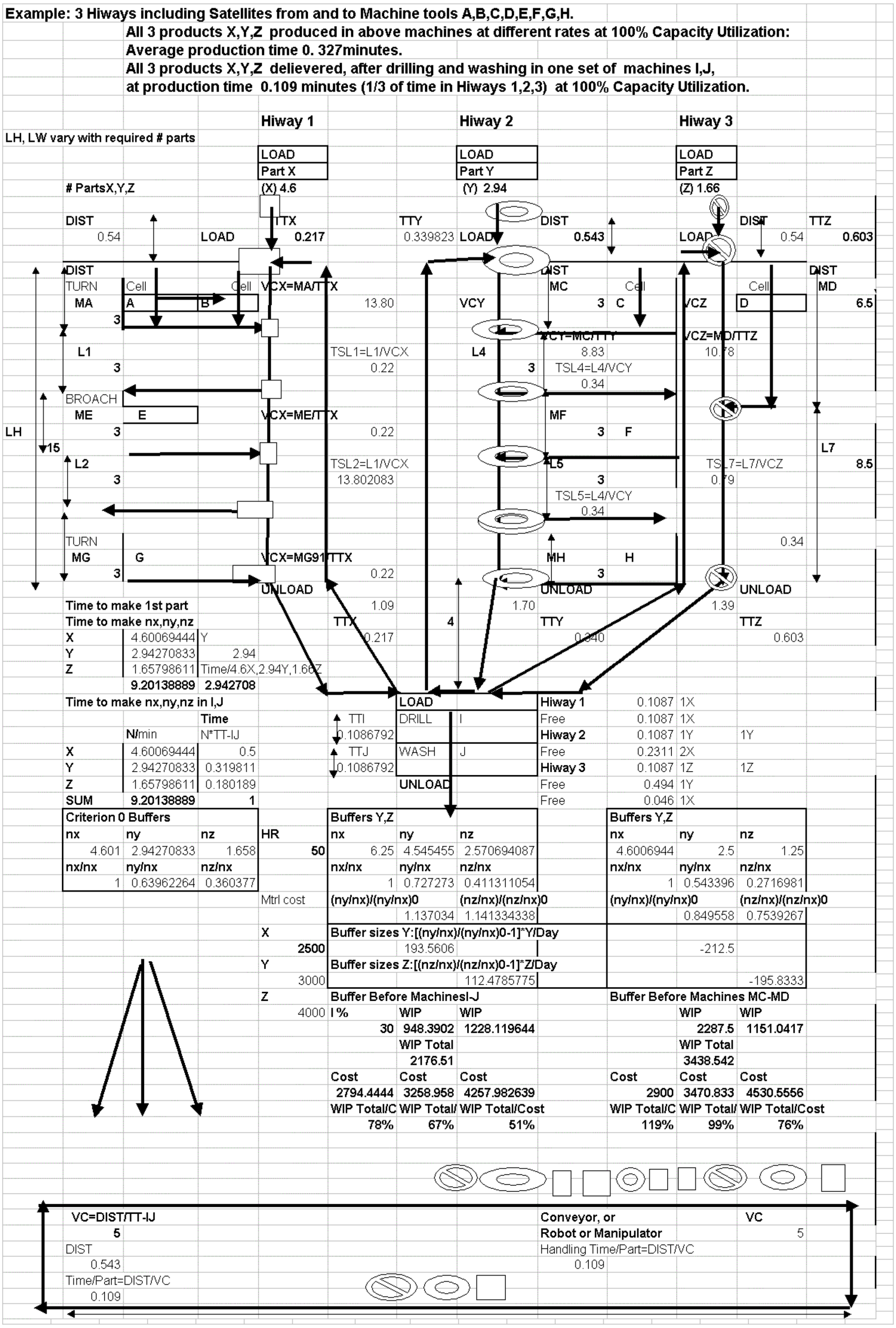

Figure 4. Simultaneous and Synchronous delivery of 3 products X,Y and Z.

3. Scheduling for Synchronous Manufacturing

The most common flow of parts in a plant is characterized by producing at a different takt-time across machines which is causing a need for buffers between the machines, or cells. The takt-time of the cell is determined by the longest operation, the bottle-neck. This flow, here called Asynchronous flow, is resulting in long lead-times and additional inventory costs from buffers, see WIP in chapter 2. Industry is trying to reduce this waste of time by methods generally referred as "Lean Manufacturing".
By balancing the flow across cells we attempt to achieve a continuous flow which is called Synchronous Manufacturing. This means any systematic way that attempts to move material quickly through the various operations, and in concert with market demands.

Figure 3.2 depicts this situation in two graphs.

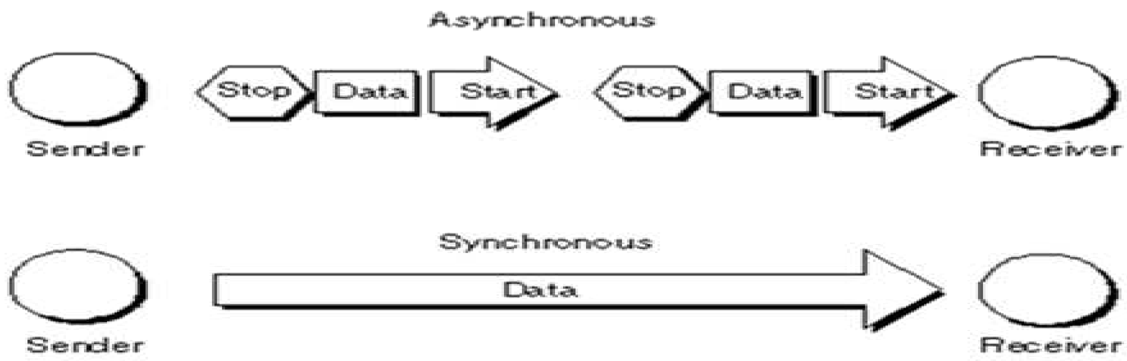

Figure 3.2

tied to the front row. All soldiers are tied to a rope with some slack, analogous to keeping a buffer of semi-finished parts, containing only the *inventory needed to keep the BN or CCR (Capacity Constraint* Resource) busy. The strategy should be to support the CCR (weakest soldier) with a time buffer, and not create buffers for any other cells. The overall scheduling is of course based on the market demands and the potential of the bottle neck cell (CCR).

Continuous Flow

A continuous Flow without buffers or interruptions is the goal. Goldrath-Fox (1986) are using the analogy of a troop of soldiers on a forced march. Since the weakest soldier dictates pace, he is tied to the front row. All soldiers are tied to a rope with some slack, analogous to keeping a buffer of semi-finished parts, containing only the inventory needed to keep the BN or CCR (Capacity Constraint Resource) busy.
The strategy should be to support the CCR (weakest soldier) with a time buffer, and not create buffers for any other cells. The overall scheduling is of

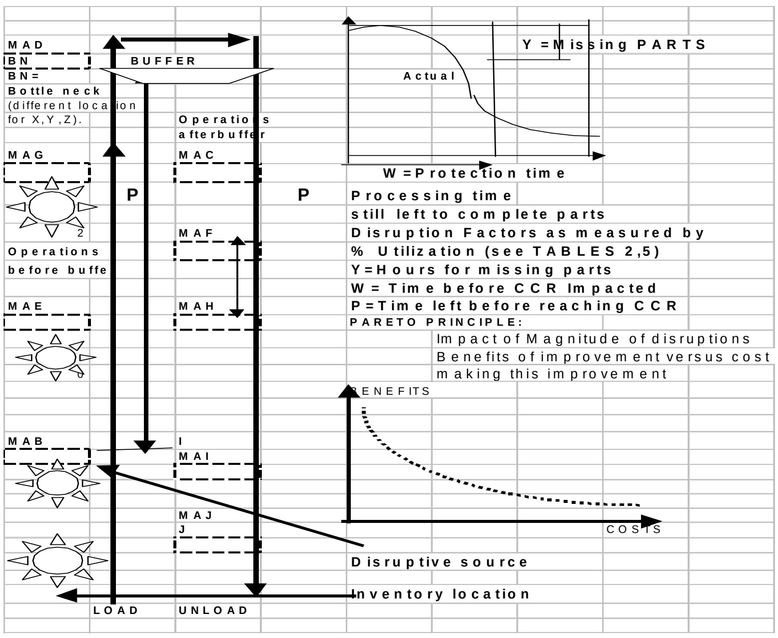

Figure 3.1

course based on the market demands and the potential of the bottle neck cell (CCR).

Time Buffer

Fig. 3.1 shows a time buffer serving the machine MAD, supported by parts from the preceding machined MAB, MAE, MAG . The proceeding machines, all operating at the same pace (takt time) as the CCR, will always have parts from it. The discrepancy between planned and actual buffers reveal disruptions to the material flow, see diagram where the hole (Y) hours of a part must be scheduled to be worked on in(W)hours. This is an example of a way of controlling and quantifying the disruptions.

In a line-type (U-Shaped) system consisting of machines, conveyors and satellites the ideal solution is obtained when parts flow without necessitating buffers. This is accomplished by varying the speeds of hiways and satellites as well as simultaneously accommodating demand changes and changes in distribution and product volumes.

Pareto Principle

The resources for this control versus benefits, shown by the other graph, driven by the Pareto Principle. This means that by recording the most significant disruptions the personnel can concentrate on where the improvements are most feasible.

Scheduling a Product Mix

When the customer driven scheduling is done for only one type of part the problem is reasonably simple. Scheduling a Product mix is much more complicated, when the firm produces a great variety of products. A constant TAKT-Time for each design is a must, as variable times across the different cells cause waiting and queuing and undue long delivery times. Lead time disruptions measured in terms of Buffer Capacity Utilization must be kept at a minimum.

Scenarios

The problems facing the firm when planning delivery of a product mix **just-in-time** include the following scenarios:

. One customer, fixed order quantity
. One customer changes order quantity
. Several customers, different order quantities
. Several customers change order quantities

One or Several customers, different order quantities for different days of the week or month of each design

The firm must perform the following basic tasks until making a decision:

. Design a scheduling method that accommodates changes in order quantities from
. the firm's customers.
. Determine how many parts of each should be scheduled day 1, 2, 3, 4, or 5 of the work- week, and ideally achieve 100 percent capacity utilization of all cells.
. Determine the optimum TAKT-Time for each design
. The Scheduling calculations per week should be valid for any Order size and distribution of product designs within the total order.

The problem is not only to achieve shortest delivery times at minimized costs of the manufacturing processes per se, but how to ideally achieve 100 percent utilization of the plant capacity. This can only be accomplished by selecting machines and lay-outs in advance in an agile fashion and for a filled order stock.

On the other hand, when orders are fixed for the next year or two with one customer, the manufacturer will strive to balance TAKT time with demand so that all orders are delivered at the same time. One useful method to do this is to utilize the machine tool power train as running an automobile, and modify speeds and feeds according to demand thereby altering the manufacturing rates, see Section 3, The Plant Master [12].

The objective in this Chapter is to solve aforementioned tasks, and provide formulas by which the user can perform the calculations, for a limited number of products, using spreadsheets. In general the complexity of scheduling, when many different products are made, a computerized system is needed.

In the following we describe several different order situations exemplified for 3 different parts X,Y, Z, Table 3, which are delivered in any desired customer quantity distribution at any desired TAKT Time, see examples in Tables 2.1 –2.7 and 3.1 – 3.4

Calculation of TAKT Time. Manufacturing Rate, Daily and Weekly Quantities, and Capacity Utilization.

The examples shown are summarized in TABLES 2.1-2.4 (different weeks for delivery of X,Y,Z) and TABLES and 2.5 (simultaneous delivery of X,Y,Z)

Assumptions

Customers will demand specified and different quantities of each design over a given time schedule. The manufacturer must decide whether the parts should be made in 3 ...t

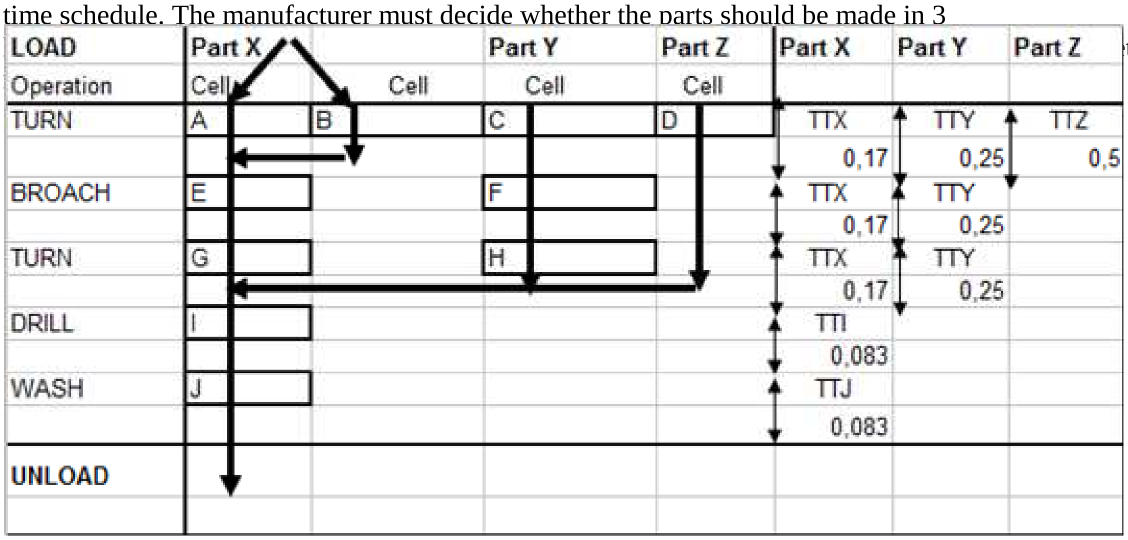

Fig.4

The manufacturer decides to produce all products X, Y, Z in a line-type (U-Shaped) system consisting of machines, conveyors and satellites, see Fig.4.

Making the parts in 3 lines is obviously more costly, as First, 2 more machines of type I and 2 more of type J would be needed in each line. Second, more resources in terms of supervision and operators would be needed.

Manufacturing of parts X,Y, Z are made in different machines or, cells, design X in types A, B, E, G, Y in types C,F,H and Z in types D. All parts are finally drilled and washed in X = Y1+Y2+Y3+Y4+Y5, Z = Z1+Z2+Z3+Z4+Z5. Indices 1, 2, etc means 1st, 2nd etc.

machine types I and J. The parts are delivered during 5-day weeks each day in scheduled various amounts, or same daily quantities, such as X = X1+X2+X3+X4+X5,

NOMENCLATURE – SCHEDULING – BALANCING FORMULAS

(Calculation of Takt-time, Manufacturing Rate, Daily and Weekly Quantities – Capacity Utilization)
The following formulas are used in order to minimize the manufacturing lead time and cost, and be the best solution for the customer as well, including plant capacity utilization. Each formula carries a simple example and all formulas are used to compute the results in the main examples, Example 1 and 2, shown in the Tables 2 and 3.

Time Value Added = Productive Time (cycle time = cutting or forming + tool & machine motions = TVA, minutes per part
Time Non Value Added = Material Handling + Waste = TNVA , minutes per part
TAKT Time = TT = TVA + TNVA, minutes per part
Manufacturing Rate = MR =1/TT, parts per minute
Manufacturing Efficiency = EFF = TVA/TT

TSUP = Time for Setup
LOTS =Lot size
Manufacturing Time = TM = TT + TSUP/LOTS

Example. Calculate Manufacturing Rate and Manufacturing Efficiency: For a cell with TVA =0.2 minutes, TNVA = 0.05minutes. Using above formulas we get TT = 0.2+0.05 = 0.25 minutes = 15 seconds, MR = 4 parts/minute, and finally Manufacturing Efficiency, EFF =0.2/0.25 = 0.80 = 80%.

MR = OQ(#shifts*hours/day*60*days/week*DW(1-Eff)
Eff = TVA/TT
ACELLHOURS= DW*3*5*8
CCELLHOURS=DW*NPW*TT/60
DW =OQ/((3*8*60*(CU*MR)*5))
CU = CCELLHOURS/ACELLHOURS
DW =OQ/((3*8*5*60*(MR*CCELLHOURS/ACELLHOURS)))

NPDX =Parts per day and shift of X = 480/TTX
NPD = #Shifts*480 (1/TTX+ 1/TTY+ 1/TTZ)
NPW =#Shifts* 5*NPD

NPDZ =Parts per day and shift of
Z = 480/TTZ
Above formula gives:
Example. TAKT Time = TTX =
0.25 minutes:
NPDX = 480/0.25 = 1920
or, when TTX is not used or
known, NPD is determined using
CU and MR:

Number of parts per day:

NPD =#Shifts*8*60*(CU*MR)

Total Number of parts per week:
NPW =5*NPD =

Total Number of parts per week of products X, Y, Z :
NPWTOT = 5*NPD =Total number of parts per week
NPWX = 5*480/TTX
NPWY = 5*480/TTY
NPWZ = 5*480/TTZ

Example. TAKT Time = TTX = 0.25 minutes, NPDX = 1920:
NPW = 9600 parts per week.
or, using:
NPW =5*NPD =

5*#Shifts*8*60/TT = 5*#Shifts*8*60*(CU*MR)

Adjustment formulas for achieving synchronous flow in cells I and J
All 3 products flow through the drilling and washing cells I and J, which are the last stations in this line. The manufaxcturing rate (MR) and TAKT time (TT) for synchronous flow is calculated based the total weekly order quantity produced during 5 days in 3 shifts (3*480*5 =7200 minutes) , determined by:
TTI =TTJ = #Shifts*8*60/ NPD.

Example: NPD = 17280, #Shifts =3,

TTI =TTJ = 0.083 minutes/part = 5 seconds/part
Determining TVA and MR:
Cell I: TNVA = 0.023; TVA= TT –TNVA = 0.06 minutes =3.6 seconds,
MR=1/TVA=16.67 parts/min.
Cell J: TNVA = 0.013; TVA= TT –TNVA = 0.07 minutes =4.2 seconds,
MR=1/TVA=14.29 parts/min.

This is shows in the spread sheet, **TABLE 2.1.**

100*(weeks to complete/ weeks to complete longest order)

Cell hours to Complete Order
Example: CELLHOURS =2500 hours. PLANTHOURS = 5000 hours

Capacity Utilization
CU = 100*2500/5000 = 50 %.

CUPLANT and CUORDER

TABLE 2.3 shows a spread sheet resulting from using above formulas to determine CELLHOURS,PLANTHOURS and CUCELL. CUPLANT and CUORDER based on the values in Tables 2.1-2.2.

Weeks to Complete Order
Delivery (weeks) **DW = Order Quantity/Parts/week = OQTY/NPW** Or, expressed in terms of MR and CU:
DW =OQTY/(3*8*60*(CU*MR)*5))
Example. OQTY = 700000, NPW =28800
DW = 24.3 weeks

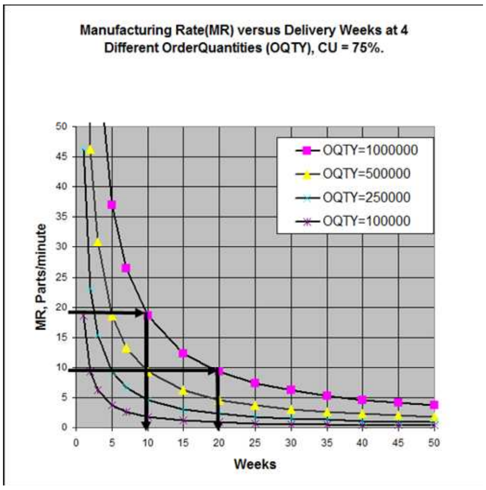

Fig.5 Daily Distribution of parts

The distribution of the quantity (NPDX, NPDY, NPDZ) of products X, Y, Z can either be the same or vary each day, but at the end of the week the quantity should be equal to the customer required number, and we have:
NPWX = NPWX1+…+ NPWX5
NPWY = NPWY1+…+ NPWY5,NPWZ = NPWZ1+…+ NPWZ5

Figs, 5 (Chartesian) and 6 (logarithmic coordinates) show graphs of MR versus Delivery Weeks at four different order quantities and at constant Capacity Utilization, CU =75%. Following the arrows in the graph pertaining to delivering an order of 1000000 parts:
20 weeks delivery is achieved at a manufacturing rate of approximately
MR = 9 parts/min, and 20 weeks delivery for about MR = 18 parts/min.

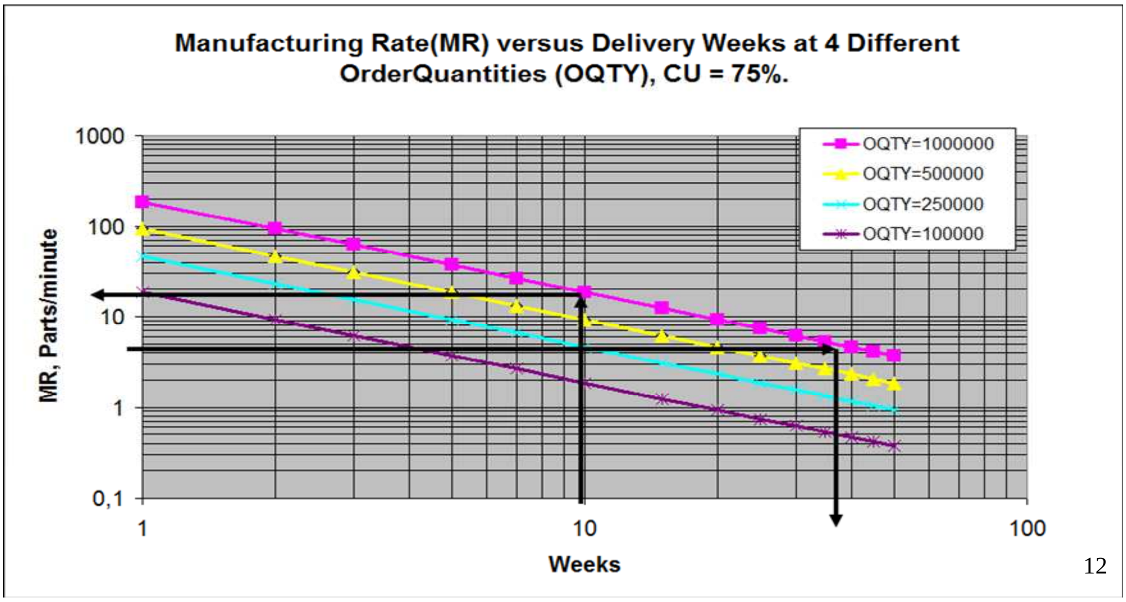

Figure 6. MR versus Delivery Weeks Different Order Quantities

Determining Manufacturing Rate for Delivery of All Products Simultaneously

An alternative scheduling strategy is as follows.
Based on the current orders the firm may strive for an optimal solution, with the intent to achieve 100% plant utilization and deliver all products simultaneously.
The requirement for this strategy is to balance the different takt times (TT) so that aforemen goal is obtained.
The following formula is used setting Delivery in weeks the same for each product:

MR= OQTY/(#Shifts*8*60*(CU*DW))*5))
where **DW** =Delivery (weeks)
Determining Manufacturing Rate for Delivery of Each Order in Desired Number of Wee
MR= OQTY/(#Shifts*8*60*(CU*DW))*5))

II. Determining Manufacturing Rate (MR) for Delivery of All Products Same Numb Weeks

TABLE 2.4 shows a spread sheet resulting from using above formula for Delivery of All Pr Simultaneously

Points A and B show for product Y that 7 weeks delivery is obtained at MR =11 and 16 weeks at MR around 5 parts/min. Hence, in this example modifying the manufacturing rate by a factor of 11/5 =2.2 will reduce delivery by the same ratio, or in this case a little more 16/7=2. Changing feeds and speeds by a factor of 3:1 will, depending on initial conditions and how much of the cycle time is cutting, lead to aforementioned MR-Ratio.

Using above formulas the following examples will guide you programming into a simple internal program and and all the many determinations will be made quickly.

Example 1. Planning for Manufacturing and Example 2. Results during Actual Manufacturing
Applying aforementioned formulas is easily done using spread sheets, in this case Excel was used. There are 2 examples, Example 1 and 2 which are summarized in TABLES 2.1 – 2.4 and 3 (different weeks for delivery of X,Y,Z), TABLE 2.5 (simultaneous delivery of X,Y,Z) and in TABLES 2.6 – 2.7 (Determining manufacturing rates for scheduled (desired) number of weeks delivery.
The Table 3 example pertains to re-scheduling of orders requiring shorter deliveries:
X = 30,Y = 30 and Z = 24 weeks.
TABLE 2.1 shows a spread sheet resulting from using above formulas to determine TT,TVA, CU for given values of MR.
TABLE 2.2 shows a spread sheet resulting from using above formulas to determine NPD and NPW based on the values in Table 2.1 and given order quantities for products X,Y,Z.
TABLE 2.3 shows a spread sheet resulting from using above formulas to determine Weeks to Complete Order
TABLE 2.4 shows a spread sheet to determine Daily Distribution of parts to Complete Order for equal daily quantities.
TABLE 2.6 shows a spread sheet resulting from using above formulas to determine Manufacturing Rate for desired number of weeks delivery,
and
TABLE 2.7 shows a spread sheet to determine Manufacturing Rate for another set of desired number of weeks delivery 14

TABLE 2.1.

Planning Number Weeks Delivery

Product	Parts	Prod-	Non VA	TAKT	Efficiency	**Cell**	**Number**
	minute	uctive				**Capacity**	
		TIME		TIME		**Utilization**	**Shifts**
		minutes	minutes	minutes			
Cell(X,Y,Z)	MR	TVA	TNVA	TT	Eff=TNVA/TT	CUCELL%	#
X	9.090909091	0.11	0.056666667	0.166666667	0.34	66	3
Y	5	0.2	0.05	0.25	0.2	80	3
Z	2.857142857	0.35	0.15	0.5	0.3	70	3
Cell(I,J)				Calc			
I	16.66666667	0.06	0.023333333	0.083333333	0.28	72	
J	14.28571429	0.07	0.013333333	0.083333333	0.16	84	
TOTAL							3

TABLE 2.2.

Resulting Weekly Delivery of Number of Parts,
Cell and Plant Hours, Cell and Plant Capacity Utilization

Product	**Order**	**Per**	**Number**	**# Parts**	**Cell**	**Plant**	**Cell**	**Plant**	**Number**	**# Parts**
	Quan	**cent**	**Parts**	**week**	**Hours**	**Hours**	**Capacity**	**Capacity**	**Parts**	**week**
	tity	**Part**	**/day/**		per week	per week	**Utilization**	**utilization**	**/day/**	
		Distri	**3 shifts**						**3 shifts**	
									CU=100%	CU=100%
Cell(X,Y,Z)	OQ	**bution**	NPD	NPW	CELLHOURS	PLANTHOURS	CUCELL%	CUPL%	NPD	NPW
X	700000	53.435115	8640	43200	79.2	120	66		13090.90909	65454.54545
Y	450000	34.351145	5760	28800	96	120	80		7200	36000
Z	160000	12.21374	2880	14400	84	120	70		4114.285714	20571.42857
Cell(I,J)										
I			17280	86400	86.4	120	72		24405.19481	122025.974
J			17280	86400	100.8	120	84	TOTAL	24405.19481	122025.974
TOT Order	1310000	100	17280	86400	446.4	600		74.4	24405.19481	122025.974

TABLE 2.3.

Planned Weekly Delivery of Number of Parts,
Cell and Plant Hours, Cell and Order Capacity Utilization

Product	**Order**	**Per**	**Number**	**Weeks**	**Cell**	**Plant**	**Cell**	**ORDER**
	Quan	**cent**	**Parts**	**to**	**Hours**	**Hours**	**Capacity**	**Capacity**
	tity	**Part**	**/day/**	**complete**	**to**	**to**	**Utilization**	**utilization**
		Distri	**3 shifts**	**Mfg**	**complete**	**complete**		
Cell(X,Y,Z)	OQ	**bution**	NPD		CELLHOURS	PLANTHOURS	CUCELL%	CUORDER%
X	700000	53.435115	8640	16.2037037	1283.333333	1944.444444	66	X
Y	450000	34.351145	5760	15.625	1500	1875	80	Y
Z	160000	12.21374	2880	11.11111111	933.3333333	1333.333333	70	Z
TOTAL			17280		3716.666667	5152.777778		72.12938005
Cell(I,J)								
I			17280		3716.666667	5152.777778	72	
J			17280		3716.666667	5152.777778	84	
TOT Order	1310000	100			11150	15458.33333		72.12938005

TABLE 2.4

Planned Customer orders per day before Manufacturing Starts

							TOTAL
							ORDER/
	Given	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	week
Cell(X,Y,Z)	MR	NPD1	NPD2	NPD3	NPD4	NPD5	NPW
X	9.090909091	8640	8640	8640	8640	8640	43200
Y	5	5760	5760	5760	5760	5760	28800
Z	2.857142857	2880	2880	2880	2880	2880	14400
Cell(I,J)							
I	16.66666667	17280	17280	17280	17280	17280	86400
J	14.28571429	17280	17280	17280	17280	17280	86400
							NPWTOT
TOT Parts/day		17280	17280	17280	17280	17280	86400

TABLE 2.5.

Determining Manufacturing Rate (MR) for Delivery of All Products Same Number Weeks

Product Cell(X,Y,Z)	**Order Quan tity** OQ	**Per cent Part Distri bution**	**Number Shifts** #	**Weeks to complete Mfg**	Parts minute MR	Prod- uctive TIME minutes TVA	Non VA minutes TNVA	TAKT TIME minutes TT
X	700000	53.435115	3	11.11111111	13.25757576	0.075428571	0.056666667	0.132095238
Y	450000	34.351145	3	11.11111111	7.03125	0.142222222	0.05	0.192222222
Z	160000	12.21374	3	11.11111111	2.857142857	0.35	0.15	0.5
Cell(I,J)								Calc
I			**3**	33.33333333	16.66666667	0.06	0.023333333	0.083333333
J			**3**	33.33333333	14.28571429	0.07	0.013333333	0.083333333
TOTAL	1310000	100	3					

Efficiency Eff=TNVA/TT	**Cell Capacity Utilization** CUCELL%	**# Parts /day/ 3 shifts** NPD	**# Parts week** NPW	**Cell Hours to complete** CELLHOURS	**Plant Hours to complete** PLANTHOURS	**Plant Capacity Utilization ation** CUPLANT%
0.34	66	10901.226	54506.12833	880	1333.333333	85
0.2	80	7491.3295	37456.6474	1066.666667	1333.333333	85
0.3	70	2880	14400	933.3333333	1333.333333	85
0.28	72	17280	86400	2880	4000	
0.16	84	17280	86400	3360	4000	
		21272.555	**106362.7757**	**9120**	**12000**	**76**

TABLE 2.6.

Determining Manufacturing Rate (MR) for Delivery of Each Product after Desired Number Weeks

Product Cell(X,Y,Z)	**Order Quan tity** OQ	**Per cent Part Distri bution**	**Number Shifts** #	**Weeks to complete Mfg**	Parts minute MR	Prod- uctive TIME minutes TVA	Non VA minutes TNVA	TAKT TIME minutes TT
X	700000	53.435115	3	9	16.36737748	0.061097143	0.056666667	0.11776381
Y	450000	34.351145	3	7	11.16071429	0.0896	0.05	0.1396
Z	160000	12.21374	3	3	10.58201058	0.0945	0.15	0.2445
Cell(I,J)								Calc
I			**3**	19	16.66666667	0.06	0.023333333	0.083333333
J			**3**	19	14.28571429	0.07	0.013333333	0.083333333
TOTAL	1310000	100	3					

Efficiency Eff=TNVA/TT	**Cell Capacity Utilization** CUCELL%	**# Parts /day/ 3 shifts** NPD	**# Parts week** NPW	**Cell Hours to complete** CELLHOURS	**Plant Hours to complete** PLANTHOURS	**Plant Capacity Utilization ation** CUPLANT%
0.34	66	12227.865	61139.3265	712.8	1080	68.85
0.2	80	10315.186	51575.93123	672	840	53.55
0.3	70	5889.5706	29447.85276	252	360	22.95
0.28	72	17280	86400	1641.6	2280	
0.16	84	17280	86400	1915.2	2280	
		28432.622	**142163.1105**	**5193.6**	**6840**	**75.92982456**

TABLE 2.7.

Determining Manufacturing Rate (MR) for Delivery of Each Product after Desired Number Weeks

Product Cell(X,Y,Z)	**Order Quan tity** OQ	**Per cent Part Distri bution**	**Number Shifts** #	**Weeks to complete Mfg**	Parts minute MR	Prod- uctive TIME minutes TVA	Non VA minutes TNVA	TAKT TIME minutes TT
X	700000	53.435115	3	10	14.73063973	0.067885714	0.056666667	0.124552381
Y	450000	34.351145	3	15	5.208333333	0.192	0.05	0.242
Z	160000	12.21374	3	18	1.76366843	0.567	0.15	0.717
Cell(I,J)								Calc
I			**3**	43	16.66666667	0.06	0.023333333	0.083333333
J			**3**	43	14.28571429	0.07	0.013333333	0.083333333
TOTAL	1310000	100	3					

Efficiency Eff=TNVA/TT	**Cell Capacity Utilization** CUCELL%	**# Parts /day/ 3 shifts** NPD	**# Parts week** NPW	**Cell Hours to complete** CELLHOURS	**Plant Hours to complete** PLANTHOURS	**Plant Capacity Utilization ation** CUPLANT%
0.34	66	11561.401	57807.00413	792	1200	76.5
0.2	80	5950.4132	29752.06612	1440	1800	114.75
0.3	70	2008.3682	10041.841	1512	2160	137.7
0.28	72	17280	86400	3715.2	5160	
0.16	84	17280	86400	4334.4	5160	
		19520.182	97600.91125	11793.6	15480	76.18604651

Rescheduling Ordor Requiring Shorter Delivery Times

The Table 3 example pertains to re-scheduling of orders requiring shorter deliveries: X = 30,Y = 30 and Z = 24 weeks.

TABLE 3.1.

Resulting Customer orders per day after Manufacturing Started

Varying Manufactured Daily Quantities after Manufacturing Rates were Set.

Product		Max/ Day	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	TOTAL Manufactured ORDER/ week	**Cell Capacity Utilization**
	MR	CU=100%	NPD1	NPD2	NPD3	NPD4	NPD5	NPWMFG	CUCELL
X	9.090909	13090.909	7000	8640	6500	9000	6000	37140	56.74166667
Y	5	7200	5000	5760	4500	6500	4500	26260	72.94444444
Z	2.857143	4114.2857	2500	2880	2700	2880	2000	12960	63
Cell									
I	16.66667	24405.195	14500	17280	13700	18380	12500	76360	62.57684121
J	14.28571	24405.195	14500	17280	13700	18380	12500	76360	62.57684121
								NPWTOTMFG	
TOT Parts/day		24405.195	14500	17280	13700	18380	12500	76360	62.57684121

TABLE 3.2.

Resulting TAKT Times, Efficiencies and Cell Capacity Utilizations

Product	Parts minute	Prod-uctive TIME minutes	Non VA minutes	TAKT TIME minutes	Efficiency	**Cell Capacity Utilization**	**Number Shifts**
Cell(X,Y,Z)	MR	TVA	TNVA	TT	Eff=TNVA/TT	CUCELL%	#
X	9.090909	0.11	0.083861066	0.193861066	0.432583333	56.74166667	3
Y	5	0.2	0.074181264	0.274181264	0.270555556	72.94444444	3
Z	2.857143	0.35	0.205555556	0.555555556	0.37	63	3
Cell(I,J)				Calc			
I	16.66667	0.06	0.035882117	0.095882117	0.374231588	62.57684121	
J	14.28571	0.07	0.04186247	0.11186247	0.374231588	62.57684121	

TABLE 3.3.

Resulting Weekly Delivery of Number of Parts,
Cell and Plant Hours, Cell and Plant Capacity Utilization

Product	**Order Quantity**	**Percent Part Distribution**	**# Parts week**	**Cell Hours** per week	**Plant Hours** per week	**Cell Capacity Utilization**	**Plant Capacity utilization**
Cell(X,Y,Z)	OQ		NPW	CELLHOURS	PLANTHOURS	CUCELL%	CUPL%
X	700000	53.435115	37140	68.09	120	56.74166667	
Y	450000	34.351145	26260	87.53333333	120	72.94444444	
Z	160000	12.21374	12960	75.6	120	63	
Cell(I,J)							
I			76360	76.36	120	63.63333333	
J			76360	89.08666667	120	74.23888889	TOTAL
TOT Order	1310000	100	76360	396.67	600		66.11166667

TABLE 3.4.

Resulting Number of Weeks Delivery

Product	**Order Quantity**	**Percent Part Distribution**	**Weeks to complete Mfg**	**Cell Hours to complete**	**Plant Hours to complete**	**Cell Capacity Utilization**	**ORDER Capacity utilization**
Cell(X,Y,Z)	OQTY			CELLHOURS	PLANTHOURS	CUCELL%	CUORDER%
X	700000	53.435115	18.84760366	1283.333333	2261.712439	56.74166667	X
Y	450000	34.351145	17.13632902	1500	2056.359482	72.94444444	Y
Z	160000	12.21374	12.34567901	933.3333333	1481.481481	63	Z
TOTAL				3716.666667	5799.553403		64.08539431
Cell(I,J)							
I				3716.666667	5799.553403	63.63333333	
J				3716.666667	5799.553403	74.23888889	
TOT Order	1310000	100		3716.666667	5799.553403		64.08539431

4. MANUFACTURING TIME/COST RELATIONSHIPS

Assessing the manufacturing cost of a part is usually done using relatively simple formulas and rules of thumb, as an accurate method involves a great number of parameters both related to time and financial factors.
There are some 15 parameters in order to evaluate time and costs per part or batch, which are given in Tables 5 and 6, including calculation formulas. An additional number of parameters are needed for metal cutting operations, which are stated in Section 3.

The cost accounting system used by the firm is usually not adopted to measure the changes in aforementioned parameters determined by adding **fixed** and **variable** costs, and changes in shop processes deal with the variable portions. The problem is how do we define fixed and variable costs.
Tooling costs consisting of holders are called fixed. Chip removing tools, or stamping dies exhibit wear, in amounts depending on the magnitude of metal removal rates, become variable cost items. Machine tool depreciation and floor space are called fixed, but when rate of usage is considered, such as going from one shift to 2 or 3 shifts, they are no longer fixed, and thus variable. Examining all costs that build up the total cost we will find that some are semi-fixed or semi-variable others more or less fixed or variable, turning into variable or fixed respectively, when the utilization percentages change.
Apparently, many existing cost accounting systems create confusion among the manufacturing people, and the new Granular segmentation approach described in Section 1, applies.
The formulas and methods described in the chapter will provide the user with tools that are applicable to all processes such as cutting, forming, stamping etc., and to Assembly.

4.1 Manufacturing Cost - Simple Formula

This relationship consists of four terms in which labor, equipment depreciation and tooling costs are separated from the total cost, and the overhead, based on the balance:

Manufacturing Cost per Batch (CMB) =Hours*[(LO + OH)/hour + Depreciation Rate/hour] + Tooling

Depreciation Rate = Investment/(Economic Life of Equipment) [$/year]

Depreciation measured per hour now becomes a variable item:
Depreciation Rate = Investment/(#Shifts*(Yearly standard hours/shift)*(Economic Life of Equipment) [$hourr]
LO = Labor Rate, $/hour
OH =Overhead Rate, $/hour

Example 1. Investment = $108,000, Economic Life of Equipment = 6 years
Depreciation =108000/6 =$18, 000 per year.
#Shifts = 1, when a standard year = 1800 hours:
Depreciation =108000/1/1800/6 =$10 per hour.
#Shifts = 2:
Depreciation =10/2 =$5 per hour

#Shifts = 3::
Depreciation =10/3 =$3.33 per hour

Example 2. Using the hourly depreciation rate from Example 1 for 2 #Shifts, and assuming manufacturing hours = 20, (LO+OH)/hour = $35 and Tooling Cost = 150:
ManC = 20*(35 + 5) + 150 = $950.00.

Applying this formula to a comparison of costs between manufacturers of automotive body panels is depicted in the bar graph in Fig. 7. The costs represent approximate values obtained in a comparative study by the author in 1987.

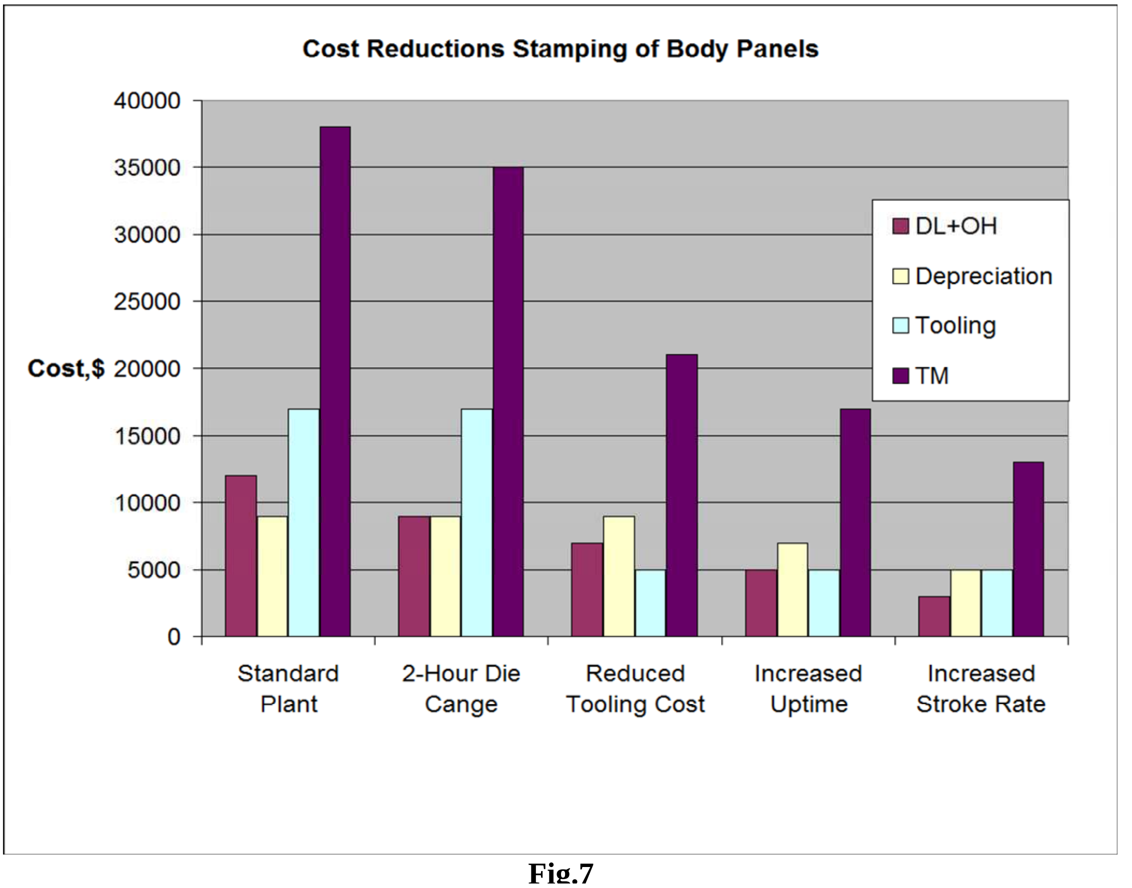

Fig.7

The chart shows how 4 successive improvements in setup times, reduced tooling cost, increased uptime and higher press stroke rate lead to considerably reduced cost compared to standard plant.

The chart data refer to a (LO and OH) shown in the upper portion of Table 4, where the OH-part represents the granular approach, Case 1. In the lower portion, Case 2, the OH-part corresponds to a rate, evaluated on the basis of all overhead costs, maintaining the labor, depreciation and tooling costs the same as in Case 1. The cost ratios compared to standard plant stamping are found in the right columns, resulting in about the same ratios whether the lower or higher overhead rate is applied. ***The conclusion is that aforementioned simple method is adequate for relative cost assessments, but not very good for absolute estimates. The formulas given below provide a more systematic and accurate approach.***

Table 4													
Comparision of Relative Costs among Firms Making Automotive Body Panels													
Using 2 different (LO+ OH) Rates													
Invest	**#Shift**	**Econ life**											
1080000	2	6											
CASE 1			LO+OH	LO+OH	LO+OH	Depreciation			Tooling	TOTAL	Ratio vs		
			$/hour	hours	$	$/hour	hours	$			standard		
Standard Plant			70	180	12600	50	180	9000	17000	38600	1		
2-Hour Die Cgange			70	160	11200	50	160	8000	17000	36200	0.937824		
Reduced Tooling Cost			70	160	11200	50	160	8000	5000	24200	0.626943		
Increased Uptime			70	100	7000	50	100	5000	5000	17000	0.440415		
IncreasedStroke Rate			70	60	4200	50	60	3000	5000	12200	0.316062		
CASE 2			LO+OH	LO+OH	LO+OH	Depreciation			Tooling	TOTAL		Ratio	
			$/hour	hours	$	$/hour	hours	$				CASE1/CASE2	
Standard Plant			140	180	25200	50	180	9000	17000	51200	1	1	
2-Hour Die Cgange			140	160	22400	50	160	8000	17000	47400	0.925781	1.013008	
Reduced Tooling Cost			140	160	22400	50	160	8000	5000	35400	0.691406	0.906765	
Increased Uptime			140	100	14000	50	100	5000	5000	24000	0.46875	0.939551	
IncreasedStroke Rate			140	60	8400	50	60	3000	5000	16400	0.320313	0.986731	

Table 4

4.2 Complete Factory and Manufacturing Cost Formula

Factory Cost (FC) = Manufacturing Cost (CM) + Material Cost (CMTRL) + Inventory Cost, or Warehousing (CI) + Value of Work-In-Process (WIP):

FC = CMan + CMTRL + CI + WIP

Manufacturing Cost (CM) = Preparatory Cost (CPRE) + Value Added Cost (CVA) + Non VA Cost (CNVA):

CMan = CPRE + CVA + CNVA

Preparatory Cost includes:

Preparatory Cost (CPRE) = Cost of Ordering materials, Cost Estimating and Rate setting, Process Planning and Scheduling, Cost of Design of Fixtures, Cost of Manufacturing Fixtures and Cost Program Testing.

Value Added Cost (CVA) = Cost of tools cutting, or forming + tool motions (in air) + tool changing + tool(die) reconditioning

Non-Value Added Cost, or waste (CNVA) = Cost shop down time, Cost rejects and Office planning deficiencies.

All these cost items vary with Delivery and Manufacturing Time, Order Volume and Annual Demand.

All these cost items vary with Delivery and Manufacturing Time, Order Volume and Annual Demand.

Manufacturing rate (MR), the efficiency (Eff), or the Capacity Utilization (CU) of the plant or process, are major factors in assessing the manufacturing cost.

Fig.8 shows optimization of Machining Processing Cost where MR and CU are varied. Processing cost is plotted versus (VA) time with Non-Value-Added (NonVA) time as parameter.

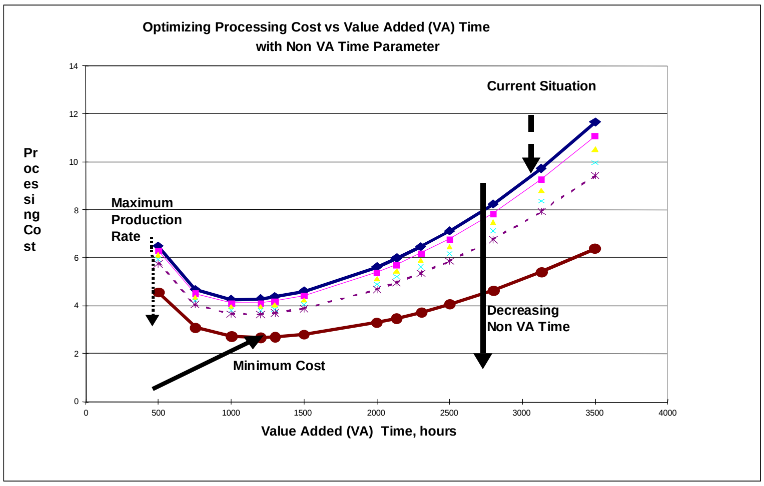

Fig.8

The current situation (marked in graph) where (VA)-time is approximately 300 hours, at which (NonVA) costs are about as high as the (VA) costs. Minimum cost occurs for proper selection of feeds-speeds-tool-lives, see Part 3. An approximately 1:3 cost ratio would be ideally possible in this case.

At Maximum Production Rate total costs run high due to very high costs for cutting tools.

20

4.3 Econometric Manufacturing Cost Models

Models based on discrete known points on cost curves such as shown in Fig.9, or cost history of parts, can be used to forecast the cost situation under various scenarios.
These models are using a mathematical approach by which for example the shape of the cost curves versus lot size can be varied, or used for cost assessments of part families.
One example is the “Learning- curve” model, which calibrated versus for example known costs at 2 or 3 fixed lot sizes, will yield the shape of the cost curve. By knowing or guestimating some other points more or less reasonable estimates across a whole spectrum of scenarios are obtained.

4.4 Colding’s Equation – DBGen (Data Base Generator)

$$Y= K - (X-H)^2/4M-(N0-L*X)*Z,$$

Setting X and Y as follows: X =LN (NP), NP =Volume, or Number of Parts, or number of years, or Year 200X, 200X+1,200X+2 etc.

Y=LN (C),C=TOTAL COST, or
Y=LN(cp), cp =Unit Cost,
or
Y= LN (S) ,S= TOTAL SALES or

LN(sp),Sp =Unit Sales Price
and
Z=LN (I), where **I** = **II/S**, or company Competence or, **"Intelligence parameter",** defined as the ratio of Intelligent Investments **(II)** and the company **Sales (S)** values**.** The value **II** is the **annual** cost of the sum of investments in R&D, Investments in Capital Equipment and Software (CI) and a new term called **IC**= Intellectual Capital. These parameters are described in the following chapter.
Colding's model is an alternative which fits manufacturing econometrics very well, see Section 2 and Section 7 Part III, for a detailed explanation of this function.

The model coupled with the cost formulas shown above and time formulas that follow, will enable the user to achieve a very good accuracy. This model includes all time elements including set-up and tooling cost and Granual Metrics can be applied. The very important factor Capacity Utilization (accounting for NonVA Time) is also included.
Obviously, when an entire product design consisting of a large number of different parts is to be cost estimated the accuracy increases with the percentage of detailing. If say 25% is detailing, and 75% of the parts are subjected to intelligent "braintrust" guestimating the result may turn out to be very good. We must also consider the time it takes to guestimate. Hence, as usual there is always a given estimating time versus a detailing percentage of parts, optimal to obtain a reliable final estimate of a new product.

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We must also consider the time it takes to guestimate. Hence, as usual there is always a given estimating time versus a detailing percentage of parts, optimal to obtain a reliable final estimate of a new product.

- Time and Cost Formulas for any Lot Size, Setup Time, TAKT Time and Hourly Rate

Times and Costs are defined either per operation or as the sum of all operations. When we deal with machining refer to the time and cost calculations including tooling costs described in Part 3.

The method is based on the user input of Takt Time (TT), Lotsize, and Setup time and Hourly Shop Rate (HR) and when including the cost of planning (CPL) also Hourly Rate (HRPL) for planners, estimators and programmers. The formulas can also be applied to forming and stamping operations with reasonable accuracy, setting the press stroke cycle as defined by the cycle time in machining. In forming and stamping operations the tooling costs are much higher but the die lives (measured as contact time) are also much longer. The ratio (TV/TE) is approximately of the same magnitude as in machining, of the order ½ to ¼ . The results are approximate if based on standard values of the ratio of tooling cost and die life (TV/T) in forming and stamping operations. When dealing with machining processes the accuracy is improved as above ratio is defined as TV divided by the economic tool-life, (TV/TE), described in the machining Part 3, Chapter 3. Setup time and Lot size have great influence, but modern physical layout and equipment designs can reduce this impact substantially, so that their influence becomes less important.

Using the formulas and the graphs described in the following the user can calculate Unit and Batch Manufacturing Time and Cost versus Takt time, Setup Time, Lot Size for any hourly rate (Including or Excluding planning, programming and scheduling hours).

In the following pages you will find descriptions of time and cost relationships depicting formulas for time and cost as functions of several variables such as Setup time and Lot size ready for internal programming.

The following formulas are used, and summarized in Table 5

Table 5.

UNIT TIME ELEMENTS (Time per Batch: Multiply by Lot Size)	
(All times in minutes)	
TM =Time of Manufacturing incl. Slack/part:	
TM =TVA+TNVA	
TVA = Value Added time =TSUP/LOTS+TT	
TNVA=Non-Value Added time, Time of slack (= waste) = TSL	
TT=TAKT Time, or Cycle Time, including Tool Replacement	
Manufacturing Rate (MR) = 1/TT	
TSUP = Time for Setup	
LOTS =Lot or Batch Size	
TSUP/LOTS = TSUP per LOT =Time of setup per Lot Size (LOTS)	
Rewriting Time of Manufacturing in terms:	
TM=TSUP/LOTS+TT+TSL, or	
TT = TI+TC*(1+TRP/T)	
TM=TSUP/LOTS+TI+TC*(1+TRP/T)+TSL	
TI=Idle time (non-cutting)	
TC =Time of cutting, or forming, or stamping etc.	
TRP=Time of Tool Replacement	
T=Tool-life	
Total Time per Batch =TMB=TM*LOTS	
Takt Time per Batch =TTB = TT*LOTS	
Capacity Utilization	
CU=TVA/(TVA+TNVA); TSL = TNVA= TVA*(1/CU-1)	
or,	
CU =(TT+TSUP/LOTS) /(TT+TSUP/LOTS+TSL)	
Manufacturing Planning	
TPL = Time of Process Planning, Programming and Scheduling	
Time of Manufacturing Including Planning per Batch	
TMPL= TMB + TPL	
The "takt" Time for TPL should be less or equal TMB	
UNIT COST ELEMENTS (Cost per Batch: Multiply by Lot Size)	
CMan =Cost of Manufacturing, excluding Planning Costs	
CMan=CVA+CNVA	
CVA = Cost of Value Added time	
CNVA=Cost of Non-Value Added time, Time of slack (= waste)	
CVA=(HR/60)*(TM-TSL) + CT + CPREP/LOTS	
CNVA=(HR/60)*TSL	
CSUP = Cost of Setup per Batch	
CSUP = (HRSUP/60)*TSUP	
CT=Cost of Tooling including fixturing	
HR= Hourly Shop Rate, excluding Setup Rate, $/Hour	
HRSUP = Hourly Setup Rate , $/Hour	
Cost of Tooling per Part CT = TC*HR*(1+TV/T)/60	
CT =TC*(CE)/T	CTE=HR*TC(TV/TE)/60, TE=TV*(1/n-1)=3*TV
CT/HR=TC*(CE)/T/60	
Cost of Tooling per Batch =CTB=CT*LOTS=Cost of Tooling including fixturing/Batch	
UNIT Cost of Manufacturing Excluding Planning	
EXACT Method, when Tooling cost calculated using the methods in Section 3:	
CMan = (TVA/60)*(1/CU)+CT +(TSUP/LOTS/60)*(HRSUP -HR)	
Cost of Manufacturing Planning	
CPL =Cost of Process Planning, Programming and Scheduling per Batch	
CPL =HRPL*TPL/60	
HRPL = Hourly Planning Rate, $/Hour	
CManPL=Cost of Manufacturing, including Planning Costs	
UNIT Cost of Manufacturing Including Planning	
CMan = (TVA/60)*(1/CU)+CT +(TSUP/LOTS/60)*(HRSUP -HR)+ (HRPL)*TPL/LOTS/60	
CManPL per Batch = CManB + CPL = CMan*LOTS + CPL	
Cost of Manufacturing Including Planning per Batch	
CManPLB= CMabB + CPL	

Setup time and Lot size have great influence, but modern physical layout and equipment designs can reduce this impact substantially, so that their influence becomes less important.

In the following employing the formulas and the nomenclature in Table 5 you will find several examples of their usage demonstrated, which will enable the reader to apply these to his or her applications.

The time and cost relationships depict times and costs as functions of several variables so they cannot be shown in one simple graph, or in one 3-D view, and are therefore shown in several nomograms.

The first example pertain to Figs. 9a,b and c, where the relative unit manufacturing cost (CM/HR) were plotted versus lotsize (LOTS) for two cases with takt times TT = 257 and 19 minutes. We assumed a plant capacity utilization, CU = 80%, and a shop hourly rate HR but for set-up a rate HRSUP = = $40/hour. Standard values of (TV/T) were used, and did not include time required for planning (TPL).

4.5 Cost of Manufacturing versus Cost of Tooling, CU, Times TT, TSUP, Lotsize

60*CM/HR = (TSUP/LOTS+TT)*(1/CU)+CT*60/HR +TSUP/LOTS*((HRSUP/HR-1) + (HRPL/HR)*TPL/LOTS,

where

TVA=TSUP/LOTS+TT, TNVA= TVA*(1/CU-1), TT= TC(1+TRP/TE) +TI, Cost of Tooling per Part CT = TC*HR*(1+TV/T)/60, TM=TSUP/LOTS+TT+ TNVA.

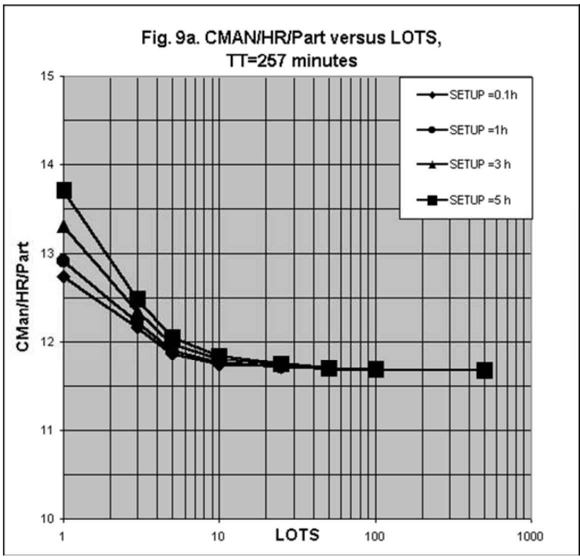


Fig. 9a. CMAN/HR/Part versus LOTS, TT=257 minutes

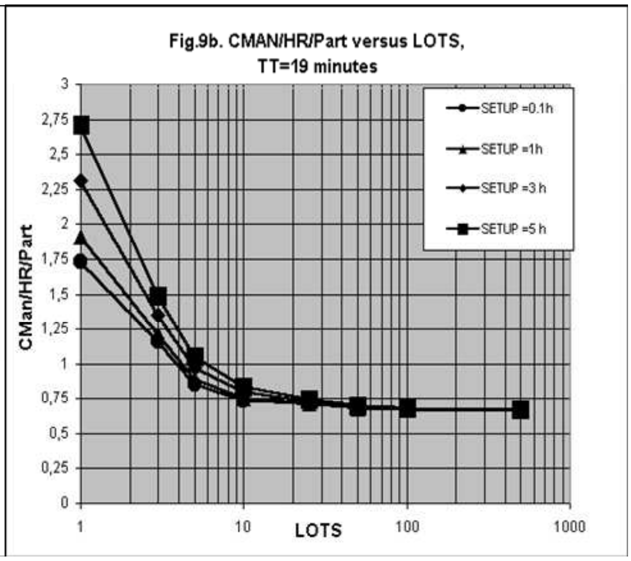


Fig.9b. CMAN/HR/Part versus LOTS, TT=19 minutes

When keeping takt time (TT) constant the calculations gave the relationships depicted in Figs 9a and b for TT = 257 and 19 minutes respectively, and for varying values of setup time (TSUP), from 0.1 to 5 hours. As shownAs shown the unit costs become independent of the duration of setup time (TSUP) for batches (LOTS) greater than 500 –1000 parts. For lotsizes below 50, the unit costs rise by a factor of up to 1.25 and 4 for takt times, or cycle times, (TT), of 257 and 19 minutes respectively. In Fig. 9c. the above nomograms are made into one, so that the influence of both (TT) and (TSUP) are more readily observed. For lotsizes above 50, the impact of set-up time is negliegible but a long cycle time yields as expected about 15 times higher cost.

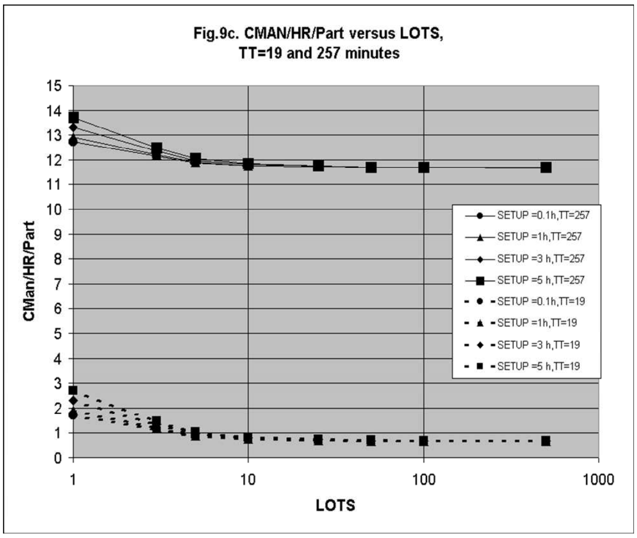
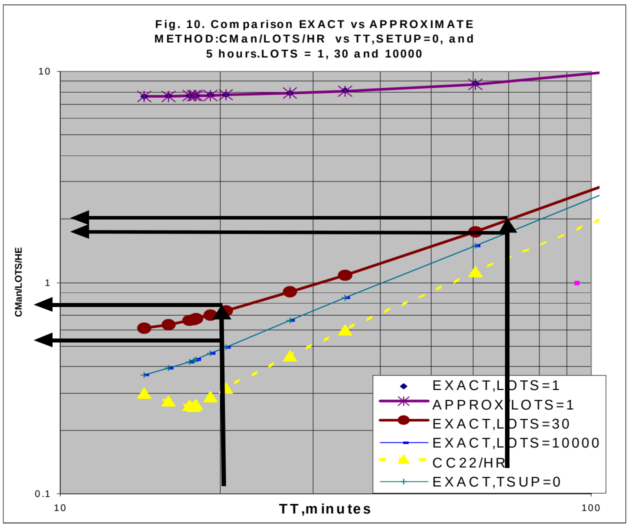


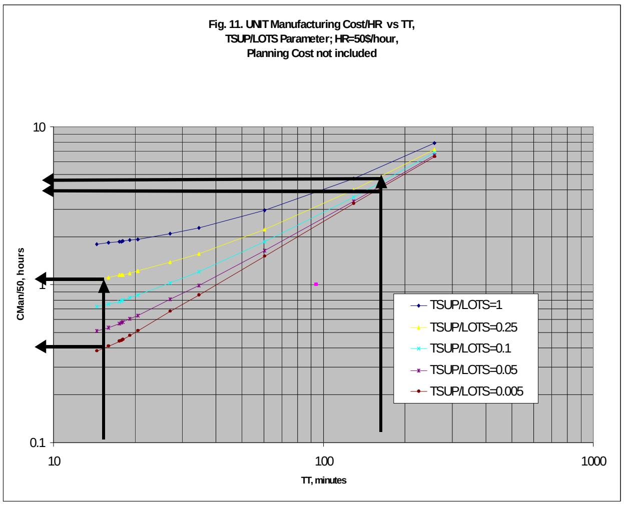
Fig.9c. CMAN/HR/Part versus LOTS, TT=19 and 257 minutes

The relative importance of cost reductions by either lowering setup or cycle time is demonstrated by these curves. In **Table 6** a few large batches.The conclusion is that selecting optimized data by a factor of 2 in machining operations is about as efficient as reducing setup time when only making 1 – 10 parts, such as in die making. At large lotsizes optimized machining data are much more effective.

Table 6

LOTS	SETUP Reduction from 5h to 3 h Cost Ratio	SETUP Reduction from 5h to 1 h Cost Ratio
1	1.6	3.5
10	1.2	1.6
100	1.03	1.07
1000	1.0	1.0





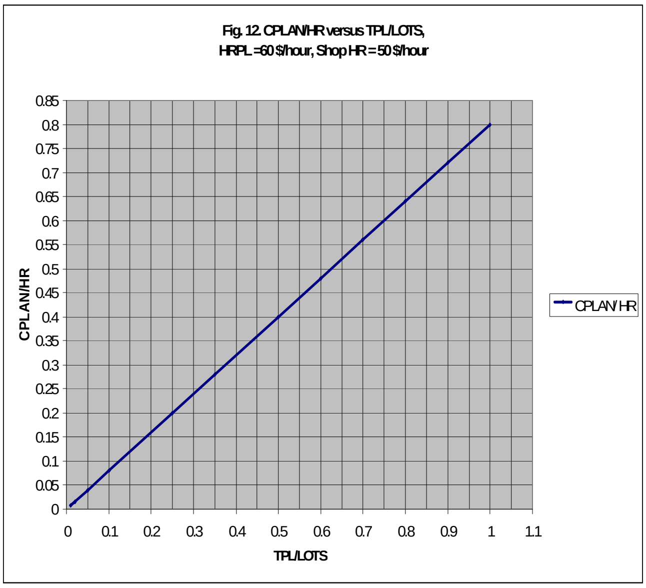


Fig. 10. shows the importance of reduced takt time (TT), in minutes, on unit cost when TSUP = 5 hours=300 minutes, for LOTS =1 part ,30 parts and 10000 parts. In the lower portion of the graph the total unit cost of cutting, tool replacement and tooling is also plotted. This curve has a sharp upwards bend, corresponding to minimum cost machining. The total manufacturing cost (sum of value-added (CVA) and non-value-added (CNVA) curves exhibit also a bend, but less pronounced than the cutting cost. This explains the reason for the bends in Fig. 11. This nomogram combined with the one in Fig.12 are the heart of the cost calculation method devised for use in this chapter. Fig. 11 shows curves of relative unit Manufacturing costs (CM/HR=50$/hour) plotted versus takt time (TT), with the ratio of setup time and lot size (TSUP/LOTS).

EXAMPLES.

TT=150 minutes and TSUP/LOTS =0.25, we find that the relative unit costs are the same when the ratio TSUP/LOTS is constant and equal to $4.70 in this case. The real cost is obtained by multiplying with HR= 50: CM = 4.7*50 = $235.

The ratio TSUP/LOTS =0.25 may mean for example either LOTS=1and TSUP =0.25 hours, LOTS=100 and TSUP =25 hours, LOTS=1000 and TSUP =250 hours, or LOTS=1and TSUP =0.25 hours. The batch costs (CManB) will amount to $235, $23,500, or $235,000 respectively.

The nomogram, Fig. 12, converts the relative unit cost values obtained in Fig.11 into relative unit cost for other shop hourly rates (HR) than HR=50$/hour used in Fig.11.

EXAMPLES. Using the data of previous Example we go to the relative cost 4.7 in the

4.6 Value of Work-In-Process (WIP)

WIP is explained in Part III: Enterprise Econometrics:

The formula to calculate WIP reads:

WIP=(i/100)*[(CM/2 + CMTRL) + (CM + CMTRL)*(1-TM/TNOMC)]

where i = Interest Rate, TNA =Time of Value-Added Operations, TNVA = Time of Non-Value-Added Operations, TM = TNA + TNVA = Time of Manufacturing, TNOMC = Time of Nominal Capacity, ManC = Total Manufacturing Cost. CMTRL = Cost of Material.

Finally, after having calculated both Manufacturing and Planning costs, we determine the Factory cost by adding the costs of material and Work-In-Process.

4.7 Factory Cost (FC)

Factory cost is calculated using the following relationship:

FC = CM + CPL + CMTRL + WIP

Inventory Cost (**IC**) is calculated using the formula in previous chapter, and added to FC if applicable. When determining savings from better machining data, shorter cycle times and new capital investments etc., then use the WIP formula and calculate the difference as a contribution to the other calculated savings.

EXAMPLE. The WIP formula is used to determine WIP after which Factory Cost is determined and shown in **Table 7.** The calculations are based on a capacity utilization CU = 80% (TNOMC set at CU=100%), an interest of 25% and TAKT Times (TT) = 60 and 18 minutes, with setup time in both cases 5 hours. Assuming CPL = $480 and CMTRL = $2, WIP and Factory Costs are tabulated below.

Table 7.

FC = CManB + CPL +CMTRL + WIP								
CU= 0.8		TT	SETUP =5 h	CPL	CMTRL	CManB	WIP	**FC**
LOTS	I %	minutes	minutes	$	$	$	$	$
1000	25	60	300	480	2000	2948.747	1116.031	6544.778
1000	25	18	300	480	2000	1883.202	929.5603	5292.762

No machines required: M = D*p/n/(1-C/100

D =# units/year, p= processing time, hours/unit, N = Total hours/year during which the process operates, C = Desired capacity cushion,(9% =< C =>27%),

C = 100% - Utilization Rate (%),

Utilization = Average output rate*100/Maximum capacity, or effective capacity (%).

Capacity Gap = Projected demand - current capacity.

The examples shown are summarized in TABLES 2.1-2.4 (different weeks for delivery of (X,Y,Z) and TABLES and 2.5 (simultaneous delivery of X,Y,Z)).

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THE PLANT MASTER – THEORY AND APPLICATIONS

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ABSTRACT

The PLANT MASTER (PLM) is a Manufacturing Execution System (MES) Software that Determines Optimum Synchronous Flow of Parts through any Configuration of Plant Design, or for a new Plant Configuration, Operating at Minimum Cost and Optimal Utilization Capacity. It is based on the Volume Continuity Principle and Constant TAKT Times within each Processing or Assembly Unit. The theory is first explained generally and is applied to a Manufacturing System simultaneously producing three different parts in various lot sizes in three transfer lines (high-ways) with conveyors and satellites. Through-put times (deliveries) are estimated employing Colding´s Forecasting Relationship (Colding, 2000), a nonlinear log-log 3-D relationship, containing 5 constants H, K, L, M, N0. The cost and delivery time is measured by the disturbance percentage (Y) as a function of the number of production cells (stations) (X) with the Intelligence performance metrics (I) as parameter. The Scheduling Calculations are valid for any Order Size, Part Distribution, TAKT Time and Capacity Utilization. Product and Factory costs are determined including Work-In-Process (WIP) inventory costs.

KEY WORDS

Synchronous Flow, Scientific Management, Machining

1. SCIENTIFIC MANAGEMENT

Scientific management (also called Taylorism, the Taylor system, or the Classical Perspective) is a theory of management that analyzes and synthesizes workflow processes, improving labor productivity. The core ideas of the theory were developed by **Fredrick Winslow Taylor,** M.E., Sc.D., (March 20, 1856 - March 21, 1915) in the 1880s and 1890s, and were first published in his monographs, *Shop Management* (1905) and *The Principles of Scientific Management* (1911). Taylor believed that decisions based upon tradition and rules of thumb should be replaced by precise procedures developed after careful study of an individual at work. Taylor was an American mechanical engineer who sought to improve industrial efficiency, and is the founder of *Scientific Management*, which is the title of his famous book published in 1911. Taylor, Frederick, *Scientific Management* (includes “Shop Management” (1903), Principles of Scientific Management” (1911) and “Testimony Before the Special House Committee” (1912)). The theory is devoted to rational thinking and is adapted to the efficiency of transfer lines. Taylor’s approach is also often referred to, as

Taylor’s Principles, or frequently disparagingly, as *Taylorism*. Taylor’s scientific management consisted of four principles: Replace rule-of-thumb work methods with methods based on a scientific study of the tasks. Scientifically select, train, and develop each employee rather than passively leaving them to train themselves.
Provide “Detailed instruction and supervision: Divide work nearly equally between managers and workers, so that the managers apply scientific management principles to planning the work and the workers actually perform the tasks. All working shall be studied scientifically and standardized methods shall be developed for the tasks subjected to a good cooperative agreement between worker and management.
This division of labour with an operator having eight chiefs was criticized by other bureaucrats and administrators envisioning one boss, including other critics meaning people being gears in a machinery without permission to think by themselves.
Metal cutting was Taylor’s key processing method when developing his principles, conducting an enormous amount of tests using high speed tools, resulting in Taylor’s equation: $V*T^{(n)}$, which is still in use (Taylor, F.W, 1907). This relationship is a straight line in double-logarithmic axes (T-V). This author was the first researcher challenging this linearity when employing radioactive tracers as a short-time machinability test method which found slightly bent curves plotting tool-life (T) versus cutting speed (V) rather than a straight line. The radioactive method resulted also in bent curves with T versus feed or ECT (Equivalent Chip Thickness). These results (Colding, 1959) were deemed wrong by Swedish professors but Professor M.C.Shaw at MIT became very happy as Colding’s relationships proved the validity of his theories and employed him.
After serving professor Shaw two years Colding was hired by Dr. Merchant and spent two years with him as a research supervisor. He then returned to to industry in Sweden and became Dr. Technology and later Professor at KTH (Royal Institute of Technology). He continued improving his tool-life relationships which are to-day well known in science, and is expressed mathematically by (Colding 2004):

$$ln (V) = exp[K - ((ln ECT - H)^2/4M - (NO - L*ln ECT))*ln(T)] \qquad (1)$$

This nonlinear log-log 3-D relationship contains 5 constants H, K, L, M, N0.

Eighty five years after Taylor’s death Dr. **M. E. Merchant** published an historic summary “An Interpretive Look at 20^{TH} Century Research on Modelling of Machining”. (M. E. Merchant, Institute of Advanced Manufacturing Sciences, Cincinnati,Ohio. Published in: Machining Science and Technology, Volume 2, Issue 2 December 1998 , pages 157 – 163).

<u>Peter Drucker</u>’s (November 19, 1909–November 11, 2005) (Drucker, 1998), college professor, who was often called the world's most influential business guru and whose thinking transformed corporate management in the latter half of the 20th century, in his description of Frederick W. Taylor is saying was the first man in recorded history who deemed work deserving of systematic observation and study. On Taylor’s ‘scientific management’ rests, Not much has been added to them since - even though he has been dead all of sixty years. Mr. Drucker pioneered the idea of privatization and the corporation as a social institution. He coined the terms "knowledge workers" and "management by objectives." His seminal study of General Motors in 1945 introduced the concept of decentralization as a principle of organization, in contrast to the practice of command and control in business.

COLDING's MODEL AND THE PLANT MASTER (PLM)

The Scientific Management principle was recreated in 1968 by a CIRP group: Gunther Spur, Toshio Sata and Bertil Colding under leadership of Professor **Janez Peklenik**, developing a Seminar series on Manufacturing Systems. In Liverpool 2007 we had our 40th anniversary (Colding,2007) when Colding introduced his latest models.

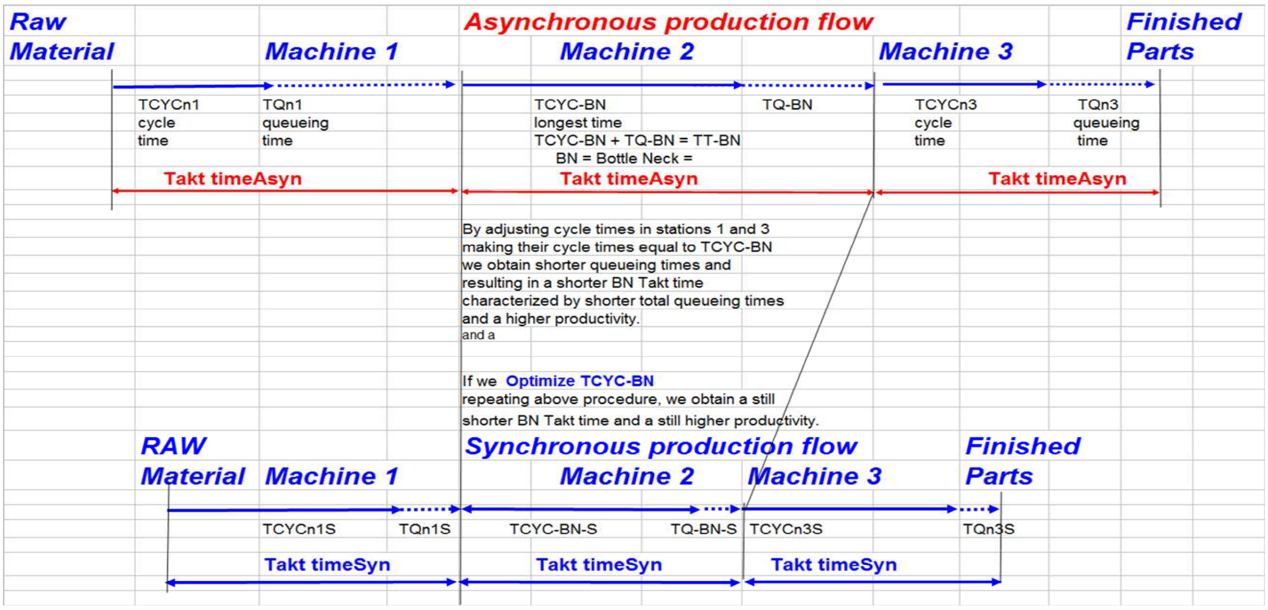


Figure 1 Going from asynchronous to synchronous part flow

An example of the Scientific Management principle anno 2008, is PLM, a software for quick and accurate service, based on accurate algorithmic relationships. These are easily altered depending on business cycle changing conditions, resulting in he small time losses due to disturbances. The system should try to eliminate buffers and result in a synchronous part flow, obtained by adjustment of the Manufacturing Rate for all work stations. The common lengthy method of adjusting the flow in an already built cell or a transfer line must be eliminated and be done before start of manufacture.

Constant TAKT time, synchronous flow, reduces disturbances to a minimum

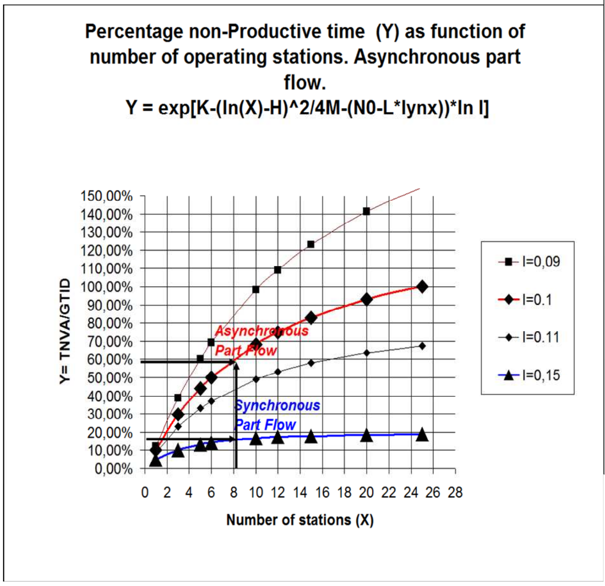


Figure 2 Disturbance percentage (Y): Synchronous versus asynchronous part flow.

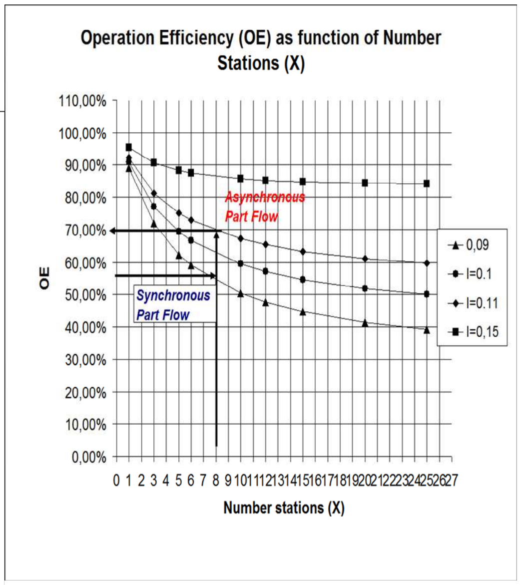


Figure 3 Operation Efficiency (OE): Synchronous versus asynchronous part flow.

compared to a system with uneven product flow, an asynchronous flow of parts. This paper deals with applications of this principle producing three different parts in various lot sizes in three transfer lines (high-ways) with and satellites. The principle is shown in Figure-1.The ratio (Takt timeAsyn/TCYC-BN- Syn) defines a Disturbance percentage (Y) used in the Model, which employs Colding's forecasting relationship, please refer also to Figures -2 and -3.

2.1. COLDING´s TIME OF DELIVERY FORECASTING RELATIONSHIP

Colding´s Forecasting Relationship is applied in order to predict the values of the disturbance percentage (Y) for the most common production flows:

*Y =exp[K –(ln X - H)^2/4M - (NO-L*ln (X))*ln(I)]*

(2)

where $Y = TNVA / TVA$, TVA = Value Added Time, $TNVA$ = Non-Value Added Time. (Y) is measured as function of the number of production cells (stations) (X) with the Intelligence performance metrics (I) as parameter: I = 0.09, 0,10,0,11, 0,12 and 0,15. The graph is designed from 5 known values of X –Y - I in the plant.

This nonlinear log-log 3-D relationship, containing 5 constants H, K, L, M, N0, was originally developed for determining tool-life in machining. Adjustments to constant cycle, or takt times is relatively easy for machining operations provided with suitable software (Colding, 2004).

2.2.1. Operations Efficiency OE versus Disturbance percentage Y.

The relationships are:

$OE = TVA / (TVA + TNVA)$, or (3)

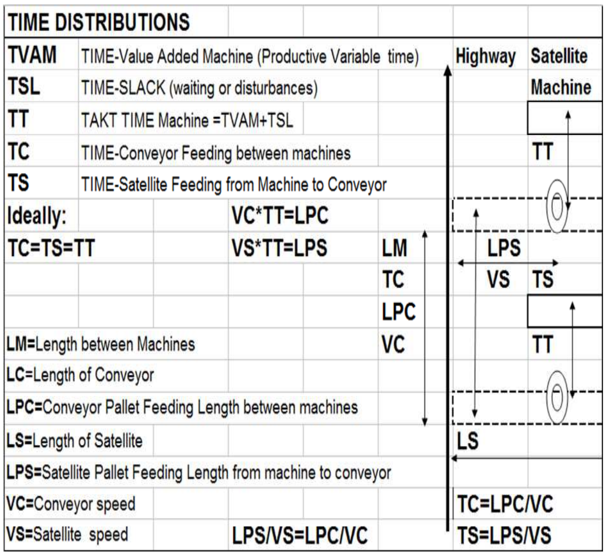
$OE = 1/(1 + Y)$, (4)

TVA = Value Added Time,

$TNVA$ = Non -ValueAddedTime.

Colding`s Manufacturing Execution system (MES), called Plant Master (PLM) , is emplo these forecasting relationships in order to est the time of delivery.

3. TACTED PRODUCTION SYSTEMS



Colding described a Manufacturing Execution System (MES) called Plant Master (PLM),which is a TPS (Takted Production System) applied to metal metal cutting machines (Colding, 2001) and in particular Intelligent Adaptive Grinding Machines , for use in an Open Control System (OCS), such as in NC and CAD/CAM control systems. The system is foreseen to use Adaptive Operator Interfaces (AOI) and Human Machine Interfaces (HMI). The main feature of this PLM-system is to increase productivity of machining plant operations based on a synchronous part flow across all machines in the cell, and in concert with market demands. This Process planning - Optimization - Scheduling system, emphasizes the importance of constant Takt Time to substantially increase productivity using Criteria for Synchronous Flow.(Goldratt,1986). In addition to allowing optimization of the machining process in the planning stage, the software will provide the means for "Live" monitoring of the process productivity by the operators. The program guides the supervisor and operator how to change settings on the CNC in order to run slower or faster, but yet at minimum cost conditions. The system (Colding and Semere) is based on the Volume Continuity Principle and Constant Takt Times within each Processing or Assembly Unit. The program accounts for Machine break downs, re-work, operators report sick, when rush orders appear, or when demand does not match the forecast, (Colding, 2005).

4. MACHINING SYSTEMS WITH CONVEYORS AND SATELLITE STATIONS

In the following we will show an application of the PLM principle to a machining system with three highways for three different products, where the final drilling and washing operations are performed simultaneously.

An economic solution depends on the entire system flow: Machine, conveyor and satellite designs, see Figure-4. The ideal solution is obtained when parts flow without necessitating buffers. In this constant tact-time system, we vary the machine cycle times, including the speeds of highways and satellites including accommodating demand changes and changes in distribution of product volumes. Additionally the software will assist in developing Conveyor & Satellite design and determine the number of pallets including conveyor and satellite speeds.

Figure 4 - Highway, conveyer and satellite

For machining systems with conveyors and satellite stations the software, following the 10 steps below, instantaneously calculates:

1. Determine Customer Time Proposals for each Machine and Product design
2. Determine Tact-Time (throughput) based on Bottle Neck Operation for each Product design
3. Determine Distance between Machines
4. Determine alternative Flow Layouts and Lengths of Highways: This step will, in cooperation with the customer, include Balancing and Adjustments of TACT Times for some machines in order to avoid buffers and get a continuous flow.
5. Determine Length of Satellites
6. Determine Highway speeds
7. Determine Satellite Speeds
8. Determine Number of Highway Pallets
9. Determine Number of Satellites and Satellite Pallets
10. Determine System Cost

5. THE MACHINING SYSTEM: MACHINES, CONVEYORS AND SATELLITES

The ideal solution is obtained when parts flow without necessitating buffers, a synchronous flow.

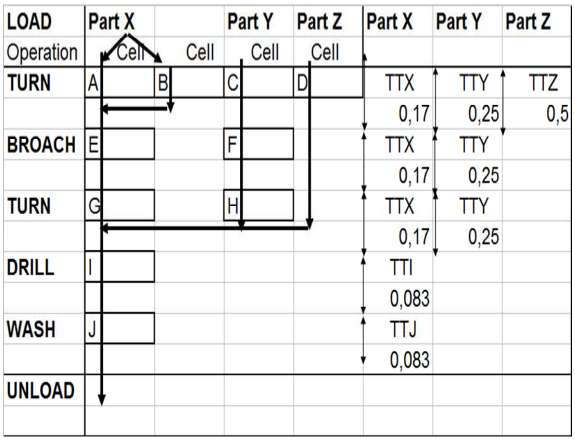


Figure 5 Manufacture of products X, Y, Z in a line-type (U-Shaped) system.

An Unbalanced system, an asynchronous flow, requires buffers and more time for delivery. Balanced TAKT Time (BTT) (Ruth, 1997),(Mierzejewska),(Joachim,1999), of 3 products X,Y,Z: time can be changed by a factor of 2 per stations. The manufacturer decides to produce order to speed up production. Synchronous flow is obtained for all products X, Y, Z in a line-type (U-Shaped) (Miltenburg, 2001) system consisting of machines, conveyors and satellites, see Figure-5. In a line-type (U-Shaped) system consisting of machines, conveyors and satellites the ideal solution is obtained when parts flow without necessitating accommodating demand changes and changes in distribution of product volumes

Assuming 3 designs produced during 1 shift/day:50%X, 32%Y,18%Z.

All 3 designs made simultaneously except for Drill-Wash (schedule)

Days/year	Hours/ day	Design	# Ops	# Parts year	Per cent	# Parts/ day	# Parts/ hour PH	Parts/ min
240	8							
		X:Front hub	6	**530000**	50	2208	**276**	**4,60**
		Y:Rear hub1	5	**339000**	32	1413	**177**	**2,94**
		Z:Rear hub2	3	**191000**	18	796	**99**	**1,66**
		Total	14	**1060000**	100	4417	552	

The manufacturer decides to produce all products X, Y, Z in a line-type (U-Shaped) system consisting of machines, conveyors and satellites, see Figure-5. Making the parts in 3 lines is obviously more costly, as First, 2 more machines of type I and 2 more of type J would be needed in each line. Second, more resources in terms of supervision and operators would be needed. Manufacturing of parts X,Y, Z are made in different machines or, cells, design X in types A, B, E, G; Y in types C,F,H and Z in types D. All parts are finally drilled and washed in machine types I and J. The parts are delivered during 5-day weeks each day in scheduled various amounts, or same daily quantities, such as

$X = X1+X2+X3+X4+X5$,, $Y = Y1 + Y2+Y3+Y4+ Y5$, $Z = Z1+Z2+ Z3 +Z4+Z5$. Indices 1, 2, etc means 1st, 2nd etc. day of the week. The flow of products through the manufacturing cells and the types of operations are shown in principle in Figure-5. The Bottle Neck machine per product (X,Y, Z) determines TAKT TIME (including set-up) for all other operations within X,Y.Z. The cells A and B, being the BN cells, are operating in parallel in Synchronous flow is finally achieved by determining the TAKT Time (***TT***) for the drill and wash equipment (cells in which the flow time is short), as all products X, Y, Z flow through these cells. (TT) consists of two times, Value Added (VA) and Non Value Added (NVA) times.

15 % of (TT) for (NVA) is a good value. Hence, modifying the manufacturing rate, and cycle time by changing feeds and speeds will impact the cutting portion of the cycle time, i.e. 85% of (TT). Adjustments in the machine tool power train can modify cutting time by a factor of 4:1 in industrial production, and therefore TT will be changed by a factor 2:1 up to 3:1. This is accomplished by varying the speeds of highways and satellites as well as the machine cycle times simultaneously.

5.1 THE SIMPSON-MAZDA REQUIREMENTS

Table 1-Product Volumes

Table-1 shows the product requirements: producing per year a total of 1060000 hubs X, Y. and Z at 530000, 339000, 191000 respectively.

5.2. THE PLANT MASTER

The PLANT MASTER is displayed in Figure-6, showing loading and unloading, plant dimensions, synchronous Tact times, TTX, TTY, TTZ, highway speeds VCX, VCY, VCZ, and conveyer speeds at the unload dock.

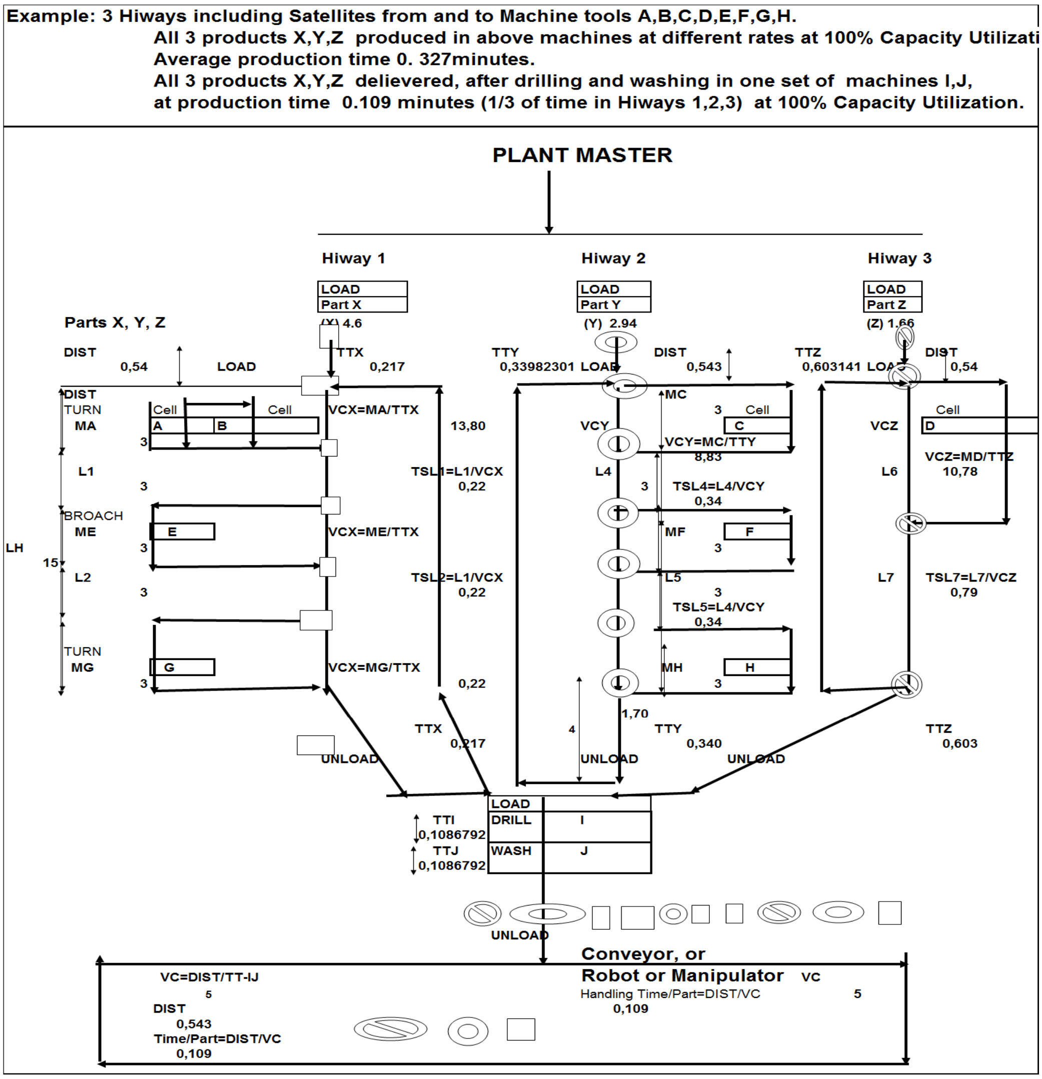


Figure 6 – 3 Highways, Satellites & Machines

6. THE CUTTING DATA PROGRAM

COLCUT (Colding,2006) is the critical program for modification of machining data so that the station cycle times become equal. Using the predetermined number of parts in Table - 1 and convert to time in seconds in Table-3. Tact-times for each of the 3 highways we find the values displayed in Figure-6:TTX = 0,217,TTY = 0,543 and TTZ = 0,603 minutes. These values correspond to the station cycle times, i.e. the sum of times for cutting, changing tool and work piece. As the latter quantities are constant we have to set the machine settings such that above tact-times are met.

COLCUT is the program for modifications of machining data so that each station adjusts each operation time to a constant tact-time in a series of operations. This would require an enormous amount of planning and frustrations, without a

software program. The program enabling the user to quickly establish these data, by trying different feeds until the proper cycle time is reached. Table-3 - Time Summary, displays the respective cycle times per type of operation for the 3 highways which are calculated using the COLCUT programs for Turning, Drilling and Broaching. In the following these determinations are demonstrated in detail for longitudinal turning. The resulting tables 4a - 4g provide the user with all data needed for production planning such as machine settings, forces, torque, power and batch times and costs.

Table 3 - Time Summary

Calculation of Synchronous Times					
LOAD	Part X		Part Y	Part Z	
Operation	Cell	Cell	Cell	Cell	
TURN	A	B	C	D	
13,04				20,39	36,19
BROACH	E		F		
19,83				20,39	
TURN	G		H		
13,04				20,39	
DRILL	I				
6,52					
WASH	J				
6,52					
UNLOAD					

Table 4a- Machinability Databases

Select Tool Grade from DBG Constants Turning								
MC	Tool	Tool-life constants						Taylor
Material Code	Grade							n=NO-
2.1								
Low alloy steel	GC4025							
Non-hardened								
1. Machinability Constants General Turning								
		M	H	L=	N0	K	LF/L	n
		1,71	-2,839	-0,01	0,24888	6,743	7,453	0,242
	Noserad	Surface finish constants						
	r2	M	H	L=	N0	K	LF/L	
	1,6	-0,6	-3,004	-0,2	1,34776	5,06	-38,28	
2. Machinability Constants Module: Turning - Grooving -								
	Grade	M	H	L=	N0	K	LF/L	n
	GC225	0,96	-2,217	-0,02	0,26769	5,77	8,1764	0,25
3. Machinability Constants Module:Thread cutting etc.								
2,1	CDE	0,21	-1,888	-0,02	0,28774	5,577	26,117	

Table 4b-Resulting basic values

Calculating CEL, AREA, ECT an			
Cutting Edge Length	Chip cross sectiona area	Equivalen Chip Thickness	Chi Flo Ang
CEL	AREA	ECT	CFA
mm	sqmm	mm	Degr
1,52	0,10	0,07	
3,39	0,75	0,22	
3,54	1,49	0,42	
3,65	1,98	0,54	

6.1 TOOL GRADE AND DATABASE CONSTANTS

First we need the constants of the machinability equations per type of operation found from the database in order to determine the equations for tool-life, forces and surface finish see Table-4a.

After inputting work and tool specifications shown in Table-4b, the program determines automatically CEL (Cutting Edge Length), AREA(Chip cross sectional), ECT (EquivalentChip Thickness and CFA (Chip Flow Angle), Table-4c. Note how ECT varies with feed, f, the value of which depends on the Equivalent Chip Thickness (ECT), which varies with tool geometry and depth of cut.

Table 4c-Input Parameters

Operation data selections	Enter your data in yellow cells.								
	Feed/rev	Start Diameter	Tool Axial Depth of Cut	End Diameter	Tool Nose radius	Tool Rake Angle Default values	Lead angle ISO	Lead angle US	Helix Angle Def valu
1st row: your feed and tool-life 2nd row: same feed, economic life 3rd row: big feed, optimum tool-life 4th row: same feed only consider tool change which determines automatically new shorter tool-life.	f	DIA	aa	DIAe	r		κ	LA	HA
	mm	mm	mm		mm	Degrees	Degres	Degrees	Degrees
	Copied from Geometry table above								
Feed-Tool- life Given	0,1	25	1	23	0,8	6	75	15	
Economic	0,2	25	2,5	20	1,2	6	75	15	
Minimum Cost	0,6	25	2,5	20	1,2	6	75	15	
Max Production Rate	0,8	25	2,5	20	1,2	6	75	15	

Table 4d-Resulting Machine Settings and Cut T

Longitudinal		MACHINE SETTINGS						
Calculated values appear only after entering economic tool-life, T, in Cell T.						RMS=40*RA,min		
	MC	Equivalent Chip Thickness	Tool-life	Feed	Cutting speed	RPM	Feed Rate	Surf Finish Bottom
Cell T	2.1							
Economic or Optimum Tool-life								
T min	Tool Grade	ECT	T	f	V		FR	Ra
15	GC4030	mm	min	mm	m/min	RPM	mm/min	µm
MA #	1001							
Feed-Tool- life Given	Hardness	0,066	60	0,10	355	1129	113	0,8
Economic Tool-life	Calibration	0,221	*15*	0,20	373	1187	356	2,2
Minimum Cost		0,421	*15*	0,60	270	859	515	6,9
Max Production Rate		0,544	4509,6	0,80	290	922	738	9,3

TOOL CHANGE SCHEDULES PART TIMES & COSTS

Table 4e-Resulting Times and Tool Changes

Turn,Broach,Drill											
	MA #	OP #	TIMES PER PART'				TOOL CHANGE SCHEDULES, COSTS PER PART				
Calculated values	1001	1003	Batch size		5000		Hourly Rate	100	$/h		
Operation data selections	MC 2.1 Tool Grade GC4030	Feed per rev. f mm	Cutting Time per part tc seconds	Time Indexing tool per part tindex/p seconds	Time changing work piece/p t-wpiece/p seconds	Cycle Time per part tcyc seconds	NO. Parts per Tool Change	Cycle time bf tool change tcyc min	Tool Repl-lacement Time trep minutes	Tool ing Cost/part ctool/p $	Cycle Cost/part c-cycle/p $
Operation type	Machine ID	Enter your data in yellow cell									
TURN	AB,G	0,10	3,55	4,94	4,55	13,04	1014	220	2,00	0,020	0,382
BROACH	E	0,18	6,61	6,61	6,61	19,83	136	22	2,00	0,024	0,575
TURN	C,F,H	0,20	1,49	8,69	10,21	20,39	603	205	2,00	0,005	0,572
TURN	D	0,80	0,55	14,35	21,29	36,19	632	381	2,00	0,001	1,006
DRILL	I	0,11	1,52	1,00	4,00	6,52	593	64	3,00	0,017	0,198
WASH	J	0,11	1,52	1,00	4,00	6,52	593	64	3,00	0,017	0,198

7. CALCULATION No. SHIFTS, WEEKLY QUANTITIES & DELIVERY

The following formulas are used in order to minimize the manufacturing lead time and cost, and be the best solution for the customer as well, including plant capacity utilization:

TAKT Time = TT, minutes per part

Manufacturing Rate, parts per minute:
$MR = 1/TT$, (5)

Time Value Added, minutes per part:

$TVA = TT + \text{TSUP}/\text{LOTS}$ (6)

Time for Setup, TSUP, minutes
Lot size , LOTS

Time Non Value Added (waste), minutes per part: $TNVA$

$TM = TVA + TNVA$ (7)

Capacity Utilization:
$CU = TVA/TM =$

$TVA/(TVA + TNVA)$ (8)

Example. $MR = 5$, $TNVA/\text{TT} = 0.2/0.8$, and we get $CU = 1\text{-}0.25 = 0.75 = 75\%$, and finally $TT = 1/(0.75{*}5) = 0.267$ minutes = 16 seconds.

These basic data are ideal and must be modified using disturbance relationships illustrated in Figure-2. Assuming a disturbance percentage for Synchronous flow of 20% we can estimate data at 50 and 100% for asynchronous flow, usual figures in today's plants. Tables-5a-c display how data change with the size of disturbance percentage, a symptom of difficulties in planning accurately**.**

Table-4e and -4f display resulting times and costs after adjusting machining data according to the cycle times produced in Table-3 using the takt times TTX, TTY, TTZ computed from the plant output requirements for each Highway

BATCH TIMES AND COSTS				
Set-up Time minutes	Time per Batch TIME/b hours	Number tool changes/ Batch NO.Tch batch	Tooling Cost per Batch Ctool/b $	Total Cost per Batch Ccyc/b $
30	18	23	98	1959
	28	28	120	2924
	28	6	26	2908
	50	1	5	5082
	9	19	84	1039
	9	19	84	1039
Rapid traverse rate, m	TV, minutes			
	2000	2,59		

shown in the PLANT MASTER Figure -6 upper row.

Product	Parts/ min	Number Parts/week			
Cell(X,Y,Z)					
	Ideal part flow Distur-bance percen-tage (Y):	Ideal part flow Distur-bance percen-tage (Y):	Synchronous part flow Distur-bance percen-tage (Y):	Asynchronous part flow Distur-bance percen-tage (Y):	Asynchronous part flow Distur-bance percen-tage (Y):
	0,00%	0,00%	20,00%	50,00%	100,00%
X	4,60	11042	9201	7361	5521
Y	2,94	7063	5885	4708	3531
Z	1,66	3979	3316	2653	1990
Cell(I,J)		22083	18403	14722	11042
I	9,20	22083	18403	14722	11042
J	9,20	22083	18403	14722	11042

Table 5b - Number Shifts versus Disturbance Percentage

Product	Parts/	Number Shifts Required			
	min				
Cell(X,Y,Z)					
	Ideal	Ideal	Synchronous	Asynchronous	Asynchronous
	part flow	part flow	part flow	part flow	part flow
	Distur-	Distur-	Distur-	Distur-	Distur-
	bance	bance	bance	bance	bance
	percen-	percen-	percen-	percen-	percen-
	tage (Y):	tage (Y):	tage (Y):	tage (Y):	tage (Y):
	0,00%	0,00%	20,00%	50,00%	100,00%
X	4,60	1	1,2	1,500	2,000
Y	2,94	1	1,2	1,500	2,000
Z	1,66	1	1,2	1,500	2,000
Cell(I,J)					
I	9,20	1	1,2	1,500	2,000
J	9,20	1	1,2	1,500	2,000

Table 5c Delivery Weeks versus Disturbance percentage.

Product	Parts/	Delivery Weeks to complete order			
	min				
Cell(X,Y,Z)					
	Ideal	Ideal	Synchronous	Asynchronous	Asynchronous
	part flow	part flow	part flow	part flow	part flow
	Distur-	Distur-	Distur-	Distur-	Distur-
	bance	bance	bance	bance	bance
	percen-	percen-	percen-	percen-	percen-
	tage (Y):	tage (Y):	tage (Y):	tage (Y):	tage (Y):
	0,00%	0,00%	20,00%	50,00%	100,00%
X	4,60	48	57,6	72	96
Y	2,94	48	57,6	72	96
Z	1,66	48	57,6	72	96
Cell(I,J)					
I	9,20	48	57,6	72	96
J	9,20	48	57,6	72	96

8. CALCULATION OF MANUFACTURING AND FACTORY COST

Tables-5a-c display and explain why current plants exhibit such gross inaccuracy forecasting outputs.

The accuracy of the estimates depends not only of the skill in assessing the ideal costs but also on the capability of estimating machine break downs, re-work, operators report sick, when rush orders appear, or when demand does not match the forecast, (Colding,2005). The methods shown also display how Manufacturing and Factory costs are determined, inclusive the impact of Work-In-Process (WIP).

Tables- 6a and 6b show the variation of Cost of Manufacturing, CM, and Factory Cost , FC, as function of disturbance percentage, 20% for synchronous and 50 and 100% for the common asynchronous product flows.

Table 6a- Resulting Costs per Day

Factory Cost			
Synchronous versus asynchronous part flow			
Days/year	Days/	# Shifts	Hours/
	week	for X,Y.Z	shift
180	5	2	8
Hours/	Hours/	Hours/	Order size
day	week	year/Order	
16	80	2880	1060000
Pieces/	Synchronous	Asynchronous	Asynchronous
day	part flow	part flow	part flow
5889	Disturbance	Disturbance	Disturbance
	percentage (Y):	percentage (Y):	percentage (Y):
	20,0%	*50,0%*	*100,0%*
CMTRL, Material, $ /order	$983 333	$983 333	$983 333
PPC, Production Planning $/order	900 000 kr	900 000 kr	900 000 kr
OK, Order Cost, $/order	1 450 000 kr	1 450 000 kr	1 450 000 kr
	Parts X+Y+Z	Parts X+Y+Z	Parts X+Y+Z
Cost	*Cost*	*Cost*	*Cost*
per day	*per day*	*per day*	*per day*
i = Policyränta perår, %			
20			
CM, Manufacturing Cost	$18 701	$18 701	$18 701
CMY, Disturbed Manufacturing			
Cost (Tooling not affected)	$22 235	$27 536	$36 371
CMTRL,Cost material	$5 463	$5 463	$5 463
PPC, Cost Production Planning	$5 000	$5 000	$5 000
OC, Order Cost	$8 056	$8 056	$8 056
PLK = PPC + OC	$13 056	$13 056	$13 056
CMY+CMTRL+PLK	$40 754	$46 055	$54 890
WIP, Work-In-Process	$6 202	$8 547	$13 163
FC, Factory Cost	**$52 418**	**$60 065**	**$73 516**
Tooling Cost	$1 031	$1 031	$1 031
Tooling/CM %	5,51%	5,51%	5,51%
Tooling/FC%	1,97%	1,72%	1,40%
Tooling/piece	$0,18	$0,18	$0,18
FC, Factory Cost/piece	**$8,90**	**$10,20**	**$12,48**

9. CONCLUSIONS

New techniques were constantly introduced in Production Engineering departments during the 2000 century, but applications of Scientific Management in manufacturing planning as Taylor envisioned is not very widespread 100 years later,often due to lack of production engineers with advanced education. This paper shows how great savings can be made using detailed knowledge provided by software programs, in particular using PLANT MASTER and COLCUT.

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Part III. ENTERPRISE ECONOMETRICS - Econometric Models and Forecasting

By Professor Bertil Colding

Foreword

The Time/Cost Determinations and Relationships in Part III is an expansion of the text given in Part II including an in-depth description of the use of "Granular Metrics", rather than averages. When we deal with machining refer to the time and cost calculations including tooling costs described in Part I.
Company managers are urged to employ this Econometrics in order to ascertainrealistic results. Only a simple internal program can be introduced and all the many determinations will be made quickly.
An excellent Globalized Econonomics Textbook is recommended [7]: Eonomics, by Lipsey, R.G.Simon, Fraser University; Courant, P.N., The University of Michigan; Purvis,D.D.,Queen's University; Steiner, P.O., (1993), The University of Michigan; Harper Collins College Publishers

Time and Cost Formulas for any Lot Size, Setup Time, TAKT Time and Hourly Rate, Times and Costs are defined either per operation or as the sum of all operations. ***The relationship between COST of SALES, PRODUCT and PROFIT in Chapter 2 is an important feature for running a company efficiently. Remember:***
Never dimension product volume demand for maximum total sales but for maximum total profit.
Never dimension product volume demand for maximum unit profit but for the volume of maximum total profit.
In Chapter 5 a number of PAYBACK, PRODUCTIVITY AND PERFORMANCE METRICS are described including in section 5.6 Six-Sigma, which is a philosophical approach based on a quality initiative within General Electric Company that demands the effective use of data to analyze business issues.

Colding's Equation, based on a non-linear log-log relationship that fits real life econometrics very well, *is used in Chapters 7 and 8*, employing the Competence or, "Intelligence parameter" as the third parameter **I,** where **I** = **II/S**, is defined as the ratio of Intelligent Investments **(II)** and the company **Sales (S)** values**.** The value **II** is the **annual** cost of the sum of investments in R&D, Investments in Capital Equipment and Software (CI) and a new term called **IC**= Intellectual Capital. *Chapter 7 describes the INTELLIGENCE PARAMETER (I) AND INTELLIGENT INVESTMENT CAPITAL (II) referring to the innovative concept by the Swedish economist Leif Edvinsson, who wrote the book with Michael S. Malone, (1997), Intellectual Capital, Realizing Your Company's True Value by Finding Its Hidden Brainpower"[10] .*),
*Professor Colding has further expanded their analyses to include**:** Life of Investments, Value of Investment Capital as a function of Sales, Product Volume and Profit and how to determine the Intelligence Parameter in terms of Cost and Profit.*
Chapter 8 deals with ECONOMETRIC MODELS AND FORECASTING including Creating prognoses by predicting Sales-Cost curves based on Cost and Sales price per part. The text depicts the advantages of the employment of Colding's Equation and how to develop your own software.

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INTRODUCTION

Ultimately, the profitability of a company depends on its value and its shareholders, which is approximately equivalent to maximizing profit of sold products. The most advanced stage of systems planning refers to the optimization of the entire enterprise including product design, sales and manufacturing and delivery of finished products at the dock , based upon what the customer requires of its products being the most important criterion.
One of the most crucial tasks facing the company management is to establish a good sales-cost-profit forecast that will hold short-term and will secure survival in the long run.The most common forecasting technique is “intuition”, a method which is usually wrong 50% of the time.
The presentation begins with the Basics of Enterprise and Manufacturing Econometrics followed by the mandatory factors “Interest” (money paid for the use of money lent for a given time) and “Investments in industrial assets” commonly used in evaluation of financial decisions, and a brief survey of simple capital inventory and Work-In-Process models. Then follows a survey of different performance metrics.
The core of this chapter describes a relatively straightforward method (comparable to the optimization techniques used in manufacturing and machining), to forecast sales-cost-profit.
Applying this model the shop owner, plant manager, or CEO, can make intelligent decisions and techniques in order to make the right decisions. This involves applying the methods to improve manufacturing performance described in Sections 2 and 3
The technique is similar to the one used in optimizing feeds and speeds versus tool-life, described in Section 3, Chapter 2. The benefits include the ability to forecast optimum values of sales, costs and enterprise profit, including optimum and break-even lot sizes.

1. ECONOMETRIC RELATIONSHIPS - PROFIT OPTIMIZATION

1.1 Basics of Enterprise and Manufacturing Econometrics

Among the many laws that govern the performance of a business there are some that are quite simple and well known to anyone. For example total sales or costs are obtained by multiplying unit sales price or cost by the number of products sold, or that lowering both cost of administration, sales activities and manufacturing will improve profit. The question is by how much, that is the big question? Some laws of econometrics can be derived by mathematical means and presented as formulas. There are many others that are unknown to a lot of practitioners, who use experience, rules of thumb and intuition. There is for example too much belief in the benefits of increased sales, which often leads to lower profits. Lack of basic econometrics knowledge is often the source of inferior performance.
The financial accounting systems are in many cases not yet developed to accommodate the various changes in the manufacturing or business world in general, causing errors in determining costs and prices, see the heading “Granular Metrics”.
These laws of business are here described with graphs containing smooth curves in normal or logarithmic coordinates. In reality some of these curves are not smooth, but staggered due to various reasons. The relationships displayed in the following are nevertheless of significant importance in order to understand how to make the right decisions and to improve performance.

In the early stage of initiating a new product Costs of Planning, Product Design and R&D increase steadily up to a maximum. Then cost of Marketing, Manufacturing and Total Product Cost begin rising, as well as Sales revenue and Enterprise Profit. These major variables have similar shapes when plotted versus time or cost, either first rising and then decreasing, all containing maximum values, or vice versa containing minima. The points on the product life cycle curves, where the slope of the Sales and Profit curves are level and equal to zero, we have a maxima, but a minimum is indicated for the Cost curve as function of manufacturing cycle time.
Such points are useful in deciding what level of production produces the maximum profit or minimum unit cost.

The build up of sales and cost consist of several items of which you must consider the proper ones when financial decisions or optimization for maximum total profit take place.

1.2 Econometric Formulas
Profit = Sales – Product cost:
PR = S - C

1.2.1 Definitions of the cost items:
Product Cost = C= Cost of Design (CD)+
Cost of Administration + Sales (CAS) + Factory Cost (FC):
C = CD + CAS + FC
Factory Cost = Manufacturing Cost (CM+ Material Cost (CMTRL) + Inventory Cost, or Warehousing (CI) + Value of Work-In-Process (WIP):
FC = CManC + CMTRL +CI + WIP
Manufacturing Cost (CM) = Preparatory Cost (CPRE) + Value Added Cost (CVA) + Non VA Cost (CNVA):
CM =CPRE + CVA +CNVA

1.2.2 Cost of Sales

Fig. 5 shows in principle how Cost of Administration and Sales vary with volume. One part is considered fix and the other a variable cost. Beyond the minimum the AS costs will increase with higher volumes.

Preparatory Cost includes:

Preparatory Cost (CPRE) = Cost of Ordering materials + Process Planning +Setup.

Value Added Cost (CVA) = Cost of tools cutting, or

forming + tool motions (in air) +
tool changing + tool(die) reconditioning

Non VA Cost (CNVA) =shop down time + office planning deficiencies.

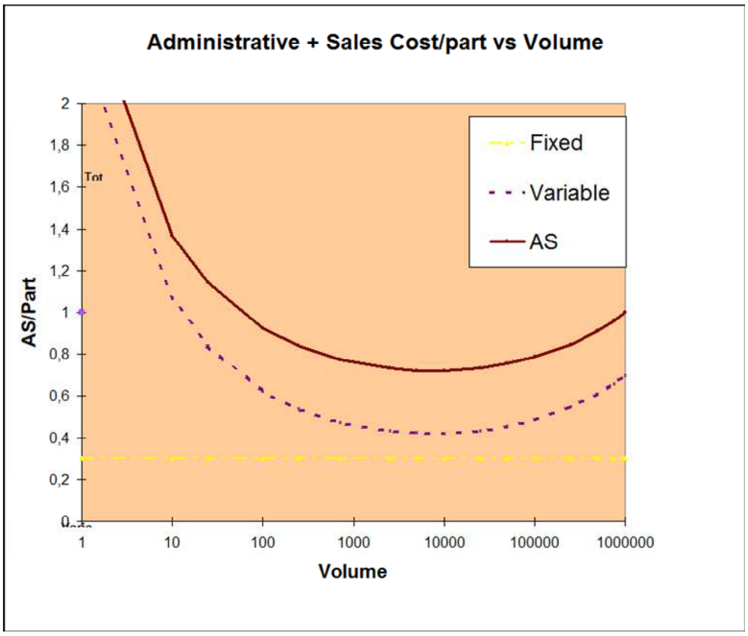


Fig. 5

All these cost items vary with Delivery and Manufacturing Time, Order Volume (Q) and Annual Demand (D).

Detailed formulas for manufacturing costs are given in this Section as well as in Sections 6 and 8, including Maximizing Enterprise Profit (Enterprise Profit Mountain).

1.2.3 Price Elasticity

The market price elasticity is responsible for the decline in total sales dollar going from point M to R in Fig.1.
A common definition of Price Elasticity (ELAS) is:
Percentage change in Sales Volume (VOL) divided by percentage change in Sales Price (SP),

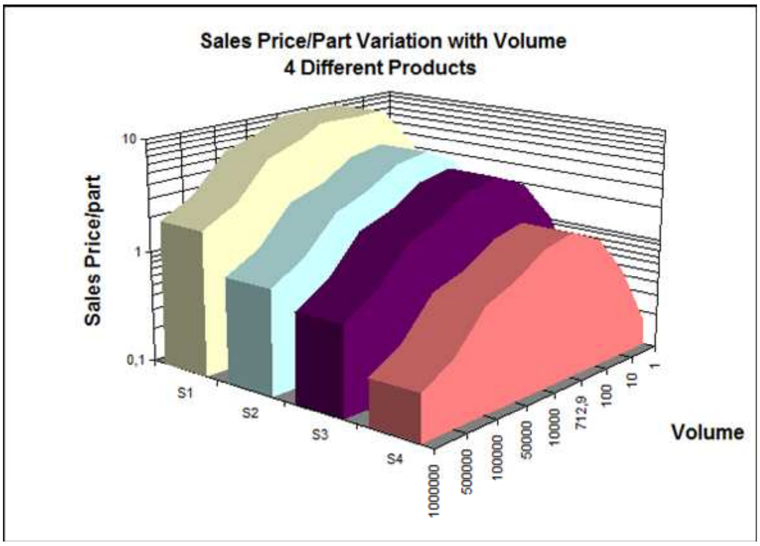


Fig.6

or using a formula:

ELAS =□VOL/□SP

Common values are around 1.5 to 2, but values as high as 200 have been encountered. Fig. 6 shows, in principle, how Sales price, or the price elasticity varies with volume for 4 different products. Each product has a different price elasticity signature.

Value added (CVA) and Non-value added (CNVA) cost items must be considered when calculating Manufacturing and Factory costs.

1.3 Manufacturing Cost

1.3.1 Complete Factory and Manufacturing Cost Formula

Factory Cost (FC) = Manufacturing Cost (CM) + Material Cost (CMTRL) + Inventory Cost, or Warehousing (CI) + Value of Work-In-Process (WIP):

FC = CMan + CMTRL + CI + WIP

Manufacturing Cost (CM) = Preparatory Cost (CPRE) + Value Added Cost (CVA) + Non VA Cost (CNVA):

CM = CPRE + CVA + CNVA

Preparatory Cost includes:

Preparatory Cost (CPRE) = Cost of Ordering materials, Cost Estimating and Rate setting, Process Planning and Scheduling, Cost of Design of Fixtures, Cost of Manufacturing Fixtures and Cost Program Testing.

Value Added Cost (CVA) = Cost of tools cutting, or forming + tool motions (in air) + tool changing + tool(die) reconditioning

Non-Value Added Cost, or waste (CNVA) = Cost shop down time, Cost rejects and Office planning deficiencies are included..

Value added (CVA) and Non-value added (CNVA) cost items must be considered when calculating Manufacturing and Factory costs. All these cost items vary with Delivery and Manufacturing Time, Order Volume and Annual Demand.

Fig. 7 shows optimization of Machining Processing Cost versus Value-Added (VA) time with (NonVA) time as parameter. The current situation (marked in graph) where (VA)-time is approximately 3000 hours, have (NonVA) costs about as high as the (VA) costs. Minimum cost occurs for proper selection of feeds-speeds-tool-lives, see Section 3. At Maximum Production Rate total costs run high due to very high costs for cutting tools

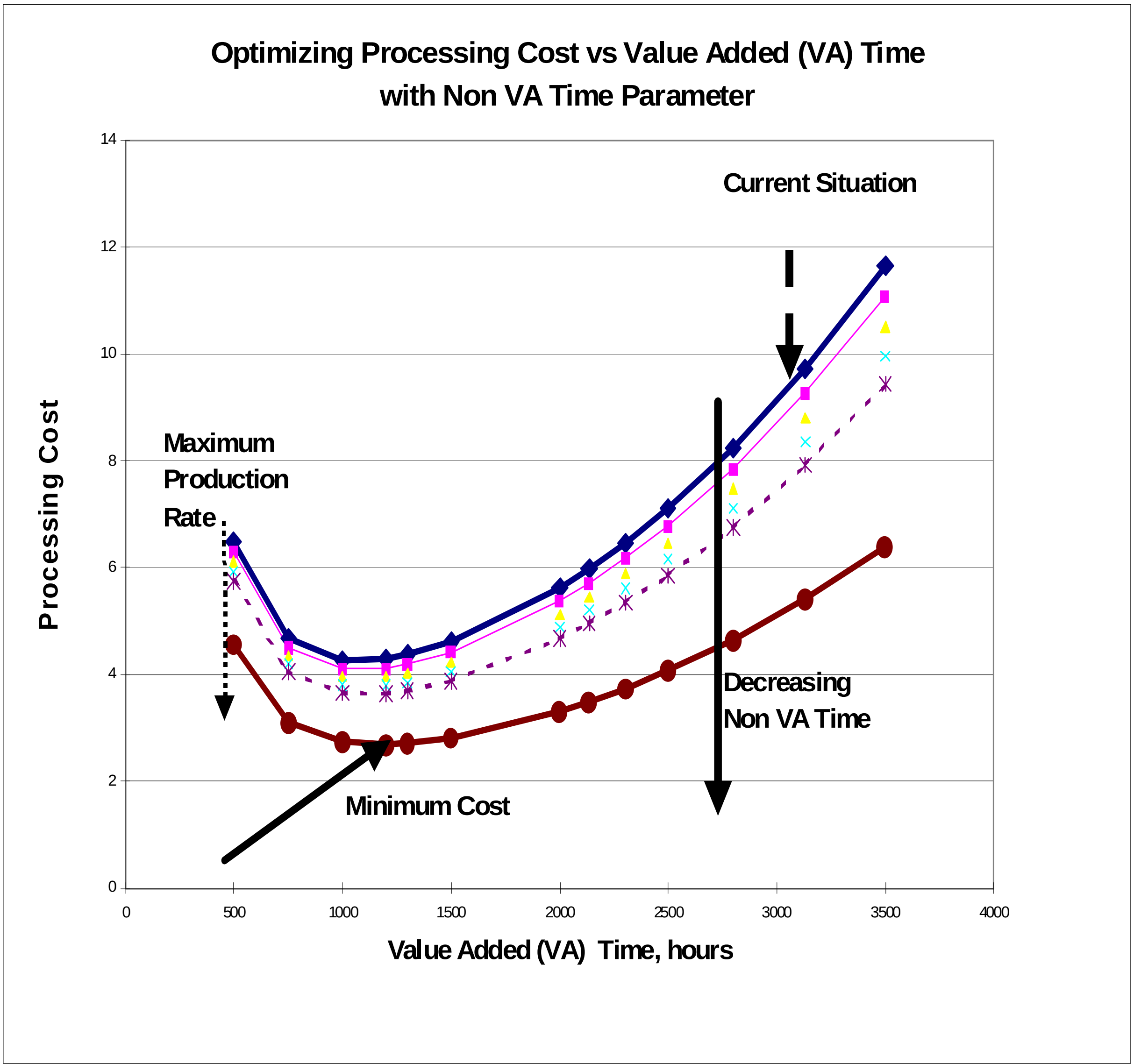


Fig. 7

1.4 Summary

In this summary we exemplify aforementioned principles considering the impact of manufacturing as well as the entire product development process on enterprise profit.

In Fig.8, depicting the principle for arriving at maximizing profit, based on both product price (price elasticity,see graph in upper right corner) and manufacturing cost (bottom right corner). The cost of work-in-progress (WIP) is also included in the model.
For each of the major company functions we scribe two boxes, one for
value-added (VA) and
another for
Nonvalue-added NonVA) activities, either for
process planning of parts (Option 1) or
for planning and optimization of all functions from Design to delivery (Option 2). Many of these costs vary with the sales volume.

FIG.5. How Enterprise Profit is Optimized

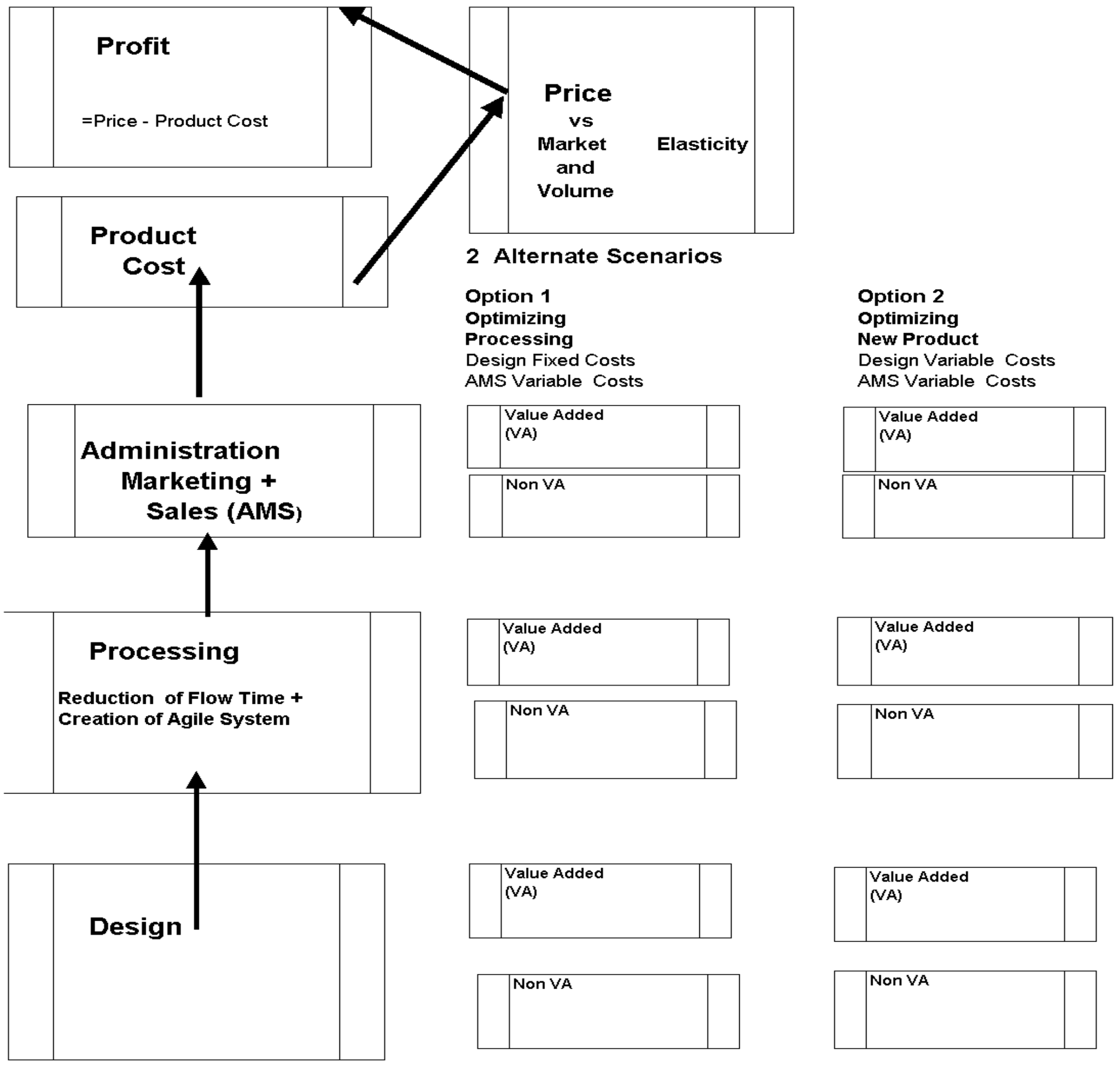


Fig.8

1.5 Maximizing Enterprise Profit

Finally,the aforementioned relationships can be translated into 3-D Views, producing Profit Mountains. Here this is exemplified by the relationship of manufacturing and sales elasticity with "takt" time and sales volume on the x-y FIG. 9. Enterprise Profit Mountain based on Product Price and Manufacturing Cost axes and profit on the z-axis, see Fig. 9.

In general the profit mountain describes how profit is affected by both takt time and sales volume considering the effect of price elasticity. The example shows that

maximum profit is achieved at a volume of 2500 parts, manufactured at a rate corresponding to 0.4 months runs. Profit is lower when running at maximum production rate, or when sales volumes are lower or bigger than indicated by the optimum values.

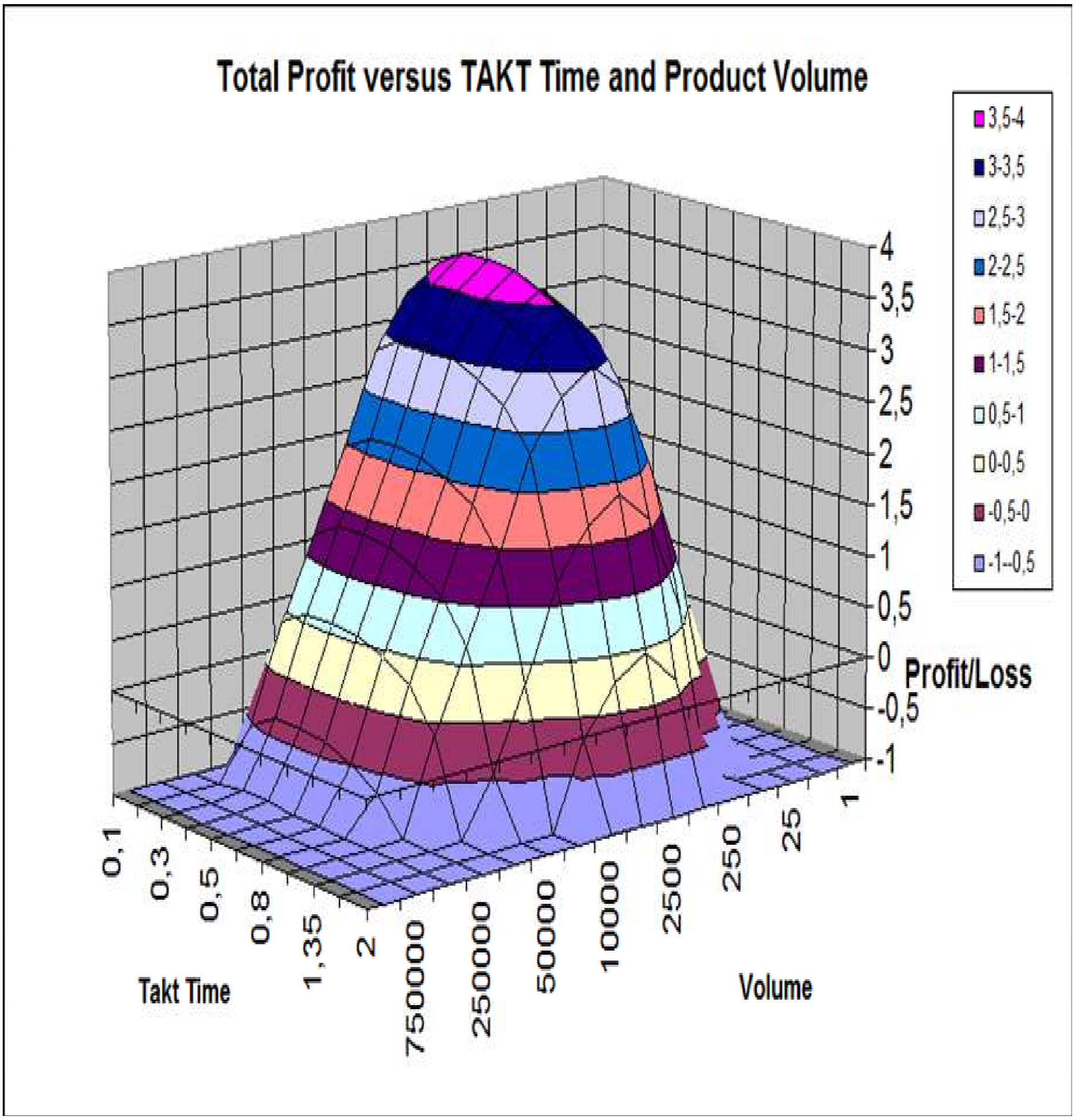


Fig. 9.

2. THE RELATIONSHIP BETWEEN COST OF SALES, PRODUCT AND PROFIT

2.1 Maximum Total Sales and Maximum Profit

Never dimension product volume demand for maximum total sales but for maximum total profit. Reason being that each additional volume of sales costs more above the maximum profit volume, the more costly the larger this volume is.

In Bild 1.1 we have set the costs of sales (S) and product (C), and profit (PR) versus product volyme (NP) for two values of the intelligens parameter (I). The Intelligence parameter is a performance measure which can be defined as the ratio between an investment capital (II), encompassing all investments within the business area and income from sales (S).
The Intelligence factor (I) is the best parameter relating the costs of sales (S) and product (C), and profit (PR), where **I** = **II/S**, or company Competence or, "Intelligence parameter", defined as the ratio of Intelligent Investments **(II)** and the company **Sales (S)** values**.** The value **II** is the **annual** cost of the sum of investments in R&D, Investments in Capital Equipment and Software (CI) and a new term called **IC**= Intellectual Capital. These parameters are described in chapter 7.
We may set I = II/PR =100*(II/S) expressing the ratio in percent.
II is called the intelligent investment capital consisting of the sum **IC+ RoD +CI,** where **IC** stands for the concept *intellectual capital* (see section X:X), **RoD** for research and development of improvements of product design and manufcturing processes, and **CI** for the investment capital needed for new equipment and necessary IT- software which is needed in the manufacturing processes. Use of the intelligens parameter is depicted more in detail in chapter 7.

The curves in Bild 1.1 are for better clarity inscribed in a double-logarithmic coordinate system. We obtain two pair of curves fpr sales and profit, one

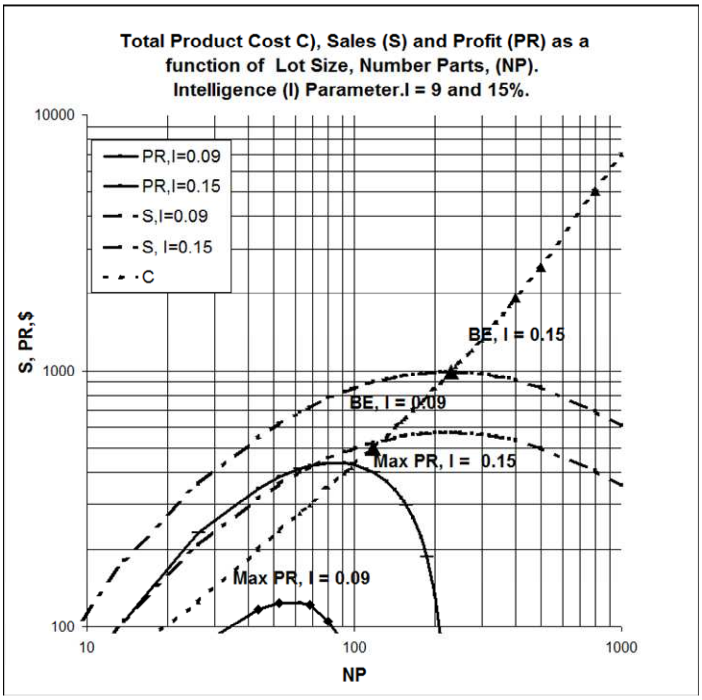


Bild 1.1

for an enterprise with poor profit (I = 0.09), and another for a competitor with a better profit (I = 0.15),the latter of which handles its intellectual capital wiser, for example very good

And x = Square Root (1/c) which is different from the **total** profit value x = - b/2c.

Hence this relatively simple mathematical treatise giving different x-values of PR and PR/NP respectively proves above statement.

Only in exceptional cases the volumes for total and unit costs will be equal, that is when:
-b/2c = Square Root (1/c), or simplified
Square (b) = 4c.
Resulting in a second degree equation for equal volumes which reads:

PR = a + b*x + b^2/4*x^2 = a + b*(x + b/4*x^2),

a condition seldom satisfied in real life.

Never dimension product volume demand for maximum total sales but for maximum total profit. Reason being that each additional volume of sales costs above the maximum profit volume, the more costly the larger this volume is.

A different type of ”break-even” analysis is customary within the engineering industry when the choice stands between e.g. two alternative manufacturing investments for constant sales. Here costs are divided up into a fixed and a variable part. The cost relationships are generally approximated to straight lines in ordinary coordinate systems, or parallel lines in double-logarithmic coordinates. The point of intersection of the lines will determine the product volume (break-even), minimum volume for the most expensive solution becomes profitable. Chapters 7 and 8 are devoted to new methods to determine costs for sales, product and profit development
We can prove the concept and mistakes by decision makers can be avoided.

You differentiate the function (total profit) with respect to x (= NP) setting the result equal to zero:

PR/dx = b + 2c*x = 0.

Solving for x we get x = - b/2c.
Then, divide PR with volume and we get the equation for unit profit:

PR / NP = a/x + b + c*x.

By differentiating this expression with respect to x:

(d(PR/x)/ dx) = -1/x^2+ c = 0, and solve for x.

The square of x amounts to x^2= 1/c.
And x = Square Root (1/c) which is different from the **total** profit value x = - b/2c.

2.2 Maximum Unit Profit

Never dimension product volume demand for maximum ***unit*** *profit but for the volume of maximum* ***total*** *profit. Only under special conditions unit and total profit become equal.*

The curves for total cost shown in Bild 1.1 attain another course if unit costs of sales (sp) and expenses (cp) are set as function of product volume, see Bild 1.2.
The Break-even values (BE, I = 0.09) and (BE, I = 0.15) respectively occur at the same volumes, but maximum unit profit (PR/NP), do not occur at the same volumes as the total profits. For I = 0.09 we get a profit (PR) at volume of approximately 55 parts, while (PR/NP) is 25 parts. This author described this phenomen in a

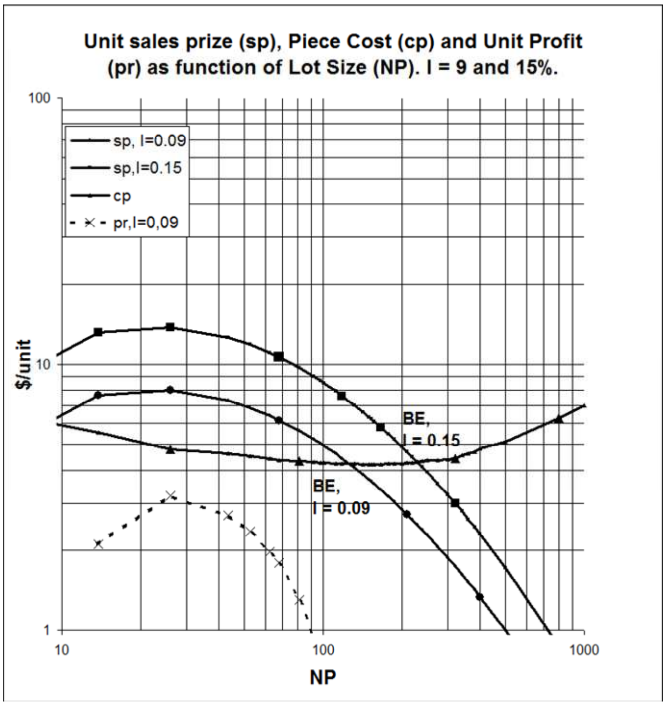


Bild 1.2

seminar for American industrialists at the University of Michigan Crysler Center in1978 [2], which was news. Thus the total unit profit is the deciding factor when making business decisions [7]. Many of the management decision makers are not aware of this fundamental knowledge. This fact causes severe financial decision mistakes.
The following mathematical treatise proves this statement using simple high school mathematics on derivatives for solving maximum problems.

Example. Approximating the **total** profit as function of sales volume with a second degree equation with the below given format:
PR = a + b*x + c*x^2.
We can prove the concept and mistakes by decision makers can be avoided.

***Hence this relatively simple mathematical treatise giving different x-values of PR and PR/NP respectively proves above statement*.**

Only in exceptional cases the volumes for total and unit costs will be equal, that is when:
-b/2c = Square Root (1/c), or simplified
Square (b) = 4c.
Resulting in a second degree equation for equal volumes which reads:

PR = a + b*x + b^2/4*x^2 = a + b*(x + b/4*x^2),

a condition seldom satisfied in real life.

2.3 Colding's Equation Enterprise Econometrics

Colding's Equation

In Sidney, Australia, 2000, Colding showed the versatility of Colding's Equation including its applicability to Enterprise Econometrics in the paper " Prediction, Optimization and Functional Requirements of Knowledge Based Systems", pp. 351-354, Annals of the CIRP Vol.49/1/2000. [18].

Colding's equation – the constants of which are determined by the DBGen (Data Bas generatorn) - is based on a non-linear log-log relationship that fits real life econometrics very well, in particular using the **Intelligence Parameter** as a third dimension:

Y= K - (X-H)^2/4M-(N0-L*X)*Z,
Setting X and Y as follows: X =LN (NP), NP =Volume, or Number of Parts, or number of years, or Year 200X, 200X+1,200X+2 etc.

Y=LN (C),C=TOTAL COST, or
Y=LN(cp), cp =Unit Cost,
or
Y= LN (S) ,S= TOTAL SALES or

LN(sp),Sp =Unit Sales Price
and

Z is best as a parameter equal to log I, Z=LN (I), where **I = II/S**, or company Competence or, "Intelligence parameter", defined as the ratio of Intelligent Investments **(II)** and the company **Sales (S)** values**.** The value **II** is the **annual** cost of the sum of investments in R&D, Investments in Capital Equipment and Software (CI) and a new term called **IC**= Intellectual Capital. These parameters are described in chapter 7.

The Intelligence parameter (I) is used as a parameter in Colding's equation with values ranging from 0 to 0.15. A constant value of I means that the ratio of II and sales is also constant, for example when I=0.05 we find for S = $100,000 a required value of II= $5,000 , or for S=$1000,000 an II-value = $50,000. **I, in terms of Sales,** is the parameter which is used to record and predict the sales-cost functions described earlier in this Chapter. Determine first the current level of Sales or Profit. Then decide which level of Sales or
Profit you want and then determine required values of I and II by calculation.

Only small increases in the value of Intellectual Capital (IC) component of II, or the ratio (I), result in huge increases in sales and profit, as depicted in **Figs.7.4.2 a-c**. The sales dependant term in the total **"intelligent" investment dollar amount II** (in $1000's) is proportional to **I** for any given sales volume using its definition (I = II/S).

This 3-D relationship, originally developed at Ford Motor Co. for determining tool-life in machining, is used in the following. It generates curves similar to the ones illustrated in Bild 6.2 och 6.3. In machining materials machinability and specified metal cutting terms are used to optimize the machining process.It is thoroughly described in the book by Bertil N. Colding:

Machining Data Selection for Lean Manufacturing, Formulas and Machinability Relationships
Turning, Face & End Milling, Drilling and Grinding
Optimization, Time and Cost Analysis – Synchronous Part Flow

Colding's equation can be applied with success in other sciences requiring only 3 historical data points including 2 prognosis points in order to obtain a future prognosis [18]. It is much easier and quicker to employ accurate values than using standard

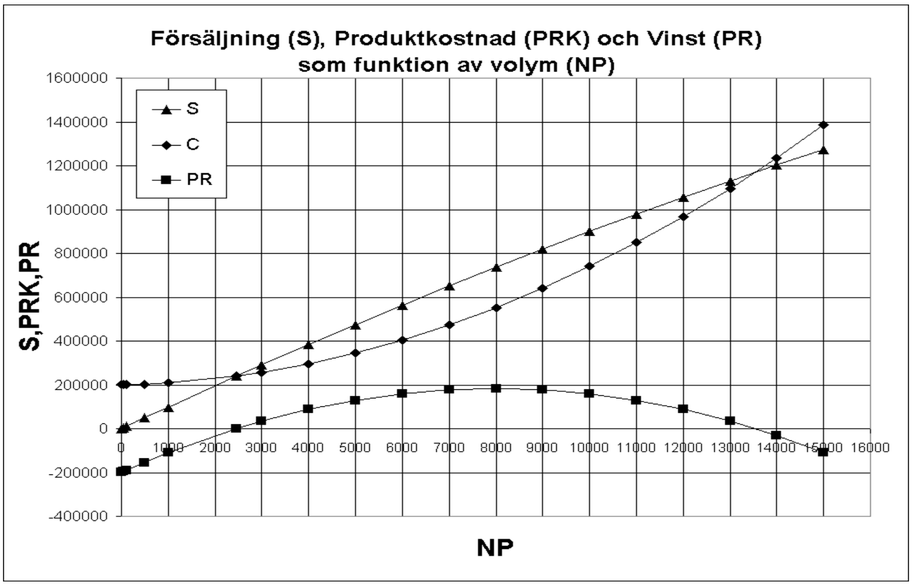


Bild 6.2

mathematical polynomials or above mentioned classical models.

The corresponding parameters in enterprise econometrics are the firm's financial records, where lot size, sales, costs and profit are prime variables.
Models based on discrete known points on cost curves, or cost history of parts, can be used to forecast the cost situation under various scenarios. These models are using a mathematical approach by which for example the shape of the cost curves versus lot size can be varied, or used for cost assessments of part families.
These major financial variables have similar shapes when plotted versus time or cost, either first rising and then decreasing, all containing maximum values, or vice versa containing minima such as for the cost curve as function of manufacturing cycle time.

2.4 Functional Requirements for Optimization

The condition for a function shall contain maximum or minimum values thereby being valid for business systems can be shown mathematically. The reader can easily perform this analysis employing his math knowledge from high school, see Fig.10.

Derivate Y in Colding's equation with respect to X, holding the intelligence factor I constants setting the result equal to zero as follows:

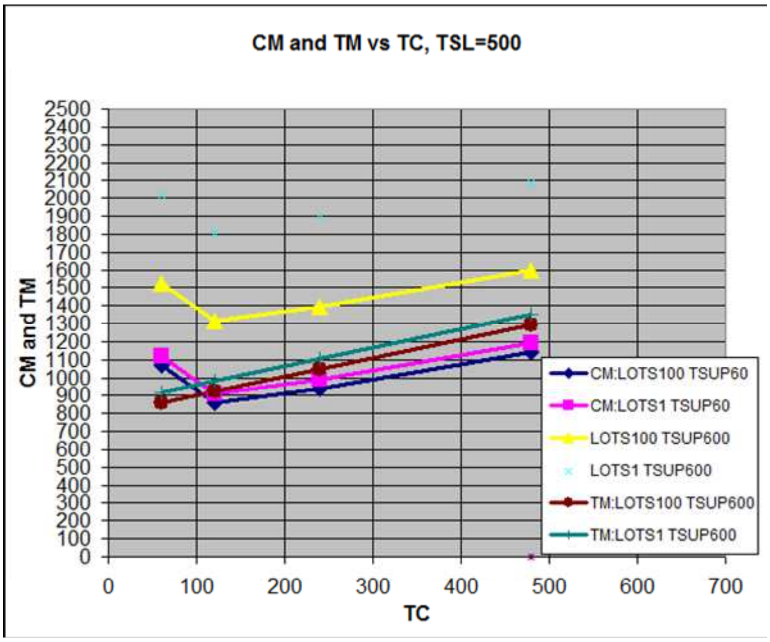


Fig.10

dY/dX = -2(X -H)/4M + LZ = 0, or after transformation:

X = H + 2MLZ.

Where X = ln NP (eller år) and Y = ln (I).

As long as the values of NP, or Year, lies within the application region of the business system, i.e.

antilog of X, we will achieve an optimal value. As an exemple, when the constants are M = 0.75, H = 5, L= 0.013 and I = 0.07, we obtain the number of parts using the formula X = H + 2MLZ, yielding X = 5,001, and antilog of X = NP =148,6 parts, see Fig.11.

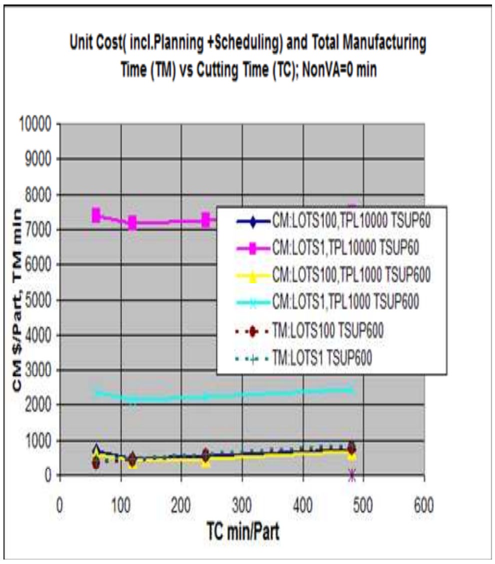


Fig. 11

2.5 Calculation Procedure - Colding's Equation Enterprise Econometrics

The ***Calculation Procedure involves using the Data Base Generator, DBgen,*** *to determine the 5 Constants in the Colding Equation showing the impact of the Intelligence Factor (I) on Financial and Sales-Cost data, DBGENSPR, or Sales (S) versus Volume (NP= Number Parts), or Sales versus Cost with Volume Parameter, or Sales versus Cost with Years Parameter.*
Profit is then obtained as the difference between S and C.

The input data must be selected as shown in Fig.1.2.3, where the Intelligence factor I is plotted versus Sales, for 3 (known) values of Volume NP (X1, X2,X3 at intelligence I1) and for 2 (estimated or known) values (X1, X2 at intelligence I2) of Sales.

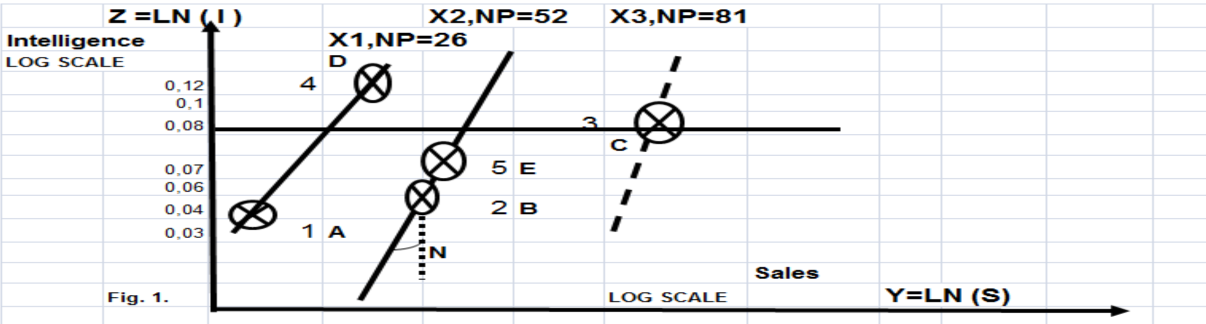


Fig.1.2.3. Intelligence Factor (I) as function of Sales, Volume (NP) Parameter.

Principle to Program DBGEN (DataBaseGenerator) in order to determine the 5 constants , is shown in Section 2.5.1. This is not a straight forward task, as only 4 constants as a function of the 5th can be calculated employing regular determination techniques. Therefore a special method and strategy was developed, for which funding was obtained from the State of Michigan.
The adopted strategy determines 4 help constants (a,b,c,HFAC), from which HMIN, and finally constants M,H, L, NO and K was calculated, see the method depicted in Section 2.5.1

.

Table 2.

1. Determine a,b,c and M from 3 pairs at T =Constant = T*.
2. Taylor slope n1 at 4th point (T*,V1,ECT1) (T2,V2,ECT1)
3. L = b(1-HFAC)/c*z*,HMIN =b/2a;H = HNIN*HFAC; M=c/4a,
N0 =n1 + b(1-HFAC)x1/(cz*)
a = x3(y1-y2)+x2(y3-y1)+x1(y2-y3),
b = y3(x2^2-x1^2) + y2(x1^2-x3^2) + y1(x3^2 - x2^2)
c = (x3-x1)(x2-x1)(x2-x3)
4. Select an arbitrary point T5,V5,ECT5 and eliminate K with
T*,V1,ECT1 and form difference (y1-y5)
5. Solve for HFAC inserting for L, M and H above formulas:
HFAC = A/(z5-z*)(x5 - x1), where
A = (cz*/b)[y1 - y5 -(z5-z*)(n1+x1(b(cz*)) +(az*/b)(x1^2 - x5^2) -
(x1z* - x5z5).
6.Using values a,b,c determine HMIN and H,L,N0 from 3.
and K from tool-life equation.

The Force Sensitivity Constant LF/L generated together with constants H,M,L, N0 and K, has no significance in Economics, but in tool wear, constitutes the key variable between tool-life (tool wear) and force ratios FH/FC and Kc/Kc1. It is derived by using the Force Ratio equation FH/FC along the H-CURVE, and is determined substituting and eliminating the ECT - and Cutting speed terms***):***

LF/L=((NO-L*H)/(2*M*(L^2)-(((NO-L*H)/2/M*L^2)^2-H^2/4*M^2/L^2)^0,5)/ln (2).

2.5.1 Calculation Method: Example 1 Profit Comparison Case 1 and 2 only changing Sales income

Here is shown the Principle to Program DBGEN (DataBaseGenerator) in order to determine the 5 constants, including the 4 help constants (a, b, c, HFAC), from which HMIN, and finally constants M,H, L, NO and K is calculated. This method enables establishing the values of Cost, Sales and Profit as functions of Product Volume, with Intelligence Parameter (I) as parameter. The resulting data conform closely with actual measured values. This method and strategy is developed as a standard for all financial terms in the following. Alternatively the reader can make a program, using the needed algorithms given above in Table2.

The decision points, one set for sales in Case 1 and another for Case 2, including for costs are shown below.

The 5 Sales Decision Points Case 1

NP		S		I
10	S1	5	I1	0,09
130	S2	4	I2	0,09
177,915257	S3	3	I3	0,09
10	S4	7	I4	0,11
130	S5	8	I5	0,11

The 5 Sales Decision Points Case 2

NP		S		I
10	S1	4	I1	0,09
130	S2	3	I2	0,09
177,915	S3	2	I3	0,09
10	S4	7	I4	0,11
130	S5	8	I5	0,11

The 5 Cost Decision Points Case 1 = Case 2

NP		C		I
10	C1	5,167527	I1	
130	C2	4	I2	
177,9153	C3	3	I3	
10	C4	5,5	I4	
130	C5	6,5	I5	

These decision points are entered into the computational tables for costs (Table 1) and sales (Tables 2) depicted below. As you will see the constants are shown in the last row (the needed algorithms are given above in Table2).

. Next to it the cost and sales values (thousands of $) are tabulated as functions of volume (NP) for given values of the Intelligence factor (I), including corresponding graph, using Colding's Equation with the new constants: **$Y = K - (X-H)^2/4M-(N0-L*X)*Z$**, ***where X and Y are; Y=LN (C),C=COST, or LN (S), Sales (S), X =LN (NP), NP =Volume, or Number of Parts, and Z = LN (I), from which the exponents yield the arithmetic values. The curves in the graphs for the Decision entries I =0,09 and 0,114 are drawn as thick curves.***

Table 1. Calculation of COST constants based on the 5 COST (C) -(NP) points and I-values using Colding´s DBGenerator.

Calculation input for determining Constants M, H,L,N0,K. H

Input:

		NP		C		I
Point 1	NP1	10	C1	5,1675	I1	0,09
Point 2	NP2	130	C2	4	I2	0,09
Point 3	NP3	177,915257	C3	3	I3	0,09

Input: Targeted Values

Point 4	NP1	10	C4	5,5	I4	0,11	Set I4 never equal to I3
Point 5	NP2	130	C5	6,5	I5	0,11	

Calculation of V01,V02 from points (1,4), (2,5)

Converting to constant I= I0

NP		I0	C	
NP1	10,0000	0,09	V01	5,167526522
NP2	130	0,09	V02	4
NP3	177,915257	0,09	V03=V3	3

Note **T0** in above table is determined by tool-life **T3** from combination (ECT3,V3) in table to the left.

Set-up module for using the DBGen

T0		NP	C			I	NP	C	N1C	N2C
0,09	NP1	10	Point 01	5,167527	Point 4	0,11	10	5,5	-0,310727718	
0,09	NP2	130	Point 02	4	Point 5	0,11	130	6,5		-2,41942559
0,09	NP3	177,915257	Point 03	3						

Slopes points 1-4, 2-5

The 5 Decision Points

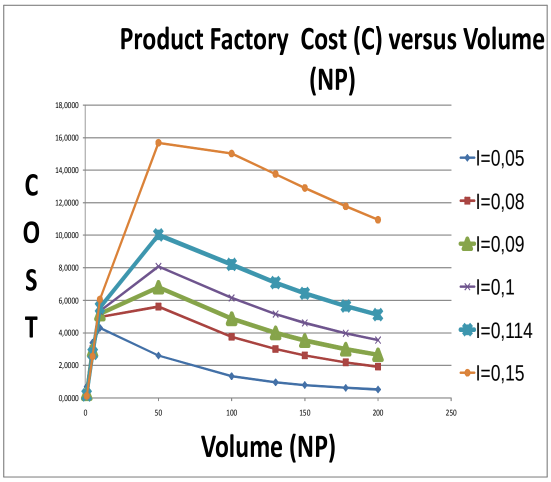
NP		C		I
10	C1	5,2	I1	0,09
130	C2	4	I2	0,09
177,91526	C3	3	I3	0,09
				0
10	C4	5,5	I4	0,11
130	C5	6,5	I5	0,11

DBGEN=DataBase Generator

Calculates S-NP Constants and LF/L .

a	b	c	HMIN=	HFAC	M=c/4a	H	L	N0	K	LF/L
-0,6575	-4,4833	-2,316829079	3,4091552	2,023015	0,8808797	6,89677262	0,822120665	1,58	8,38080302	#OGILTIGT!

NP	C I=0,05	C I=0,08	C I=0,09	C I=0,1	C I=0,114	C I=0,15
1	0,6849	0,3256	0,2702	0,2287	0,1859	0,1204
5	3,3973	3,0077	2,9173	2,8388	2,7440	2,5556
10	4,3049	4,9818	5,1675	5,3395	5,5614	6,0564
50	2,6059	**5,6165**	**6,8083**	**8,0873**	**10,0179**	**15,6861**
100	1,3346	**3,7599**	**4,8741**	**6,1480**	**8,2061**	**15,0242**
130	0,9648	3,0082	4,0000	5,1614	7,0867	13,7660
150	0,7951	**2,6201**	**3,5326**	**4,6151**	**6,4350**	**12,9103**
178	0,6214	2,1875	2,9986	3,9760	5,6470	11,7754
200	0,5204	1,9162	2,6565	3,5582	5,1175	10,9555
	0,05	0,08	***0,09***	0,1	***0,114***	0,15



Sales 1

Table 2. Calculation of SALES constants based on the 5 Cutting SALES (S) -(NP) points and I-values using Colding´s DBGenerator.

Calculation input for determining Constants M, H,L,N0,K. H

Calculation of V01,V02 from points (1,4), (2,5)

Input:

		NP		S		I
Point 1	NP1	10	S1	5	I1	0,09
Point 2	NP2	130	S2	4	I2	0,09
Point 3	NP3	177,915257	S3	3	I3	0,09

Converting to constant I= I0

	NP	I0		S
NP1	10,0000	0,09	V01	5
NP2	130	0,09	V02	4
NP3	177,915257	0,09	V03=V3	3

Input: Targeted Values

Point 4	NP1	10	S4	7	I4	0,11
Point 5	NP2	130	S5	8	I5	0,11

Set I4 never equal to I3

Note **I0** in above table is determined by tool-life **I3** from combination (ECT3,V3) in table to the left.

Set-up module for using the DBGen

T0	NP		S		I		NP	S	N1S	N2S
0,09	NP1	10	Point 01	5	Point 4	0,11	10	7	-1,676738279	
0,09	NP2	130	Point 02	4	Point 5	0,11	130	8		-3,45415248
0,09	NP3	177,915257	Point 03	3						

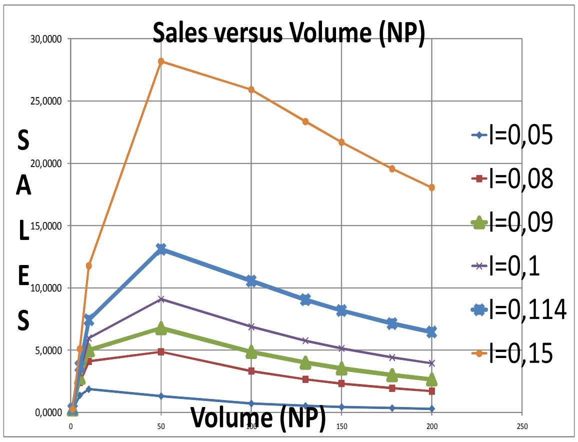
Slopes points 1-4, 2-5

DBGEN=DataBase Generator

Calculates S-NP Constants and LF/L .

a	b	c	HMIN=	HFAC	M=c/4a	H	L	N0	K	LF/L
-0,6679	-4,5872	-2,316829079	3,4341646	1,842762	0,8672409	6,32834957	0,692962688	-0,1	10,31886944	-9,20444585

NP	S I=0,05	S I=0,08	S I=0,09	S I=0,1	S I=0,114	S I=0,15
1	0,2302	0,2391	0,2414	0,2435	0,2461	0,2517
5	1,3709	2,4056	2,7697	3,1418	3,6750	5,1033
10	1,8661	4,1039	5,0000	5,9661	7,4320	11,7748
50	1,3121	4,8738	6,7716	9,0875	13,1016	28,1900
100	0,7116	3,3130	4,8708	6,8760	10,5573	25,9161
130	0,5252	2,6630	4,0000	5,7559	9,0505	23,3539
150	0,4376	2,3248	3,5329	5,1372	8,1833	21,6988
178	0,3464	1,9457	2,9986	4,4150	7,1430	19,5669
200	0,2926	1,7071	2,6559	3,9440	6,4488	18,0611
	0,05	0,08	***0,09***	0,1	***0,114***	0,15



Sales 2

Table 2. Calculation of SALES constants based on the 5 Cutting SALES (S) -(NP) points and I-values using Colding´s DBGenerator.

Calculation input for determining Constants M, H,L,N0,K. H

Calculation of V01,V02 from points (1,4), (2,5)

Input:

		NP		S		I
Point 1	NP1	10	S1	4	I1	0,09
Point 2	NP2	130	S2	3	I2	0,09
Point 3	NP3	177,915257	S3	2	I3	0,09

Converting to constant I= I0

	NP	I0		S
NP1	10,0000	0,09	V01	4
NP2	130	0,09	V02	3
NP3	177,915257	0,09	V03=V3	2

Input: Targeted Values

Point 4	NP1	10	S4	7	I4	0,11
Point 5	NP2	130	S5	8	I5	0,11

Set I4 never equal to I3

Note **I0** in above table is determined by tool-life **I3** from combination (ECT3,V3) in table to the left.

The 5 Decision Points

NP		S		I
10	S1	5	I1	0,09
130	S2	4	I2	0,09
177,915257	S3	3	I3	0,09

10	S4	7	I4	0,11
130	S5	8	I5	0,11

Set-up module for using the DBGen

T0	NP		S		I		NP	S	N1S	N2S
0,09	NP1	10	Point 01	4	Point 4	0,11	10	7	-2,788727007	
0,09	NP2	130	Point 02	3	Point 5	0,11	130	8		-4,88775529
0,09	NP3	177,915257	Point 03	2						

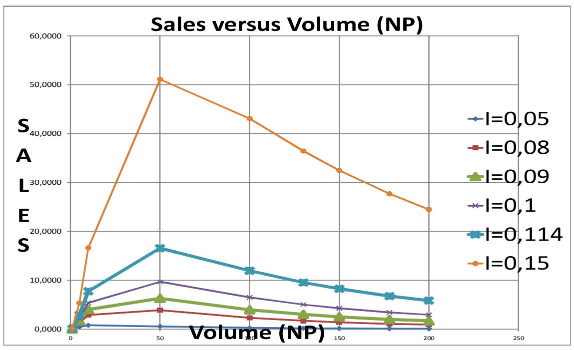
Slopes points 1-4, 2-5

DBGEN=DataBase Generator

Calculates S-NP Constants and LF/L .

a	b	c	HMIN=	HFAC	M=c/4a	H	L	N0	K	LF/L
-0,9497	-6,5498	-2,316829079	3,4482562	1,697028	0,6098648	5,85178714	0,81835077	-0,9	13,26517926	-15,4931433

NP	S I=0,05	S I=0,08	S I=0,09	S I=0,1	S I=0,114	S I=0,15
1	0,0308	0,0471	0,0523	0,0576	0,0648	0,0831
5	0,4642	1,3187	1,7131	2,1648	2,8963	5,3285
10	0,7766	2,8801	4,0000	5,3662	7,7332	16,6240
50	0,5615	3,8674	6,2725	9,6675	16,5560	51,0873
100	0,2538	2,2825	3,9578	6,4756	11,9453	43,0687
130	0,1696	1,6869	3,0000	5,0208	9,5260	36,4304
150	0,1329	1,3968	2,5186	4,2675	8,2219	32,4700
178	0,0971	1,0903	1,9986	3,4368	6,7441	27,6777
200	0,0774	0,9085	1,6842	2,9253	5,8126	24,4873
	0,05	0,08	***0,09***	0,1	***0,114***	0,15



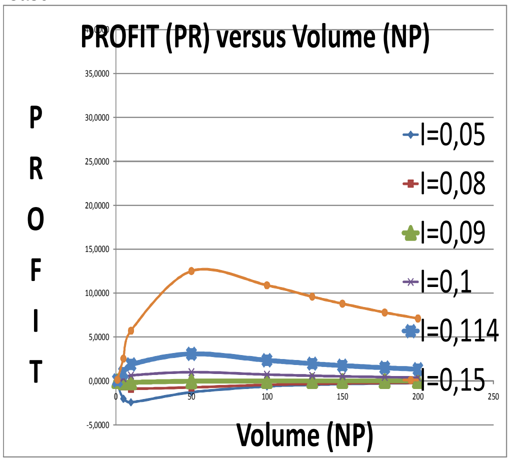
Profit is then obtained as the difference between S and C, tabulated and in graphs, shown as maxima at volumes around 50 parts.

Case 1

Table 3. Calculation of PROFIT based on the (NP) points IN Table 1 and Table 2.

NP	PR I=0,05	PR I=0,08	PR I=0,09	PR I=0,1	PR I=0,114	PR I=0,15
1	-0,4547	-0,086416259	-0,0287661	0,014797	0,0602241	0,13124188
5	-2,0264	-0,602115591	-0,1476637	0,302994	0,9309763	2,54765067
10	-2,4388	-0,877885711	-0,1675265	0,626636	1,870655	5,71832835
50	-1,2938	-0,742635727	-0,0367553	1,000235	3,0836746	12,5039418
100	-0,6229	-0,446897976	-0,0032873	0,728034	2,3511392	10,891883
130	-0,4396	-0,345154107	-7,105E-15	0,594509	1,9637776	9,58793819
150	-0,3575	-0,295316939	0,0003851	0,522132	1,748265	8,78852371
178	-0,275	-0,24170862	-2,003E-06	0,439043	1,4959664	7,79156363
200	-0,2278	-0,209094984	-0,0005976	0,385766	1,3312558	7,10559529

Case 1

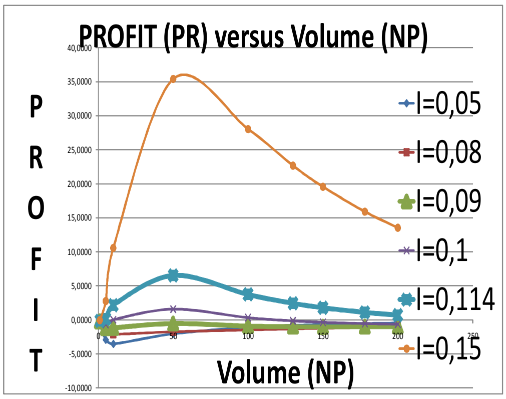


Case 2

Table 3. Calculation of PROFIT based on the (NP) points IN Table 1 and Table 2.

NP	PR I=0,05	PR I=0,08	PR I=0,09	PR I=0,1	PR I=0,114	PR I=0,15
1	-0,6541	-0,2785	**-0,2179**	-0,1711	**-0,1211**	-0,0373
5	-2,9331	-1,6891	**-1,2043**	-0,6739	**0,1523**	2,7729
10	-3,5283	-2,1017	**-1,1675**	0,0267	**2,1718**	10,5676
50	-2,0444	-1,7491	**-0,5358**	1,5802	**6,5381**	35,4012
100	-1,0807	-1,4773	**-0,9164**	0,3276	**3,7392**	28,0444
130	-0,7952	-1,3212	**-1,0000**	-0,1406	**2,4393**	22,6644
150	-0,6622	-1,2232	**-1,0140**	-0,3476	**1,7868**	19,5597
178	-0,5242	-1,0971	**-0,9999**	-0,5392	**1,0971**	15,9024
200	-0,4430	-1,0077	**-0,9724**	-0,6329	**0,6951**	13,5318

Case 2



This method and strategy is in the following developed for:.
Calculation Example 2 Forecasting Method to Estimate Sales versus Volume, Cost, Maximum Profit, including required Investments in Section 2.5.2, and for another Calculation Example 3 Forecasting Future with essential changes in company policy pertaining to new investments in Section 2.5.3.

2.5.2 Calculation Example 2 Forecasting Method to Estimate Sales versus Volume, Cost, Maximum Profit, including required Investments

This example is depicted in Table DBGENSPR, where S is plotted versus the Intelligence factor I1,I2,I3,I4 and I5, for 3 volumes (26,52,81). The calculation procedure follows that given in 2.5.1.

Table DBGENSPR.

DBGENSPR from **Sales Constants** Sheet 1

Forecasting Method to Estimate Sales vs Volume, total Cost and Maximum Profit as well as required Investments.

The method involves plotting Sales (S) versus Volume (NP) with the Intelligence factor (I) as parameter.
Profit (PR) versus Volume is then determined by plotting Product Cost (C) versus Volume (NP):

PRofit (PR) = Sales (S) - Product Cost (C)

Requirements are 5 S-NP points, selected according to below scheme:

where I, Intelligence factor.
Assumption: I, Intelligence factor, increases with sales using the logarithmic straight line equation for each volume:

I = S^N, where N is the slope as illustrated by the graph on the righ, Fig.1.

Cost per unit (cp) and Sales price per unit (sp) varies with volume, number of parts, (NP), which are determined or estimated by the manufacturing and marketing-sales departments.Sales price per unit (sp) depends on price elasticity and sales efficiency.

Total sales and cost are obtained by:S = NP*sp, C = NP*cp.

I. Determination of constants in Sales (S) equation

1. Using Colding´s relationship	**2. I, Intelligence Factor**
Y=K-(X-H)^2/4M-(N0-L*X)*Z	The Intelligence factor (I) is defined as the ratio between
M,H, L,N0,K are Constants to be determined:	Intelligent Investment Capital (II) and Sales value (S):
Setting X = LN (NP), Y = LN (S), Z = LN (I),	**I = 100*II/S %**
where **I = Intelligence Factor**	II=I*S
You need 5 points:	**II =Intelligent Investment Capital**
Point 1 = A: (NP11, S1,I1)	consisting of 3 terms:
Point 2 = B: (NP2,S2,I2)	II = Intellectual Capital (IC) + R&D + Capital Investment in
Point 3 = C: (NP3,S3,I3), representing the latest	Equipment & IT Software (CI)
company figures including Intelligent Investments (II),	For example, I-values of 0.03,0.06, 0.08, 0.12 signify that
which defines the Intelligence factor (I) on which the prognosis	the company has invested 3%, 6%,8% and 12% of its sales.
is made.	When determining Product Cost per year we have to add the portion of
Points 4 and 5 represent the targeted I-values which are	II (Intelligent Investment Capita) by dividing by the
necessary to determine the slopes N1, N2 in order to	Product Economic Life in years using proper reassignment procedures.
evaluate the constants L and N0.	**Product Cost = FC + ASC**
Point 4 = D: (NP1,S4,I4)	FC = Factory cost
Point 5 = E: (NP2,S5,I5)	ASC = Admin-sales cost
Based on 5 points	

Must use DBGen, see Table 1, or calculate Slope constant L, at a higher volume, say NP = 100, and assume N0-vaue, say - 0.2.
as well as trying different I-values to fit the prognosis for NP = 100.

Table 1. Calculation of constants based on the 5 Sales (S) -Volume (NP) points and I-values using Colding´s DBGenerator.

Calculation input for determining Constants M, H,L,N0,K. H

Input:	**A,B,C Points.Company History**					
		ECT=NP		V=S		T=I
Point 1	ECT1=NP1	26	V1=S1	984,0345	T1=I1	0,03
Point 2	ECT2=NP2	52	V2=S2	2471,099	T2=I2	0,06
Point 3	ECT3=NP3	81	V3=S3	3600	T3=I3	0,08
Input:	**Targeted Values**					
Point 4	ECT1=NP1	**26**	V4=S4	1500	T4=I4	0,12
Point 5	ECT2=NP2	52	V5=S5	2593,285	T5=I5	0,07

Converting to constant I = 0.08

	NP	I0		S
ECT1=NP1	26	**0,08**	V01	**1326**
ECT2=NP2	52	**0,08**	V02	**2704**
ECT3=NP3	81	**0,08**	V03=V3	**3600**

Set-up module for using the DBGen

T0=I0		ECT=NP		V=S		T=I	ECT=NP	V=S	N1	N2
0,08	ECT1=NP1	26	Point 01	**1326**	Point 4	**0,12**	**26**	**1500**	-0,304091	
0,08	ECT2=NP2	52	Point 02	**2704**	Point 5	**0,07**	**52**	**2593,285**		-0,313086
0,08	ECT3=NP3	81	Point 03	**3600**					Slopes points 1-4, 2-5	

DBGEN=DataBase Generator

Calculates S-NP Constants and LF/L .

a	b	c	HMIN= b/2a	HFAC	M=c/4a	H	L= b*(1-HFAC) /c*LN(T*)	N0	K	LF/L
-0,11743	-1,2054885	-0,349095	5,132669	1,009492	0,74318	5,181387	0,012977	-0,26181	9,202304	-3752,991

NP	**C1**	cp	**S** I=0.05	sp	**S** I=0.1	sp	**S0.08**	sp	**S 0.12**	sp
26	1400	54	1149	44	1419	55	**1326**	51	**1500**	58
52	2200	42	2334	90	2900	112	**2704**	104	**3070**	118
81	3000	37	3099	119	3865	149	**3600**	138	4097	158
100	3000	30	3386	130	4231	163	3938	151	4486	173
125	3000	24	3599	138	4506	173	4192	161	4781	184
150	3000	20	3690	142	4628	178	4303	165	4912	189
175	3000	17	3704	142	4652	179	**4323**	**166**	**4939**	**190**
200	3000	15	3668	141	4613	177	4285	165	4899	188
250	3000	12	3514	135	4427	170	4110	158	4705	181
			0,05		**0,1**		**0,08**		0,12	

Table 4b. Profit versus volume for 2 different Cost functions C1 and C2. Optimum at NP = 175 and 100 respectively.

NP	**PR1 0.08**	prp	**PR1 0.12**	prp
26	**-74**	-3	**100**	4
52	**504**	19	**870**	33
81	**600**	23	**1097**	42
100	938	36	1486	57
125	1192	46	1781	69
150	1303	50	1912	74
175	**1323**	**51**	**1939**	**75**
200	1285	49	1899	73
250	1110	43	1705	66

NP	C2	cp	**PR2 0.08**	**PR2 0.12**
26	1400	54	-74	100
52	2200	42	504	870
81	3000	37	600	1097
100	**3200**	**32**	**738**	**1286**
125	3700	30	492	1081
150	4600	31	-297	312
175	6000	34	-1677	-1061
200	7600	38	-3315	-2701
250	10000	40	-5890	-5295

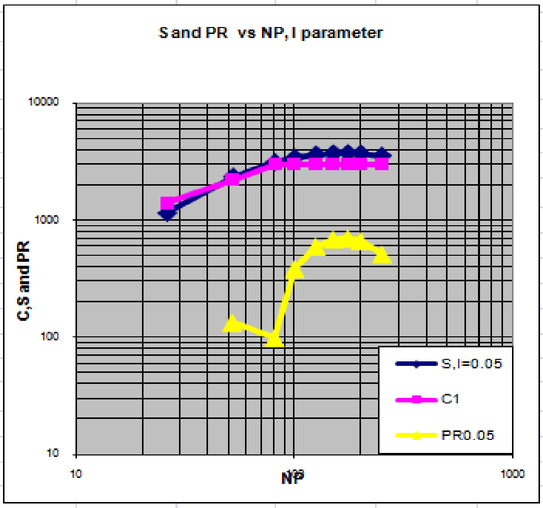


Fig. 2.

Company managers are urged to employ this Econometrics in order to ascertain realistic results. Only a simple internal program can be introduced and all the many determinations will be made quickly.

2.5.3 Calculation Example 3 Forecasting Future with essential changes in company policy pertaining to new investments.

The company profit is determined from the difference in sales and costs. Current costs and sales are for I = 0.07 and year 9 $1650 and $1605 and year 10 $1400 and $1624. Costs and sales are for I = 400 and year 15 $1600 and $2351. These figures are shown in the sixth and fourth columns in Table 3, where the cost and sales developments are also shown. It is

Table 3. Forecasting results including required investments: 2 cases.															
											Sales Constants			Blad 1	
A,B,C Points.Company History. I = 0.07							PR/I	II is obtained by II = I*S							
Year	Quarter	Year	S	sp	C	cp	0,07	I	II	II Increase		I=II/SUM (S)			
1	1	1	1115	1000	1250	1121	-135	0,07	**78**	78		**0,07**			
5	1	5	1490	800	1225	658	265	0,07	**104**	26		0,04			
9	1	9	1605	700	1650	720	-45	0,07	**112**	8		0,0267			
SUM Investments from year 1 through 9							PR/I			**112**					
Factory Cost Reduced							0,07								
10	1	10	1624	600	1400	517	224	0,07	**113,7**	1,3		**0,07**			
11	1	11	1640	500	1400	427	240	0,07	**114,8**	1,1		0,0352			
12	1	12	1654	400	1400	339	254	0,07	**115,8**	1,0		0,0235			
13	1	**13**	1667	350	1400	294	**267**	0,07	**116,7**	0,9		0,0177			
14		14	1679	300	1500	268	179	0,07	**117,5**	0,8		0,0142			
15		15	1689	250	1600	237	89	0,07	**118,2**	0,7		0,0119	**Using year 10 as base for**		
SUM Investments from year 10 through 15					I =0.1	0,098341	PR/I			**5,9**			**I is decreasing**		
Factory Cost same as above but Increasing Efficiency of Sales.							**0,098341**	II is obtained by II = I*S					I is decreasing		
10	1	10	2320	600	1400	517	920	0,098341	**228,1**	115,8		**0,0983**	0,09834		
11	1	11	2329	500	1400	427	929	0,098341	**229,0**	0,9		0,0493	0,09796		
12	1	12	2336	400	1400	339	936	0,098341	**229,7**	0,7		0,0329	0,09765		
13	1	**13**	2342	350	1400	294	942	0,098341	**230,3**	0,6		0,0247	0,09740		
		14	2347	300	1500	268	847	0,098341	**230,8**	0,5		0,0198	0,09719		
		15	2351	250	1600	237	751	0,098341	**231,2**	0,4		0,0165	0,09703		
SUM Investments from year 10 through 15										**231,2**	**Year 15 company has invested this much**				
											more than investments up to Year 9				
											119				

recommended to use the Manufacturing cost and the other cost programs, see Chapter 5, Affärs - och tillverkningsbudgetering, Funktionell Ekonomisk Företags - Tillverkningsanalys (Colding's Book in Swedish, 2003), in order to more accurately assess the cost. The new costs per item and the savings are shown in the bottom rows. Here we have employed a less detailed method that can be used   for a

Table 4a.Product Cost (C), Unit cost (cp), Sales (S) and Unit Sales Price (sp) as function of Year, I Parameter.												
								S as function of Year, I Parameter				
								Points	**Points**		**Calculated sales**	
Sales price/unit (sp) is decreases to sp = ? Year ?.							**Year**	**1,2,3**	**4,5**		**values**	
Year	**C1**	**cp/I**	**cp/I**	**cp/I**	**cp/I**			**S/I 0,07**	**S/I 0,0983**	**S/I 0,1**	**S/I 0,08**	**S/I 0,09**
		0,07	0,098341	0,08	0,09			**0,07**	0,098341	0,1	0,08	**0,09**
1	1250	1121	677	920	772		**1**	**1115**	**1845**	**1892**	1359	**1618**
2	1225	907	573	757	646		2	**1283**	**2031**	**2078**	1537	**1802**
3	1200	784	508	661	569		3	**1378**	**2126**	**2171**	1634	**1898**
4	1225	722	477	613	531		4	**1442**	**2184**	**2230**	1698	**1960**
5	1225	658	440	562	489		**5**	**1490**	**2225**	**2269**	1744	**2004**
6	1225	622	421	533	466		6	**1528**	**2255**	**2298**	1780	**2037**
7	1225	590	403	508	445		7	**1558**	**2277**	**2320**	1808	**2063**
8	1625	744	513	643	566		8	**1583**	**2295**	**2337**	1832	**2083**
9	1650	720	500	624	550		**9**	**1605**	2308	**2350**	1851	**2100**
10	1400	517	362	450	397		10	1624	2320	**2361**	1868	2114
11	1400	427	301	372	329		11	1640	2329	**2369**	1882	2125
12	1400	339	240	296	262		12	1654	2336	**2376**	1894	2135
13	1400	294	209	257	229		**13**	1667	**2342**	**2382**	1905	**2143**
14	1500	268	192	235	209		14	1679	2347	**2386**	1915	2151
15	1600	237	170	208	185		15	1689	2351,000	**2390**	1923	2157
								0,07	0,098341	0,1	0,08	**0,09**

preliminary evaluation of needed investments. The Profit development is shown in the next table. ***DBGen generates automatically Profit , Number of parts and Intelligent Investment Capital***

Profit versus volume for			
Cost function C1. Optimum at Year 13.			
Points	**Points**	**Calculated sales**	
1,2,3	**4,5**	**values**	
PR/I=0,07	**PR/I=0,098**	**PR/I=0,08**	**PR/I=0,09**
0,07	0,098341	0,08	**0,09**
-135	595	109	368
265	1000	519	779
-45	658	201	450
224	920	468	714
265	1000	519	779
-45	658	201	450
224	920	468	714
240	929	482	725
-45	658	201	450
224	920	468	714
240	929	482	725
254	936	494	735
267	**942**	**505**	**743**
179	847	415	651
89	751	323	557

2.6. Forecasting Using Polynomials

A typical model in an enterprise Profit analysis by Riggs [3], consists of two second order polynomials in Cartesian coordinates, where Cost and Total Sales are plotted versus Volume of parts. The solution requires 5 given points, or 5 constants, in order to calculate maximum Profit for one set of conditions. The deviation is small between the Riggs's approach (using his one-data-set) and the author's model. Achieving a true optimum requires multiple data sets. The author's model generates a series of curves, proving that the 5-point approach is superior.

2.7 Marginal Cost, Maximum Sales and Maximum Profit

The rate of change of slope of Sales (S) versus Cost (C) is called the "marginal revenue" or "marginal cost", also defined as difference in income or outlay caused by the next unit of output at a specific level of production, see points along L – M of the sales curve in Fig. 1, where S and profit (PR) are plotted versus cost. At a cost corresponding to point O, Profit is maximum. A further increase in sales up to the maximum sales point M results in a reduced profit. Trying to increase sales by investing in more sales and manufacturing resources, going from point M to point R, is inhibited due to less volume of products sold, or to lower market sales prices. This because the market price elasticity for

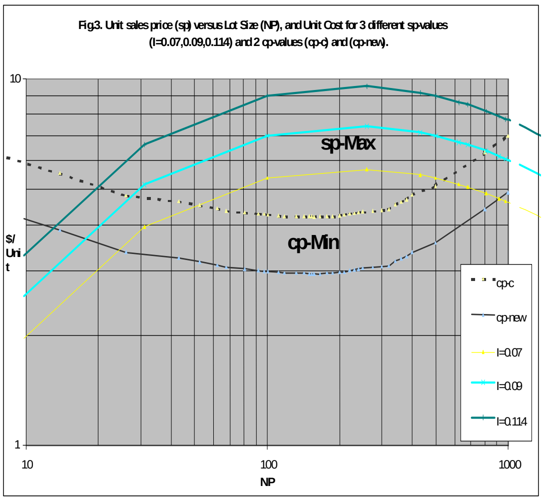


Fig.1

the product is such that more products will have to be sold at a lower price. At point R the profit goes down to zero. . In double logarithmic coordinates this point is the tangential point of a line sloping at -45 degrees as shown in the graph, see Section 3, Chapter 2. While Maximum sales occurs at a given product cost or at a given number of parts or products, Maximum Profit will occur at a slightly lower cost or smaller number of parts, as depicted in Fig. 1. Plotting Unit Sales (sp) and Unit Cost (cp) versus lot size, or product volume, as shown in Fig. 2 we find that the zone in which Profit (PR) occurs defines the 2 product break-ven cost and volume values. The points , M
and R are here defined by 3 vertical arrows.

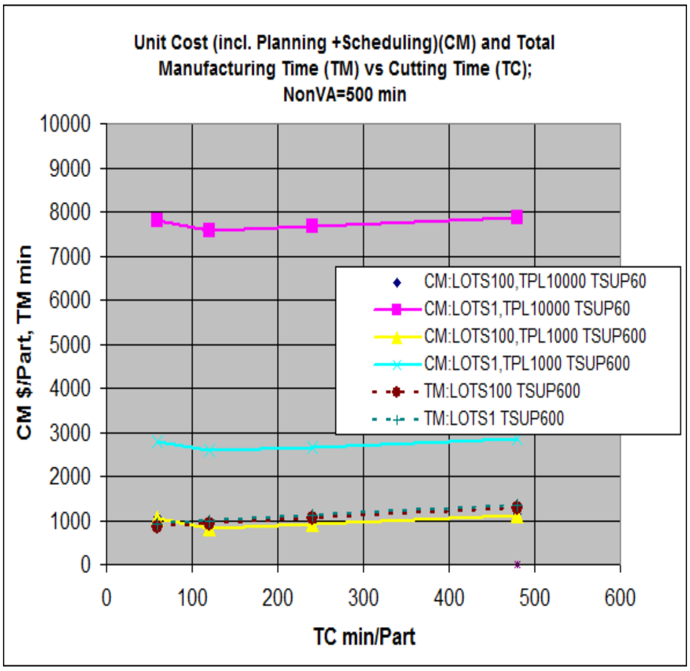
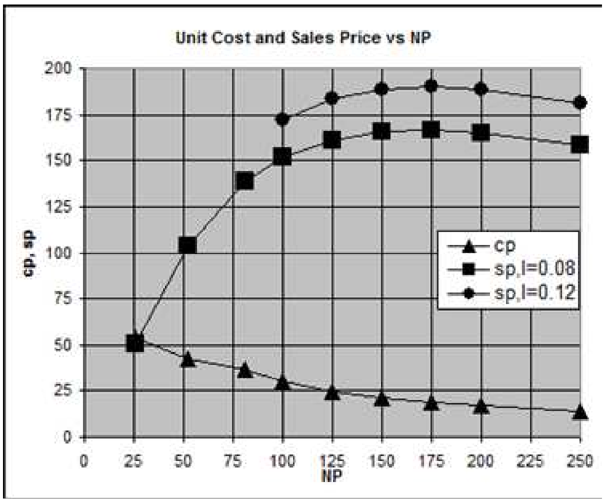


Fig 2



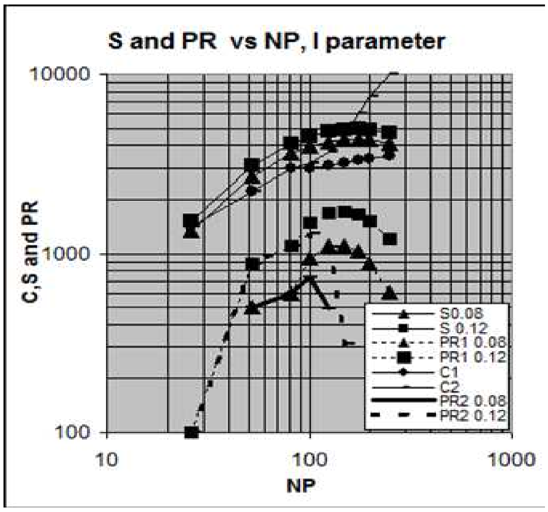


Fig. 3 **Fig. 4** displays the Total Cost (C) and Unit Cost (cp)

Fig. 3 depicts unit cost and unit sales price (for I = 0.08, 0.12) versus lot size (NP).
Fig. 4 completes the performance picture showing profit versus lot size including the limiting break-even lots for 2 different products.

3. GRANULAR METRICS

Inherent errors in existing financial metric systems are common as cost assessments tend to be based on simple evaluation methods including using

Averages. Granular segmentation of cost elements into functional quantities allows a company to focus, to measure, to learn and to innovate. A.L.Hax-D.L. Wilde (Sloan Management Review, Winter, 1999) have extensively studied various companies and found astounding discrepancies between actual and calculated costs when comparing the granular approach with the conventional using averages: for example individual order cost varied up to 10:1.

Inherent errors in existing financial metric systems related to manufacturing are summarized in TABLE 1 and in TABLE 2 there is an example pertaining to the use of overhead percentages based on labor costs. Applications related to machining economics will be demonstrated in Part I.

3.1 Current Financial Metrics

TABLE 2. refers to 4 examples, Case 1, 2, 3 and 4, comparing using averages with individual granular cost calculations. The total shop cost was calculated as the sum of costs of labor, supervision, machine depreciation and tooling. Thereafter, an overhead (OH) percentage was calculated for each product in each cell individually comparing with using the overhead based on total cost and labor rate which were applied to each individual cell. The result is different costs for each product if we use averages instead of individual granular calculations.

TABLE 1

Current Financial Metrics

- Knowledge gap between the Metrics used by the financial and manufacturing entities in firms.
- Severe misjudgments when calculating cost using averages:
  Ex.1 "high-cost" product order path ten times "low-cost" order path
  Ex 2. Manufacturing "high-cost" was 50% higher than actual
- Estimates based on processing times using average hourly rates lead to severe errors
- Severe misjudgments when evaluating the Benefits of New Technology.
- Calculated cost savings are often erroneous, impacting on the Firm's Survival
- Sub-tier suppliers are calculating prices based on simple metrics, which do not adequately consider the cost of money.
- Economic Gaps between where they are and where the "best" are.

Each case contains 2 manufacturing cells, Cell 1 and 2 with 3 and 6 machines respectively . The number of operators are 1 and 6 in Cells 1 and 2 respectively with different expenses for tooling.

Each case contains 2 manufacturing cells, Cell 1 and 2 with 3 and 6 machines respectively . The number of operators are 1 and 6 in Cells 1 and 2 respectively with different expenses for tooling.

In Case 1 the completion time in Cell 2 is double that in Cell1, while the times are equal in Case 2. In Case 2 the number of operators are 3 and 6 in Cells 1 and 2 respectively.

There is another difference making the products related to the number of required supervisors: Cells 1 and 2 require 0.2 and 0.8 supervisors in Case 1 while 0.33 and 0.67 in Case 2 respectively.

Case 3 and 4 refer to making the same parts in the same organizational environment as in Case 1 and 2, with the exception of the labor hourly rates, which for various reasons have decreased from $30/hour to $20 /hour.

TABLE 2.

LEANFLOW.XLS Sheet 3

ERRORS USING AVERAGE OH PERCENTAGES

Average OH Percentage=Percentage of Entire Shop

Average OH Percentage varies (69-110%) with # operators, # supervisors, labor rate and Manufacturing Time in below Tables, and of course also tooling cost and depreciation

ERRORS USING AVERAGE OH PERCENTAGES Amount to up to 50%.

	CELL 1				**CELL 2**		
Prod X	TIME		Prod Y	TIME			
	1			2			
#MAC			#MAC				
3			6				
#OPER			#OPER				
1		#SUPV	6				
#SUPV		1	#SUPV				
0.2			0.8				

	CELL 1					**CELL 2**	
	ProdX	TIME		Prod Y	TIME		
		1			1		
	#MAC			#MAC			
	3			6			
	#OPER			#OPER			
	3			6			
	#SUPV		#SUPV	#SUPV			
	0.3		1	0.7			

CASE 1

	$/hour	$		$/hour	$		SUM
EXACT				**EXACT**			
L	20	20		30	360		380
SUPV	30	6		30	48		54
TOOL	3	9		10	120		129
DEPR	10	30		6	72		102
SUM		65			600		665
OH		45			240		285
OH%ofL		225			67		75
L+OH $		65			600		665
USING Average OH%							
L+OH $		35			630		665
ERROR%		-46			5		0

CASE 2

	$/hour	$		$/hour	$		SUM
EXACT				**EXACT**			
L	20	60		30	180		240
SUPV	30	10		30	19.99998		29.99998
TOOL	3	9		10	60		69
DEPR	10	30		6	36		66
SUM		109			296		405
OH		49			116		165
OH%ofL		82			64		69
L+OH $		109			296		405
USING Average OH%							
L+OH $		101			304		405
ERROR%		-7.1			2.6		0

CASE 3

	$/hour	$		$/hour	$		SUM
EXACT				**EXACT**			
L	20	20		20	240		260
SUPV	30	6		30	48		54
TOOL	3	9		10	120		129
DEPR	10	30		6	72		102
SUM		65			480		545
OH		45			240		285
OH%ofL		225			100		110
L+OH $		65			480		545
USING Average OH%							
L+OH $		42			503		545
ERROR%		-36			4.8		0

CASE 4

	$/hour	$		$/hour	$		SUM
EXACT				**EXACT**			
L	20	60		20	120		180
SUPV	30	10		30	19.99998		29.99998
TOOL	3	9		10	60		69
DEPR	10	30		6	36		66
SUM		109			236		345
OH		49			116		165
OH%ofL		82			97		92
L+OH $		109			236		345
USING Average OH%							
L+OH $		115			230		345
ERROR%		5.5			-2.5		0

3.2 Results and Deviations using 3 different Reassignment bases within each cost pool

Summing up departmental costs within each cost pool when using total hours PTB as reassignment base for each department results in 37% lower cost than the actual cost. Using cost figures obtained from PTB for individual hours per department, or PTB for individual material purchases as reassignment base per department results in correct total actual cost.

The 3 reassignment bases, PTB's for total, individual hours and material as base, yield different costs per department as well as different sums when adding up the costs from the three cost pools: purchasing agents, receiving room and supervision. Obviously, when individual hours per department and pool are measured, the result gives the actual cost. The great percentage deviations that may occur between reassignment methods emphasize the importance of applying correct and "granular" cost systems.

Results using 3 different Reassignment bases within each cost pool									
Right Column: Deviations vs vs total hrs reassignment				PTB = Percent of reassignment base					
160	160 hours/month			Reassignment base: Number hours,OH					
Cost pool/		Salaries &		Total incl	Dept 1	Dept 2	Dept 3	SUM = Depts 1+2+3	
Reassignment Base	$/hour	Wages		OH = Space Cost /employee salaries & wages					
3 Purchasing agents	25	12000		Total				SUM	
PTB for total hours			PTB	100%	47%	26%	27%		
				16364	7727	1985	538	10250	-6113
PTB for Hours within pool/dept,			**PTB**	**100%**	**63%**	**25%**	**13%**		**-37%**
actual cost = hours * $/hour				**16364**	**10227**	**4091**	**2045**	**16364**	**0**
PTB for Raw materials Purchased			PTB	100%	50%	33%	17%		
				16364	8182	5455	2727	16364	0
5 Rec. room employ.	18,75	15000						SUM	
PTB for total hours			PTB	100%	47%	26%	27%		
				20455	9659	2482	672	12813	-7641,44
PTB for Hours within pool/dept,			**PTB**	**100%**	**38%**	**25%**	**38%**		**-37%**
actual cost = hours * $/hour				**20455**	**7670**	**5114**	**7670**	**20455**	**0**
PTB for Raw materials Purchased			PTB	100%	50%	33%	17%		
		0		20455	10227	6818	3409	20455	0
1 Dept supervisor	37,5	6000						SUM	
PTB for total hours			PTB	100%	47%	26%	27%		
				8182	3864	993	269	5125	-3057
PTB for Hours within pool/dept,			**PTB**	**100%**	**50%**	**31%**	**19%**		**-37%**
actual cost = hours * $/hour				**8182**	**4091**	**2557**	**1534**	**8182**	**0**
PTB for Raw materials Purchased			PTB	100%	50%	33%	17%	SUM	
				8182	4091	2727	1364	**8182**	0
SUM Based on PTB for total hours				45000	21250	5460	1479	28189	-16811
									-37%
SUM Based on actual cost				**45000**	**21989**	**11761**	**11250**	**45000**	0
within pool = hours * $/hour									
SUM Based on Raw materials Purchased				45000	22500	15000	7500	**45000**	0
Each Dept Based on on PTB for total hours			PTB	100%	47%	26%	27%		
and total cost $45000				45000	21250	11563	12188	**45000**	
Total Salaries and wages		33000							
Other = space cost:		12000							
Total		45000							
OH = Space Cost /employee salaries & wages									
		36%							
Deviations using 3 different Reassignment bases within each cost pool									
Deviation figures calculated from actual cost versus reassignments based on respectively total hrs and purchased materials.									
Dept Cost Deviations vs Total hours Base				Total	Dept 1	Dept 2	Dept 3		
SUM Based on reass hours vs PTB for total				0	-739	-6301	-9771		
Percent				**0%**	**-3%**	**-54%**	**-87%**		
Total Based on Raw materials Purchased				0	511	3239	-3750		
Percent				**0%**	**2%**	**28%**	**-33%**		
Total Based on reass hours vs PTB for total				0	-739	-199	938		
Percent				**0%**	**-3%**	**-2%**	**8%**		
Dept Cost Deviations between Reassignment Base Materials and Actual Cost									
SUM Based on reassignment hours				45000	21989	11761	11250		
within pool cos t= hours * $/hour									
SUM Based on Raw materials Purchased				45000	22500	15000	7500		
Deviation for raw material reassignment				0	511	3239	-3750		
Percent				**0%**	**2%**	**28%**	**-33%**		

4. INTEREST, INDUSTRIAL ASSETS AND BREAK-EVEN ANALYSIS

4.1 Interest and Evaluation of Investments

Simple Interest

Compound Interest

Present Value and Discount

Annuities (Machinery's Handbook p.25-28)

4.2 . Evaluation of Investments in Industrial Assets

Annual Cost Method

Present Worth Method

Prospective Rate of Return Method (Discounted Cash Flow) (Machinery's Handbook p.28-32)

4.3 . Break-Even Analysis

(Handbook p.37-39, slightly modified, adding

Nonlinear Relationships for better accuracy)

Profit Break-Even Values

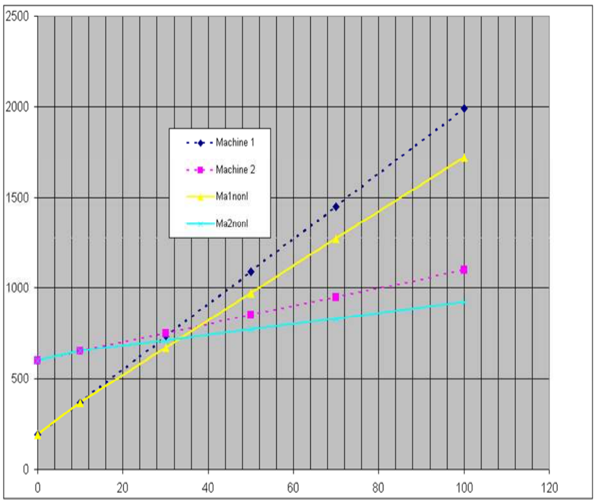


Fig. 10

Fig.10 illustrates the simplest method to measure Break-Even in order to decide in which machine tool a given quantity of parts should be made. Fixed and Variable costs of two alternative machines are here plotted versus lot size. The decision is that Machine 1 requires a lot size of 30 and Machine 2 a quantity of 40 parts in order to Break-Even.

Fig.11 illustrates the best method to measure Break-Even when all costs are included on the enterprise level, considering product sales as well. Minimum and maximum lot sizes are required in this type of analysis.

Neither the range of volumes, nor the absolute quantities are the same when either using sales or profit requirements.

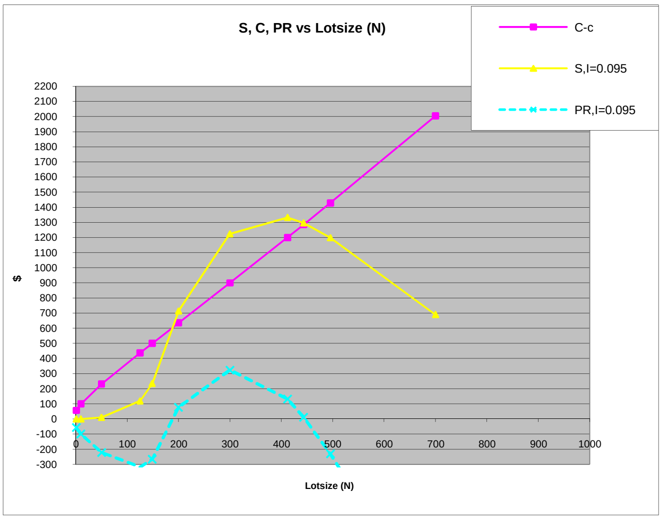


Fig. 11

5. PAYBACK, PRODUCTIVITY AND PERFORMANCE METRICS

5.1 Payback

This method is used world-wide to give a rough measure of the feasibility of investments in tooling and machine tools. It is simply the length of time required for returns from an investment to equal the amount invested:

Payback period =(Required investment)/(Annual savings)

Required payback periods vary but one-half a year up to 3 years are common numbers.

Productivity

The simplest version, or the basic ratio, is:

p= output/input, which is used in labor intensive production.

Another is related to cost:

p = (output/input)/cost

Productivity is generally used as a measure of production quantity (parts/hour), and is not a measure of profitability.

A better profitability metrics is the **Total productivity index (TP),**a single figure expressing the efficiency of the entire organization. It is defined as the dollar value of products and services produced divided by a summary value of all inputs:

TP =(sales + inventory change + plant)/(material + labor + services + depreciation + investment)

In metal cutting another version is used, see Section 3 :

p = Metal Removal Rate/(1 + Tool-life/Equivalent Tool cost Time)

5.2 Performance Metrics

A number of human and financial performance measures are used of which most are simple ratios such as cost or time per employee etc.. None of these will correctly assess the performance of companies. However, their importance is significant if these diagnostic processes are used throughout the company with the purpose of better using current resources, i.e. to accomplish desired results in the shortest possible time.

This involves critically examining total business operations and arrive at prioritized improvement action plan. The priority should be placed on providing high-quality products and services to customers.

One basic tool can be using a graphic representation of the build up of cost with time as a product passes through its entire cycle in the business operation.

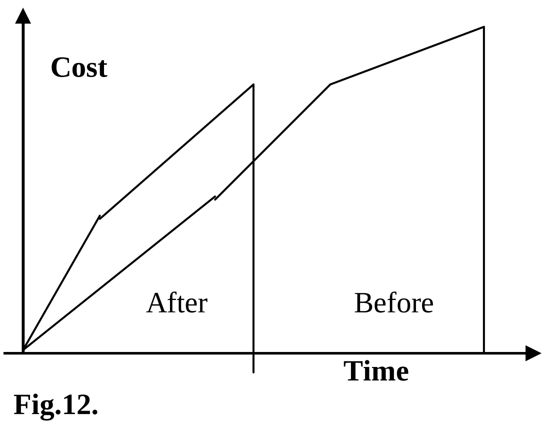


Fig.12.

As business operations improve, the cost-time profile shrinks along both axes while enhancing quality and responsiveness to customer needs.A strategic activity is people -measurement linked to financial goals as well as to individual rewards.

Having developed these customized strategic metrics the implementation steps must be defined and executed in order to result in lean sales and manufacturing activities.

5.4 Performance Metrics - Intellectual Capital

Instead of a performance number related to Payback =Investment/ Savings, or
p = (output/input)/cost etc. here we define an **IC-type** "Competence" or, "Intelligence" parameter **(I).** This Intelligence parameter **(I)** is defined in terms of an Intelligent Investment amount (**II)** as function of the company sales (S):
I = II/S =100*(II/S) in Percent
where Intelligent Investment amount **II** consists of the sum of three performance functions: **II** = IC+R$D+CI
IC = Intellectual Capital = An "Intelligence**"** term defined as the sum of the following activities: "Ability to create excellent customer and internal relationships + Renewal & Development To - **Improving Product, Manufacturing and Design + Patents Development and the ability to use external experts efficiently".**
R&D =Research & Development in Engineering and Manufacturing.

CI =Capital Investment in Equipment and Software, the components of which are determined as annual costs using the Handbook methods and Tables pertaining to chapters "Interest" and "Evaluating Investments in Industrial Assets", pp.25-32.

The Intelligence parameter is described in detail under the heading "Intellectual Capital and Intelligent Investments".

5.5 Performance Metrics – Factory Capacity and Factory Profit

The relationship of Factory Profit to Operations Efficiency and Capacity Utilization are critical when assessing factory performance.
These factors are measured by 2 time factors and a Degree of Return factor, which leads to a summary performance factor, called **Performance Index**:

CU = Capacity Utilization = (TVA+TNVA)/TNOMC
Operations Efficiency = OE = TVA/(TVA+TNVA)
Degree of Return = DR = (FSP –FC)/FC,
where FSP is factory sales price.

5.6 Six-Sigma

is a philosophical approach based on a quality initiative within General Electric Company that demands the effective use of data to analyze business issues. Whether the decision is a make-buy decision, a product change question, or a manufacturing process decision, the decision on how to proceed is dependent on the available data. This quality initiative requires going from current number of defects to six-sigma, say 4 defects per million in every element in every process every day. The process includes:
Measuring the process out puts
Analyzing the process inputs for criticality
Improving the process by modifying inputs
Controlling the process by controlling the appropriate input

5.7 Performance Index

PI = CU*DR,
where TNA =Time of Value-Added Operations, TNVA = Time of Non-Value-Added Operations, TM = TNA + TNVA = Time of Manufacturing, TNOMC = Time of Nominal Capacity, FSP = Factory Sales Price, CMan = Total Manufacturing Cost. FC = Factory Cost =CMan + CMTRL + WIP, CMTRL = Cost of Material, WIP =Work-In-Process (see Chapter 6). Please see detailed time/cost nomenclature in Section 2, Chapter.4.
The relationship between OE and CU reads:
CU = TVA/OE/TNOMC

5.8 Examples

EX.1. TNVA = 0; OE = 1.0 = 100%.
TVA = 20 hours, TNOMC = 40 hours; CU = 20/40 = 0.5 = 50% (50% capacity available for other parts). CMan = $1000, CMTRL = $500, WIP = $300; FC =$1800
SF = $2000; Degree of Return = DR = (2000 –1800)/1800 = 0.111= 11.1%.
Performance Index = PI = CU*DR = 0.5*0.111 = 0.0566 = 5.56 %.

EX. 2. TNVA = 10 hours, TVA = 20 hours, TNOMC = 40 hours;
OE = 20/(20+10) =0.666 = 66.7%.
CU = (20 + 10)/40 = 0.75 = 75% (25% capacity available for other parts)..
FC =$1600
SF = $2000; Degree of Return = DR = (2000 –1600)/1600 = 0.25 = 25.%.
Performance Index = PI = CU*DR = 0.75*0.25 = 0.1875 = 18.75%.

EX. 3. TNVA = 10 hours, TVA = 20 hours, TNOMC = 30 hours;
OE = 20/(20+10) =0.666 = 66.7%.
CU = (20+10)/30 =1 =100% (0% capacity available for other parts)..
FC = $1500
SF = $2000; Degree of Return = DR = (2000 –1500)/1500 = 0.333 = 33.3%.
Performance Index = PI = CU*DR = 1.0*0.333 = 0.333 = 33.3%

6. CAPITAL INVENTORY AND WORK-IN-PROCESS MODELS – MATERIALS - FACTORY COST

6.1 Inventory Costs and Economic Order Quantity

Analyses of inventory costs recognize just two patterns: costs that vary with the size of the order and costs that vary inversely with order quantity. Capital and holding costs increase as the order size increases, because larger orders mean higher inventory levels. These (carrying) costs vary approximately linearly with orders. The (procurement) costs are varying inversely with order size. The total cost of inventory versus lot size exhibits a minimum cost value corresponding to the so-called economic order quantity, EOQ. The formulas to determine EOQ are shown below.

Annual procurement cost = O*D/Q, O =Ordering cost, D =Annual demand, Q =Order size; Annual Carrying Cost = (H + I*P)*Q/2, H = Holding cost (facilities, transport etc.),

I = Interest rate, P =Price

Cost of Inventory = CI = O*D/Q + (H + I*P)*Q/2

6.2 Economic Order Quantity (EOQ)

EOQ = SQROOT[(2*O*D)/(H + I*P)]

This generally used EOQ formula may give great errors as it does not consider for example variation of sales price and manufacturing cost with lot size as shown in Chapter 1.

EXAMPLE:

O=$80, D=80000, H=$0.10, P=$0.40 per container, I = 15% including charges for taxes and insurance as well as interest.

The above formula yields:

EOQ= 7016 units.

6.3 Value of Work-In-Process (WIP)

The formula to calculate WIP reads:

WIP=(i/100)*[(C Man /2 + CMTRL) + (CMan + CMTRL)*(1-TM/TNOMC)]

where i = Interest Rate, TNA =Time of Value-Added Operations, TNVA = Time of Non-Value-Added Operations, TM = TNA + TNVA = Time of Manufacturing, TNOMC = Time of Nominal Capacity, ManC = Total Manufacturing Cost. CMTRL = Cost of Material,

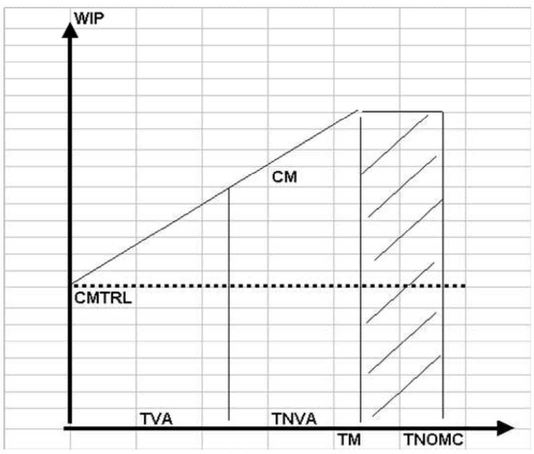


Fig. 13

WIP =Work-In-Process. Please see detailed time/cost nomenclature in Part II.

Operations, TM = TNA + TNVA = Time of Manufacturing, TNOMC = Time of Nominal Capacity, **ManC = Total Manufacturing Cost. CMTRL = Cost of Material,**

WIP =Work-In-Process. Please see detailed time/cost nomenclature in Section 2, Chapter 4.

Fig. 13. represents a graphic illustration of the build-up of the formula to calculate WIP, showing how the sum of manufacturing cost and cost of material changes with time. The difference between Time of Nominal Capacity (TNOMC) and the actual manufacturing time (TM) represents non-utilized time in a production cell.

6.4 Factory Cost (FC)

Factory cost is calculated using the following relationship:

FC =CMan + CMTRL + WIP

Cost of Inventory (**CI**) is calculated using the formula in previous chapter, and added to FC if applicable.

When determining savings from better machining data, shorter cycle times and new capital investments etc., then use the WIP formula and calculate the difference as a contribution to the other calculated savings.

EXAMPLE. In TABLE 3. the WIP formula is used to determine WIP as function of Cost of Manufacturing (CMan). Interest Rate (i) and defect Rejection Factor (RJF) were held constant, but TVA and TNVA were varied to maintain reasonable good

TABLE 3.

Nomenclature:TM, CM and FC=CM +WIP + CMTRL, see Chapter 5.4.

TVA0= excl rejects,hours	RJF=Reject factor	TVA=Processing time incl rejects=TVA0(1+RJF),hours	HR $/hour	i = interest charge per year,%
5400	0.05	5670	50	20
3600	0.05	3780	50	20
3000	0.05	3150	50	20
1500	0.05	1575	50	20
800	0.05	840	50	20
80	0.05	84	50	20

TNVA =Time Non Value-added (waste) hours	TM=Time Manufacturing = TVA + TNVA hours	TNOMC=Nominal capacity hours	CU=Capacity Utilization %	OE=Operation Efficiency %
1600	7270	7540	96.419098	74.277854
800	4580	5,040	90.873016	78.60262
0	3150	3600	87.5	95.238095
100	1675	1800	93.055556	89.552239
60	900	900	100	88.888889
20	104	104	100	76.923077

CMTTL $	CM=TM*HR $	TM hours	FC $ CMTRL=20	FC $ CMTRL=25	FC $ CMTRL=1000	CM $	WIP $ CMTRL=20	WIP $ CMTRL=25	WIP $ CMTRL=1000
200000	363500	7270	643885.68	432632.36	403660.48	363500	80385.676	44132.361	39160.477
100000	229000	4580	499730.95	286536.51	257298.41	229000	70730.952	32536.508	27298.413
25000	157500	3150	422187.5	207812.5	178412.5	157500	64687.5	25312.5	19912.5
20000	83750	1675	336065.97	123635.42	94502.083	83750	52315.972	14885.417	9752.0833
10000	45000	900	289500	79500	50700	45000	44500	9500	4700
1000	5200	104	245720	35720	6920	5200	40520	5520	720

percentages of: Capacity Utilization = CU = (TVA+TNVA)/TNOMC and Operations Efficiency = OE = TVA/(TVA+TNVA)The calculations of CM was for simplicity determined using solely an hourly shop rate multiplied by Time of Manufacturing (TM), assuming tooling cast was included. **T**he results are plotted in Fig.14 a, b and Fig.14c. Factory Cost (FC) as function of (TM) is shown in Fig.14 c. WIP is plotted versus Manufacturing Cost for 3 different levels of Material Cost (CMTRL) in Fig.14 a.

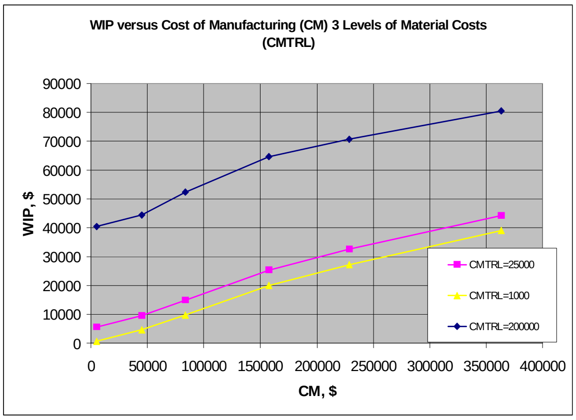


Fig. 14 a

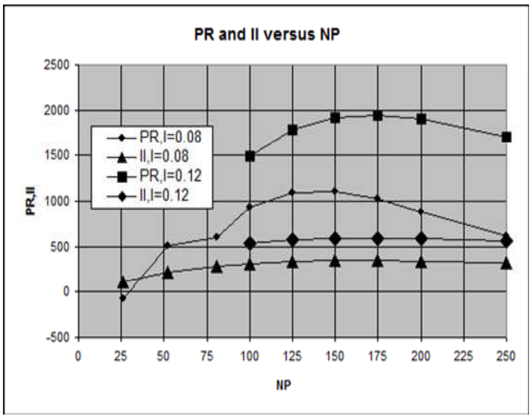


Fig. 14 b

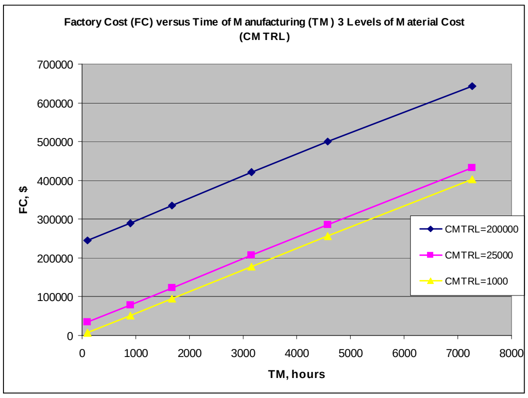


Fig. 14 c

7. INTELLIGENCE PARAMETER (I) AND INTELLIGENT INVESTMENT CAPITAL (II).

The following section treats the build-up of the intelligent investment capital (II) including its use to determine the value of the intelligence parameter (I). It is based on the work by Professor Leif Edvinsson, the world's leading expert on Intellectual Capital (IC). He has been Vice President and the world's first Corporate Director of Intellectual Capital at Skandia of Stockholm, Sweden and has held the world´s first professorship on Intellectual Capital at Lund Universtiy, Sweden since 2000. Applications of the methods related to product cost and the company profit are shown with examples.

7.1 Intellectual Capital and Intelligent Investments

Many different forms of performance ratios are in use with the purpose of improving various company functions, including how to better the cooperation between people and to make the organization "lean". A most recent trend deals with how to benefit from talented people and superior knowledge. The insurance firm Skandia is extensively making use of performance ratios in five focused areas related to both company history and to -morrow's prospects:

The point of classifying is to develop a set of measures that can be used to assess progress measures in 5 groups developed by insurance company Skandia:

- **Financial :** income per employee, market value per employee etc.
- **Customer:** number of customer visits, satisfied customer index, lost customers
- **Process :** administrative error rate, IT expense per employee
- **Renewal and Development:** training per employee, R&D expense/administrative expense, satisfied employee index
- **Human :** leadership index, employee turnover, IT literacy.

An increasingly popular classification divides intellectual assets into three categories:

1. **Human Capital -** that in the minds of individuals: knowledge, competences, experience, know-how etc.
2. **Structural Capital -** "that which is left after employees go home for the night": processes, information systems, databases etc.
3. **ustomer Capital -** customer relationships, brands, trademarks etc.

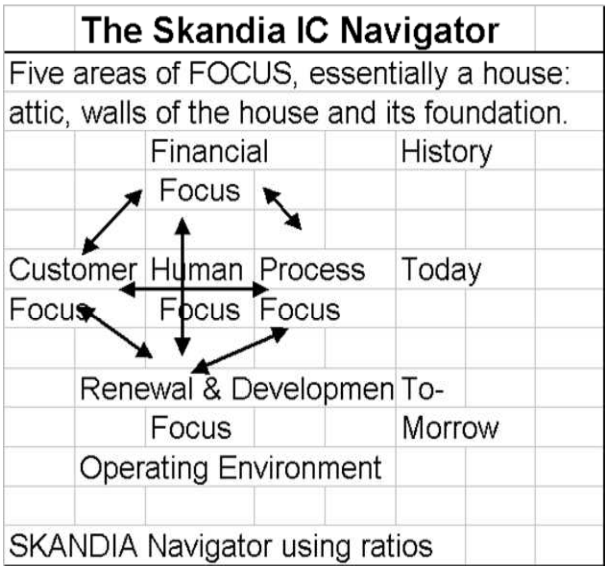


Fig. 7.1

There are variants on such a classification. One is to separate out those assets protected by law - **intellectual property.** This includes trade-marks, patents, copyrights, licences.

Intellectual Capital (IC) in the Forecasting Model

The term "Intellectual Capital" (IC) is included in the forecasting model as a component of an nvestment dollar amount. The Intellectual Capital is an additional term to the more traditional

value in comparison with the traditional R&D and capital investment accounts. Employing aforementioned definition of Intellectual Capital the value of excellent customer and internal relationships must be evaluated by the company management, while the two other terms “dollar values of talented people with superior knowledge + external experts and the value of software and other IT-technology “ are readily accounted for.
With the definition of Intelligent Investment Capital II as the sum of Intellectual Capital, R&D and Investment Capital we can easily determine IC as the difference between the calculated value of II and the sum of the values for R&D and CI:

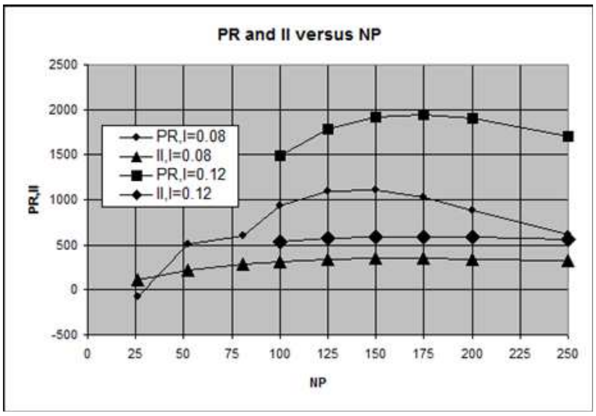


Fig7.1.1

Cost of Administration + Sales (CAS) + Factory Cost (FC): C = CD + CAS + FC;

CD = CD0 +II
where CD0 (Cost of Design) refers to costs of the standard operations.

The aforementioned build up of **the Intelligent Investment (II)** including placing it under cost of design is not required to apply the forecasting model. The user is recommended to customize and consult the internal financial documents in order to assess the individual contributions to the cost factors **IC,R$D and CI.**

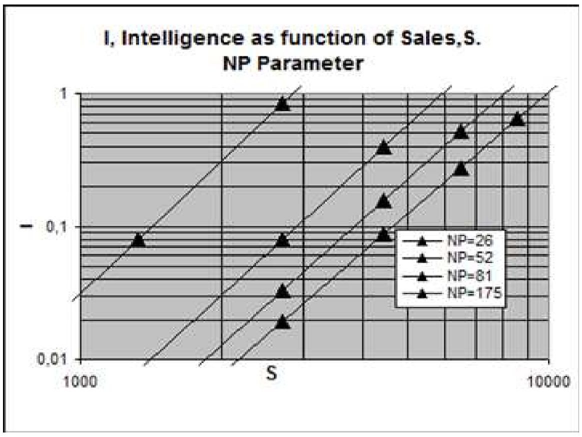


Fig.7.1.2

7.1.1 Definitions - Intellectual Capital and Intelligent Investments

The author’s definition of an IC-type T“Competence” or, “Intelligence” **parameter (I), used in the described forecasting model, is an “intelligent” investment dollar amount, called II** , The Intelligence parameter (I) defined as a ratio of:

Amount of Intelligent investment (II) capital and the Sales revenue (S) from the product, or part**,**

I = II/PR =100*(II/S) in Percent
where **II** consists of the sum of three performance functions**:**Intelligent Investment Capital II = IC+R$D+CI

IC = Intellectual Capital = "Ability to create excellent customer and internal relationships + Renewal & Development in order to Improve

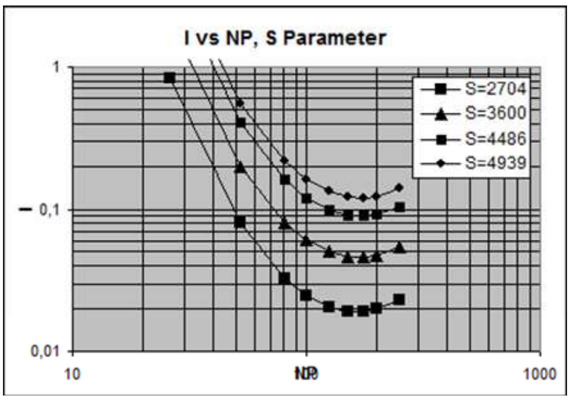


Fig.7.1.3

7.2 Intellectual Capital (IC) in the Forecasting Model

The term “Intellectual Capital” (IC) is included in the forecasting model as a component of an nvestment dollar amount. The Intellectual Capital is an additional term to the more traditional investment terms R&D and Capital Investment (CI), thus a new performance factor included in Intelligent Investment Capital. With this author’s definition it is possible to obtain a measure of its value in comparison with the traditional R&D and capital investment accounts. Employing aforementioned definition of Intellectual Capital the value of excellent customer and internal relationships must be evaluated by the company management, while the two other terms “dollar values of talented people with superior knowledge + external experts and the value of software and other IT-technology “ are readily accounted for.
With the definition of Intelligent Investment Capital II as the sum of Intellectual Capital, R&D and Investment Capital we can easily determine IC as the difference between the calculated value of II and the sum of the values for R&D and CI:

IC = II –(R$D+CI)
And the percentage IC as function of II:
IC/II = 1 –(R$D+CI)/II
he Intelligent Investment capital (II) is determined by the sales forecasting equation.

Table 11.2 shows inputs and results of an example applying this approach,
Table 11.3 shows in tabulated form how IC/II varies with (R$D+CI) and in Fig. 11.6 a graphical representation. For example going from point C at I = 7.00% to point D’ at I = 9.83% requires an investment of
II = $2,281.000 in order to reach sales of
S = $22,320.000.

wo data combinations from the table show the following alternate distributions of the cost drivers:

R$D+CI	**IC**	**IC/II**
2,200.000	81.000	3.55%
1,800.000	481.000	21.09%

This implies a $400.000 reduction of required capital investments (R&D kept constant) when the Intellectual Capital percentage is raised from 3.55% to 21.09%.
This can be accomplished by increasing either the value of excellent customer and internal relationships, or/and the dollar value of talented people with superior knowledge + external experts, or/and the value of software and other IT-technology.

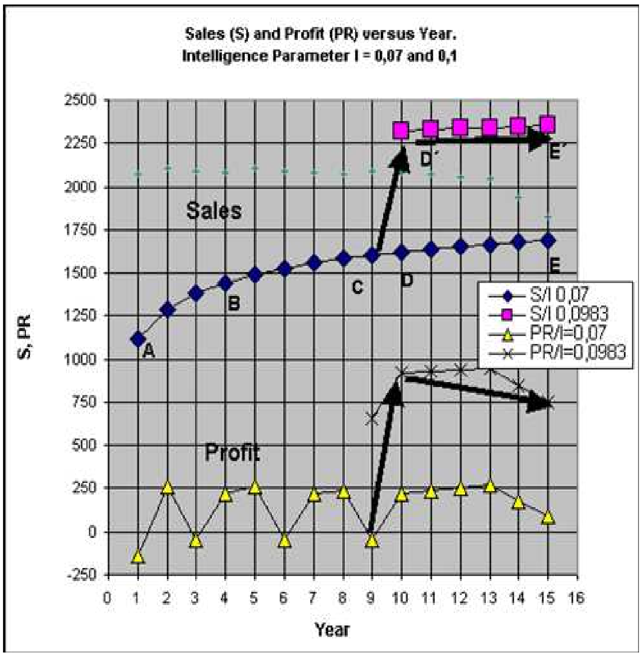


Fig.7.2.1

7.2.1The Intelligence parameter (I)

is used as a parameter in Colding’s equation with values ranging from 0 to 0.15. A constant value of I means that the ratio of II and sales is also constant, for example when I=0.05 we find for S =

$100,000 a required value of II= $5,000 , or for S=$1000,000 an II-value = $50,000. **I, in terms of Sales,** is the parameter which is used to record and predict the sales-cost functions described earlier in this Chapter. Determine first the current level of Sales or Profit. Then decide which level of Sales or Profit you want and then determine required values of I and II by calculation.

Only small increases in the value of Intellectual Capital (IC) component of II, or the ratio (I), result in huge increases in sales and profit, as depicted in **Figs.7.4.2 a-c**.The sales dependant term in the total **"intelligent" investment dollar amount II** (in $1000's) is proportional to **I** for any given sales volume using its definition (I = II/S).

The Intellectual Capital (IC) plays an increasing role for any company in order to satisfy its goals. According to references in the literature small increases in the tangible value of Intellectual Capital (IC), may result in huge increases in sales and profit. However, easy-to-understand and simple applicable measures for these intangibles are not available, so the author has developed a model for conveniant use described in chapter.
The different components that constitute intellectual capital are described in a book entitled The Navigator, by Leif Edvinsson together with Michael S. Malone on "Realizing Your Company's True Value by Finding Its Hidden Brainpower".

Using Fig.11.5 we find for 100 parts PR/S **= - 2%.**
If sales price/part is $1, current sales is $100, we have a loss PR = $-2. Consequently the cost of administration, design, sales and manufacturing amounts to C =$102. T**he Intelligent Investment** is **(II)=$7** and **I =7%.** The Intellectual Capital **(IC)** is assumed to be $1 or 14.3% of II.

Performance improvement can be obtained by raising I to 10% and II to $10. Fig. 7.2.3 shows, assuming the same sales price /part, PR/S =29% and PR = $29, second row in TABLE 5a. The product cost must therefore be reduced to 100 – 29 =$71. Increasing the investment in Intellectual Capital **(IC)** from $1 to $4 will result in **IC/II** = 40% (assuming investments in R$D and CI are not raised) . The next two lines in the Table show the results for increasing sales to $300 using Fig. 7.2.4. The changes in the other performance measure in terms of Cost **(Ic) is also** tabulated.
The increased investment in an IC staff pays off very handsomely.

Sales Constants Blad 6
Method II: 5 points Input, see Fig.11.5

Table 11.2

Method II: 5 points Input, see Fig.11.5														
Company History:		Year	C	S	PR	PR/S	II	I =II/S	R&D	CI	IC	IC/II	Added	Added
Points A,B,C (Today)			$	$	$	%	$	%	$	$	$	%	Invest	IC/II
A	History	1	1250	1115	-135	-12,11%	78,1	7,00%	30	45	3,1	3,91%	ment II	
B	History	5	1225	1490	265	17,79%	104,3	7,00%	35	65	4,3	4,12%	versus	versus
C	Current	9	1650	1605	-45	-2,80%	112,4	7,00%	40	70	2,4	2,09%	Year 9	Year 9
Accumlated investments years 1 through 9							112,4							
Forecasting years 10, 13 and 15 with small new investments													$	%
D	point D	10	1400	1624	224	13,77%	113,6544	7,00%	40	70	3,7	3,22%	1,3	1,16%
		13	1400	1667	267	16,02%	116,7	7,00%	40	70	6,7	5,74%	4,3	3,87%
E	point E	15	1600	1689	89	5,26%	118,2	7,00%	40	70	8,2	6,95%	5,9	5,22%
Accumlated additional investments years 10 through year 15											5,9		**5,9**	5,22%
Forecasting years 10, 13 and 15 with new investments														
D'	point D'	10	1400	2320	920	39,64%	228,1	9,83%	80	120	28,1	12,32%	115,8	103,03%
		13	1400	2342	942	40,22%	230,3	9,83%	80	120	30,3	13,16%	118,0	105,00%
E'	point E'	15	1600	2351	751	31,94%	231,2	9,83%	80	120	31,2	13,49%	118,9	105,79%
Accumlated additional investments years 10 through year 15											31,2		**118,9**	105,79%

Table 11.3

Forecasting year 10		Year	II	I =II/S	R&D	CI	R&D +	IC	IC/II	Added	Added	R&D +	
			$	%	$	$	CI	$	%	Invest	IC/II	CI	IC/II %
D'	point D'	10	228,1	0,1	80	0	80	148,1	64,93%	115,8	103,03%	80	64,93%
					80	50	130	98,1	43,01%	115,8	103,03%	130	43,01%
					80	100	180	48,1	21,09%	115,8	103,03%	180	21,09%
					80	120	200	28,1	12,32%	115,8	103,03%	200	12,32%
					80	130	210	18,1	7,94%	115,8	103,03%	210	7,94%
					80	140	220	8,1	3,55%	115,8	103,03%	220	3,55%
					80	148,1	228,1	0,0	0,00%	115,8	103,03%	228,10803	0,00%

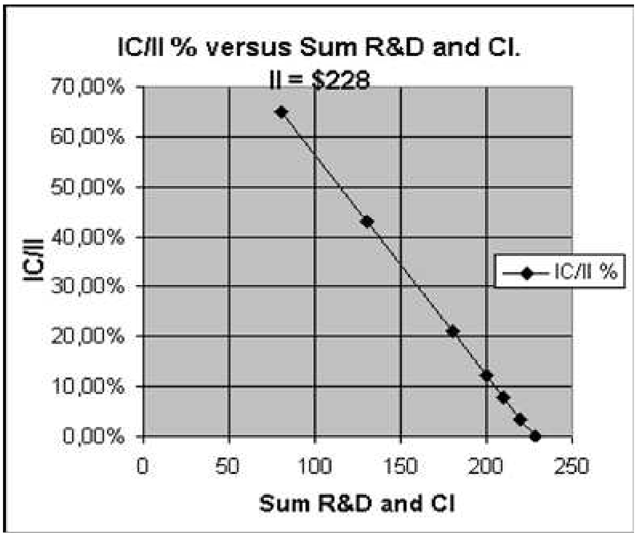


Fig. 7.2.2

Using above separati'on of these aforementioned expenses (Granular approach)
the cost of **II** is evaluated as the cost of their sum.

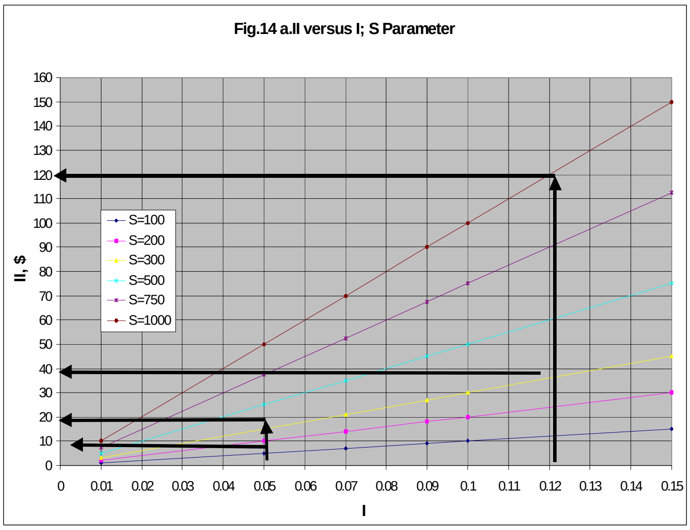


Fig.7.2.3

The aforementioned build up of **the Intelligent Investment (II)** including placing it under cost of design is not required to apply the forecasting model. The user is recommended to customize and consult the internal financial documents in order to assess the individual contributions to the cost factors **IC,R$D and CI.** Fig.7.2.3 shows the variation of the Intelligent Investment (II) versus Intelligence parameter (I) with sales (S) being the parameter.
Here sales (S) ($1000's) is a parameter, varying sales from $100 up to $1000.
As seen for I =0.05, and sales S=$300, we calculate required Intelligent Investment term II to be 300*0.05 = $ 15. For I =0.12, and sales S=$300, we calculate II to be = 300*0.12 = $ 36, and if the sales goal is $1000 we obtain II = $120.
Fig.7.2.4 displays an example when plotting PR/S versus number of parts (NP) where I is parameter.

7.3 The Intelligence parameter (I) in terms of Cost and Profit

The financial terms **Intelligent Investment,** cost, sales and profit are all related to the **Intelligence parameter by the following formulas:**

- **The Intelligence parameter (Ic) in terms of**

Intelligent Investment Capital (II) and Cost:
Ic = 100* (II /C) in Percent;
C = II/Ic

- **Profit versus the Intelligence parameter (I) and Intelligent Investment Capital (II):**

PR = S –C = II/ I – II/ I c,

- **Profit versus Sales:**
-

(PR/S) =1-C/S = 1- (II/ Ic)/S

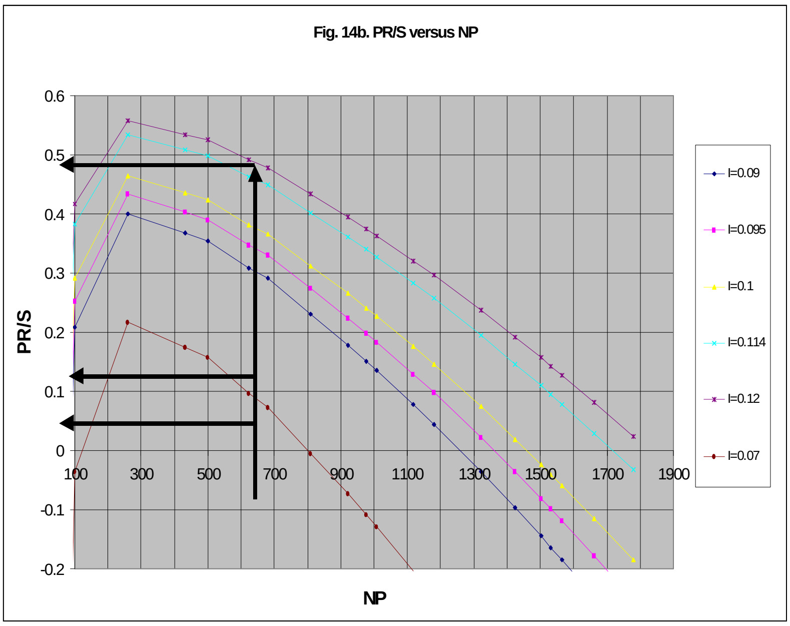


Fig.7.2.4

he performance measures PR and PR/S cannot be described in a simple formula, as they depend on the sales price and cost variation with cost and volume. Colding's equation is used to establish this relationship, see the step-by-step method below.

7.4 Determination of I and II.

In the enterprise econometrics decision process the volume, number of parts (NP), is another essential parameter relate to I and II.

Fig.7.4.1 displays how I and II vary with sales (S) at volumes NP 100 and 810 respectively.

Fig.7.4.2a in Section 7.4.2 shows the variation of the Intelligent Investment (II) versus Intelligence parameter (I) with sales (S) being the parameter.

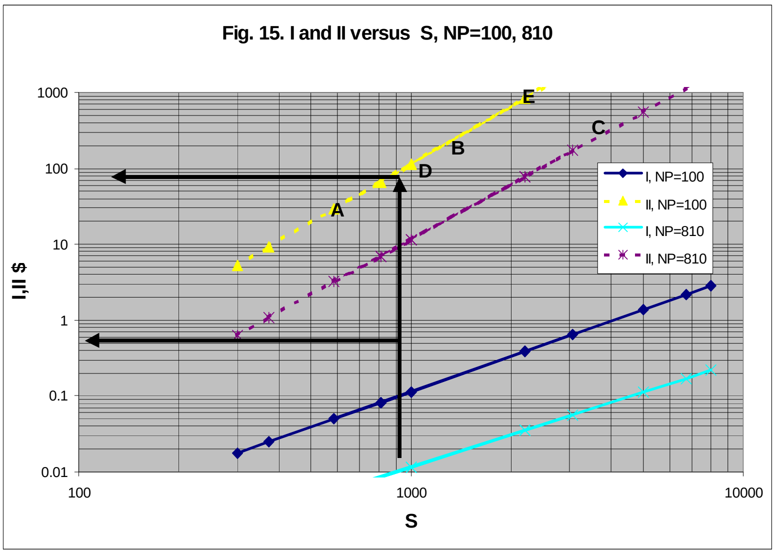


Fig.7.4.1

Here sales (S) ($1000's) is a parameter, varying sales from $100 up to $1000.

As seen for I =0.05, and sales S=$300, we calculate required Intelligent Investment term II to be 300*0.05 = $ 15. For I =0.12, and sales S=$300, we calculate II to be = 300*0.12 = $ 36, and if the sales goal is $1000 we obtain II = $120.displays how **I** (lower portion) and **II** (upper portion) vary with sales at 2 different lot sizes NP=100 and 810 parts. **Table 11.1** you find tabulated values of I for a series of increasing sales values at NP= 100,200,300, 500 and 1000 parts.

TABLE 4. Example, Calculation of I as function of S , NP Parameter

S	NP1=100	NP2=200	NP3=300	NP3=500	NP3=1000
100	0.003555864	0.001010122	0.000606078	0.0004003	0.000335341
200	0.010099135	0.002813116	0.001669179	0.0010874	0.000894726
300	0.018598183	0.005121382	0.003019056	0.0019511	0.00158856
400	0.028682911	0.007834326	0.004597025	0.002954	0.00238723
500	0.040138931	0.01089431	0.00636967	0.0040751	0.003274171
587	0.051107325	0.013808424	0.008052694	0.0051356	0.004109025
810	0.083001698	0.022222222	0.012892471	0.0081699	0.006482414
1000	0.114	0.030339867	0.01754248	0.0110704	0.008735855
1500	0.209938066	0.055234846	0.031729215	0.0198633	0.015510251
2000	0.323775435	0.084494338	0.048313119	0.0300738	0.02330824
2200	0.373748633	0.097272727	0.055534525	0.0345039	0.026675591
3061	0.614604096	0.158469147	0.089993368	0.0555496	0.042579453
4000	0.919566076	0.235310628	0.133057439	0.0816983	0.062188997
5000	1.286842857	0.327219854	0.184365298	0.1127036	0.08529442
6000	1.693437928	0.428391668	0.240661989	0.146589	0.110414714
7000	2.135937056	0.537977687	0.301477152	0.1830733	0.137344574
8000	2.611692163	0.655323102	0.36644875	0.2219411	0.165927215

EXAMPLE.

Your current values are at NP = 100000 parts, S = $500,000 and II = $20,000.

Using the formula:
II = S*I, will determine
I =20/500 = 0.04,
or **Table 11.1** showing 0.04 or 4%. If your product cost for the batch is $490, 000 you have profit of PR=$10,000 and PR/S = 0.02 or 2%.

Company managers are urged to employ this Econometrics in order to ascertain realistic results. Only a simple internal program can be introduced and all the many determinations will be made quickly.

If the wanted value of Profit is $50,000, a better sales prize or a lower cost are required. If the sales is the same as above the profit-sales-ratio must be raised to PR/S = 50000/500000 = 0.1, and the cost must be reduced C=$450,000.
i.e. I =20/500 = 0.04,
a desired I of 0.114, then calculate :
II = $84,018

In order to achieve I=0.114 we need to invest in II=$57,000 when sales is $500,000 for 100 parts. Product costs have to be reduced, or a new sales price prognosis has to be agreed upon with the customers**. Fig. 7.4.2b** shows PR/S =0.39, consequently yielding a profit PR=0.39*500000= $195,000. The aforementioned build up of the Intelligent Investment (II) including placing it under cost of design is not required to apply the forecasting model. The user is recommended to customize and consult the internal financial documents in order to assess the individual contributions to the cost factors IC,R$D and CI.

7.4.1 I and II versus Sales and Volume.

In the enterprise econometrics decision process the volume, number of parts (NP), is another essential parameter related to I and II.

Fig.7.4.1 displays how **I** (lower portion) and **II** (upper portion) vary with sales at 2 different lot sizes NP=100 and 810 parts.

TABLE 4 you find tabulated values of I for a series of increasing sales values at NP= 100,200,300, 500 and 1000 parts.

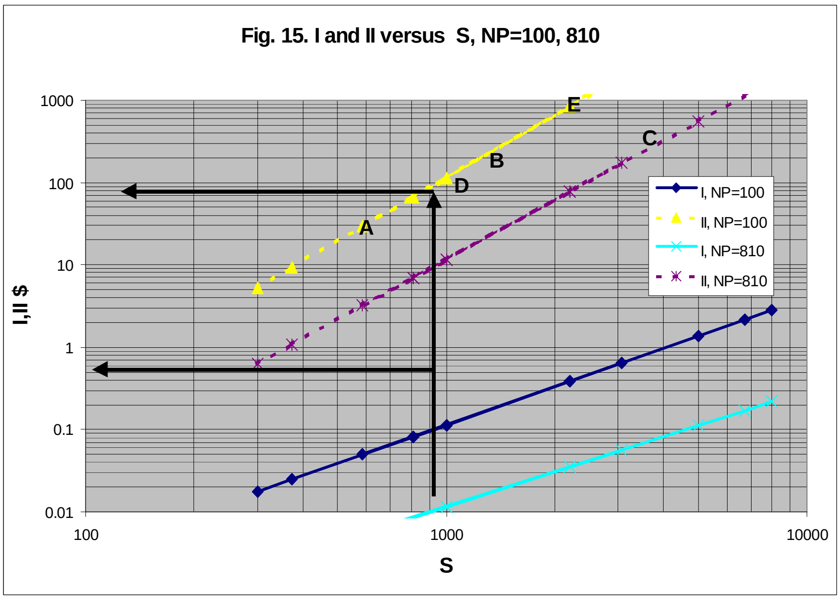


Fig.7.4.1

TABLE 4. Example, Calculation of I as function of S , NP Parameter

S	NP1=100	NP2=200	NP3=300	NP3=500	NP3=1000
100	0.003555864	0.001010122	0.000606078	0.0004003	0.000335341
200	0.010099135	0.002813116	0.001669179	0.0010874	0.000894726
300	0.018598183	0.005121382	0.003019056	0.0019511	0.00158856
400	0.028682911	0.007834326	0.004597025	0.002954	0.00238723
500	0.040138931	0.01089431	0.00636967	0.0040751	0.003274171
587	0.051107325	0.013808424	0.008052694	0.0051356	0.004109025
810	0.083001698	0.022222222	0.012892471	0.0081699	0.006482414
1000	0.114	0.030339867	0.01754248	0.0110704	0.008735855
1500	0.209938066	0.055234846	0.031729215	0.0198633	0.015510251
2000	0.323775435	0.084494338	0.048313119	0.0300738	0.02330824
2200	0.373748633	0.097272727	0.055534525	0.0345039	0.026675591
3061	0.614604096	0.158469147	0.089993368	0.0555496	0.042579453
4000	0.919566076	0.235310628	0.133057439	0.0816983	0.062188997
5000	1.286842857	0.327219854	0.184365298	0.1127036	0.08529442
6000	1.693437928	0.428391668	0.240661989	0.146589	0.110414714
7000	2.135937056	0.537977687	0.301477152	0.1830733	0.137344574
8000	2.611692163	0.655323102	0.36644875	0.2219411	0.165927215

7.4.2 Determination of I as function of Sales and Volume

Your current values are at NP = 100000 parts, S = 00,000 and II = $20,000.
Using the formula:
II = S*I, will determine
I =20/500 = 0.04,
or TABLE 4 showing 0.04 or 4%. If your product cost for
the batch is $490, 000 you have profit of PR=$10,000 and PR/S = 0.02 or 2%.

If the wanted value of Profit is \$50,000, a better sales prize or a lower cost are required. If the sales is the same as above the profit-sales-ratio must be raised to PR/S = 50000/500000 = 0.1, and the cost must be reduced C=\$450,000.
i.e. I =20/500 = 0.04,
For a desired I of 0.114, then calculate :
II = \$84,018

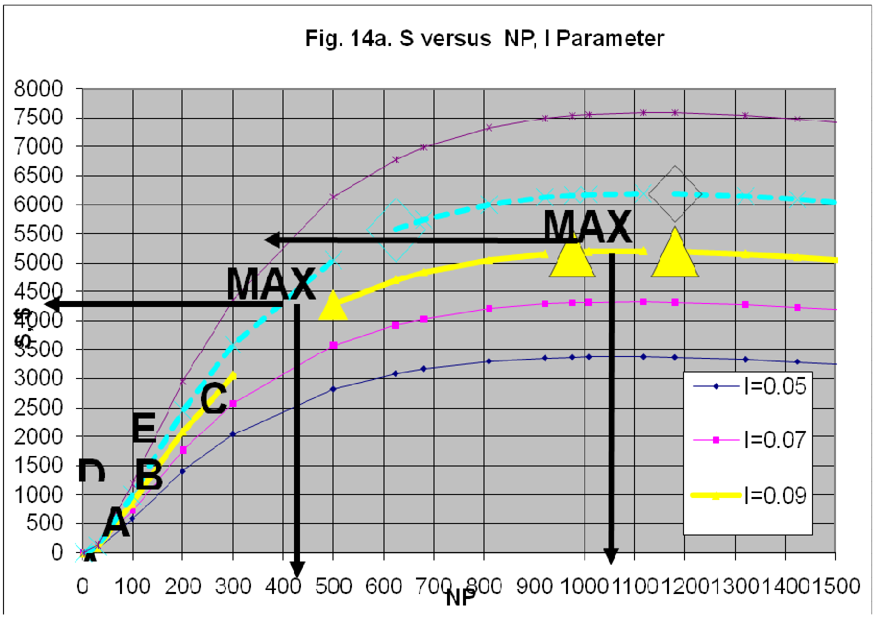


Fig.7.4.2a

TABLE 4 shows several possible options how to get there related to the required intelligent investment capital (II) and (I). In order to achieve I=0.114 we need to invest in II=\$57,000 when sales is \$500,000 for 100 parts. Product costs have to be reduced, or a new sales price prognosis has to be agreed upon with the customers. **Fig. 7.4.2 b** shows PR/S =0.39, consequently yielding a profit PR=0.39*500000= \$195,000.
1. PR = S – C = II/ I – II/ Ic,
eller som funktion av försäljningen:
2. (PR/S) =1-C/S = 1- (II/ Ic)/S.

Fig. 7.4.2 a shows the variation of the Intelligent Investment (II) versus Intelligence parameter (I) with sales (S) being the parameter. Here sales (S) (\$1000's) is a parameter, varying sales from \$100 up to \$1000.As seen for I =0.05, and sales S=\$300, we calculate required Intelligent Investment term II to be 300*0.05 = \$ 15. For I =0.12, and sales S=\$300, we calculate II to be = 300*0.12 = \$ 36, and if the sales goal is \$1000 we obtain II = \$120.

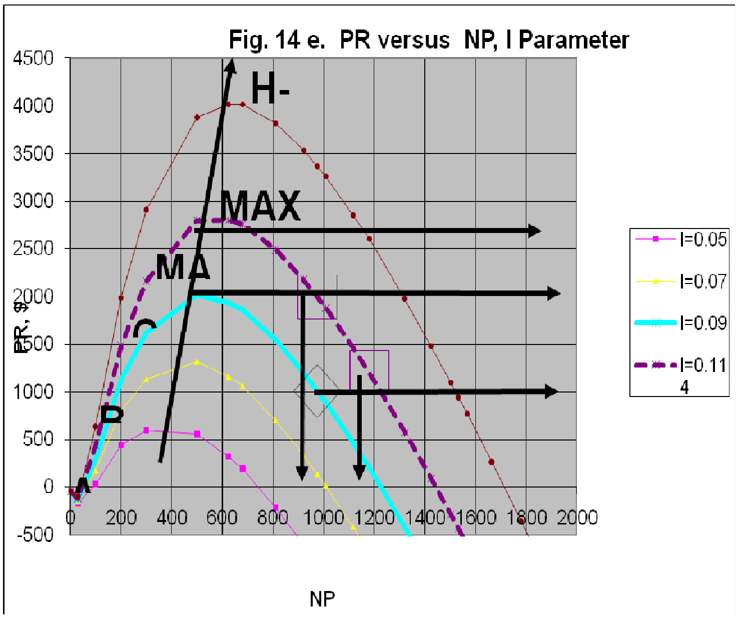


Fig.7.4.2b

Fig. 7.4.2b displays an example when plotting PR versus number of parts (NP) where I is parameter.

The financial terms **Intelligent Investment,** cost, sales and profit are all related to the **Intelligence parameter by the following formulas:**

The Intelligence parameter (Ic) in terms of
Intelligent Investment Capital (II) and Cost:
Ic = 100* (II /C) in Percent; C = II/Ic
Profit versus the Intelligence parameter (I) and Intelligent Investment Capital (II):
PR = S –C = II/ I – II/ I c,
Profit versus Sales:
(PR/S) =1-C/S = 1- (II/ Ic)/S
The performance measures PR and PR/S cannot be described in a simple formula, as they depend on the sales price and cost variation with cost and volume. Using Colding's equation we can establish this relationship, employing the step-by-step method in Section 8.5.

7.5 Intelligent Investment Capital II = IC+R$D+CI

The aforementioned build up of the Intelligent Investment (II) including placing it under cost of design is not required to apply the forecasting model. The user is recommended to customize and consult the internal financial documents in order to assess the individual contributions to the cost factors IC, R&D and CI.

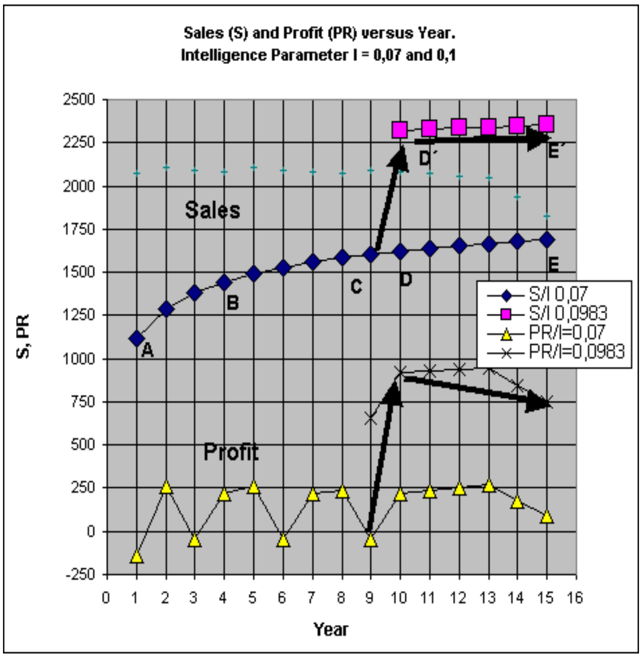


Fig.7.4.2c

The impact of the role of Intellectual Capital (IC) plays an increasing proportion of the **the Intelligent Investment (II)** term the higher the profit goals are.
We find that the sum of the 3 intelligent investments factors in R&D, Capital Investments (CI) and Intellectual Capital (IC) have to be augmented to satisfy our goals.
TABLE 5.a shows inputs and results of an example applying this approach.
Using **Fig.7.4.2c** we find for 100 parts PR/S **= - 2%.** If sales price / part is $1, current sales is $100, we have a loss PR = $-2. Consequently the cost of administration, design, sales and manufacturing amounts to C =$102T**he Intelligent Investment** is **(II)=$7** and **I =7%.** The Intellectual Capital **(IC)** is assumed to be $1 or 14.3% of II.

7.6 Summary Analysis

A **performance improvement** can be obtained by raising I to 10% and II to $10. Fig. 14 b shows, assuming the same sales price /part, PR/S =29% and PR = $29, second row in TABLE 5a. The product cost must therefore be reduced to 100 – 29 =$71.
Increasing the investment in Intellectual Capital **(IC)** from $1 to $4 will result in **IC/II** = 40% (assuming investments in R$D and CI are not raised) . The next two lines in the Table show the results for increasing sales to $300 using Fig. 14 b. The changes in the other performance measure in terms of Cost **(Ic) is also** tabulated.
The increased investment in an IC staff pays off very handsomely.

TABLE 5.a. Summary Analysis

Sales S=$100(1000's)										
I %	**PR/S%**	**PR $**	**C $**		**II $**	**R&D $**	**CI $**	**IC $**	**IC/II %**	**Ic %**
Current										
7	**-2**	**-2**	**102**		**7**	**1**	**5**	**1**	**14.3**	**6.86**
Improvement										
10	**29**	**29**	**71**		**10**	**1**	**5**	**4**	**40**	**16.9**
Sales S=$300										
Current										
7	**21**	**63**	**237**		**21**	**3**	**15**	**3**	**14.3**	**8.86**
Improvement										
10	**46**	**138**	**162**		**30**	**3**	**15**	**12**	**40**	**18.5**

8. ECONOMETRIC MODELS AND FORECASTING

8.1 Introduction

One of the most crucial tasks facing the company management is to establish a good sales-cost-profit forecast that will hold short-term and will secure survival in the long run. The most common forecasting technique is "intuition", a method which is usually wrong 50% of the time. This is true even when assuming the company has a reasonably good grip on what the competion is doing and what the customer requires of its products.

This chapter presents a relatively straightforward method, comparable to the techniques used in manufacturing and machining. It mainly deals with a model by which the shop owner, plant manager, or CEO, after inputs from manufacturing and marketing people, can make intelligent decisions and techniques in order to calculate profit. This involves applying the methods to improve manufacturing performance described in Parts II and III.The technique is similar to the one used in optimizing feeds and speeds, described in Part I. The benefits include the ability to forecast optimum values of sales, costs and enterprise profit, including optimum and break-even lot sizes.

8.2 Forecasting Models

Econometric mathematical models are used to improve the accuracy of human decisions. Optimum solutions of sales-cost-profit functions are usually achieved by curve fitting using standard algorithms, such as polynomials or linear programming, and unfortunately often based on linear equations.Even the " Least square models" are usually inaccurate when applied to company econometrics. This is partly due to the fact that a large number of data points (which are usually not available) are needed to ascertain good accuracy when forecasting, and partly due the difficulty estimating the location of the sales-cost maximum point.

8.3 Functional Requirements for Optimization and Laws of Nature

A function of 3 parameters, Z=f(X,Y), is never linear in the Enterprise World when plotted in Cartesian or log-log coordinates. However, certain laws of nature are linear such as:

Distance (Z) =Velocity (Y)*Time (X)

In a Cartesian Graph plotting Z versus X with Y parameter is illustrated by straight lines at different slopes Y1,Y2,Y3: Z=Y1*X, Z=Y2*X,Z=Y3*X . In a log-log graph the same functions are parallel parametric lines at slope 1 (45 degrees): log Z= log Y1 + 1*log X,
log Z= log Y2 + 1*log X, log Z= log Y3 + 1*log X.

Einstein's Energy (Z) =Mass(Y)*SQ(Velocity (X)) is quadratic in cartesian coordinates, but a series of straight parallel lines at slope 2 in log-log.

A typical more advanced model approximating an enterprise Sales-Cost-Profit analysis may consist of Two (non-linear) polynomials in Cartesian coordinates:

C=A1+B1*N+C1*N^2 ; S=C1*N* D1N^2, where C = Cost, N =Volume of parts, S=$ Sales.

8.4 Econometric Models and Forecasting

8.4.1 Introduction

Business forecasting is of extreme importance for planning in all major activities such as planning of sales, manufacturing , budgeting, financial and strategic planning. The objective of forecasting is to reduce risk in decision making.

One of the most crucial tasks facing the company management is to establish a good sales-cost-profit forecast that will hold short-term and will secure survival in the long run.The most common forecasting technique is "intuition", a method which is usually wrong 50% of the time. This is true even when assuming the company has a reasonably good grip on what the competion is doing and what the customer requires of its products.

This chapter presents a relatively straightforward method, using the so called DBgen (Data Base Generator), employing Colding's Equation. Using this technique the shop owner, plant manager, or CEO, can make intelligent decisions in order to forecast **optimum** values of sales, costs, enterprise profit, and needed investments, including optimum and break-even lot sizes. The user must first enter estimated future data for manufacturing, administration and sales, This involves applying the methods to improve manufacturing performance described in Parts II and III.

8.4.2 Forecasting Models

Econometric mathematical models are used to improve the accuracy of human decisions.

The techniques generally used involve mostly linear models but also in some cases nonlinear models and include:

Moving Averages and Smothing Methods
Regression Analysis
Multiple Regression
Time Series Analysis and Classical Decomposition
Models Based on Learned Behaviour

of which some are extremely complicated with relatively poor to fair accuracy. Many software packages are available which contain several methods, from which the one that best fits your data and intuition is employed. These forecasting programs of complicated interrelationships of business parameters require qiute a bit of time to pursue and many companies cannot afford a staff of forecasting specialists. The author's program, described below, is much easier and quicker to use and can therefore be employed by small companies.

Solutions to sales-cost-profit forecasting problems are usually achieved by curve fitting using " Least square models" including standard algorithms such as polynomials, unfortunately often based on linear equations. Even these are usually inaccurate when applied to company econometrics. This is partly due to the fact that partly due the difficulty in estimating the location of the sales-cost maximum or minimum points, and partly because a large number of data points are needed to ascertain good accuracy when forecasting. None of these methods employ functions that are focused at the real world relationships with maximum sales and profit as well as minimum cost behaviour including market price elasticity. Such relationships are obtained by using the DBgen (Data Base generator), the results of which can be adjusted in order to include most of the commonly used linear and nonlinear forecasting models. This is done by simply modifying the value of one data point.

8.4.3 Logarithmic Transformations and Laws of Nature

Some of the basic business models can be transformed into Logarithmic functions resulting in straight lines in log-log coordinates, whereby linear regression can be easily employed. The DBgen is 3-dimensional logarithmic function Z = f (X,Y) which is a straight line in the Y-Z plane. Log-log graphs are also useful when there are big variations in data. It may therefore be useful to the reader to compare how graphs plotted in Cartesian and logarithmic coordinates appear to the viewer.

The reader should also note that negative numbers cannot be visualized using log-log axes, an example of this is when company profits are turned into losses.

Above described linear models in Cartesian coordinates are usually not linear and therefore often poor approximations of the laws of business.

However, certain laws of nature are linear such as:

Distance (Z) =Velocity (Y)*Time (X)

In a Cartesian Graph plotting Z versus X with Y parameter is illustrated by straight lines at different slopes Y1,Y2,Y3: Z=Y1*X, Z=Y2*X,Z=Y3*X . In a log-log graph the same functions are parallel parametric lines at slope 1 (45 degrees): log Z= log Y1 + 1*log X, log Z= log Y2 + 1*log X, log Z= log Y3 + 1*log X.

Einstein's Energy (Z) = Mass(Y)*SQ(Velocity (X)) is quadratic in cartesian coordinates, but a series of straigt parallel lines at slope 2 in log-log, see adjacent graphs with Cartesian (Fig. 8.4.1) and logarithmic (Fig. 8.4.2) axes respectively. The shape of the two Einstein curves (z1 and z2) are also compared with a sales forecast, based on a logarithmic function.

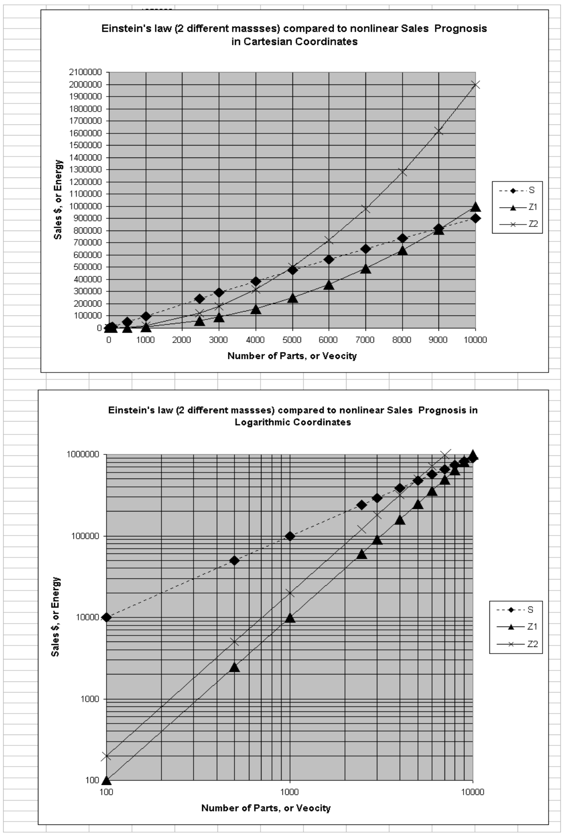


Fig. 8.4.1 and 4.2

Example of a Nonlinear Model

An example of the results of forecasting using a nonlinear model (not logarithmic) from Riggs ( ) are exhibited in Table 10.1. In order to illustrate the use of this forecasting model we employ two (non-linear) polynomials in Cartesian coordinates for the Sales-Cost-Profit analysis:

C= E*NP+ D*NP^2+ F; S=A*NP-B*NP^2+C, where C = Cost, NP =Volume of parts, S=$ Sales. Hence Profit (PR):

PR = S – C = C – F +(A - E)*NP - (B-D)*N^2.

As you see the solution requires 6 given points from the company history in order to solve above systems of equations in order to determine the values of the constants to predict the trend for larger volumes. Depending on which points of the historic data set you will use there will be a different set of constants. Entering the constants for each case into the equations forecasts will be generated. We use company historic data of sales and cost plotted versus volume of parts (NP) ranging from 100 to 1000 parts

Table 10.1

Sales Constants				Blad 4			
James L. Riggs, 1981, Production Systems,pp98-99., John Wiley & Sons,Inc.							
A	B	C	D	E	F		
100	0,001	0	0,005	4	200000		
6 Constants							
	S 3 Constants		C 3 Constants				
S = A*NP - B*NP^2+C			sp = A - B*NP				
C =D*NP^2+E*NP+F			cp =D*NP+E+F/NP				
PR = S - C =A*NP - B*NP^2+C - D*NP^2-E*NP-F=NP(A-E)-(B+D)NP^2+C-F							
NP					NP		
	S	C	PR			sp	cp
1	99,999	200004,005	-199904,006		1	99,999	200004,005
10	999,9	200040,5	-199040,6		10	99,99	20004,05
50	4997,5	200212,5	-195215		50	99,95	4004,25
100	9990	200450	-190460		100	99,9	2004,5
500	49750	203250	-153500		500	99,5	406,5
1000	99000	209000	-110000		1000	99	209
2462	240138,556	240155,22	-16,664		2462	97,538	97,54476848
3000	291000	257000	34000		3000	97	85,66666667
4000	384000	296000	88000		4000	96	74
5000	475000	345000	130000		5000	95	69
6000	564000	404000	160000		6000	94	67,33333333
7000	651000	473000	178000		7000	93	67,57142857
8000	736000	552000	**184000**	**Max**	8000	92	69
9000	819000	641000	178000		9000	91	71,22222222
10000	900000	740000	160000		10000	90	74
11000	979000	849000	130000		11000	89	77,18181818
12000	1056000	968000	88000		12000	88	80,66666667
13000	1131000	1097000	34000		13000	87	84,38461538
14000	1204000	1236000	-32000		14000	86	88,28571429
15000	1275000	1385000	-110000		15000	85	92,33333333

Depending on how you select these points (NP = 10,100,500, or 100,500,1000,or 50,500,1000) the forecast will be different. These will appear as a series of curves in a graph, and you pick the constants that generate the most likely trend according to the company experts.
In the Table we have the most likely developments of sales, cost and profit as well as the unit sales price and unit cost versus volume. The unit sales price (sp) was estimated versus the price elasticity of the product and the relationship between total sales (S) and volume (NP) is calculated as S = NP*sp. The unit cost (cp) was estimated by the manufacturing
department and is determined by C = NP*cp. In Figs 8.4.3 and 8.4.4 these relationships are plotted. Maximum profit will be achieved making 8000 parts. The two break-even points also appear in both of the graphs.

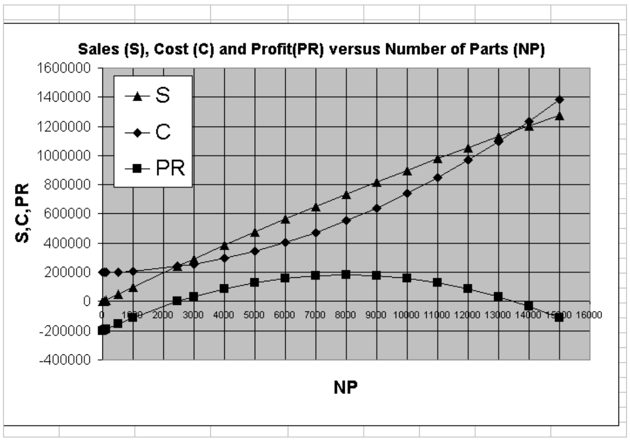


Fig. 8.4.3

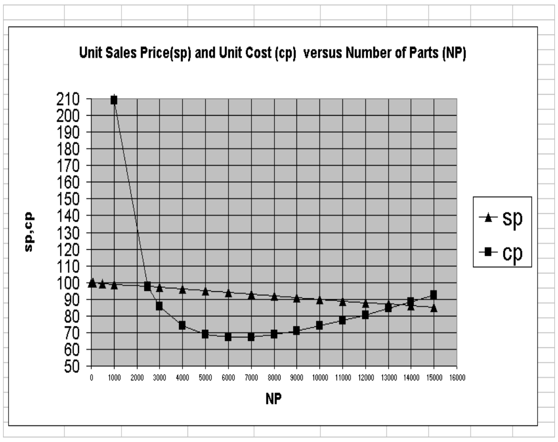


Fig. 8.4.4

It is obvious that the aforementioned method is rather cumbersome and time consuming, and must be developed by personnel trained in mathematics.

A simpler method is described in the following, which involves determining a new sales prognosis using various values of the parameter I = "Intelligens Parameter", which measures the firm's level of competence, or knowledge- and ability-to-apply. The method estimates required capital investments based on predicted total cost reductions in manufacturing or/and in administration and sales departments.

8.5 Procedure Predicting S-C-Curves Based on Cost/part and Sales Price per Part

The method involves obtaining first at least 3 value-combinations from the company history, including 2 forecast values at the time when a decision is to be made on the performance goals for the next couple of years. This involves determining a new sales prognosis as well as predicting possible total cost reductions in manufacturing or/and in Administration and Sales, including capital investments. The issue is an appraisal of the effect of improved values of the company Competence or, knowledge-and ability-to-apply I = "Intellectual ratio", on the enterprise performance.

First we use an example describing the method step-by-step. In the next chapter the method is explained more in detail.The decision making is described applying the above model to a given product or part, coupled with the manufacturing cost reduction techniques, including Sales and marketing cost reduction techniques, the formulas of which are not dealt with in this presentation. The results give values on profit and "break-even" limits as to selling part volumes as well optimal data.

After applying the Granular Metrics concept the model of (S) versus (C) with (I) as parameter will produce true values of the product Price Elasticity function sales price per part (s-p) as function of the number of parts made (N), and how manufacturing cost per part (c-p) varies with lot size (NP). This means that the prognosis of how sales price and cost/part varies with volume are simultaneously determined. You may also negotiate with customers searching a new Sales Price/part (sp) versus Volume (NP) function.

The method is very straightforward, and comparable to the procedure to for example determine speeds, feeds and tool-life in metal cutting, which is described in Part I. Note that when defining the sales income (S) and costs of product (C) we must rinse out the cost items (trash) that are not directly related to the product and apply functional values, as depicted in the chapter on "Granular Metrics".

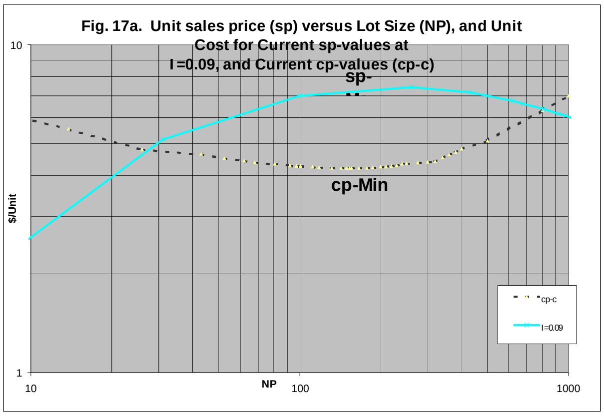


Fig. 8.5.1

Multiply your values by the tabulated figures valid for $-100000's such as 0.1, 10, 100 etc., when yours are in the ranges $10000,1000000,10000000 respectively.

Here is how the firm improves the company performance, strictly following the proceeding methodology. The first requirement is that the firm possesses a sales and cost prognosis as function of the volume

TABLE 5 Sales and Cost Prognosis

NP	sp-c	S	cp-c	C
	I=0.09			
100	7	700	5.5461395	554.61395
200	8.0111544	1602.2309	4.8036018	960.72036
300	7.3334221	2200.0266	4.6349041	1390.4712
500	7	3500	4.5178966	2258.9483
680	6.163096	4190.9053	4.3713685	2972.5306
810	5.6288399	4559.3604	4.3278677	3505.5728
1000	4.9312965	4931.2965	4.2635526	4300
1180	4.4286497	5225.8067	4.2298465	4991.2188
1300	4.0732231	5295.19	4.2191085	5484.8411
1400	3.8396647	5375.5305	4.2134784	5898.8698
1500	3.678176	5517.264	4.2098721	6314.8082
1600	3.6170368	5787.2588	4.2096652	6735.4644
1700	3.5515406	6037.619	4.2087879	7154.9395
1800	3.374001	6073.2017	4.209341	7576.8138
1900	3.1790094	6040.1179	4.2154901	8009.4311
2000	3.0394455	6078.8909	4.2264413	8452.8827

Multiply your values by the tabulated figures valid for $-100000's such as 0.1, 10, 100 etc., when yours are in the ranges $10000,1000000,10000000 respectively.

Here is how the firm improves the company performance, strictly following the proceeding methodology. The first requirement is that the firm possesses a sales and cost prognosis as function of the volume of parts sold. The method is based on your current financial numbers and will finally result in alternative prognoses such as maximum profit and optimum part volumes related to cost and sales. 5 data points are required, of which 3 points A, B and C are based on company history, where point C represent the current financial situation.

The values for points D and E have to be selected for the same volumes of parts as for point A and B. The value of I for point C is used as a basis for all continuing calculations. Hence, in this example points A, B, C refer to volumes called NP1,NP2,NP3 and points D,E to NP1,NP2 respectively.

Step 1. The sales and cost prognoses are exemplified in TABLE 5 and graphically displayed in Fig. 17 a.

TABLE 5 Sales and Cost Prognosis

NP	sp-c	S	cp-c	C
	I=0.09			
100	7	700	5.5461395	554.61395
200	8.0111544	1602.2309	4.8036018	960.72036
300	7.3334221	2200.0266	4.6349041	1390.4712
500	7	3500	4.5178966	2258.9483
680	6.163096	4190.9053	4.3713685	2972.5306
810	5.6288399	4559.3604	4.3278677	3505.5728
1000	4.9312965	4931.2965	4.2635526	4300
1180	4.4286497	5225.8067	4.2298465	4991.2188
1300	4.0732231	5295.19	4.2191085	5484.8411
1400	3.8396647	5375.5305	4.2134784	5898.8698
1500	3.678176	5517.264	4.2098721	6314.8082
1600	3.6170368	5787.2588	4.2096652	6735.4644
1700	3.5515406	6037.619	4.2087879	7154.9395
1800	3.374001	6073.2017	4.209341	7576.8138
1900	3.1790094	6040.1179	4.2154901	8009.4311
2000	3.0394455	6078.8909	4.2264413	8452.8827

The values of sales and cost are obtained by multiplying the unit sales prices (sp) and unit costs (cp) with volumes (NP).

Step 2. Determine your values of II for points A,B,C, and calculate I=II/S for each point

After deciding on new goals determine your anticipated values of II for points D,E, and calculate I=II/S for each point .TABLE 6 shows the calculation procedure. First determine I based on your current values of II and sales for points A,B,C, for sales S1,S2,S3 and volumes NP1=100, NP2 = 200 and NP3 =300 parts, as shown in spreadsheet 6A . The value at point C in the current financial situation in terms of I is 0.09. In the lower portion of 6A the calculated value 0.09 is used to perform the most essential calculations of this method, i.e. determining Sales, costs, optimum volumes at maximum profit for any values of I. Based on the results the firm has a tool to decide the needed amount s of Intelligent Investment Capital II = IC+R$D+CI in order to reach its goals.

TABLE 6 A. I = II/S, II =(R&D + CI + IC)

Point	NP	S	II	II	II	I-Value	I	I	I
			NP1=100	NP2=200	NP3=300		NP1=100	NP2=200	NP3=300
A,NP1,S1	100	587	30			I1	0.051		
B,NP2,S2	200	810		18		I2		0.022222222	
C,NP3,S3	300	3060			275.5	I3			0.09
D,NP1,S4	100	1000	114			I4	0.114		
E,NP2,S5	200	2200		214		I5		0.097272727	
NP1,S01	100	855	76.92468737			I3	0.09		
NP2,S02	200	2087		187.85362		I3		0.09	
NP3,S03	300	3060			275.5	I3			0.09

TABLE 6B.

NP	n		I	L	N0	CTaylor
	n1 =N0-L*LN(NP1)					
100	-0.664028389					4229.041552
	n2 =N0-L*LN(NP2)					
200	-0.676754868					10648.89722
	n3 =N0-L*LN(NP3)			0.01836	-0.579	
300	-0.684199381					15899.80708
	n4 =N0-L*LN(NP4)		I			
500	-0.693578358		0.0899992			22726.12466
	n5 =N0-L*LN(NP5)					
1000	-0.706304837		0.0899992			28448.9304
	n6 =N0-L*LN(NP6)					
1500	-0.71374935		0.0899992			28201.84409

Formulas to calculate slope (n) from S and I, NP=Constant	
n =LN(S1/S2)/LN(I2/I1)	

Formulas to calculate L and N0 from NP and slope (n)	
n1 =N0-L*LN(NP1)	L =(n1-n2) /LN(NP2/NP1)
n2 =N0-L*LN(NP2)	
n3 =N0-L*LN(NP3)	N0=N1+L*LN(NP1)

TABLE 6C.

Formulas to calculate S from I and slope (n) at NP=Constant	
At NP1	CTaylor = S1*I1^n1= S2*I2^n1
At NP2	CTaylor = S1*I1^n2= S2*I2^n2
At NP3	CTaylor = S1*I1^n3= S2*I2^n3
Etc..	

The sales amounts for I=0.09 are S01=855, S02= 2057, SO3=3060. These are obtained using the formulas:
S01= S4*EXP(LN(S4/ S1)*LN(I4/I3)/LN(I1/ I4))
S02= S5*EXP(LN(S5/ S2)*LN(I5/ I3)/LN(I2/ I5))
S03=S3 at I3

Step3. Determine the values of Slope (n), and Taylor Constant CT
Example: In TABLE 6A

Applying the enterprise intelligence equations in the I-S-Plane:
S1*I1^n = S2*I2^n,

The slope (n) for a constant value of (NP) is calculated from the following formula taking two points on a line:
n1=LN(S01/S4)/LN(I4/I3)

n2=LN(S02/ S5)/LN(I5/ I3)
or, alternatively from CT:
n = (ln CT - ln S)/ln I,
where CT corresponds to the Taylor constant C. Similarly, the value of CT is the Sales dollar amount when I =1 (T=1 in metal cutting).
Spreadsheet 6B shows these formulas applied to determine the slopes (n) for given values of volumes (NP), and the formulas to calculate L and N0. Slopes n1, n2 are calculated from I=0.09 and the corresponding history values of I at points A and B. For example …..
Example: ……
…..
Step 4. Determine the values of the constants L and N0 of the Enterprise forecasting Equation ln (S) = K - (ln (NP) -H)^2/4M-(N0-L* ln (NP))*ln (I).
After having determined the above slopes n1 and n2, the relationship between sales and the Intelligence parameter can be established for any lot size (NP). This is done by applying the 3rd term on the right side of the forecasting equation, which shows the variation of the slope with the values of lot size:
n = (N0-L* ln (NP)
and solving for NO and L:
n1 = (N0-L* ln (NP1)
n2 = (N0-L* ln (NP2)
using the formulas:
L = (n1-n2)/[ln (NP2/NP1)]
and
N0 = n1 + L* ln (NP1)
or from:
N0 = n2 + L* ln (NP2)
Knowing NO and L the slopes for any other lot size are determined:
n3 = (N0-L* ln (NP3)
n4 = (N0-L* ln (NP4)
n5 = (N0-L* ln (NP5)
detc.
Only a simple internal program can be introduced and all the many determinations will be made quickly.

Step 5. Determine the values of Sales (S) from the calculated Slopes n1, n2, n3 etc. an the Taylor Constants from the formulas in spreadsheet 5C .

The purpose is to be able to determine sales and volumes for any values of I, using the formulas:
S1*I1^n = S2*I2^n,
The slope (n) for a constant value of (NP) is calculated from the following formula
n = (ln CT - ln S)/ln I,
where CT corresponds to the metal cutting Taylor constant C. Example results for a number of sales values are displayed by the straight lines at constant values of (NP) in the graph of

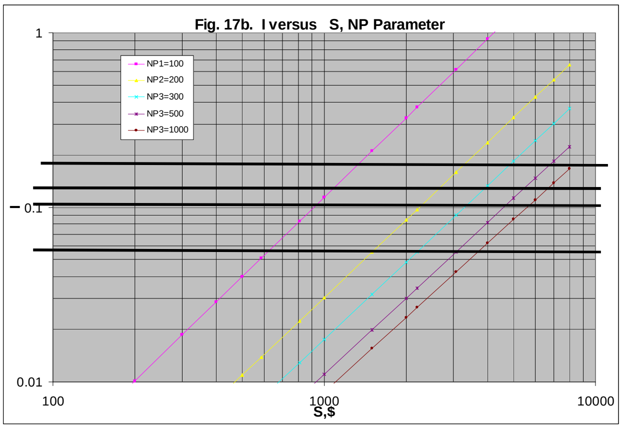


Fig. 8.5.2

Fig. 8.5.2, and tabulated in earlier shown TABLE 4.
Fig. 8.5.2 illustrates how sales varies with the Intelligence parameter (I) with lot size (NP) as parameter. Hence, by reading off pairs of values (NP, S) for e.g. I = 0.05, 0.09. 0.114 and 0.15 sales can be drawn as curves versus lot size with (I) as parameter. This is analogous to machining when plotting cutting speed versus Equivalent Chip Thickness when tool-life is parameter.

8.6 Step 6. Final Results: Sales and Maximum Profit, Optimum and Break-Even Lot Sizes

The results are shown in TABLE 7, and in Fig. 8.5.3. The selected values of I are 0.05, 0.09

TABLE 7								
cp	C	NP		S			PR	
			S, I=0.05	S, I=0.09	S,I=0.15	PR,I=0.05	PR,I=0.09	PR,I=0.15
5.55	555	100	586.4769864	854.72592	1194.451741	31.863039	300.1119689	639.8377938
4.8	960	200	1406.355854	2087.2799	2948.928165	445.63549	1126.559571	1988.207801
4.63	1390	300	2041.151916	3061.1368	4353.563202	650.68068	1670.66554	2963.091962
4.52	2260	500	2819.761112	4277.6781	6144.76729	560.81282	2018.729757	3885.818994
4.3	4300	1000	3369.706639	5193.2568	7562.961999	-930.29336	893.2567787	3262.961999
4.21	6320	1500	3251.866178	5056.6882	7421.56214	-3068.1338	-1263.311759	1101.56214

and 0.15.
Multiply your values by the tabulated figures valid for $-100000's such as 0.1, 10, 100 etc., when yours are in the ranges $10000,1000000, 10000000 respectively

.

You find Optimum Lot Sizes and Maximum Profit along the H-CURVE in Fig.18, at about 350, 425 and 500 units respectively.

Break-Even Lot Sizes lower limits at about 100 or less, and higher limits around 700, 1200 and 1600 parts respectively. The corresponding maximum $ sales in order to avoid a loss are approximately $3,000, $5,000 and $7, 500 (times 10, 100, 1000 depending on which metrics used).

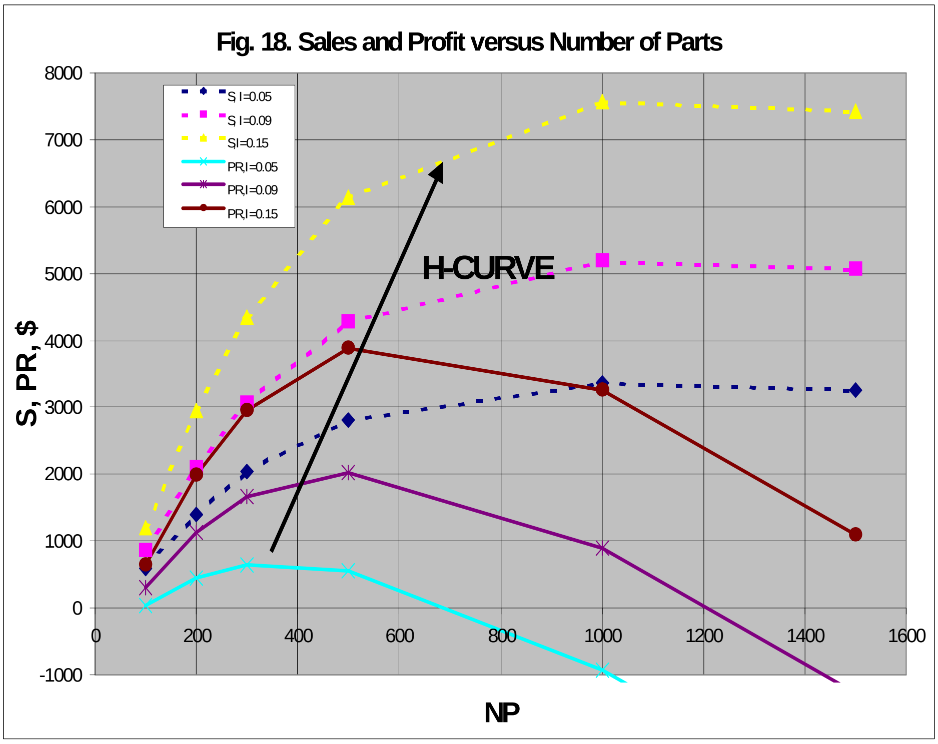


Fig. 8.5.3

8.7 Creating an Econometric Forecasting Model

You start with 3 historic company values: Points A, B,C (current value) of sales (S) and total cost (C) and select among the curves in Fig. 16 b, the series of (I) that best fits your 3 points A,B,C, or among the tabulated values in TABLE 5. Use the manual non scientific method to draw a curve between your 3 points, or the "least-square method" if you have a lot of data. When you have recorded its value, say I =0.095, you have at your disposal a series of tabulated corresponding dollar values of costs, sales and profit, in particular the combination resulting in Maximum Profit (PR-max).

By reducing Cost of Manufacturing, Material and Administrative, Sales Expenses you use the methods shown below, Method 1 or 2, in order to determine the requirements for reaching your goal.

Using these S-C Relationships for a given **(I)** such as I = 0.095 in Fig. 8.7.1 or 8.7.2, and plotting sp and cp versus volume N you have the corresponding part sales and cost functions, curves 1 in Fig.17. If your marketing people have established a new sales/part prognosis and your manufacturing engineers a new cost/part prognosis, curves 2, you can now, by calculating S from the sp-N - function and C from the cp-N-Function determine, using TABLE 4. and Fig. 14 a, establish a new S-C function and its corresponding **new I - value**.

Here is how you use above mentioned methodology for improving your company performance.

Having determined the three (3) points from Company History + the two (2) calcculated modernization points the Enterprise constants M, H, L, N0, K. can now be determined and hence the forecasted volumes of products or parts (N) (Guestimated forecasting points should be avoided as intuition is usually wrong in 50% of all cases). Determination of the constants M, H, L, N0, K, cannot be made without using a specialized computer program, so Table 5 and

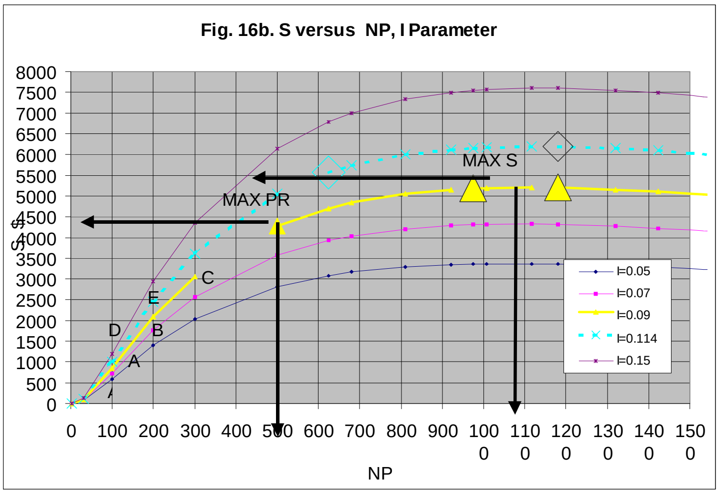


Fig. 8.7.1

Fig. 8.7.1. and 8.7.3. were constructed in order for the reader to do a useful analysis.

Table 5 shows tabulated values of sales and profit versus cost.

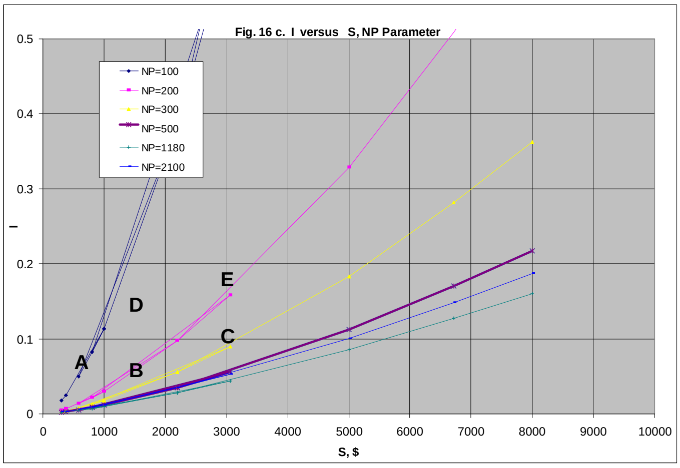


Fig. 8.7.3

The cost (C) can also be calculated from the cost per part (cp) versus volume (N), which is determined by your engineers and financial people using the formula:

C = cp*N,

recalling the N-Values already calculated from the new sales price per part function.

The result is new S-C-Curves with new profit values by which management can now do a reasonably accurate planning of resources and actions for the near term as well as for the future. This includes forecasting Future Maximum Profit and Optimum Sales.

Fig. 16 a shows the plots of Sales versus NP after multiplying the sp-values by NP, including your points A,B,C,D,E, Maximum sales occurs at approximately 1200 parts, an increase above 1200 will result in a reduced sales income as the unit price goes below a certain value. The corresponding profits may be very small or a loss will result, depending on the unit cost values at 1200 parts. Maximum profit will be obtained for about 500 to 600 parts depending on which scenario applies in this example.

The 3-D model plotted in the sales (S) – versus (I) - Plane when Volume (NP) is parameter is displayed in Fig.16c. The graph shows the location of the points A,B,C,D,E in Cartesian coordinates, while Fig. 8.7.4 in log-log coordinates, similar to metal cutting “Taylor lines”, which is more convenient to use. These “Taylor lines” for tool-life (T) versus cutting speed (V) with (ECT) parameter are here replaced by I for T, and S for V, with volume of parts (NP) being the Parameter instead of ECT. The difference is that here the so-called Taylor slope (n) is negative (see Section 3, Chapter1), which means that "Intelligence parameter"**(I)** increases with an increase of sales (in metal cutting tool-life decreases with increased cutting speed). This intelligence equation reads in the I-S-Plane:

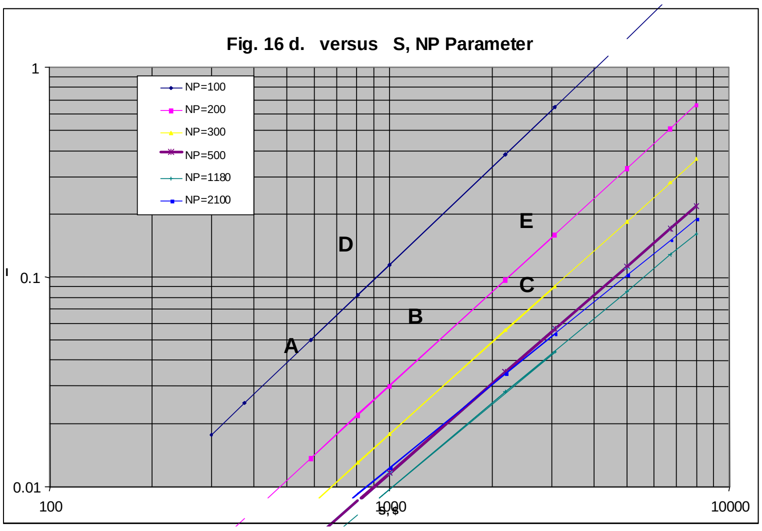


Fig.8.7.4

S1*I1^n = S2*I2^n,

where n is of the order – 0.4 to – 4, while in metal cutting about n < 0.05 < 0.5.

The slope (n) for a constant value of (NP) is calculated from the following formula

n = (ln CT - ln S)/ln I,

where CT corresponds to the metal cutting Taylor constant C. Similarly, the value of CT is the Sales dollar amount when I =1 (T=1 in metal cutting).

where CT corresponds to the metal cutting Taylor constant C. Similarly, the value of CT is the Sales dollar amount when I =1 (T=1 in metal cutting).

Alternatively, taking two points on a line:

$$S1 \cdot I1^{(n)} = S2 \cdot I2^{(n)}$$

and calculate n as follows:

n = ln (S1/S2)/ln (I2/I1)

EXAMPLE. Taking points A and D for NP=100 parts in Fig.8.7.5 we have

For point A: (I1 = 0.05, S1= 600), and point B:''

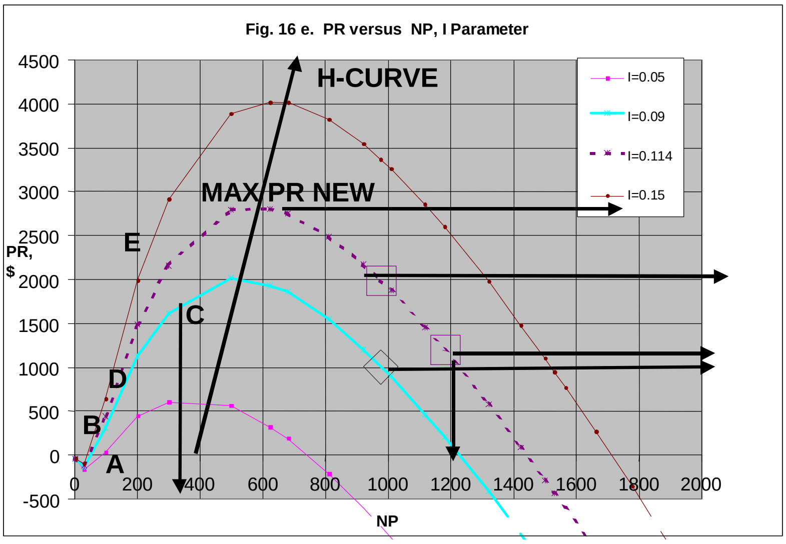


Fig.8.7.5

(I2 = 0.1 S2= 900),

and

n = ln (900/600)/ln (0.05/0.1) = - 0.585

The constant CT is determined using the Taylor equation using either point (A) or point (D) and you get the same result:

CT = S*I^n = 600*0.05^(-0.585) = 900*0.1^(-0.585) = $3,461.

After the values of I have been determined for your 5 points total costs and sales are calculated for any value of I, and a series of curves representing different profit scenarios result, see Figs, 16 e.

8.8 Forecasting Using Polynomials

A typical model in an enterprise Profit analysis by Riggs [8] consists of two second order polynomials in Cartesian coordinates, where Cost and Total Sales are plotted versus Volume of parts. The solution requires 5 given points, or 5 constants, in order to calculate maximum Profit for one set of conditions. The deviation is small between the Riggs's approach (using his one-data-set) and the author's model. Achieving a true optimum requires multiple data sets. The author's model generates a series of curves.

8.8.1 Forecasting Using Intellectual Capital

The use of Colding's model in manufacturing and enterprise econometrics is described in [9]. Applying

equation (1) to the business situation the parameters *X*, *Y* and *Z* are defined as follows: *X* = *NP* = Volume of parts, *x* = LN (*NP*), *Y* alternatively = *sp* =Unit Sales Price, or *cp* =Unit Cost, *y* = LN(*sp*), or *y* =LN(*cp*),

In all cases we define: *Z* = *I*, and *z* = LN (*I*), where ***(I)*** is

defined as company "Competence" **or, "Intelligence" Parameter.**

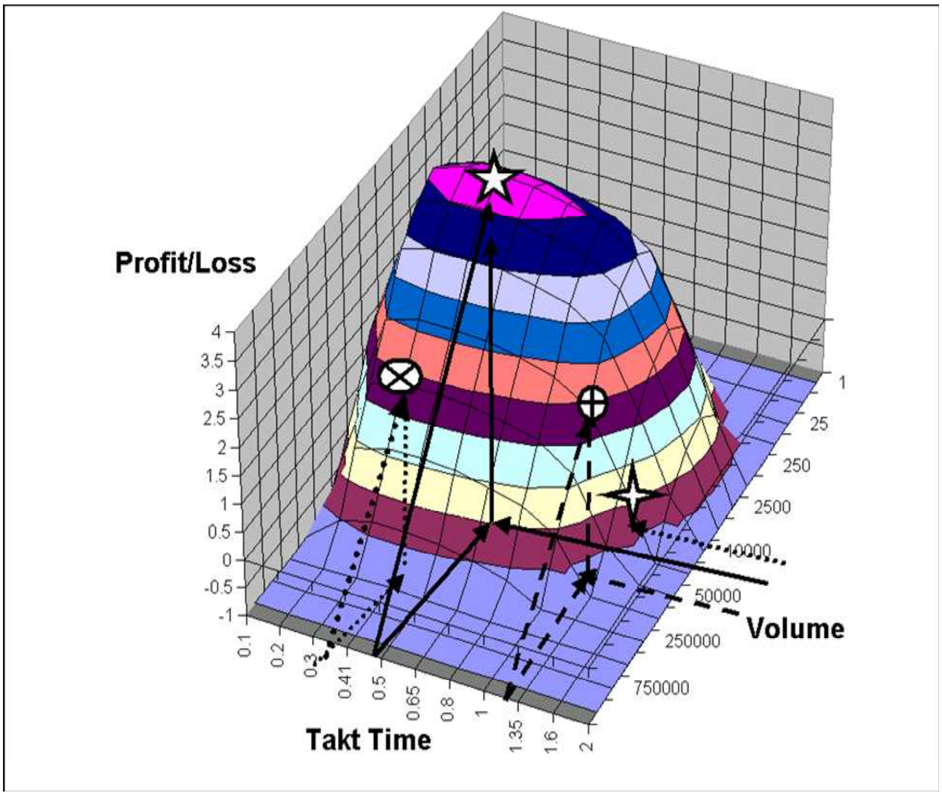


Figure 8.8.1: Profit Mountain: Profit/Loss versus Volume and Takt Time..

The Intelligence parameter (I) is defined as a the Sales revenue (S) from the product, or part :

***I=II/S*=100*(*II/S*)%** **(3)**

(II) is an Investment dollar amount, consisting of the sum of three performance functions**:**

IC = Intellectual Capital = "Ability to create excellent customer and internal relationships + Renewal & Development in order to Improve Product, Manufacturing and Design + Patents Development and the ability to use external experts efficiently” [10].

R&D = Research & Development in Engineering and Manufacturing.

CI **= Investment in Equipment and Software**.

8.9 Forecasting Global Warming

Some of the existing forecasting models, are based on linear models, such as the disputed prediction of global warming due to increase of carbon dioxide in the atmosphere. Colding's equation, based on the predictions of the curves in the "Taylor" plane (S versus Temperature Rise with years 2100, 2200, 2300 and 2400 parameters) are shown in log-log coordinates illustrate how deceptive the interpretation of the results of any model can be when plotted in different 3D-planes. The result may be interpreted as an approximately 0.7-degree Celsius increase for S about 400 ppmv no matter whether the year is 2100 or 2400. [18].

The predictions from the Colding relationship are compared with the temperature rise profiles in Figure 1.17, on p.34 in the book by Jepma and Munasinghe [12] for the Intergovernmental Panel on Climate Change (IPCC). The two profiles of temperature rise as function of year are drawn for 2 of values of the CO2 concentration called S, measured in ppmv-units, and denoted Smeas =450 and 650 in Figure 8.9.1 . The Author's evaluation technique, based on 5 predicted points of Figure 17.1, are tabulated in below Table 2 and marked with triangles in Figure 8.9.1. New predictions are generated for S=250, 450, 550, 650 and 850 ppmv with maximum values indicated by the H-CURVE..The climate model predicts a maximum temperature rise year 2500 , independent of the value of S. The deviations in t and 650 are very small, but the maximum temper respectively using the author's model.

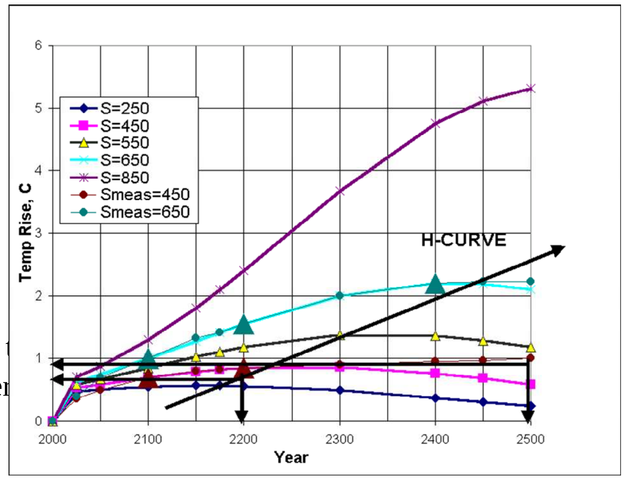
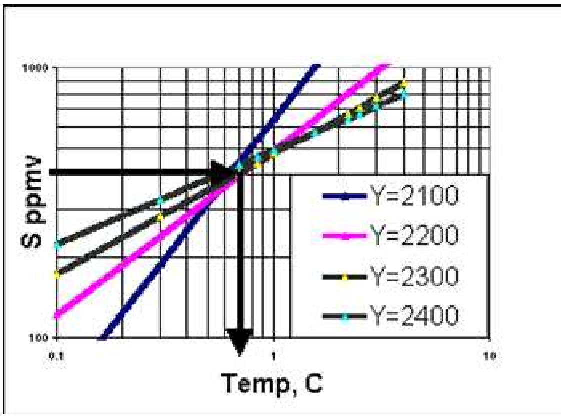


Figure 8.9.1: Temperature Rise versus Year, S Parameter, Smeas = Values from Measurements.

Table 2: Input for Evaluation, compare with Table 1.

Point	Year	Temp Rise ,C	S ppmv
1	2100	1	650
2	2200	1.55	650
3	2400	2.2	650
4	2100	0.7	450
5	2200	0.85	450

The calculated curves in the "Taylor" plane (S versus Temperature Rise with years 2100,2200,2300 and 2400 parameters) are shown in log-log coordinates in Figure 8.



The calculated curves in the "Taylor" plane (S versus Temperature Rise with years 2100,2200,2300 and 2400 parameters) are shown in log-log coordinates in Figure 8.9.2.

Figure 8.9.2 also illustrates how deceptive the interpretation of the results of any model can be when plotted in different 3D-planes. The result may be interpreted as an approximately 0.7-degree Figure 8.9.2:

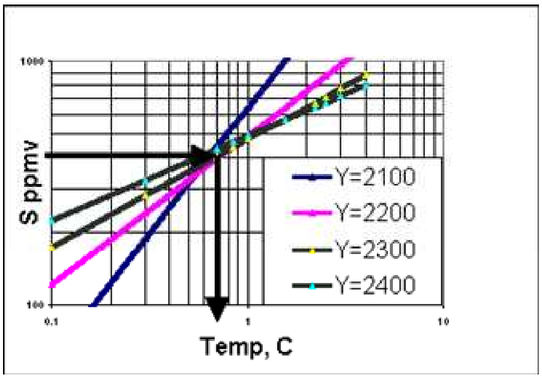


Fig.8.9.2 CO2 concentration (S) versus Temperature Rise, Year Parameter.

Celsius increase for S about 400 ppmv no matter whether the year is 2100 or 2400.

Above Colding study was made 10 years ago (1999-2000) indicating no influence on the earth temperature due to CO2[18]. To-day (2009-10) UNs so called experts predict that the changes in incredibly small amounts of CO2 in our atmosphere will increase the mean temperature of our planet so much that disasters will occur. This author does not believe at all in these UN predictions. I am sure that the following analogous prediction would scare manufacturers: Prediction: only one parameter dictates cutting tool-life, or tool temperature, say cutting speed. We manufacturing researchers have much better knowledge than the UN experts in dealing with complicated problems as we have measured tool-life since A.W.Taylor established his approximate equation around the year 1900. He, as we living researchers, know that work and tool materials, lubricants including feed, depth of cut, nose radius, lead angle and in milling also cutter diameter, engaged depth of cut and number of teeth have considerable influence on tool temperature. I am therefore convinced that we are far superior in predicting the mean temperature of our planet employing our knowledge and experience. Unfortunately, the UN climate panel has not yet consulted us!!

9. Summary

The results of the Author's predictive model indicate small deviations, compared with statistical and other algorithmic models in several areas from metal cutting to enterprise econometrics. The strength of this model, derived from metal cutting tool-life research, lies in the fact that only 5 points are needed to generate a number of forecasting curves, which contain maximum, or minimum points, displaced as H -CURVES shown in several graphs. Straight lines in log-log coordinate systems should be avoided, as these are only subsets of the real physical functions.

10. CAPITAL BUDGETING – Complete Techno-Economic Accounting System.

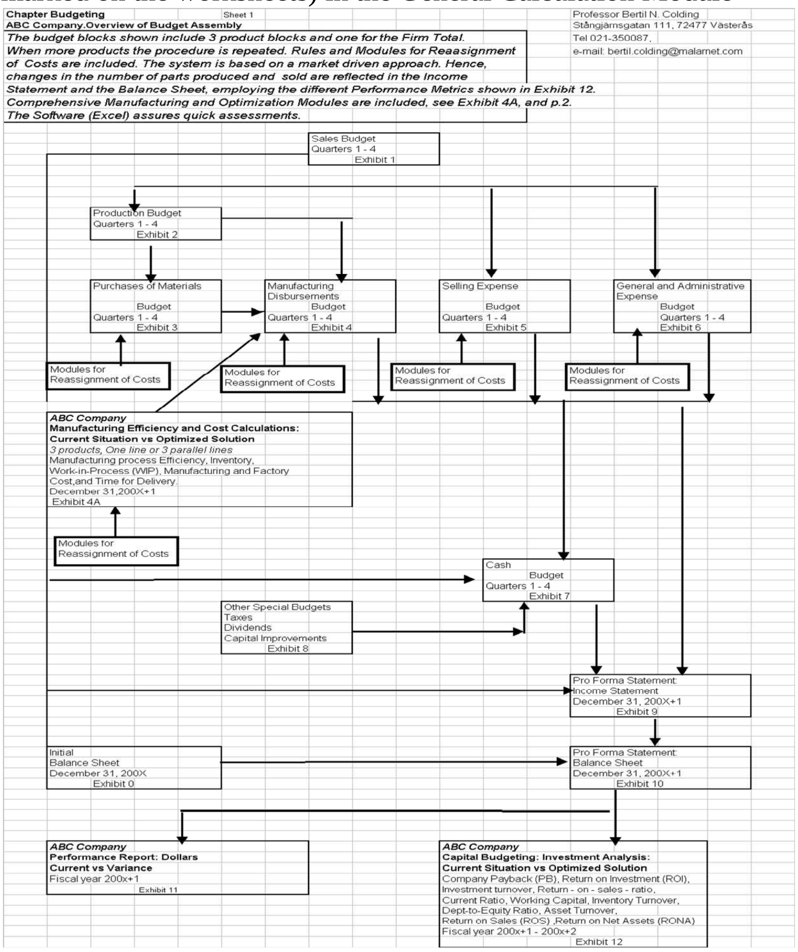
Copyright Bertil Colding, 2001[24]

(Compare with Peter Alnestig, Anders Segerstedt, (1997), Produktkalkyler, Sveriges Verkstadsindustrier Förlag, AB Industrilitteratur, [9].)

This chapter describes a complete techno-econometrics accounting system with application in a machining plant making 3 different products*. The* ***complete assemblyof the 16 accounts is detailed in the author's booklet [24].***

There are 2 different enterprise and manufacturing budgets, one for the current situation and another with improvements accomplished by investments in new machine tools, IT technology and optimized machining data. The investments were necessary in order to be able to manufacture greater product volumes as forecasted by the sales department, and to increase company profit. The company personell is assumed to have acquired the needed knowledge (Intellectual Capital) by having thoroughly studied Parts I, II and III of this book. The manufacturing and optimization budgets are shown at the end of the budget assembly.

The amended software (Excel) assures quick assessments of each budget activity, after the user has entered the company specific data (marked on the worksheets) in the General Calculation Module for each activity. All other necessary budget items are transferred to their budgets, or are automatically calculated.



System Description

Below budget assembly describes results pertaining to two different situations in Company ABC: Current Situation and Optimized Situation, the latter in regard to new investment in the manufacturing process which resulted in shorter processing times. This in turn increased the yearly part volume from 18000 to 25920 parts as forecasted by sales. Exhibit 4A presents complete budgets for the two cases which shows up in the Income statement, Exhibit 9 and in the Capital Budget Exhibit 12, where the company performance metrics were compared.

It was assumed that the General and Administrative expense budgets remained the same as in the current budget, but in the optimization budget the Sales expense budget was increased. In the Purchases of Materials budget the cost for more materials was accounted for, and it was assumed that the receiving room employees had to increase from 5 to

10.1 Overview of Budget Assembly

The budget blocks shown include 3 product blocks and one for the Firm Total. When more than 3 different kinds of products are made the procedure is repeated. Rules and Modules for Reassignment of Costs are included. The system is based on a market driven approach. Hence, changes in the number of parts produced and sold are reflected in the Income Statement and the Balance Sheet, employing the different Performance Metrics shown in Exhibit 12.

Around the year 2000 strong interest was created in the USA on developing better financial budget systems replacing the ABC Cost system by Granular Econometrics and other strategies.

This author begun developing such a system when serving on *MITI* (*Manufacturing Innovation & Technology for Industry)* team, depicted in the

“Proposal SUMMARY: NEXT GENERATION METRICS-for improvement of the Performance of American Industry”

10.2 Proposal SUMMARY: NEXT GENERATION METRICS-for improvement of the Performance of American Industry

MITI Manufacturing Innovation & Technology for Industry

Develop. NEXT GENERATION METRICS, an enterprise wide Adaptive Cost Accounting System that segments at granular levels, but retains a strategic perspective within a unified framework, which adoptively captures the predictable and unpredictable explosion in market growth in order to generate massive market values. The new metrics will address the following six major target components:

Customer	Financial	Future	Quality
People	Process	Supplier	Performance

+ **Introduction.** Most performance metdcs such as the one by SAE, or by other agencies and private sources, are based on consensus methods. This type of groundwork is of value for this effort and be used in selecting the important parameters in the design of the new accounting system. The current interest for performance metdcs including the most recent concept called Intellectual Capital (IC), *will* also be helpful in creating industry interest for metrics. Besides, it seems clear that performance metdcs based on decisions by consensus provide no substitute for accounting systems
+ **MITI.** The team has access to a wealth of knowledge for optimization of business performance, in particular with applications to automotive machining processes, die making, assembly and facilities planning. MITI can already provide software metdcs through its affiliated members, providing a sound basis for starting the development of the planned adaptive accounting system.
+ **Customers.** This proposal is aimed at the chain from OEMs to 1" tier suppliers and sub-tier suppliers of primarily the automotive industry as well as small medium firms in general, including government agencies.
+ **Mission.** The project mission is to provide the tools, services, and processes needed to make any U.S. manufacturer the most cost-productive; the most robust; the most adaptable, the most sustainable; and the most competitive in their industry through a non-competitive collaboration of the latest technology, deep expert knowledge, and systematic insight.

\# **System Benefits**

· Produce "Real" Value to the Customer and shareholders
· Increase Enterprise Profit
· Evaluate Competition
· Increase U.S. Market Share
· Establish a "win-vAn" situation with suppliers
·

MITI Metric Team Business Plan

· funding of approximately $1.5million is estimated to cover the first 1.5 years of development.
· First 1.5 years - Develop and Deliver a Metric Prototype Software for trial and feedback from key lead users in government and industry, and from financial and political entities.
· MITI will contribute to the financing of the project in connection with paid service projects for selected industries.
· After 1.5 years - Identify gaps and needs of metric users and develop industry specific competitive data software for various user groups. After revisions MITI, as a business, starts marketing customized industry versions of the New Generation Metdcs.
· After 5 years - Finalizing a National New Generation Metrics Industry Standards Document

A detailed business plan will be available when DOC indicates a preliminary commitment to support this MITI initiative.

IDENTIFICATION AND ANALYSIS OF NEEDS

Current Situation
MITI has identified a long-standing need of "best" metrics, with which to measure enterprise proficiency in the manufacturing industries of America, notably the automotive industry and its 1 **st** tier suppliers and sub-tier suppliers.
The current situation for U.S. manufacturers, with its oldest installed industrial base in the world, can be restated briefly as follows:

- U.S. Trade balance deficit, gone from $40B to $165B in 5 years.
- Lost market share to offshore manufacturers
- Losing technology it has invested in to companies in countries with superior Next Generation Manufacturing Technologies and Methodologies
- Although U.S. is currently number 1 in productivity as a whole, its automotive'industry is way behind the Japanese in productivity. The dollar rebound against the Yen made the U.S. auto manufacturers artificially cost competitive versus Japanese manufacturers, but these are de facto producing at 15-30% lower cost. Asia-pacific prices are undercutting American parts manufacturers by 30-40%. Adding the fact that the big three are outsourcing by Default and have begun relying on **global Is'** tier suppliers we have identified a great problem for the economy in the near future.
- U.S. is holding on to measures of success relevant to past eras - and short changed itself of awareness and development of assets needed for future success

There is currently a knowledge gap between the metrics used by the financial and manufacturing entities in individual firms. This fact often causes severe misjudgments when evaluating the benefits of new technology. The majority of current sub-tier suppliers are calculating prices that are based on simple metrics, which do not adequately consider the cost of money. Furthermore, calculated cost savings are often erroneous, as these do not reflect all associated costs, neither the impact on the firm's survival, **nor seeing the gaps between where they are and where the "best" are.**
Often in the same business world, the majority of our transactions occur without any conscious effort to reconcile them to measures of performance or targeted metrics that we choose to assure success in most any circumstance. Instead, organizations tend to "do what they've always done (and get what they've always goften.)' In today's world of accelerated change, where the key success factors of markets and business in general are being redefined by paradigm shifts of major proportion- all bets are off.
These "best" practice metdcs relationships between the major components: customer satisfaction, sales volume, price and manufacturing productivity are severely lacking in the design of today and tomorrow's manufacturing systems. Also lacking are the skills, knowledge, and processes necessary to apply these techno-economics measures, including the understanding of their **impact on the short and long term future of our enterprises.**
This need for intelligent performance measures (intellectual Capital) have not received the critical attention it deserves on a national level, including their importance for the defense sector.
While the U.S. is applying scattered national resources and a nonholistic approach, the offshore competitors have adopted a holistic strategy, as demonstrated by foresighted manufacturing investments. We have to take on Japan and Europe Inc. in a systematic approach, so that Economic Security will become synonymous with National Security. Ultimately, If we do not, the losers are American citizensiconsumers.
It is very likely that the automotive situation applies to the defense and aerospace industry as well as neither their suppliers possess economic knowledge or resources to substantially improve their competiveness against foreign part manufacturers.

Mission

Assets for, and proficiency in executing organizational and manufacturing processes ust be developed around Measures chosen to assure success in today's as well as in he future global markets and operating environments. We suggest that it is time to give evelopment of a Next Generation set of Value Based Metrics high priority for US Industry and the infrastructure that industry depends on for success in a Global economy here there is no place for the complacent to hide.

MITI proposes, in collaboration vath government agencies and industry, to create an Enterprise de Adaptive Cost Accounting Metdcs, a New Generation Compass for America, that will benefit he whole industry, **including lst** tier and sub-tier suppliers to the giant firms, **in particular the utomotive industry,** and the defense and aerospace industry. A metdcs standard that *VAII* promote holistic planning on the part of government and non-government entities involved in international security affairs. The goal is to reinvent American manufacturing enterprises for global environmental sustainability and assured competitiveness and national economic security. In this initiative MITI proposes to create metdcs in order to identify the entire Value stream in order to bring a specific product from concept/design through manufacture to a finished product, encompassing the requirements of Lean Production and Lean Enterprise. We VJill assign performance measures of the specific actions required to meet the customer's demand and develop a Master Guidance Metrics system crucial for reshaping thinking and choice making that Wil guide companies to better plan their futures. This v,/ill include establishing the relationship between manufacturing Value Added and non-value added (waste) activities. In our high change global environments the proposed Metrics vall mirror every proficiency needed for success in both current and future environments.
By integrating the cost/metdcs systems so that contemplated changes anywhere in the organization reflect their individual impact on **productivity** and enterprise profit by providing a process and mechanisms for leveraging America's **industrial** assets.
In undertaking this development MITI v,/ill explore the feasibility of applying new performance metrics such as Intellectual Capital (IC), and also the NASA Knoviledge Management System (for controlling and scheduling the duties on board space flights) to enterprise development and metrics.
MITI will initially base the project on the needs of the automotive industry and its chain of suppliers.

The Metrics and Bench-Trending team at MITI is committed to undertake the metrics development and using it as a targeting and guidance system for competitive manufacturing to: Achieve, Sustain and Improve the level of manufacturing enterprise proficiency that **will help** assure:

- America's industrial competitiveness
  Shifts readiness for Amedca's military peace keeping to industry
- Achievement of National Security via strategic economic robustness
- Enhancement of Quality of life and environment
- Focus on trade and job creation

Establishing 21st Century measures of Success
Creating and returning Wealth to its Communities

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12. Appendix (see [25] Colding,B.N., (2008), (Adobe format), **Machining Data Selection for Lean Manufacturing, Formulas and Machinability Relationships**

Including Algorithms for determining the five constants in the Colding Model.

13. CV Jubeldoktor Nils Bertil Colding,

Stockholm Town Hall, November 19, 2010.

Bertil Colding became civilingenjör (MSc) in machining technology at KTH in 1951, and he was in 1954 selected as the Swedish representative for the MIT Foreign Student Summer Project, where he became chairman of the seminars on the efficiency and importance of the Marshall plan in the different countries of the FSSP representatives. After the teknologie licentiat exam in 1955, and a Master of Science from MIT 1957 he presented his doctoral thesis ”A Wear Relationship for Turning, Milling and Grinding - Machining Economics”in 1959 at KTH, having Rector Ragnar Woxén as the first opponent. The thesis became the runner up to Colding’s equation, which finally during the years 2002-2010 laid the foundation for the software ColCut *(*CC), machining programs for determining Machine Settings & Optimization of Machining Process Planning & Costing, copyrighted by Colding International Corporation Inc.,.
He was 2 years Instructor in Metals Processing, MIT, and 2 years as Research Supervisor ”Forming and Grinding” at the Cincinatti Milling Machine Co, where he developed the forming method and the lathe for making the nose cone of the first US space rocket in 1958.

Academic Appointments

Colding is since 1968 active within the world renown international body CIRP (The International Academy for Production Engineering), where he in 1968 together with professors Gunter Spur, Berlin, Toshio Sata, Tokyo och Janez Peklenik, Ljublijana founded ”CIRP Seminar for Manufacturing Systems”, an activity in industrial circles is called FMS (Flexible Manufacturing Systems). In 1970 – 1976 he served as Vice president and President, CIRP Group C (Cutting). Appointed in1967 KTH Professor in mechanical technology succeeding Ragnar Woxén, and later visiting professor Industrial Engineering University of Michigan 1976-1978, thereafter guest researcher in Ford Motor Co., 1979.

Industrial Employment

Colding worked for ASEA 1959, where he established optimal machining data within the entire group. The ASEA President Curt Nicolin appointed him group manager of the investment program for NC and Automation.

Colding posses long experience as innovator as well as consultant within Swedish and American industry including production systems developer and salesman , in the US foremost with tasks for cost optimization of manufacturing processes such as within American Axle, Ford Motor Co., General Motors, Tecumseh Products, and several medium sized companies. After 7 years as Vice President, Sandvik Inc. 1979-86, and finally entrepreneur, he returned to Västerås 2001, after 25 years service in USA.

Awards. Knighted to the **Order of the Polar Star** (Kungliga Nordstjärneordern (RKNO)) in 1971. He received in the USA the NASA Space Shuttle and Technology Award, as well as the Great Seal of California, and a Distinguished Engineering Achievement from SME, and finally the William B. Johnson Eagle Vision Award from SME in 1986.
He is presently board member of the SMR (Swedish Association of Mechanical Engineers) including chairman of its production engineering committee and a frequent international lecturer. He has published books in machining, lean manufacture and enterprise econometrics, beginning in 1962.