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Productivity Improvements In A Mature Factory, A Pragmatic Approach

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Abstract

In the highly competitive semiconductor industry, wafer manufacturer are under constant pressure to deliver higher quality, faster and on time at competitive cost, especially being a mature European factory in direct competition to Far East factories.
Philips' Manufacturing Excellence Program covers all aspects of the required tasks: *improve overall factory productivity* towards competitiveness without violating such aspects as short lead times, deliver on time with world class quality.
Since mature factories face enormous competitiveness also in respect to resources, extensive theoretical studies and analysis cannot be afforded. Therefore well-known and proofed tools such as 'The Break Through Project Management Tool' had been chosen, beside other operations and project management tools, to increase factory capacity by improving overall productivity without or with little investments by at least 10% in 2004 and 2005, from thereon 5% per year. All aspects of equipment and operational performance had been evaluated, analysed, prioritised, organized, deployed and successfully executed or will be over time. Prioritizing, focusing and managing the real 'vital few' priorities (e.g. TOP 5 bottle neck tools) in the factory, in all means regarding productivity improvement, was the real 'Break Through'. The improvements in 2004 fulfilled our expectations by far.
Backbone of all of these activities is a high level of management attention and focus, strong leadership of Central Industrial Engineering and involvement of the people on the factory-floor.

Introduction

The Böblingen wafer factory is among the longest operating 200mm factories in Europe. The product portfolio covers a wide variety from consumer electronics to display drivers. Over 400 different part numbers within 30 different process flows are presently produced in the factory. The production process consists of over 400 visits to approximately 350 different production equipments and takes approximately 40 days. Lot size is 25 wafers. The transportation is done manual by operators. The factory is run 24 hours a day, seven days a week and produces roughly 800 wafers / day.
In the highly competitive semiconductor industry, wafer manufacturer are under constant pressure to deliver higher quality, faster and on time at competitive cost. Since quality, short cycle times and on time delivery is expected, as given and as competition increases, semiconductor manufacturers must pay close attention to production costs.
Over the past years, cost reduction programs for variable costs such as spares, services, consumables, materials and work force had been successfully established and well maintained to lower the cost per unit out. This will probably continue over time, but dramatic savings are no longer to be expected.
One other aspect towards competitive cost per unit is, to improve the ratio of 'fixed cost / capacity' by increasing *production capacity*. Since new facility construction can cost upwards of a billion dollars, with some type of equipment costing several million dollars each, the impact on the fixed cost part is significant and will probably not improve production cost and therefore competitiveness.
If capacity could be increased possibly with no or just little investments, the profit increase may be tremendous, assuming the factory is running or is expected to run fully loaded.

$$\text{Unit cost} = (\text{Fixed Cost} / \text{Factory Out Capacity}) + \text{Variable Unit Cost} \quad (1)$$

Objective

The objective of the program is to improve committed factory out capacity by more than 10% in 2004 and 2005, from thereon 5% per year without violating yield, quality and cycle time targets with no or just little investments. Progress shall be measured against a representative wafer start profile including the capacity increase over years. *Central Industrial Engineering*, responsible for this *Key Parameter Indicator*, shall take over the leadership for this project.

The Problem

But wafer factories and especially mature, long operating once, are among the most complex manufacturing operations in existence. Equipment is usually arranged by type and wafers have to criss-cross the factory as they move from operation to operation. Equipment has been installed according process, technology and capacity requirements over years, which led to a great variety of different types of tools with different process and performance capabilities. Reentrant flow precludes a neat, orderly, "production-line" arrangement of equipment

Permanent chances of technology mixes and the above listed constraints, makes it difficult to calculate the maximum factory out capacity as well as forecasting cycle time and as a consequence to define an improvement and measurement plan. Furthermore, extensive, dynamic modeling and data analysis is simply not possible due to limited human resources. Considering the concerns mentioned above, a radical change in attacking such a project is needed.

Methods

The Break Through Project Management Tool

To achieve a major break through in projects beyond normal continuous improvements within a reasonable time, *the Break Through Methodologies* are the first choice within Philips Semiconductors. What are the selection criteria's for typical break through projects: significant improvements of a '*Key Parameter Indicator*' are required, such as to improve committed factory out capacity up to 10% a year.

The benefits of the break through methodology are quite obvious. It is a rigorous approach to provide the right

… Priorities, by selecting the 'vital few' break through improvement programs
… Deployment of targets, by breaking each program or task down to manageable projects
… Organization of break through program's, by applying structured and transparent improvement methodologies and by allocating well trained and experienced project managers on request
… Methods and tools for executing projects, such as '*Tree Diagrams*', '*Fact Sheets*' included in the *MEDIC* tool

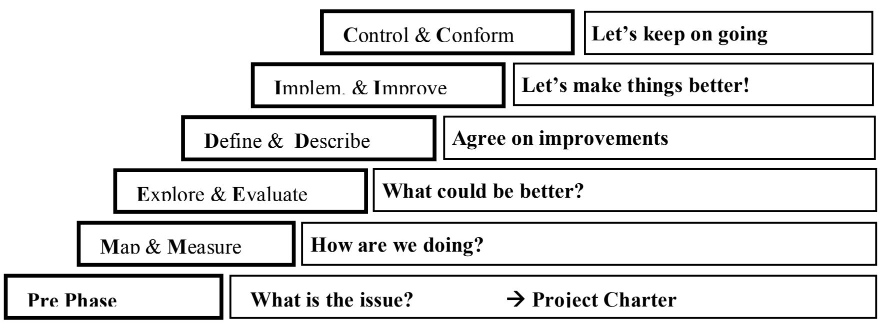


Diagram 1: MEDIC planning tool

MEDIC is a planning tool for all kind of process improvements projects. It is based on the *Plan-Do-Check-Learn Cycle* and consists of six steps that together provide the discipline and common language for improving process performance. Basically, both tools provide everything needed to achieve major break. The pre MEDIC phase had been finished with the sign off of the project charter as described in the objectives above.

Map and Measure

How are we doing? This question can only be answered, if we have the complete picture of the existing performance, understanding the losses and to identify the potentials, understanding 'what goes wrong in the Factory'. The team needs to gain complete clarity about the existing process performance and finally establish *Key Performance Indicators*, logically a *Primary* and a *Secondary* one. A benchmark is useful to compare the project target with what is ultimately possible. Finally, to get a thorough understanding of current process performance and ways of working, a suitable "as-is" map of the process is needed.

Key Parameter Indicators

Since in wafer factories part number mixes, demand, technologies change almost daily, you must agree upon a few basics parameters and measures before you get started. Otherwise you will lose track and control of your project.

The unit costs within Philips Semiconductors are defined as *Controllable Cost per Mask Layer Out* in Euros. This key parameter is used to benchmark factories within Philips. Therefore, the success of the project is measured in *Percent Increase of Mask Layer Out per day* as *Top or Primary Key Parameter Indicator (KPI).*

Table 1: Fictitious Mask Layer Out per day

Product Type	Wafer Outs / day	No of Mask Layers	Mask Layer Out / day
A	100	20	2.000
B	200	18	3.600
C	200	22	4.400
D	300	25	7.500
Total	**800**		**17.500**

Static Cycle Time is the Secondary Key Parameter Indicator directly impacted by improvement actions and should be controlled therefore as well. Other Sub KPI's, defined in the objective, such as Yield, Quality, Investment targets should not be violated, but are subject of the regular business review process.

Some 'Factory Physics'

The capacity of a wafer factory is strictly limited by the throughput of its *bottlenecks*. Therefore the factory capacity per day equals the maximum throughput of the bottleneck tool per day. Since only at Litho Tools rework process are common and well adjusted, Line Yields in mature factories get close to the 100% margin, both terms were set to one. The simplified Throughput formula is

Factory capacity = Design Rate x Availability (A) x Bottleneck Utilization (U) (2)

It had been defined, that one of the objectives is, not to violate *cycle time performance*. Since the *Cycle Time Budget* is also a great opportunity to increase capacity, a good understanding of the theory is essential. PSB is forecasting its cycle time according the VUT equation.

Cycle Time	=	Variability x Utilization x Eff. Process Time	(3)
Variability	=	$(c^2a + c^2e) / 2$	(4)
Squared coeff. of arrival variation c^2a	=	c^2d (oper –1)	(5)
Squared coeff. of departure variation c^2d	=	$1 + (1-U^2) * (c^2a-1) + (U^2 / \sqrt{m}) * (c^2e-1)$	(6)
Squared coeff. of eff. process time c^2e	=	$c^2o + (1+c^2r) * (1-A) * (MR / To)$	(7)
Squared coeff. of natural process time c^2o	=	$(\text{sigma } To / To)^2$	(8)
Squared coeff. of meantime to repair c^2r	=	$(\text{sigma } MR / MR)^2$	(9)
Utilization (CTF)	=	$(U * \sqrt{m}) / (m * (1- U))$	(10)
Time (eff. process time Te)	=	Raw Process Time (To) / Availability (A)	(11)
Cycle Time	=	Variability x Utilization x Raw Process Time / Avail	(12)

Modeling Tools

Simple, Static Capacity Model: S/CAM

To calculate the impact of changes in respect to capacity the standard capacity model of PSB, called S/CAM, is used. The Software allows capacity planners quickly to answer 'what if questions' to determine when load exceeds planned capacity and shows when new equipment would be required. It is based on SEMI E10 Standard. All capacity relevant data are required as input, such as product starts per day over a horizon of up to five years, sorted acc. product codes / technologies / processes. Also equipment performance data are required, such as no. of tools on board / planned, process flow based on released operations (routings) and no. of qualified tools / operation as well as SEMI E10 relevant data. The planning accuracy is better than +/- 5%.

Simple Cycle Time Model

Twice a year Industrial Engineering (IE) is recalculating the *Factory's Cycle Time*, based on the VUT equation, using an Excel template. The model is also used to analyze the impact of different scenarios on the factory's total cycle time.

Base Line Setting

At the beginning of the project in early 2004, IE set up a most likely *Wafer Start Portfolio* for a planning horizon of three years. The start profile had been agreed upon internally and also aligned to the factory's external commitments. From thereon the '*Reference Model*' had been and will be used to measure the progress of the project.

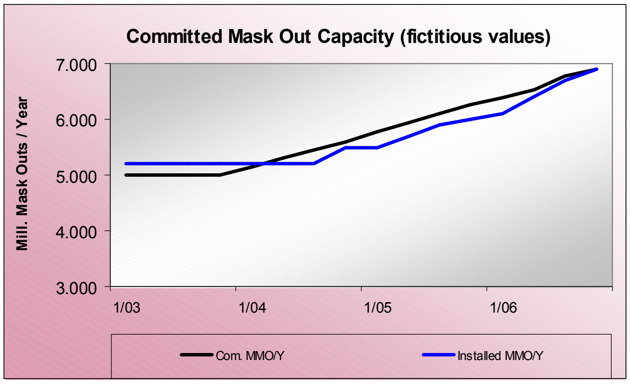


Diagram 2: Committed mask out capacity (fictitious outs)

Table 2: Committed mask out capacity (fictitious outs)

Philips S/C GmbH, Böblingen — STP XY — REVISION: xy

FAB MASK OUT (k-MASK PER PERIODE)

PDC	PHILIPS S/C	2005 1Q	2005 2Q	2005 3Q	2005 4Q	2005 TOTAL	2006 1Q	2006 2Q	2006 3Q	2006 4Q	2006 TOTAL
		90	91	91	84	356	90	91	91	84	356
1	Process 1	0,100	0,100	0,200	0,250	0,650	0,102	0,102	0,204	0,255	0,663
2	Process 2	1,000	1,230	0,615	0,500	3,345	1,020	1,255	0,627	0,510	3,412
3	Process 3	5,000	10,000	9,000	10,000	34,000	5,100	10,200	9,180	10,200	34,680
5	Process 5	4,000	6,000	7,000	7,000	24,000	4,080	6,120	7,140	7,140	24,480
9	Process 9	2,000	2,000	3,500	0,400	7,900	2,040	2,040	3,570	0,408	8,058
10	Process 10	0,000	0,400	0,400	3,000	3,800	0,000	0,408	0,408	3,060	3,876
11	Process 11	0,102	0,000	0,000		0,102	0,104	0,000	0,000		0,104
12	Process 12	0,000	0,000	0,000		0,000	0,000	0,000	0,000		0,000
13	Process 13	2,000	0,000	20,000	60,000	82,000	2,040	0,000	20,400	61,200	83,640
14	Process 14	40,000	45,000	50,000	65,303	200,303	40,800	45,900	51,000	66,609	204,309
15	Process 15	220,000	190,000	250,000	285,124	945,124	224,400	193,800	255,000	290,826	964,026
17	Process 17	70,000	65,000	40,000	8,463	183,463	71,400	66,300	40,800	8,632	187,132
18	Process 18	0,500	0,200	0,500	12,675	13,875	0,510	0,204	0,510	12,929	14,153
19	Process 19	10,000	5,000	6,000	7,000	28,000	10,200	5,100	6,120	7,140	28,560
20	Process 20	0,700	3,000	3,000	2,000	8,700	0,714	3,060	3,060	2,040	8,874
	PROCESS INSTALL										
	TOTAL	473,8	455,2	676,1	1118,2	2723,4	483,3	464,3	689,6	1140,6	2777,9

Philips S/C — FM_WR_0508_Rxyz.xls — August 24, 2005

Measure

Finally, the utilization per tool group had been calculated based on the reference model. The outcome is listed in a utilization report called *Bottle Neck Report,* sorted top down from highest utilized tool.

Table 3: Bottle Neck Report, TOP 5 Bottle Necks

Tool group	Baseline Q1 2004	Q4 2004	Q4 2005
Implant	102%	115%	136%
Photo	98%	112%	135%
Sputter	102%	109%	128%
CVD	89%	102%	124%
Polish	99%	111%	123%

Prioritize

Since the capacity of a wafer factory is strictly limited by the throughput of its *bottlenecks*, it is pretty straight forward, to focus on the most limiting bottleneck tools in the factory in the first run. We decided to do so with the *TOP 5 limiting tool groups*. Once the capacity gaps for those tools will be closed, it will be continued with next bottlenecks and so on.

Factory capacity = BN Design Rate (To) x BN Availability (A) x BN Utilization (U) (2)

If the factory capacity is given and the maximum theoretical utilization is limited to 100%, but set to 80% for cycle time reasons, then it's obvious which parameters needs to be evaluated and worked on for our bottleneck tools. Prio 1 is to improve *Bottleneck Utilization* from today 80% towards 91% by reducing *Variability* and increasing the *Number of Qualified Tools* per process. Prio 2 is to increase *Bottleneck Tool Availability* towards benchmark or performance of comparable tools or, as a rule of thumb, towards 3rd best performance over last 12 months. Prio 3 is to improve *Bottleneck RPT* towards benchmark or theoretical best value.

The Secondary Key Parameter, *Overall Factory Cycle Time*, should not be violated!

Cycle Time = Variability x Utilization x Design Rate / Avail (12)

If Cycle Time should be improved to sponsor bottleneck tools, even if load and therefore utilization on "*Sponsor Tools*" increases, the variability and design rate needs to be improved and tool availability reduced. This will be attacked in a second step of improvement projects.

Map

All capacity relevant parameters are defined in the *SEMI E10 Standard*, therefore this structure had been chosen to map, explore and evaluate all productivity improvements respectively. To keep data collection fast and easy, just the basic

SEMI E10 parameters had been selected for being mapped. Parameters influencing the bottleneck rate are *Design Rates, Unscheduled Downs, Scheduled Downs, Engineering Times, Standby Time* and other *none SEMI E10* times.

Explore and Evaluate

Having got this understanding, than it is time to find capacity losses and explore possibilities for improvement. It is necessary to understand the source of variation in the process, as well as the cause and effect mechanisms. The phase ends when the team can explain the root causes of main problems and opportunities, rank causes and conclude what conditions have to be improved or redesigned. Knowing the parameters influencing the capacity of the tool set, it is obviously to go through step-by-step, to get a clear picture of the actual performance of the factory.
Achieving a real break through in a short time frame and considering the situation of poor performing tools, the analysis phase should be short and effective, corrective action should be started immediately and therefore we should take advantage of existing data and common understanding. In a second run, when most well known major detractors for better tool performance are eliminated, a more detailed and in depth analysis should be performed.

Design Rate

The parameters influencing the design rate are *Tool Design*, may also lead to *Tool Type to Tool Type Differences, Tool-to-Tool and Run-to-Run Variation, Process Parameters* and *Variation* over time, driven by declining targets e.g.
The following diagrams show the results of the evaluations performed on our PVD tool park. To evaluate the design rate, the process times of all three tool-sets had been analyzed for given operations over a period of three months. The results had been stored in Excel for further analysis. To complete the analysis and get a reference for the internal collected data, a Philips internal benchmark hat been performed for Enduras. Enduras are widely used within Philips.

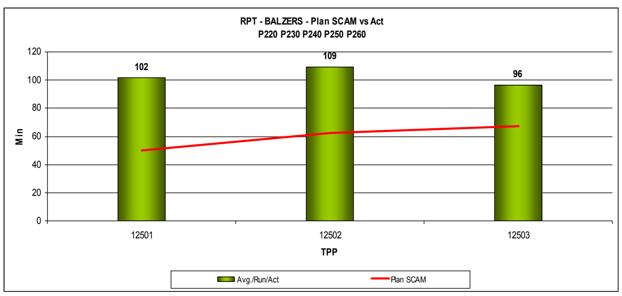


Diagram 3: Mean process times for three diff. operations

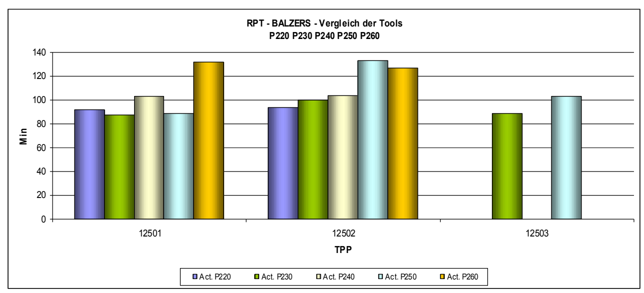


Diagram 4: Tool to tool variation for 3 diff. operations

Significant differenences had been seen between the three tool types, between tool to tool in the same tool set, from run to run and also between acual versus plan. Surprisingly enough, in daily operation people on the shop floor propably had been aware of this, but never had gotton the clarity to react and drive actions. Similar results had been seen in other tool groups such as implant or CVD.

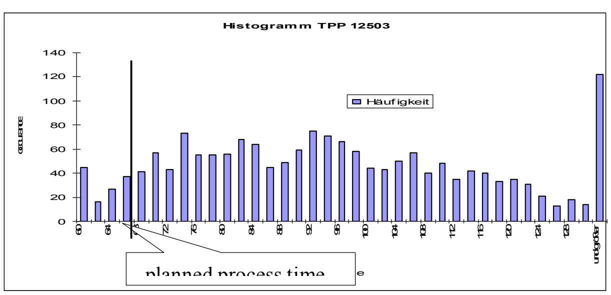


Diagram 5: Distribution of process time of a tool set

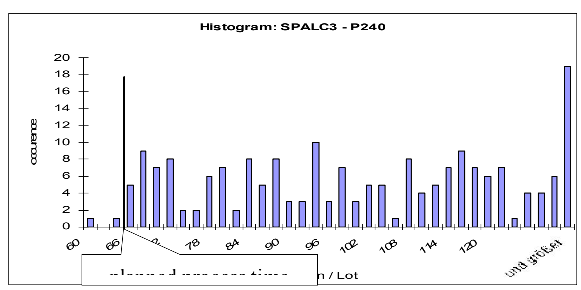


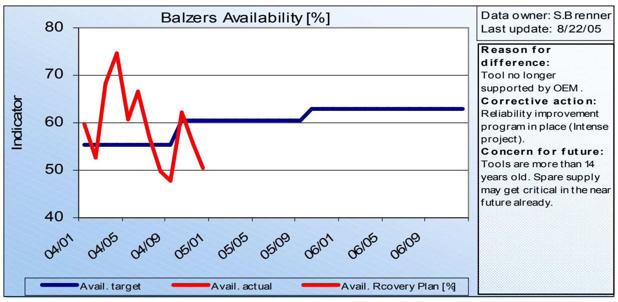
Diagram 6: Distribution of process time of a single tool

The above charts show the wide spread distribution of process times of a sputter tool set for a single operation. Theoretically, the planned process time may be met sometimes, but in most cases it is much higher using up the cycle time budget, are in most cases not on Benchmark level. The differences between tools are even more significant. Root causes good be variability of process times, declining process times due to declining targets, not enough staffing, tool to tool differences, run to run differences, patchwork layout of tools, poor logistic on the shop floor, plan input too optimistic. Further analysis and interviews on the shop floor have proven this as facts.

Availability

The parameters influencing the tool availability are *Unscheduled Down* incl. *Meantime Off Line, Wait for Service or Maintenance, Wait for Spares, Meantime to Repair, Scheduled Downs incl. Preventive Maintenance* and *Eng. Time.*

Unscheduled



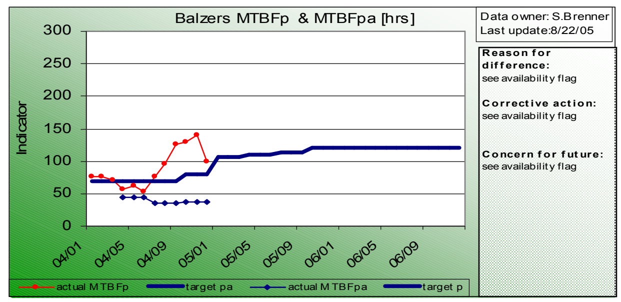
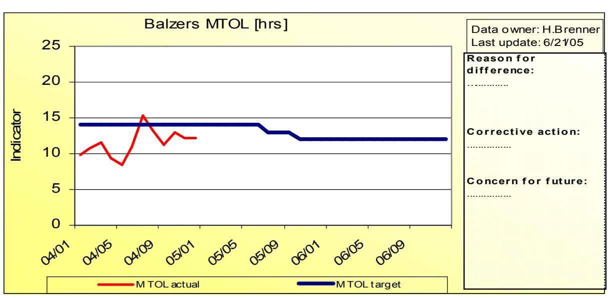


Diagram 7: Manufacturing Availability Balzers (5x tools) **Diagram 8:** MTBFp & MTBFpa

We observed 3 types of tool performance characteristics. Tools are on target, tools are on target but worse than benchmark and tools are below target. Common observation had been, that all of the tool groups did not perform stable, even worse the variability was too high. Root causes had been identified as manifold, old worn out tools with no specific reliability engineering improvement program in place, spare supply critical due to cost targets and / or supply problems, maintenance coverage just guaranteed for 2 shifts instead of 3 shifts, lack of skill, lack of data tracking discipline, lack of exchange of experience within Philips and/or the suppliers.



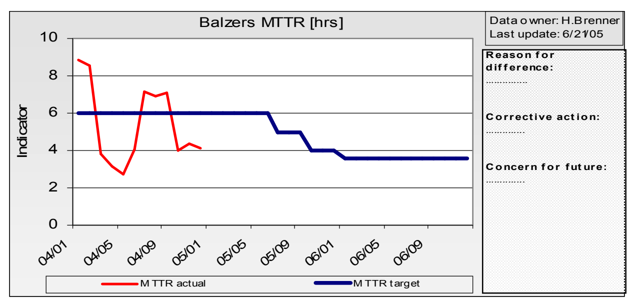


Diagram 9: MTOL **Diagram 10:** MTTR

The graphs show data from our weekly production status meeting. Surprisingly again, even if the actual data were below target or declining, no proper action had been taken to correct the situation for good reason. Concurrent goals in the factory are among the main drivers for this situation. To complete the picture and get a reference for the internal reported data, an internal benchmark hat been performed for Enduras since this tool type is widely used within Philips.

Scheduled Downs

Scheduled Downs seem to be better controlled and in most cases on or better target. Engineering down times have minor impact on the total performance, nevertheless the targets seem to be too high compared to actual situation and considering the number of engineers on board. The plan should be revised.

Standby Time or extra Cycle Time Budget

The understanding within Philips Semiconductors Böblingen for the term *Standby Time* is, that it will be used as a extra time budget to buffer for *No Operator, Variability of Processes, No WIP, Variability of Arrivals / Departures, Variability of Tool Availability* and *Others.*

Based on the theory, that an average cycle time budget of 25%, results in a cycle time factor of 3x (1x raw process time + 2x waiting time) or in a static cycle time of roughly 2x mask level, all tools have a 25% budget independent from their performance or the number of qualified tools per operation. The idea is, that bottleneck tools may use up more of the regular cycle time budget of 25% gaining capacity by being sponsored by lower utilized tools (sponsors).

Variability of Arrivals and Departures – No WIP

The following graphs show the variability of arrivals and departures at Litho, mainly impacted by the upstream process and / or the manual transportation. Bottlenecks never ever should starve. It is highly recommended that bottlenecks should have a suitable buffer to protect from starvation. For continuous arrivals, manual transportation needs to be staffed according our headcount model. The efficiency had been proven in the past already.

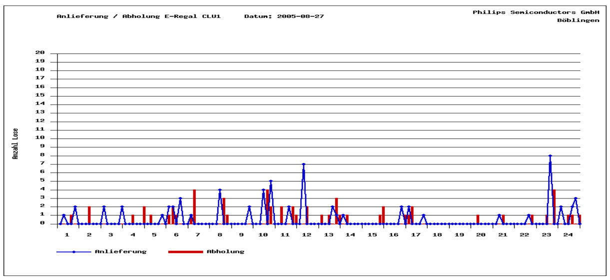


Diagram 11: Distribution of arrivals at Litho

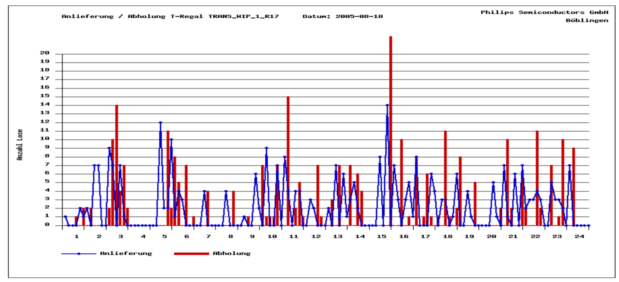


Diagram 12: Distribution of departures at Litho

Variability of tool availability

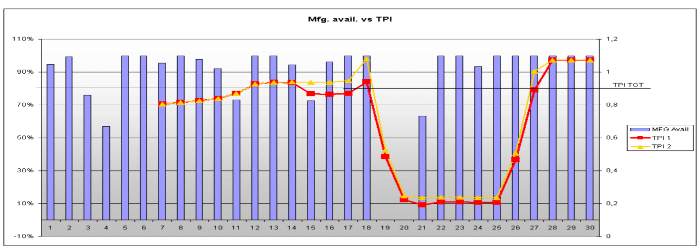


Diagram 13: TPI Factor

Variability of tool availability is contributing to cycle time and should be monitored. Philips is using the TIP Factor.

TPI = (mean act. avail. (7days) – standard deviation of avail. (7 days)) / avail. plan (13)

TPI should be better than 0,9. Actually, the target had not been met the last 12 months. Further analysis are required.

Variability of Process or No Operator

The root causes had been discussed already in the raw process time section.

Sponsor Tools

The following chart shows an extract of a typical routing, listing the most relevant data for calculation the *Total Cycle Time* in the factory. A complex manufacturing line, such as a wafer factory, never will be balanced perfect at a certain point in time due to chances in the product portfolio, investments, de-investments, change in tool performances a.s.o.
The chart shows the negative impact of a none uniform start rate (ca^2) of 11, influencing the first two gates already. It also can been seen, that cycle time factors vary from 1,5 up to 16. Impacted mainly by poor ce^2 values, low tool availabilities and long repair times at the same time or only two tools qualified and highly loaded. On the other hand, plenty of ‘S*ponsor Tools*’ are available as well.

Potentials Cycle Time Budget

All observations lead towards two directions, the variability of all parameters is too high and there are plenty of not fully loaded tools, which could compensate for cycle time losses of our bottleneck tools.

Table 4: Cycle Time Model (VUT equitation)

	Total CT [days]	44,2										
		CTtot	CTF	Cd²calc	Ca²=Cd²-1	Ce²	Mr	A	To	Te	U	n
WTP	XSNCS0F1	3,0	3,3	7,3	**11**	0,6	5,5	0,97	0,90	0,93	**0,6**	2
CF-Cluster	C3251QF1	10,1	6,1	3,3	7,3	1,1	7,1	**0,85**	1,67	1,96	0,8	**2**
Foto-Messtools	MEDIMEF2	0,6	3,8	2,8	3,3	4,0	1,0	**0,75**	0,17	0,22	0,8	4
Inspektion	INZWINF1	0,7	3,7	2,7	2,8	4,4	1,0	**0,75**	0,18	0,24	0,8	4
AME5000 Etch	RIAC01F1	2,0	1,5	1,9	2,7	1,0	10,0	0,92	1,30	1,41	**0,7**	5
Strip	PLAS21F2	1,9	2,5	1,7	1,9	1,8	5,7	0,88	0,75	0,85	**0,7**	2
Foto-Messtools	MADIMEF2	0,6	3,1	2,1	1,7	3,5	1,0	**0,75**	0,20	0,27	0,8	4
WTP-Megas.	XMGAB3G1	5,9	2,1	1,5	2,1	0,9	8,0	0,84	2,78	3,33	**0,7**	2
LVZ ALV	ALV000G1	0,2	3,3	3,4	1,5	9,0	1,0	0,90	0,05	0,06	**0,6**	2
BTU OXID	OT0062G1	16,9	2,4	7,0	3,4	0,2	6,5	0,96	7,20	7,50	**0,7**	2
WTP	XHFH10G1	2,3	2,5	4,7	7,0	0,6	5,5	0,97	0,90	0,93	**0,6**	2
WTP	XHPH20G1	2,2	1,7	3,3	4,7	0,4	5,5	0,97	1,30	1,35	**0,6**	3
WTP-Megas.	XMGAB1G1	6,9	2,5	2,2	3,3	0,9	8,0	0,84	2,78	3,33	**0,7**	2
BTU OXID	OT0028G1	11,8	1,6	5,1	2,2	0,2	6,5	0,96	7,25	7,55	**0,7**	3
CM-Cluster	CO907EH1	16,5	5,5	2,1	5,1	0,7	4,4	0,85	3,00	3,53	0,8	**2**
Foto-Messtools	MEOVERH1	0,8	3	2,0	2,1	3,0	1,0	**0,75**	0,25	0,33	0,8	4
Inspektion	INZWINH1	0,6	3,5	2,5	2,0	4,4	1,0	**0,75**	0,18	0,24	0,8	4
Implanter	IINW1DH1	9,7	12	3,3	2,5	4,5	9,0	0,73	0,80	1,10	0,9	2
Implanter	IINW2DH1	9,3	16	4,3	3,3	5,9	9,0	0,73	0,60	0,82	0,9	2

Define and Decide

Now the team can begin to structure the elements, improvement areas, judge the potential improvements, the feasibility for implementation and realization, choose promising tasks and decide whether to work on or put on hold. *The Tree Diagram* is a perfect planning tool to fulfill the *'Define and Decide Task'*, showing the whole project on one page.

Tree diagram

The Tree diagram helps to define the breakthrough objective and to break down the objective in smaller, easier to handle and therefore easier to realize breakthrough projects in five steps:

1. Describe the breakthrough objective ('gap to close')
2. Identify the improvement areas
3. Define the impact of each improvement area on the gap to close
4. Decide to 'Go' or 'Stop' for each improvement area (based on impact).
5. Define projects for the 'non-stopped' areas

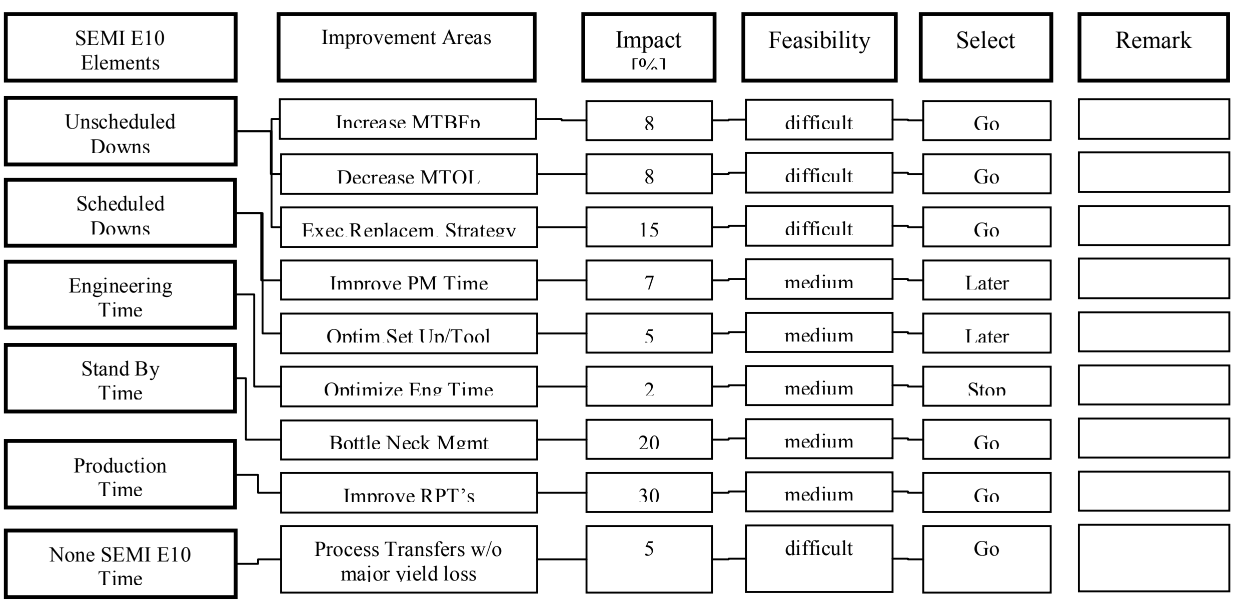


Diagram 14: Tree Diagram

The team decided, to put a hold on improving engineering times since the benefit is quite little, just to run an assessment whether the planned times are reasonable or not. It also had been agreed upon, to work on Scheduled Downs later since those tasks seem to be reasonable managed and the benefit less than for unscheduled downtimes. The next step now is, to break improvement areas down to manageable projects per bottleneck tool group and keep on deciding where to focus on. Once the decisions are made and agreed upon, *Project Charters* need to be written for each sub-project.

Project Charters

This is a major step in the definition phase and essential for implementation and improvement. The Project Team charter consists of six items that have to be defined by the project leader and the team and to be agreed by the management.

… Business Case: Why should we do this? What problem will be solved or opportunity will be won?
… Goal Statement: objectives, targets, indicators and timing.
… Project scope: What is within and what is outside the scope of the project?
… Project plan: First activity breakdown and milestones.
… Project team: Who is with what kind of role, for what activity in the team? Resource commitment.
… Operating principles of the team: how do we work together as a team?

Table 5: Detailed Tree Diagram

Improvem. Area	Sub-Project	Implant	Litho	PVD	CVD	Polish	Proj.Charter
Increase MTBF	Root Cause Analysis / reliability impr. program	Go	Go	Go	Later	Later	X
	Reengineering tooling parts	Stop	Stop	Go	Stop	Stop	X
	Tool upgrades	Stop	Stop	Go	Stop	Stop	X
	Identify weak tools/parts, find beneficial upgrades/used tools	Go	Stop	Go	Go	Go	X
	Copy best know methods, internally or from suppliers	Go	Go	Go	Go	Go	X
	Regular housekeeping	Go	Go	Go	Go	Go	
Decrease MTOL	Maintenance. in 3rd shift	Go	Done	Done	Go	Go	X
	Mainten. skill upgrade	Go	Go	Go	Go	Go	X
	Autonom. Mainten. / OCAPS	Go	Go	Go	Go	Go	X
Improve PM Time		Later	Later	Later	Later	Later	
Optimize Set Ups	& tool qual.'s	Later	Later	Later	Later	Later	
Opt. Eng. Time	Optimize Qual., Eng. work	Stop	Stop	Stop	Stop	Stop	
	Quick check of plan input	Go	Go	Go	Go	Go	NA
Opt. Standby Time	Sufficient spare supply	Go	Go	Go	Go	Go	X
	No wait for Operator, Optimize Oper. Staffing	Go	Go	Go	Go	Go	X
	Optimize Maint. Staff.	Go	Go	Go	Go	Go	X
	Cross functional training	Go	Go	Go	Go	Go	X
	Optimize transportation, continuous delivery	Go	Go	Go	Go	Go	X
	Buffer Bottle Necks upstream	Go	Go	Go	Go	Go	X
	Buffer BN's downstream	Later	Later	Later	Later	Later	
	Reduce variability of avail.	Later	Later	Later	Later	Later	
	Identify 'sponsors' for BN's	Later	Later	Later	Later	Later	
	qualify min. 3 tools per oper.	Go	Go	Go	Go	Go	NA
Improve RPT's	towards BM	Later	No	Go	Later	Later	X
	Tool to tool	Later	Later	Go	Later	Later	
	Run to run	Later	Later	Later	Later	Later	
	Economy process	Later	Later	Later	Later	Later	
None Semi E10 Time	Transfer processes to idling tools without yield loss	NA	Go	NA	NA	NA	X
	Impr. data tracking accuracy	Go	Go	Go	Go	Go	X

Implement and Improve

The implementation phase starts with the drawing of a detailed implementation plan – showing What, When, Why, Who type details for all ‘Go-Projects’. Further detailed plans maybe available on working level, but not necessarily required. As example, the *Litho* part will be reported.

	05												06												07			Owner	Mentor	Cost	Invests
Month's 2005 / 2006	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**				
Target B14 Litho Cluster	**3**	**3**	**3**	**7**	**7**	**7**	**11**	**11**	**11**	**15**	**15**	**15**	**16**	**16**	**16**	**17**	**17**	**17**	**18**	**18**	**18**	**19**	**19**	**19**	**20**	**20**	**20**				
Improve Tool Avail.	0	0	0	0	0	0	0	0	0	0	0	0	0,5	0,5	0,5	1	1	1	1,5	1,5	1,5	2	2	2	2	2	2	G.Broos	S.Brenner	35	
Decrease CT Budget 10% = 7% Cap., later by 15% = 9% Cap.	0	0	0	0	0	0	7	7	7	7	7	7	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	H.Mezger	S.Brenner		
unknown FSI improvements	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	2	3	3	3	3	3	3	3	3	3	G.Kolwe	S.Brenner		65
Reduce Eng Time	0	0	0	0	0	0	0	0	0	0,5	0,5	0,5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	H.Sahr	S.Brenner		
Reduce Rework	0	0	0	0	0	0	0	0	0,5	0,7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	H.Sahr	S.Brenner	15	
Layer Balancing w/ B12 & B11 Cluster w/o major Yield Losses	0	0	0	0	0	0	0	0	0	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	H.Sahr	S.Brenner		80
Total expected capacity gain	**0**	**0**	**0**	**0**	**0**	**0**	**7**	**7**	**7,5**	**10**	**11**	**11**	**16**	**16**	**16**	**18**	**18**	**18**	**21**	**21**	**21**	**22**	**22**	**22**	**23**	**23**	**23**			50	145

Reason for difference:
Projected Start delayed due to ....
Corrective action:
Focus on Layer Balancing project, most gain.
In case of actual capacity gap, reduce temp. Cycle Time Budget
Concern for future:
B14 Tool Performance below target (availability) Since spare supply may be a constrain to cost targets, it may be difficult to stay on target.

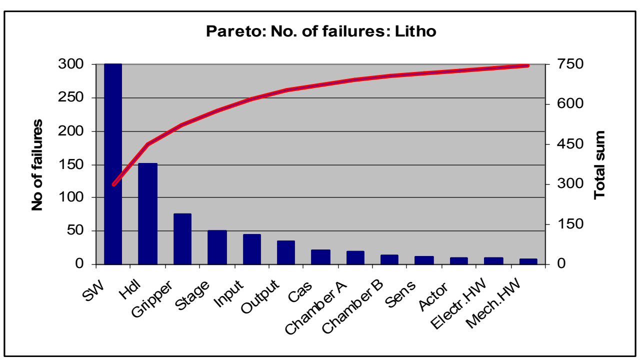
Diagram 15: Detailed implementation plan including capacity gains

Availability

It had been found out during the explore and evaluate phase, that on the shop floor the data tracking discipline had not been considered as acceptable. Also some reports, not according newer SEMI E10 standards, had been discovered. In a separate task, this had been cleaned up to have reliable data available in the near future.

Increase MTBF

A reliability team, as defined in the project charter, had been implemented, with the required experience to achieve committed improvements. Standard reliability analysis and improvement actions have been performed over time, such as *Pareto Analysis*, for continuous improvement towards new targets. Existing improvement or action plans had been incorporated in our learning plans. To support the improvements even further, *Supplier - User – Meetings* had been reactivated and the internal ‘*Best-Known Method Database’* challenged, to copy exact from best-known methods.



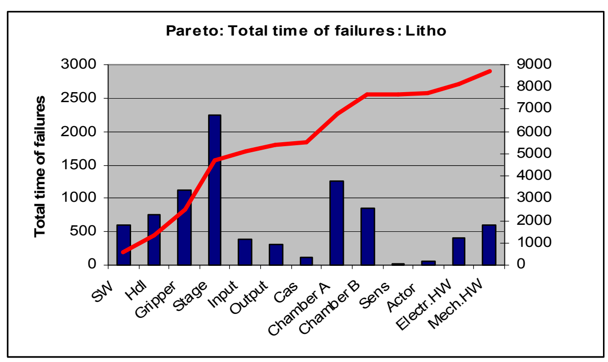


Diagram 16: Pareto chart, no. of failures (Litho)

Diagram 17: Pareto chart, total time of failures (Litho)

Degrease MTOL

Since only two maintenance shifts had been covered, cross-functional training programs, skill upgrades and implementation of *OCAP’s* (out of control action plans) had been first choice for implementation to assure night shift coverage. Assuming a tool availability of 75% and a success rate of repairs of roughly 50% in night shifts, approximately 4% improvement can be achieved easily.

Optimize Engineering Times

A quick capacity plan assessment had been performed and an offset of 1% identified and corrected (+1%).

Optimize Standby Times

A procedure, describing the business process, for all aspects of bottleneck management, is in preparation. From then on, bottleneck tools will be prioritized in respect to spare supply, no. of maintenance technicians, no operators, buffers, i.e.

Sufficient Spare Supply

An expert team had been installed with the goal, to assure sufficient spare supply for all bottleneck tools but considering other KPI's, such as cost targets, as well. All aspects such as second source supply, European wide purchase of parts, virtual stock are in consideration, but not finally decided yet.

No wait for Operator

A factory-wide operator efficiency improvement program had been started to increase operator efficiency by 10%. Parallel, proper staffing regarding factory utilization and cycle time requirements, based on our headcount model, is guaranteed. Temp to fixed operator ratio had been reconsidered to gain maximum flexibility.

Optimize transportation, continuous delivery

The behavior of central transportation should be observed carefully for unnecessary and unacceptable losses.

Buffer

Buffering is always critical and contra productive to other business KPI's. In a first set up, it is planned to double the incoming buffer capacity of bottleneck tools and observe the impact on capacity and cycle time for a period of 3 months.

Qualify min. 3 Tools per Operation

An automatic control system has been installed to control and assure that on the shop floor at least 3 tools are qualified and running per operation.

Identify sponsors for bottleneck tools

To calculate new targets for cycle time factors other than average 3x, the cycle time excel template should be fed with corrected utilization, availability, MTOL, MTTR, qualified no. of tools and all other relevant data. Driven by the utilization of bottleneck tools, sponsor tools need to be identified and new targets for cycle time factors calculated. New targets will be deployed in BBSC's.

None Semi E10 Times

The bottleneck report showed, that Litho's high-end tool group had been overloaded with 135%, the medium type of tools running only at 111%. During the explore- and evaluate phase, plenty of layers had been identified, to get transferred to the medium type of tools, without yield loss. Some minor investments had been required and released. This will lead to an average load of 123%. The gap of 23% will be closed with defined and agreed upon actions.

Control and Conform

A project is not finished until there is confidence that the gain will be held. As a minimum this involves ensuring that changes are anchored, and new ways are working are institutionalized.

Flag Diagram

A Flag diagram closes the loop. It shows in a very easy way the highest level of breakthrough goal and performance indicators of the sub-projects as branches. You can check during your review session if they deliver what you need. By having the project results in one overview the visibility is high and that makes it possible to recognize those areas where support is needed. If the indicators deviate from their targets you can react immediately to this deviation. Flag Diagram's are widely used to control all KPI's down to sub-projects. Top Flag's are reviewed once a month from factory management, others on weekly reviews in status meetings on the shop floor under the responsibility of IE.

Summary Capacity Increase

The objective of the program is to improve committed factory out capacity by more than 10% in 2004 and 2005, from thereon 5% per year without violating yield, quality and cycle time targets with no or just little investments. For the planning horizon until end of 2006, this will lead to a total capacity increase of 27%. Summing up all improvements our TOP3 bottleneck tool group, PVD, will gain 27% with the planned investments. Litho will improve 23,8%, but will miss the target of total 27% slightly. Implant as TOP1 bottleneck will gain 21,5%. Additional, not identified improvements or investment would be required to meet the target.

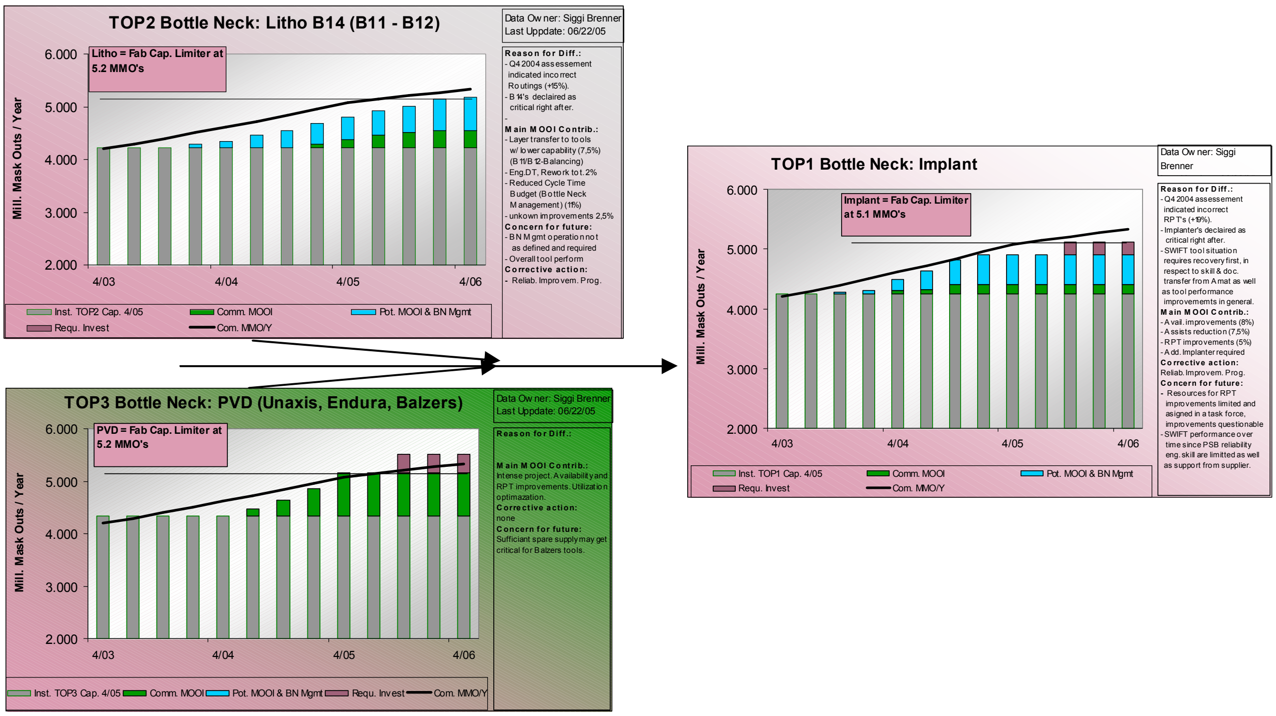


Diagram 18: Flag Diagrams of TOP 3 bottlenecks

Summary Cycle Time

Cycle Time had been considered as Secondary KPI and is controlled during regular business review meetings only. The trend in 2005 is rather positive and well within target. This proofs, that the corrective action, gain cycle time by supporting bottleneck tools by sponsors, works on the shop floor.

Summary and Conclusion

What was the real break through for this project? Nothing magic, nothing new. The breakthrough management tool assures that all aspects of project management are covered, requires a clear leadership, guarantees that the team is prioritizing, focusing and managing the real 'vital few' priorities (e.g. TOP 5 bottle neck tools) in the factory, in all means regarding productivity improvement. The improvements in 2004 fulfilled our expectations by far and will be in 2005 as well. Backbone of all of these activities is a high level of management attention and focus, strong leadership of Central Industrial Engineering and involvement of the people on the factory-floor.

References

1. Wallcace J.Hope & Mark Spearman, Factory Physics, Irwin McGraw-Hill [A book reference …]