A look in to the world of KPI's. The project consists of theoretical KPI calculations and an interview with the CEO at a company which delivers MES systems.

Work Centers KPI's

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What is a KPI?

To be successful in business a company needs to set up goals and then reach them. To ease the way toward the final goal the company needs indications to see if it is performing in the right direction. To indicate this, KPIs, or key performance indicators, are of great use. It is known that different companies have very different KPIs depending on the business and the current goals that need to be achieved. Different KPIs are used in different parts of an enterprise and can for example indicate the downtime of a certain machine or the efficiency of the workers. A KPI is derived from measurements, data or other KPIs. It is a number or a percentage amount that is always quantifiable with a formula. If the KPI is going to be of any value, the same formula needs to be used every time the KPI is calculated. The ISO 22400 is a standard that defines KPIs. It also explains how to exchange KPIs in between different MOM (manufacturing operations management) applications and the general relationship between KPIs. The ISO 22400 defines 34 different KPIs to be utilized by a company to create value. This report performs KPI calculations on 3 different connections between two units in an assumed production site. These connections affect the KPIs in different manners and the report illustrates this with a production schedule and figures along with the new KPIs.

The Usage of KPIs

KPIs can be used to evaluate and improve different parts of a company. They are indicators that can show whether a company's strategies are working or not and can therefore be helpful for a company to reach its goals and become more successful. When selecting a company's KPIs it is therefore of importance to be selective and only choose those that can help the company progress towards their goals. Having too many KPIs can be very time consuming and costly since they can be defined on to something that don't support what the company want to achieve. Another reason for not having too many is that KPIs might not be very relevant to the company and can draw focus from the ones that are actually key. Therefore, it is necessary to think before implementing different KPIs in the company whether these will contribute to anything. Things that need to be thought of before implementing are for example who they are meant for, what they would contribute to and if they are meant for long term planning or short term planning.

By monitoring a companys KPIs on a daily, monthly or quarterly basis for example, it is possible to see if the actions set by the company has made any difference and then evaluate if the company should continue with the current actions or implement others. By monitoring more frequently it is then possible to faster set new actions if the current ones do not seem to work. However, by monitoring too frequently can lead to actions being replaced when they have not had any chance to make any impact yet, and there is a chance to make rash decisions.
Another thing to bear in mind is that the company can change to other KPIs if necessary. Since new information becomes available over time, KPIs that were relevant the previous period may not be relevant at the present period and therefore should be replaced with others.
KPIs are also good because they make it easier for employees to understand what the managers expect from them. To also make the KPIs visible for the employees further clarifies how they are performing and makes it possible for them to take actions that is in the interest of these KPIs.

KPI's in the real world

A brief look at Guardus

Mr Kirsch is CEO at Guardus in Germany which is a company that develops Manufacturing Execution Systems used by companies in the production industry sector. Sectors where Guardus solutions are used are for example the automotive, aerospace, electronics and medical technology sector. The Guardus solutions belong to the leading systems in this field being implemented at over 150 companies from 22 countries. The software solutions represent the interface between the operational part and the global PPS (production planning) and ERP (enterprise resource planning) solutions. Even though different software systems might be differently tailored for the companies in question, one common detail is that every system has a small part which integrates KPIs. And the KPIs used are almost always derived according to the ISO 22400 standard.
Guardus Manufacturing Execution Systems generally provide the opportunity to incorporate KPI's since it is necessary to be able to properly analyze and evaluate the production. Everything is compatible with the ISO 22400 standard, which Andreas also claims is a very straight forward and useful aid if one wants to learn more about certain KPI's. Moreover, Andreas also leads the international work group in the ISO for Manufacturing Operation Management which has worked out the details of the ISO 22400 that took effect in January 2014. The reason there is a standard becomes very clear when it is understood what Guardus

is doing. To implement Guardus' systems, which uses KPI's, at a company is significantly facilitated if the KPI's are following a standard which the system is based on [4].

Mr. Kirsch about the usage of KPI's

Since Guardus solutions are used by a lot of companies and the fact that Mr Kirsch is very experienced in this sector he also knows a lot about how companies use these systems and thus KPI's. According to him KPI's could basically be used by anyone at a company for evaluating whatever is needed to be evaluated. There are different KPI's for different parts of a company and with a larger and more advanced production process, more KPI's are needed to get a proper overview of the whole production. Mr. Kirsch believes that any production company, independent of size, would be able to use the ISO 22400 standard. The difference is as stated before, the amount of KPI's needed to be used.
Andreas claims that KPI's are mostly used as an internal evaluation of a company even though it is possible to compare KPI's between different companies as well. Regarding comparisons between companies it also depends what KPI's that are being looked at. Some KPI's may be derived from information that isn't available for someone who isn't involved in the company's production. And if the company doesn't want to share that information it isn't easy to compare companies using exactly those KPI's [4].

Theoretical KPI scenarios

Delimitations and project structure

The calculations will be done on 3 different connections between Unit 1 and Unit 2. These 3 connections are; Serial 1, Serial 2 and Parallel Homogenous. In the Serial 1 and Parallel Homogenous, the status of the process follows a certain priority order;

1) Production
2) Break
3) Setup
4) Repair
5) Delay

E.g. if unit 1 is in delay mode but unit two is in production mode then the process is in production mode and if unit one is in break mode and unit two is in setup mode the process is in break mode. The assumption of good quality of the production depends on the scenario.

In Serial 2, both units must be in production mode for the whole process to be in production mode, thus following priority order;

1) Repair
2) Delay
3) Setup
4) Break
5) Production

The schedules for the two separate units are displayed in figure 1 to the left.

Unit 1	Unit 2
PBDT	PBDT
PBDT	PBDT
PBDT	PBDT
PBDT	PBDT
PBDT	PBDT
PBDT	PBDT
PBDT	PBDT
PBDT	PBDT
PBDT	PBDT
PBDT	PBDT
PBDT	PBDT
PBDT	PBDT
Setup	
Production	
Repair	
Production	
Delay	
Production	
Repair	
Production	
Production	
Setup	
	Setup
Break	Production
	Delay
	Production
	Production
	Break
Setup	Production
Production	Repair
Production	Delay
Production	Production
Production	Setup
Production	
Break	Setup
Production	Production
Production	Production
Delay	Production
Repair	Break
Production	Production
Setup	Production
	Production
	Setup
PBDT	PBDT
PBDT	PBDT
PBDT	PBDT
PBDT	PBDT

Figure 1: Schedules for unit 1 and unit 2 respectively

Serial 1 scenario

Serial 1: This process consists of two units, Unit 1 and Unit 2, and an inventory placed between them as figure 2 illustrates. The figure illustrates the production process from 00:00 to 24:00 with half-an-hour intervals for the first scenario. The inventory makes it possible to keep the products produced from Unit 1 stored, in wait for Unit 2 to be ready, and to keep Unit 1 operational independently the status of Unit 2. As seen in figure 1, unit 1 starts a significant time earlier than unit 2 which leads to the assumption that the inventory never is empty. The quality of the product is based on weather Unit 1 and Unit 2 achieve good quality in its production. Since Unit 1 produces more pieces than Unit 2 it is assumed that the product from Unit 1 can be sold independently.

All the schedules are collected in Appendix – Schedule where it is easier to see how the schedules have been combined.

Serial 1
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
Setup
Production
Repair
Production
Delay
Production
Repair
Production
Production
Setup
Setup
Production
Delay
Production
Production
Break
Production
Production
Production
Production
Production
Production
Break
Production
Production
Production
Break
Production
Production
Production
Setup
PBDT
PBDT
PBDT
PBDT

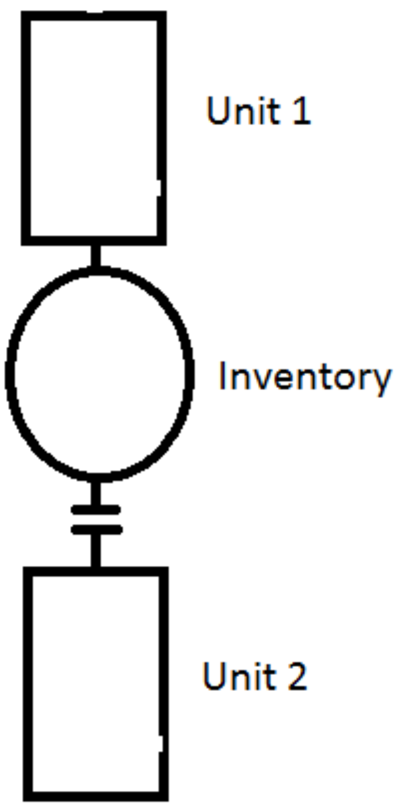

Figure 2: Scenario setup 1 and the corresponding schedule

Made up schedule		Serial 2
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT
Setup	Setup	Setup
Repair		Repair
Production		
Production	Production	Production
Production	Production	Production
Repair	Production	Repair
Production	Delay	Delay
Repair	Production	Repair
Production	Production	Production
Setup	Setup	Setup
Break	Break	Break
Setup	Setup	Setup
Delay	Production	Delay
Production	Production	Production
Production	Production	Production
Production	Production	Production
Production	Production	Production
Break	Break	Break
Production	Repair	Repair
Production	Delay	Delay
Production	Production	Production
Production	Setup	Setup
Production		
Setup		
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT
PBDT	PBDT	PBDT

Serial 2 scenario

This scenario is similar to scenario 1 except for the removed inventory between Unit 1 and Unit 2, meaning that if any of the two units are out of order, the whole production stops. Scenario 2 is illustrated in figure 3. Here, to make sense of the serial coupling, the schedule of the two units have been changed. Because Unit 1 and 2 now are dependent of each other, it doesn't make sense to start Unit 1 4 hours before Unit 2, thus the change in the schedule. The production schedule is "optimized" (thus setup, break and production are chosen to fit between the units) to fit as good as possible and delay and repair are randomly introduced by a random function in Excel. The same amount of delays and repairs as introduced in the original unit schedules are used. The figure illustrates the production process from 00:00 to 24:00 with half-an-hour intervals for the second scenario.

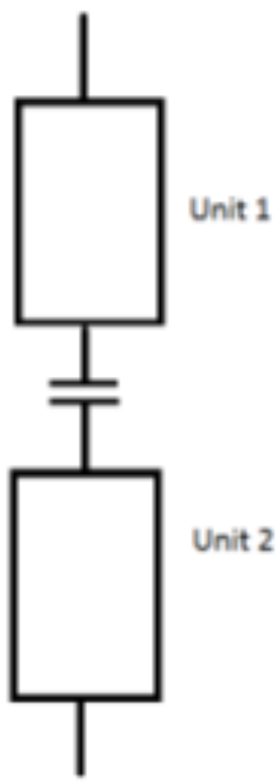

Figure 3: Scenario setup 2 and the corresponding schedule

Parallel homo 1
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
PBDT
Setup
Production
Repair
Production
Delay
Production
Repair
Production
Production
Setup
Setup
Production
Delay
Production
Production
Break
Production
Production
Production
Production
Production
Production
Break
Production
Production
Production
Break
Production
Production
Production
Setup
PBDT
PBDT
PBDT
PBDT

Parallel Homogenous scenario

This scenario consists of the same units as the scenarios before, but with the adjustment that they are working in parallel doing the same thing. This means they can produce independently of each other. Worth noting is that the production schedule becomes the same as for scenario 1, only the number of pieces produced will differ. If a scenario having parallel units, producing different products, it's the same in every manner to scenario 2 and if inventories are added, to scenario 1. Figure 4 illustrates the parallel homogenous scenario with a boolean condition always set to 1.

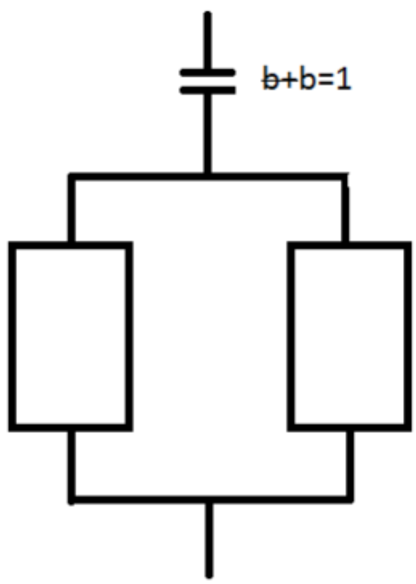

Figure 4: Scenario setup 3 and the corresponding schedule

Calculation method

Serial 1

The SQ is simply the sum of the SQ for unit 1 and unit 2, as we assumed that the half finished products from unit 1 were sellable even if not finished and gone through unit 2. This holds for the RQ as well. The good quantity is taken as the good quantity output from unit 2, as that is the good quantity actually produced. Then we have another 42 units that went through unit 1 but not unit 2 and will be sold as half finished. The PRTU will be the sum of the PRTU for unit 1 and unit 2 as every product will have to go through both units.

Serial 2

The PRTU in this case is the sum of the PRTU from unit 1 and unit two, because just as in serial 1 the product has to go through both units. The PQ is calculated as taken the average amount of products produced in every hour times the number of hours we have production. The average number of products produced per hour is 40, which gives a PQ of 320. The good quantity is taken as the same percentage of the produced quantity as for serial 1. This number is rounded to the closest integer. The RQ, PSQ and SQ are also calculated in this way a rounded to the closest integer.

Parallel homogenous

Since the scenario with parallel units have the same production schedule as scenario 1 with units in serial all of the KPIs that are just time-based will have the same values, which is seen in KPIs. However, the KPIs that also depends on the number of produced items becomes different from scenario 1 with the units in serial since the number of items produced between these two scenarios differs. The PRTU for the parallel scenario has simply been divided by two, assuming that the two units work about equally much. For PQ, GQ, RQ, PSQ and SQ the values for unit 1 and unit 2 have just been added to each other since the two units in the parallel scenario works independently.

Results

Based on the calculations described above the following result was given:

KPI (unit)	Unit 1	Unit 2	Serial 1	Serial 2	Parallel	Comment
APT (min)	390	330	600	240	600	
AUST (min)	120	120	120	120	120	
ADET (min)	60	60	60	90	60	
TTR (min)	90	30	60	120	60	
PBDT (min)	480	480	480	480	480	
PBRT (min)	60	60	90	60	90	
AUPT (min)	510	450	720	360	720	APT+AUST
AUBT (min)	660	540	840	570	840	APT+AUST+ADET+TTR
PBT (min)	900	900	900	900	900	
PRTU (min/Pcs)	0,3	0,3	0,6	0,6	0,15	first 500 pcs respective first 450 pcs
PRTU (min/Pcs)	30	30	60	60	15	Pcs above 500 resp. 450
PQ (Pcs)	508	456	456	320	964	
GQ (Pcs)	456	414	414	291	870	
RQ (Pcs)	10	10	20	14	20	
PSQ (Pcs)	27	24	51	36	51	
SQ (Pcs)	42	32	74	52	74	
Utilisation efficiency (%)	59,09	61,11	71,428571	42,10526	71,428571	APT/AUBT
Setup Ratio (%)	23,53	26,67	16,666667	33,33333	16,666667	AUST/AUPT
Technical efficiency (%)	72,22	78,57	83,333333	53,33333	83,333333	APT/(APT+ADET+TTR)
Allocation efficiency (%)	73,33	60	93,333333	63,33333	93,333333	AUBT/PBT
Availability (%)	43,33	36,67	66,666667	26,66667	66,666667	APT/PBT
Effectiveness (%)	100	95,45	75,3	40	58,75	(PRTU1*PQ+PRTI2*PQ)/APT
Quality ratio (%)	89,76	90,79	90,789474	90,9375	90,248963	GQ/PQ
Scrap ratio (%)	8,27	7,02	16,22807	16,25	7,6763485	SQ/PQ
Rework ratio (%)	1,97	2,19	4,3859649	4,375	2,0746888	RQ/PQ
Actual to planned scrap ratio (%)	155,56	133,33	145,09804	144,4444	145,09804	SQ/PSQ
OEE (%)	38,89	31,78	45,576316	9,7	35,34751	Avail*Effec*Quali
NEE (%)	50,86	43,33	54,691579	14,55	42,417012	AUPT/PBT*effec*quality
MTBF (min)	150	240	260	96	260	(AUST+APT+TTR)/(number(FE)+1)
MTTF (min)	127,5	225	240	72	240	(AUST+APT)/(number(FE)+1)
MTTR (min)	22,5	15	20	24	20	TTR/(number(FE)+1)

The data in the two columns labeled as Unit 1 and Unit 2 are taken from [2]. Serial 1, Serial 2 and Parallel are of course the result for the three scenarios described earlier. Some of the calculations are not from the ISO 22400-2 standard but they need no more explanation than the one given in the dictionary found in Appendix. The ones marked with a * isn't a part of the ISO 22400-2 standard.

Discussion

There is not much use in comparing the KPI's between the different production scenarios. For example when the units are coupled serially and every product has to go through both units that means the PRTU will be twice as large compared to the parallel coupling. This will instead have to be thought of as different products being produced in the different scenarios. For the serial coupling without a tank between the units we also changed the schedule around, which makes for quite unfair comparison.

However in all real world scenarios it is apparent that the use of KPI has great benefit for an enterprise. As noted in the interview with Andreas, KPI can benefit enterprise in vastly different sectors and of vastly different sizes. What is important to understand then is which KPI's are the most important ones, and how many need to be used. One can use KPIs in many ways, for scenario analysis and also with benchmark KPI's to get an idea of the performance of different parts of the enterprise relative to its peers.

Doing the calculations, it becomes clear that the ISO 22400 standard doesn't tell how to combine KPIs from different units and some of the numbers become somewhat deceptive. Like the ones that include APT and PQ in the serial scenarios, where unit 1 produces more products than unit 2. Under the assumption that the product from unit 1 can be sold separately that unit still contributes to the benefit of the company. The KPI calculations does not include unit 1's exceeding production which results in a situation where the production actually is better than what the KPI's are showing.

References

[1] International standard; ISO 22400-2; 2014. *Automation systems and integration – Key performance indicators (KPIs) for manufacturing operations management - Part 2: Definitions and descriptions.*

[2] ISO 22400-10. *Automation and integration: Manufacturing Operation Management – Operational sequence description of data acquisition.*

[3] ISO/TC 184/SC 22400-10 TR Examples. *Key performance indicators for manufacturing operations management.* N54.

[4] Telephone interview with Andreas Kirsch, CEO at Guardus, 17/5 2016

Appendix – Dictionary

Dictionary	*=not iso-standard
ADOT	Actual unit down time
APT	Production
AUST	Setup
ADET	Actual unit delay time
TTR	Time to repair
PBDT*	Planned break down time
PBRT*	Planned break time
AUPT	Actual unit processing time
AUBT	Actual unit busy time
PBT	Planned busy time
PRTU*	Planned run time per unit
PQ	Produced quantity
GQ	Good quantity
RQ	Rework quantity
PSQ	Planned scrap quantity
SQ	Scrap quantity
OEE	Overall equip. Effectivness
NEE	Net overall equip. effectivness index
MTBF*	Mean time between failures
MTTF*	Mean time to failure
MTTR*	Mean time to repair

Appendix – Schedule

	Unit 1	Unit 2	Serial 1	Parallel homo 1	Made up schedule		Serial 2
00:00	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
00:30	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
01:00	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
01:30	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
02:00	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
02:30	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
03:00	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
03:30	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
04:00	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
04:30	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
05:00	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
05:30	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
06:00	Setup		Setup	Setup	Setup	Setup	Setup
06:30	Production		Production	Production	Repair		Repair
07:00	Repair		Repair	Repair	Production		
07:30	Production		Production	Production	Production	Production	Production
08:00	Delay		Delay	Delay	Production	Production	Production
08:30	Production		Production	Production	Repair	Production	Repair
09:00	Repair		Repair	Repair	Production	Delay	Delay
09:30	Production		Production	Production	Repair	Production	Repair
10:00	Production		Production	Production	Production	Production	Production
10:30	Setup		Setup	Setup	Setup	Setup	Setup
11:00							
11:30		Setup	Setup	Setup			
12:00	Break	Production	Production	Production	Break	Break	Break
12:30		Delay	Delay	Delay			
13:00		Production	Production	Production			
13:30		Production	Production	Production			
14:00		Break	Break	Break			
14:30	Setup	Production	Production	Production	Setup	Setup	Setup
15:00	Production	Repair	Production	Production	Delay	Production	Delay
15:30	Production	Delay	Production	Production	Production	Production	Production
16:00	Production	Production	Production	Production	Production	Production	Production
16:30	Production	Setup	Production	Production	Production	Production	Production
17:00	Production		Production	Production	Production	Production	Production
17:30	Break	Setup	Break	Break			
18:00	Production	Production	Production	Production	Break	Break	Break
18:30	Production	Production	Production	Production			
19:00	Delay	Production	Production	Production	Production	Repair	Repair
19:30	Repair	Break	Break	Break	Production	Delay	Delay
20:00	Production	Production	Production	Production	Production	Production	Production
20:30	Setup	Production	Production	Production	Production	Setup	Setup
21:00		Production	Production	Production	Production		
21:30		Setup	Setup	Setup	Setup		
22:00	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
22:30	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
23:00	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT
23:30	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT	PBDT