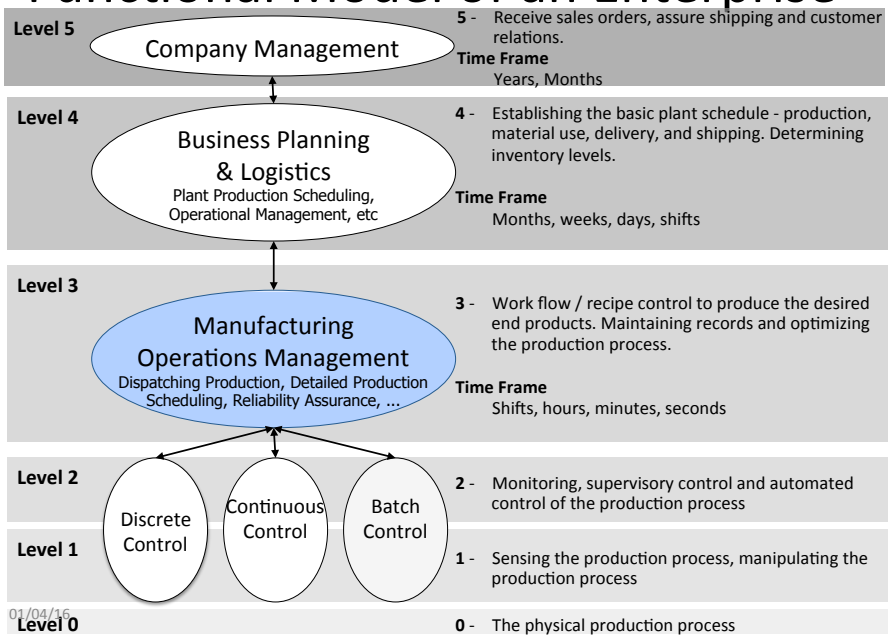
Market-Driven Systems

Marknadsstyrda System

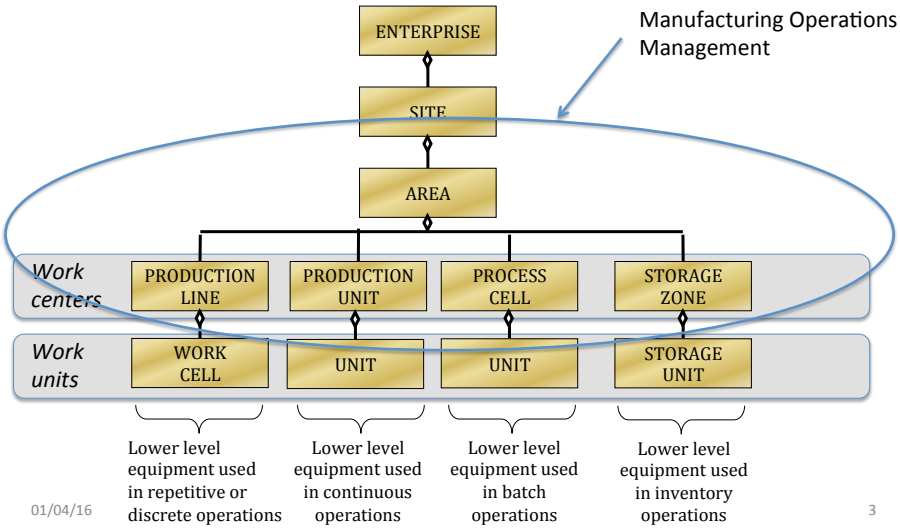
FRTN20

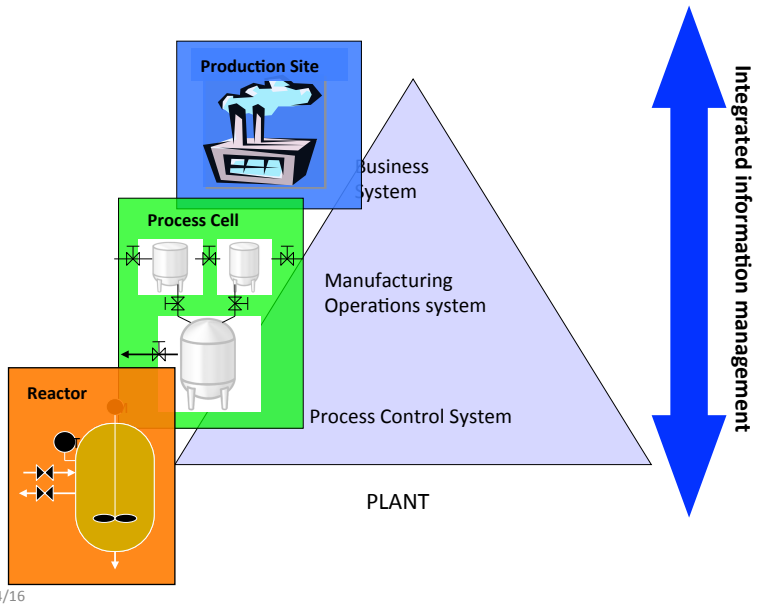
Lecture 4 –Key Performance Indicators (KPI)

Functional Model of an Enterprise



Physical Model of an Enterprise



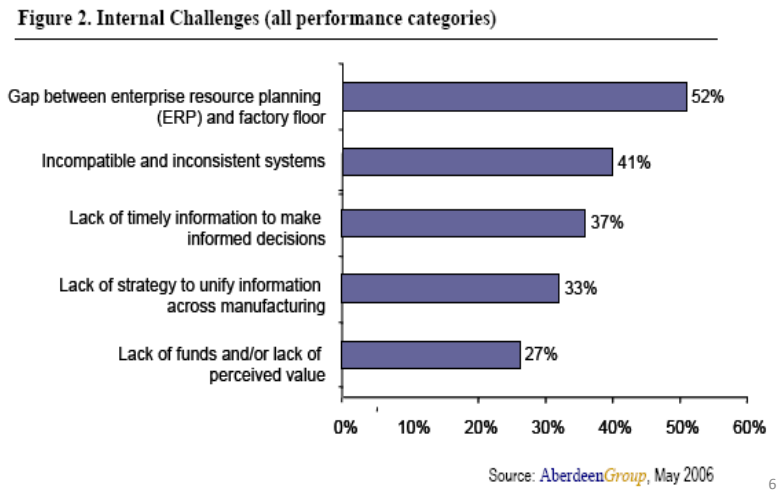


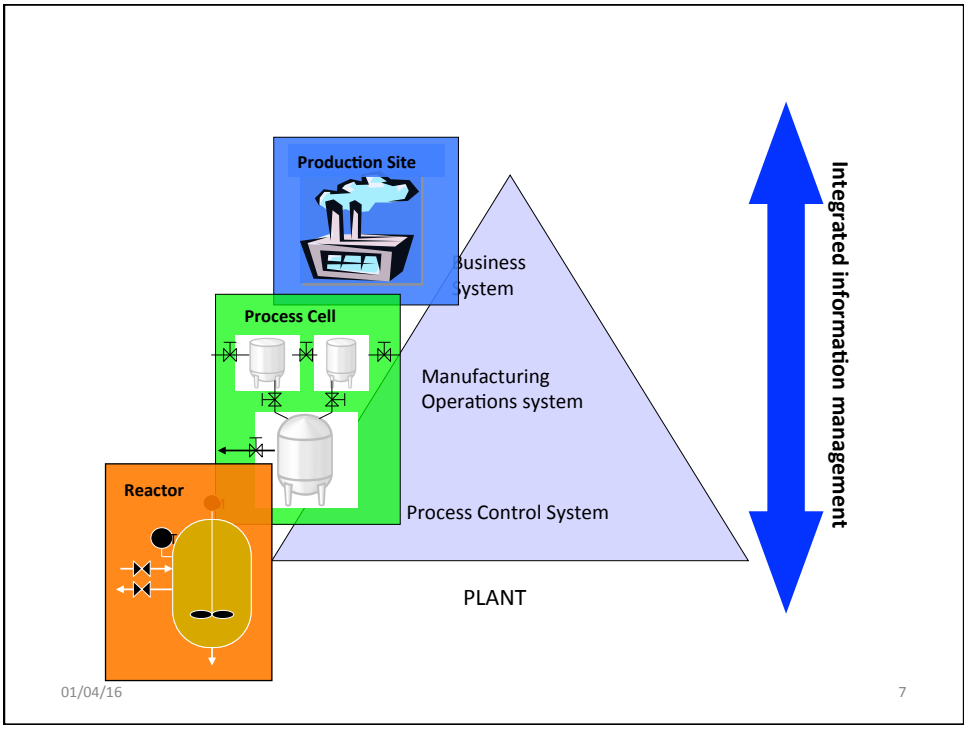
Visibility into plant operations is now being seen as a major hurdle to improving business performance

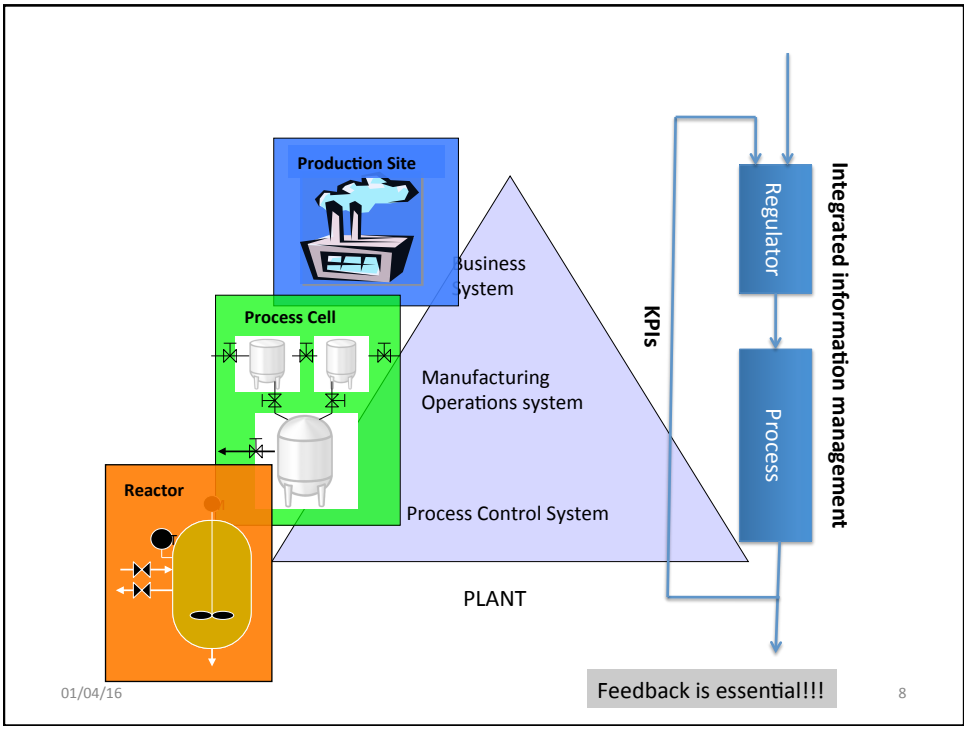
(Source: Forrester Research)

What are your biggest problems with global manufacturing?" Percentage of 50 global manufacturing companies responding:	
Poor visibility into plant operations	38%
Inaccurate demand forecasting	36%
Poor communication	24%
Supply shortfalls	18%
Poor customer satisfaction	8%

What Manufacturers Consider the Major Challenges they are Facing!




Production Site
Business System
Process Cell
Manufacturing Operations system
Reactor
Process Control System
PLANT
Integrated information management
01/04/16
7


Production Site
Business System
Process Cell
Manufacturing Operations system
Reactor
Process Control System
PLANT
KPIs
Regulator
Process
Integrated information management
Feedback is essential!!!
01/04/16
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Key Performance Indicators

- Key performance indicator (KPI) is a measure of performance.
- Such measures are commonly used to help an organization define and evaluate how successful it is, typically in terms of making progress towards its long-term organizational goals.
- KPIs can be specified by answering the question ”**What is really important to different stakeholders**?”. KPIs may be monitored using Business Intelligence techniques to assess the present state of the business and to assist in prescribing a course of action. The act of monitoring KPIs in real-time is known as **Business Activity Monitoring (BAM)**.
- There are Marketing-KPIs, Supply-chain-KPIs, Production-KPIs etc.

KPI in Process Control - Definitions

- **Variable Costs** or **Direct Variable costs** (”rörliga kostnader”)
  - Costs that depends on the production
  - Raw material costs, production-related energy costs
  - Cp OPEX (operating Expenditures)
- **Fixed costs** (”fasta kostnader”)
  - Costs that are independent on how much that is produced
  - Salary, depreciation of equipment and machines, rent, heating, maintenance
  - Cp CAPEX (Capital Expenditures)

KPI in Process Control - Definitions

- **Contribution margin** (”täckningsbidraget”)
  - The price for a product minus the variable cost
  - Must cover the fixed costs
  - The rest contributes to the profit
  - Varies depending on
    - Market
    - Raw material costs
    - Energy costs
- **Constrained by the market** (”marknadsbegränsad”)
  - A production system is constrained by the market if it is not running at maximum capacity due to market reasons
  - No possibility to increase the profit by increasing the production
  - Instead reduce variable costs or improve the quality

KPI in Process Control - Definitions

- **Availability** (”tillgänglighet”)
  - How large part of the time that the system has been producing
  - Percentage over, e.g., a year
  - E.g., 70% - 99.5%
- **Downtime** (”stopptid”)
  - Inverse of availability
- **Production rate** (”produktionstakt”)
  - Product per time unit
  - Tonne/h, kg/h, …
- **Production capacity** (”produktionskapacitet”)
  - The theoretical maximum amount of in-spec product that can be produced per time unit
- Mathematical definitions are found in ISO 22400

KPI in Process Control - Definitions

- **Effectiveness** (”anläggningsutnyttjande”)
  - The actual production as a percentage of the production capacity
  - Mathematical definition in ISO 22400
- Example:
  - Production in April = 5272 tonne
  - Downtime 94 hours out of 744 → 12,6%
  - Availability = 87.4%
  - Average production rate = 5272/(744-95) = 8.1 tonne/hour
  - Production capacity = 220 tonne per 24 hour = 6280
  - Effectiveness in April = 5272/6280 = 77.3%

KPI in Process Control - Definitions

- Product that does not meet the specifications is off-spec
  - Downgrade to a lower quality (less profit)
  - Reject
- **Overall Equipment Efficiency** (OEE)
  - Efficiency measure that also takes quality into account
  - OEE = Availability*Effectiveness*Quality
  - (”TAK = Tillgänglighet * Anläggningsutnyttjande * Kvalitet”)
  - However, some companies use production rate instead of effecitiveness
  - Amount of produced product of the right quality
  - Mathematical definition in ISO 22400

KPI in Process Control - Definitions

- **Yield** (”utbyte”)
  - Measures how effectively the raw material is used
  - Kilo product / kilo raw material
  - Mathematical definition in ISO 22400
- Several of the above quantities can be used as Key Performance Indicators (KPIs)
  - ”nyckeltal”
  - Economical
  - Technical
    - E.g. reasons for stops, yield, important flows and concentrations, energy balances

Improvements of Continuous Production Plants

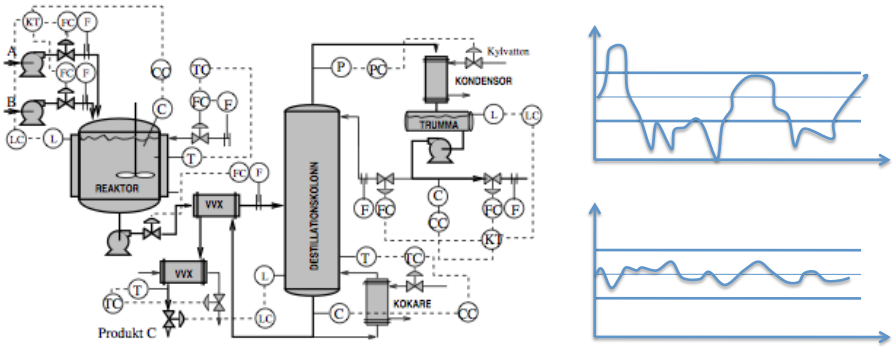
- Control performance
  The control performance is often regulatory, e.g. holding a measured and/ or computed quantity at its desired value.
- Process performance
  The process performance is a measure of how well the process meets its objectives. This could for example be production rate.
- Economic performance
  The economic performance is measured in financial terms, e.g., financial production rate which is expressed as Money (Euros/dollars/SEK) per production time.

=> The most important performance measurements are refered to as KPIs

Control Improvements

- Control improvements → smaller variations
  - Increase the production rate
    - Set point closer to upper ”safety limit”
  - Decrease consumption of energy or raw material
    - Set point closer to lower ”quality” limit
  - In both cases the setpoint must really be changed
    - ”target shift”

Control Improvement



The plant improves the control of concentration in the reactor. The variation in the concentration is reduced by 40% (**control improvement**)

Reasons for Control Improvements

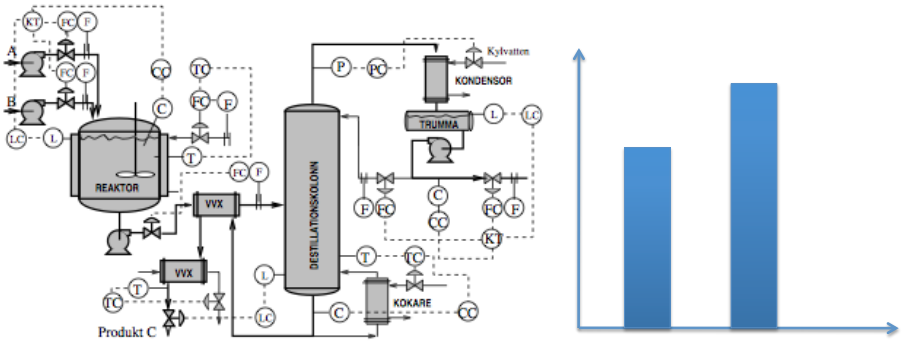
- Automatic instead of manual control
- Better controller tuning
- Change in controller structure (e.g, PID instead of PI)
- Change control loop structure
  - Use different measurements
  - Move sensors and actuators
- Change sensors and actuators
  - Better sensors and actuators
- ……..

Examples of Process Improvements Caused by Control Improvements

- Increased production rate
- Faster change over times
- Faster start up times
- Improved quality
- Decreased raw material and enercy consumption
- Lower utility costs
- Less labor
- Fewer unwanted byproducts
- Better yield

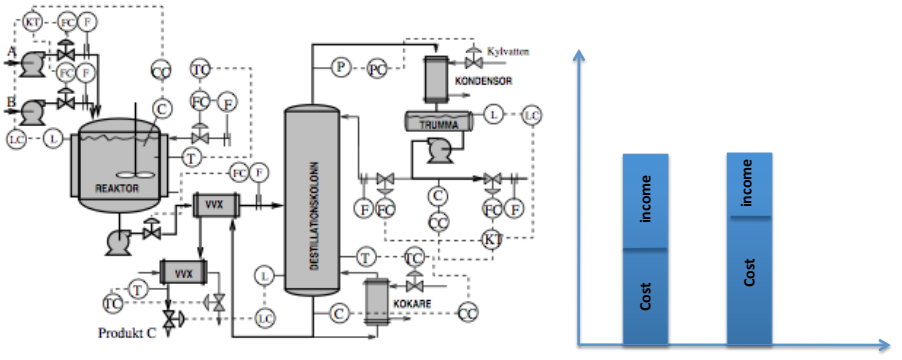
Economic improvement: Process Improvements stated in term of increased profit (€, $, SEK)

Process Improvement



The plant improves the control of concentration in the reactor. The variation in the concentration is reduced by 40% (**control improvement**). The control improvements allow the elimination of delays for product analysis, so the plant can not turn out 10% more product per day (**process improvement**).

Economic Improvement



If there is market for the additional product, there will be an economical improvement.

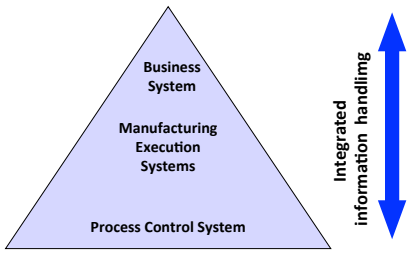
If there is no market for the additional product, there will be an economical net loss since the aditional product will require additional raw material.

KPIs – ISO 22400

- There is an ongoing activity defining the KPIs used in Manufacturing
- ISO 22400 Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management

ISO 22400

- Multi-part standard
  - Part 1: Overview, concepts and terminology
  - Part 2: Definitions and descriptions
  - Part 3: Exchange and use
  - Part 4: Relationships and dependencies
- So far, focus has been on part 2 and 1



ISO 22400 – Part 2

- Subtitle: Definitions and descriptions of KPIs

- Published 2014
- What does it contain?
- Chapter 6: Description of KPIs
  - 34 KPIs are described through their name, Formula, UoM, Effect model, etc
- The elements in the formula are listed in Chapter 5
- The structure of the KPI definition is given in Chapter 4
- The effect models (root-cause) are presented in AnnexA

Description of KPIs

KPI definition	
Content:	
Name	
ID	
Description	
Scope	
Formula	
Unit of measure	
Range	
Trend	
Context:	
Timing	
Audience	
Production methodology	
Effect model diagram	
Notes	(Here is space for constraints, usage and other info)

Example: 6.1 Worker Efficiency

KPI definition	
Content	
Name	Worker Efficiency
ID	
Description	The worker efficiency considers the relationship between the Actual personnel work time (APWT) related to production orders and the actual personnel attendance time (APAT) of the employee.
Scope	Personnel
Formula	Worker Efficiency = APWT / APAT
Unit of measure	%
Range	Min: 0% Max: 100%
Trend	The higher the better
Context	
Timing	Periodically
Audience	Supervisor, management
Production methodology	Discrete, batch, continuous
Effect model diagram	see A.3
Notes	When calculating worker efficiency be careful of possible double counts if the worker is working on several work units or production orders simultaneously

Example: Worker Efficiency

5.1.3.1. Actual Personnel Work time (APWT)

The actual personnel work time shall be the time that a worker needs for the execution of a production order.

5.1.3.5. Actual Personnel Attendance Time (APAT)

The actual personnel attendance time shall be the total time that worker is available to work on production orders. It does not include actual time for company authorized break periods (i.e. lunch). It is the difference between login and logout excluding breaks.

Example: Worker Efficiency

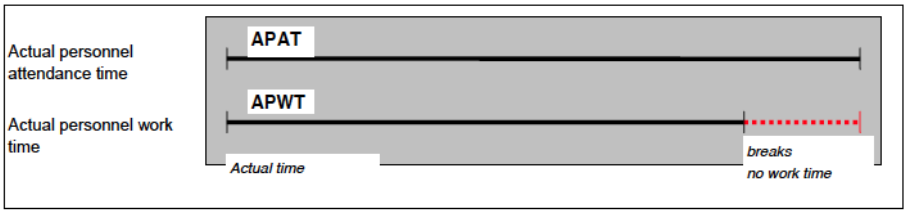


Figure 5 - Time lines for personnel

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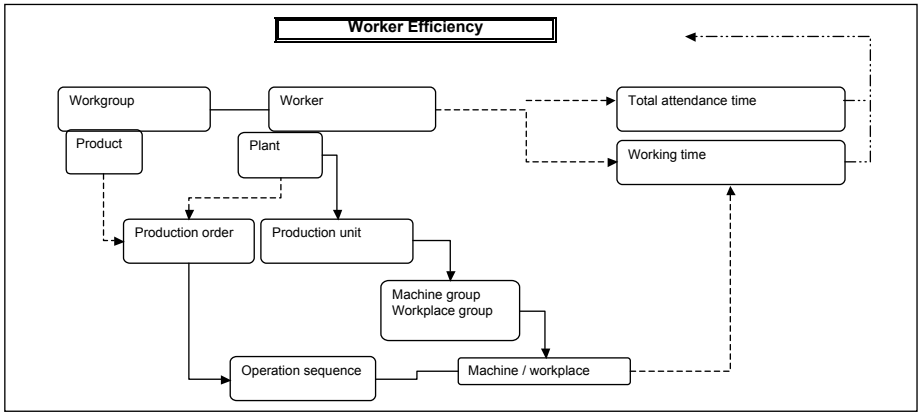
Example: Worker Efficiency



A 1. Effect Model for Worker Efficiency

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Example: Overall Equipement Effectiveness Index

KPI definition	
Content	
Name	Overall Equipment Effectiveness Index
ID	
Description	The OEE Index represents the availability of a work unit (see **Error! Reference source not found.**), the effectiveness of the work unit (see **Error! Reference source not found.**), and the quality ratio (see **Error! Reference source not found.**) KPI's integrated in a single indicator.
Scope	Work unit, product, time period, product, defect types
Formula	OEE Index = Availability * Effectiveness * Quality ratio
Unit of measure	%
Range	Min: 0% Max: 100%
Trend	The higher, the better
Context	
Timing	On-demand, periodically, real-time
Audience	Operator. supervisor, management
Production methodology	Discrete, batch, continuous
Effect model diagram	See A.8
Notes	Overall Equipment Effectiveness (OEE) is an indicator for the efficiency of work units, work centres' and areas with several work units or an entire work centre. The OEE Index forms the basis for improvements by better production information, identification of production losses, and improvement of the product quality by optimized processes. The calculation of OEE based on the hierarchy structure (see fig 2) is only useful if the characteristic of the work unit processes would be comparable. Before starting a benchmark based on the OEE index the criteria for a comparability should be checked.

Example: Availability

KPI definition	
Content	
Name	Availability
ID	
Description	Availability is a ratio that shows the relation between the actual production time (APT) and the Planned busy time (PBT) for a work unit..
Scope	Work unit, product, time period, product
Formula	Availability = APT / PBT
Unit of measure	%
Range	Min: 0% Max: 100%
Trend	The higher, the better
Context	
Timing	On-demand, periodically
Audience	Supervisor, management
Production methodology	Discrete, batch, continuous
Effect model diagram	See A.10
Notes	Availability indicates how strongly the capacity of a work unit for the production is used in relation to the available capacity. The term availability is also called degree of utilisation or capacity factor.

Example: Availability

5.1.3.6. Actual production Time (APT)

The actual production time shall be the time during which a work unit is producing. It includes only the value-adding functions.

5.1.2.4. Planned Busy Time (PBT)

The planned busy time shall be the operating time minus the planned downtime.

Note: The planned down time can be used for planned maintenance work. The planned busy period is available for the detailed planning of the work unit for expected production orders.

Example: Availability

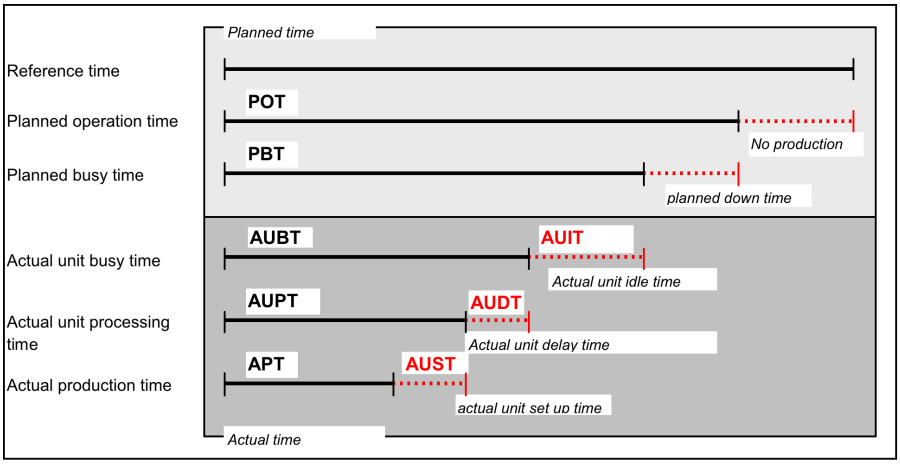
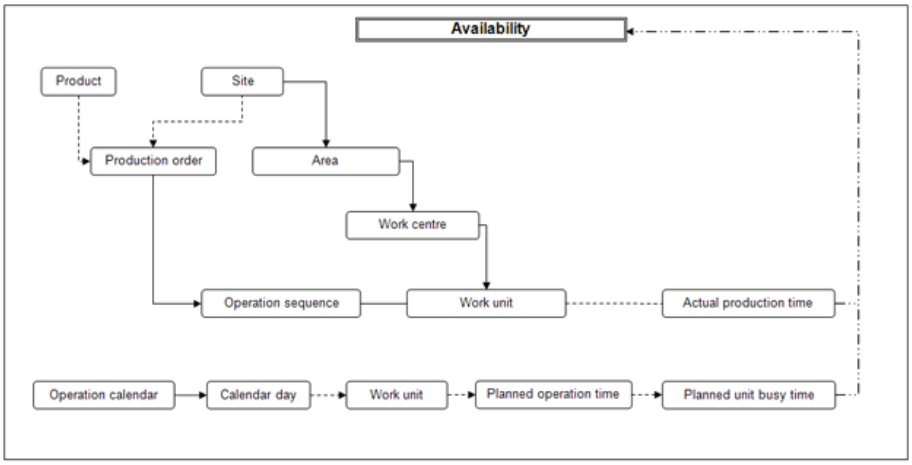


Figure 3 - Time lines for work units

Example: Availability



A 8. Effect Model for Availability

KPIs defined

The following 34 KPIs are defined in ISO 22400 – Part 2

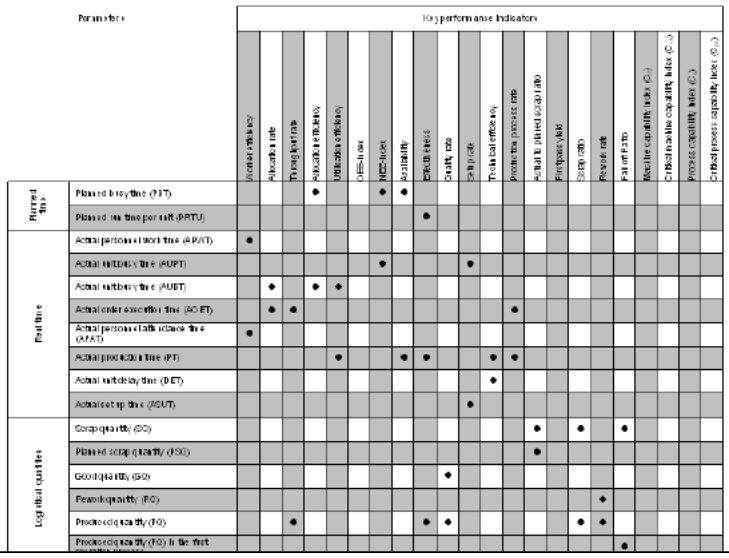
8.1 Worker Efficiency
8.2. Allocation Ratio
8.3. Throughput rate
8.4. Allocation efficiency
8.5 Utilization efficiency
8.6. Overall equipment effectiveness index
8.7 Net equipment effectiveness index
8.8 Availability
8.9 Effectiveness
8.10 Quality Ratio
8.11 Setup Rate
8.12 Technical efficiency
8.13 Production process ratio
8.14 Actual to planned scrap ratio
8.15 First pass yield
8.16 Scrap ratio
8.17 Rework ratio

KPIs defined

The following 35 KPIs are defined in ISO 22400 – Part 2

8.18 Fall off ratio
8.19. Machine capability index
8.20 Critical machine capability index
8.21 Process capability index
8.22 Critical process capability index
8.23 Comprehensive energy consumption
8.24 Inventory turns
8.25 Finished goods ratio
8.26 Integrated goods ratio
8.27 Production loss ratio
8.28 Storage and transportation loss ratio
8.29 Other loss ratio
8.30 Equipment load ratio
8.31 Mean operating time between failures
8.32 Mean time to failure
8.33 Mean time to restoration
8.34 Corrective maintenance ratio

Parameter-Indicator Matrix



ISO 22400

- Part-1: Overview, concepts and terminology
- Part-2: Definitions and descriptions
- Part-3: Exchange and use (draft)
- Part-4: Relationships and dependencies (draft)

ISO 22400 – Part 1

- Subtitle: Overview, concepts and terminology

- Published 2014
- What does it contain?
  - Concept of KPIs (Chapter 4)
  - Definitions and descriptions - Part2 (Chapter 5)
  - Exchange and use – Part3 (Chapter 6)
  - Relationships and dependencies – Part4 (Chapter 7)

ISO 22400 – Part 1

- Subtitle: Overview, concepts and terminology
- Chapter 4: Concept of Key Performance Indicators
  - General
  - Criteria for KPIs
  - Characterisation of KPIs
  - Types of KPIs
  - Categories of KPIs
  - Generating KPIs
  - Identification and Selection
  - Structure of KPI
  - Presentation of KPI

Types of KPIs

- Ratio: a functional relation between two elements of the same unit-of-measure
- Utilization: a ratio with time as the unit of measure.
- Efficiency: …
- Effectiveness: …
- Rate: a functional relation between two elements of differnet UoM where the unit of the denominator is time.
- Capability index: ….

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ISO 22400 – Part 1

- Subtitle: Overview, concepts and terminology
- Chapter 5: Definitions and Descriptions (Part2)
  - General model
  - Table structure of KPI (table format)
  - Root cause diagram (Effect models)
- Chapter 6: Exchange and Use (Part3)
  - General
  - Abstract structure (UML structure)
- Chapter 7: Relationships and dependencies
  - General
  - Model of Relationship and dependencies
  - Effectiveness of KPIs
  - Maturity Model

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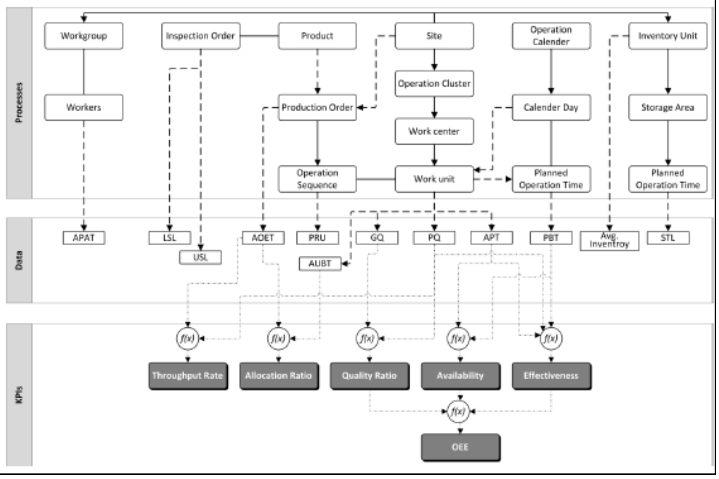
ISO 22400 – Part 1

- Subtitle: Overview, concepts and terminology
- Chapter 7: Relationships and dependencies (Part4)

If you change one KPI, another one might be effected.



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Do the KPIs fit all industries?

Name / Title of indicator:	Worker Efficiency
Description	
Benefit / Application:	Provides information about the ratio of production order related working hours of employees in relation to the total attendance time of the employees.
Time behaviour	Periodic
Definition and Calculation	
Formula:	Worker Efficiency = WOT / TAT
Unit/Dimension:	%
Rating:	Min: 0% Max: 100% Trend: the higher the better
Analysis / Drill Down:	Based on working group
Remarks	
Notes / Explanation:	It has to be noted that the work time relating to orders of the worker is to be divided accordingly if the worker works on several workplaces at the same time. .
Corporate level	Master, Chief, Management
Effect model:	see A.3
industrial sectors:	continuous, batch, discrete

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All industries?

- A small study is being performed examining how well the proposed KPIs fit to the process industry.
- Example: First pass yield. Allocation degree

Are there any business reasons for using KPIs?

A company is considered a *Business Mover*
if it has improved:

a) More than 10% on one or many of the financial metrics

b) More than 1% on over half of the finacial metrics

From: MESA and Industry Directions survey "Metrics that Matter", Oct 2006.

Characteristics of *Business Movers*	
Definition: Level of Business Improvement	Improved over 10% on one or improved over 1% on six of 11 business/finance metrics in survey
Metrics Capability	***Business Movers* Difference**
Operations and business metrics effectively linked	67% more likely to be at least somewhat effective (65% vs. 39%)
Metrics data collection automation	50% more likely to have fully automated (15% vs. 10%)
Timeliness of displaying KPIs to operators whose activities they reflect	Over 2.5 times as likely to display results to operations in 24 hours or less (46% vs. 18%)
Latency between business metrics and operations that caused results	43% more likely to have weekly or 24 hours latency (50% vs. 35%), less likely quarterly or annually (10% vs. 16%)
Use of MES & operations dashboards	33% use MES vs. 25% of others; 33% use dashboards vs. 17%
Results	***Business Movers* Edge**
Know what they measure for business	Over six times less likely to answer "don't know what metrics are in use"
ROI on applications	31% of applications achieved ROI in under two years vs. 11% for others
Improvements against operations KPIs	Over 2.75 times as likely to improve over 10% on at least one operations KPI or over 1% on 10 operations KPIs (83% vs. 22%)

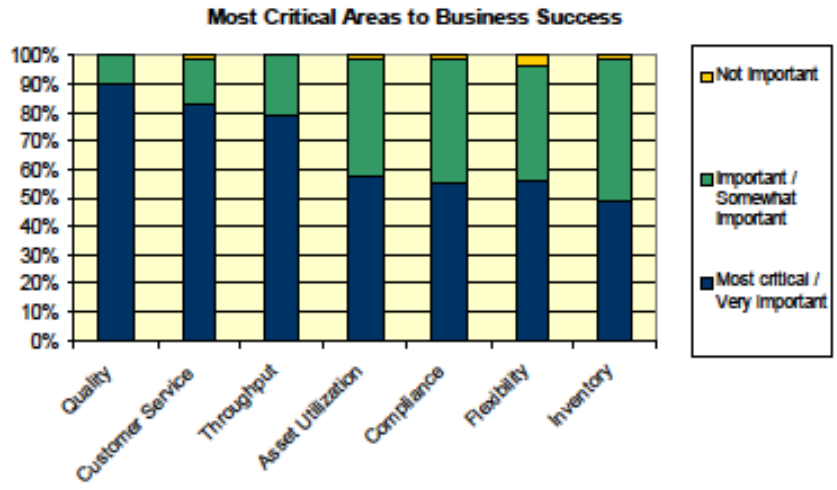
Are there any business reasons for using KPIs?

Typical for Business movers is that they:

1) Have well defined KPIs
2) Have informed employees
3) use IT systems to get measurements, calculate Kpis and display the results.

From: MESA and Industry Directions survey ”Metrics that Matter”, Oct 2006.

Are there any business reasons for using KPIs?



From: MESA and Industry Directions survey ”Metrics that Matter”, Oct 2006.

SUMMARY

- ISO 22400 is a standard about Key Performance Indicators (KPIs) for Manufacturing Operations Management (level 3)
- The standard defines commonly used KPIs within level 3.
- 34 KPIs are defined
- Part 1 and Part 2 was released in 2014
- Part 3 and Part 4 – work is ongoing.

- Using KPIs has shown to be successful when improving the performance of a company!

Functional Model of an Enterprise