Co-funded by the Erasmus+ Programme of the European Union

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Performance Measurement System (PMS)

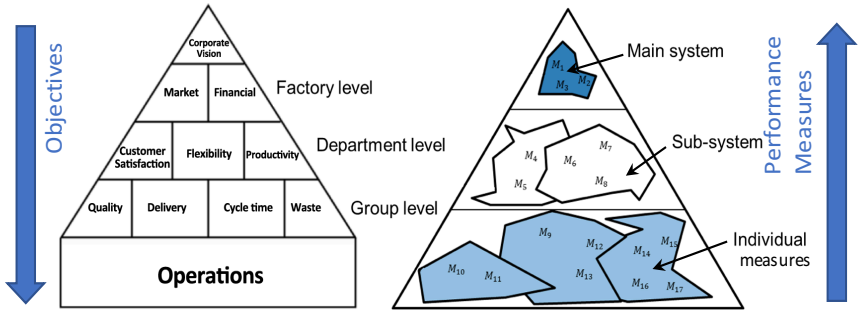
Standards and Data integration

Agenda

- Performance Measurement System (PMS)
- International Standards
- Key Performance Indicators (KPIs)
- A tree-like structure of KPIs for lean production

The performance pyramid

Adapted from (Cross and Lynch, 1992) and (Tangen, 2004)



OBJECTIVEs are defined from the top to the bottom
PERFOMANCE MEASURES from the bottom back to the top

Performance are inter related (horizontally) and cross related (vertically)

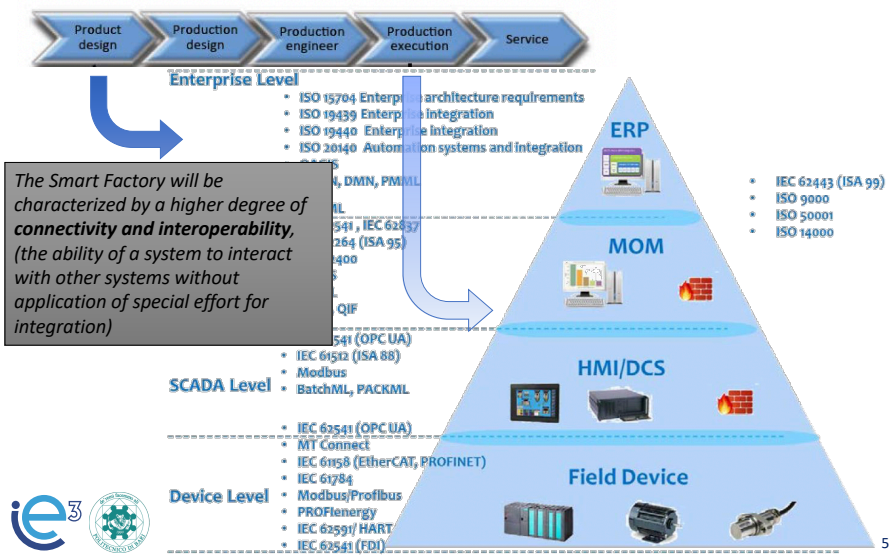
The performance pyramid

Adapted from (Cross and Lynch, 1992) and (Tangen, 2004)

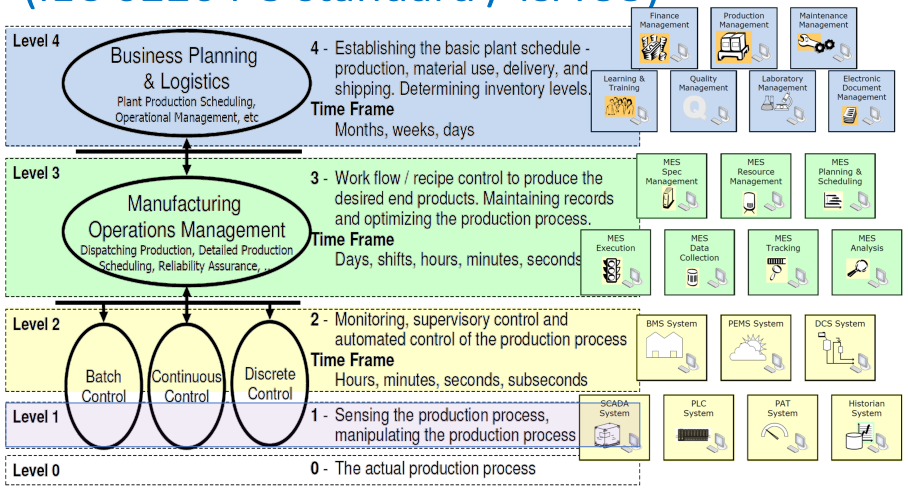
- Cross and Lynch (1992) proposed the performance pyramid with the purpose to link the hierarchical view of business performance measurement with the business process control and review
- On the top of the pyramid there is a corporate vision that depends on market and financial goals (e.g. market share, return on investment, etc.)
- At an intermediate level, objectives deal with achieving and maintaining high productivity and quality, with fast response, sufficient flexibility, and short lead times
- At the bottom level there are the “operations” mainly characterized by non-financial indicators (e.g. Cycle Time, material losses, Mean Time To Failure, etc.)
- The pyramid points to a range of target related to both external effectiveness and internal efficiency

The pyramid architecture of automation

Adapted from IEC White Paper "Factory of the future", 2015



Functional Hierarchy (IEC 62264-3 standard / ISA 95)



IEC62264 - Enterprise-control system integration

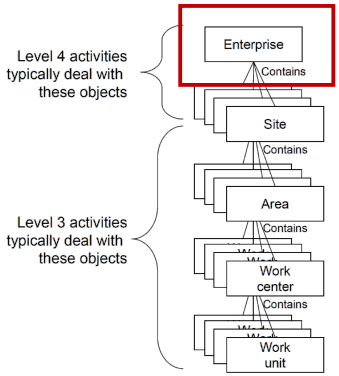
Level 4 activities

- determining the optimum inventory levels of raw materials, energy sources, spare parts, and goods in process at each storage point. These functions also include materials requirements planning (MRP) and spare parts procurement
- modifying the basic plant production schedule as necessary whenever major production interruptions occur
- establishing the basic plant production schedule
- planning production capacity
- developing optimum preventive maintenance and equipment renovation schedules in coordination with the basic plant production schedule
- collecting and maintaining raw material and spare parts usage and available inventory, and providing data for purchase of raw material and spare parts
- collecting and maintaining overall energy use and available inventory and providing data for purchase of energy source
- collecting and maintaining overall goods in process and production inventory files
- collecting and maintaining quality control files as they relate to customer requirements
- collecting and maintaining machinery and equipment use and life history files necessary for preventive and predictive maintenance planning
- collecting and maintaining manpower use data for personnel and accounting
- modifying the basic plant production schedule for orders received, based on resource availability changes, energy sources available, power demand levels, and maintenance requirements

Level 3 activities

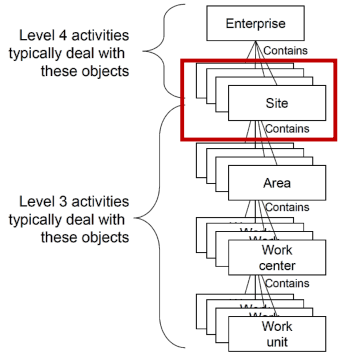
- managing manufacturing operations
- managing maintenance on production equipment
- managing laboratory and quality testing of materials
- managing movement and storage of materials
- reporting on area production including variable manufacturing costs based on the enterprise standard cost model
- collecting and maintaining area data on production, inventory, manpower, raw materials, product quality, spare parts and energy usage
- performing of data collection and off-line analysis as required by engineering functions
- performing needed personnel functions such as: work period statistics (for example, time, task), vacation schedule, work force schedules, union work rules, in-house training, and personnel qualification
- establishing the immediate detailed production schedule for its own area including maintenance, transportation and other production-related needs
- locally optimizing the costs for its individual production area while completing the production schedule established by the Level 4 functions
- modifying production schedules to compensate for plant production interruptions that may occur in its area of responsibility

Enterprise definition in IEC62264



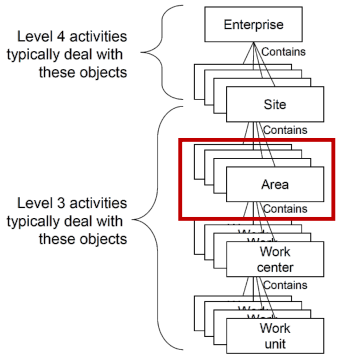
- An enterprise is a collection of sites and areas and represents the top level of a role-based equipment hierarchy.
- The enterprise is responsible for determining what products will be manufactured, at which sites they will be manufactured, and in general how they will be manufactured.
- **Level 4 functions are generally concerned with the enterprise and site levels.** However, enterprise planning and scheduling may involve areas, work centers, or work units within an area.

[Production] Site definition in IEC62264



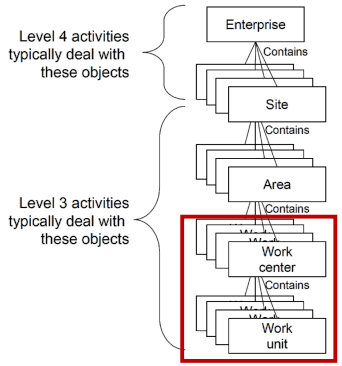
- A site is a physical, geographical, or logical grouping determined by the enterprise.
- It may contain areas, production lines, process cells, and production units. **The Level 4 functions at a site are involved in local site management and optimization**. Site planning and scheduling may involve work centers or work units within the areas.
- A geographical location and main production capability usually identifies a site. Sites generally have well-defined manufacturing capabilities.

[Production] Area definition in IEC62264



- An area is a physical, geographical, or logical grouping determined by the site. It may contain work centers such as process cells, production units, production lines, and storage zones. **Most Level 3 functions typically occur within the area.** The main production capability and geographical location within a site usually identify areas.
- **Areas generally have well-defined manufacturing capabilities and capacities.** An area is made up of lower-level elements that perform the manufacturing functions.
- Depending on the planning and scheduling strategy selected, the Level 4 functions may stop at area level, or they may schedule the functions of the lower-level elements within the areas.

Work center / unit definition in IEC62264



- Work centers are elements of the equipment hierarchy under an area.
- For manufacturing operations management there are specific terms for work centers and work units that apply to batch production, continuous production, discrete or repetitive production, and for storage and movement of materials and equipment.

Performance Measurement Systems (PMS)

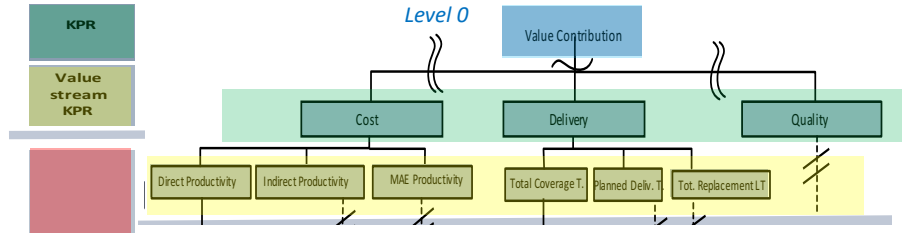
- A PMS consists of a **set of metrics** that are able to quantify the efficiency and effectiveness of manufacturing operations (Neely, 1995)
- **Top down perspective** depending from both internal and external factors
- Therefore, Key Performance Indicators (KPIs) are defined as a **set of quantifiable and strategic measurements** in a PMS that reflect the critical success factors of an enterprise
- The appropriate selection and better understanding of the KPIs can help a firm achieving the desired goal

ISO 22400:2014 Standards

Key performance indicators for Manufacturing Operations Management (MOM)

- Purpose: **operation management** and **continuous improvement** in production systems
- MOM is the set of activities within "**Level 3**" of a manufacturing facility that coordinate the **personnel, equipment and material** in manufacturing
- Defines a **standardized set of 40 KPIs**, including specifications on time- models, computation methodology, applicability, **inter-relations and inter- dependencies**, exchange and use, etc.
- KPIs are **designed to be exchanged** from one MOM application to another, or from a MOM application to other enterprise applications in the business domain at "Level 2"

KPR/KPI tree (1/4)

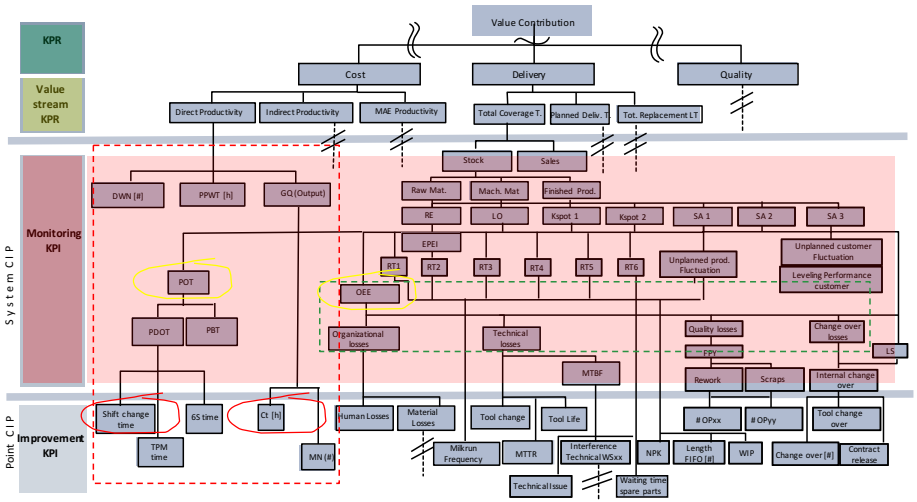


A five-level hierarchical structure of indicators

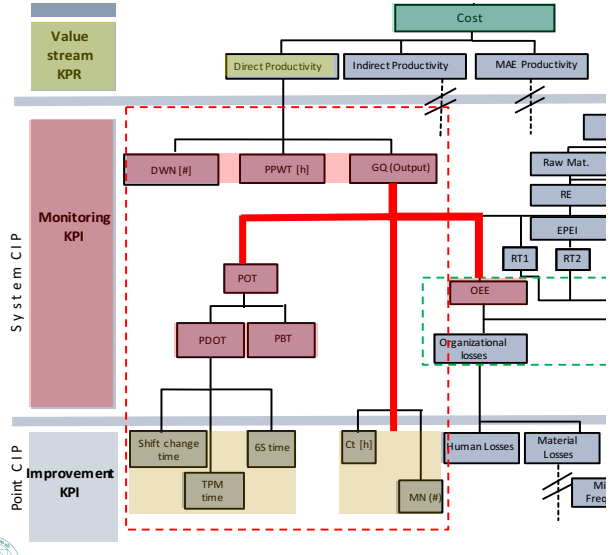
- measuring performance at a specific level
- investigating the effect that different KPIs have on each other

*At the **KPR** level synthetic performance measures as Total Cost, Delivery Service, and Quality contribute to determine the overall value of a given value stream (product or production area)*

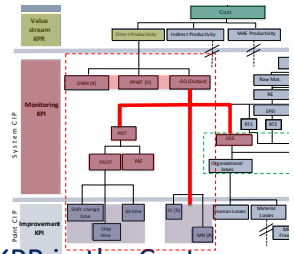
KPR/KPI tree (2/4)



KPR/KPI tree (3/4)

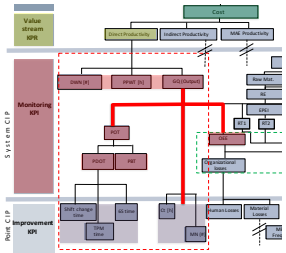


KPR/KPI tree (3/4)



- Example
- We can explore one of the value stream KPR in the Cost domain
- The focus is on the Direct Productivity (PDIR) (u/h) of the shop floor workforce in the time horizon of the evaluation (usually a shift)
- with reference to a given product (value stream)
- *KPIs not compliant to ISO 22400:2014!*

Direct Productivity (1/2)



*PDIR = GQ / (DWN * PPWT) (u/h)*

GQ produced good quantity (u)
output of the system in the time horizon

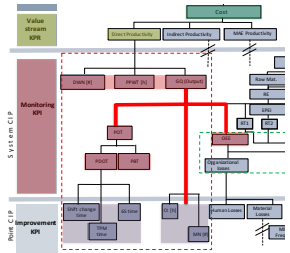
DWN planned number of direct workers (num)
the workforce who carry out specific production activities in the shop floor

PPWT planned working time per person (h) (APWT)

*GQ = POT * MN * OEE / CT (u)*

POT Planned Operation Time (h)
MN Number of the parallel operating machine (num)
OEE Overall Equipment Effectiveness
quality losses, technical av., and process efficiency
CT Cycle Time (h/u)

Direct Productivity (2/2)



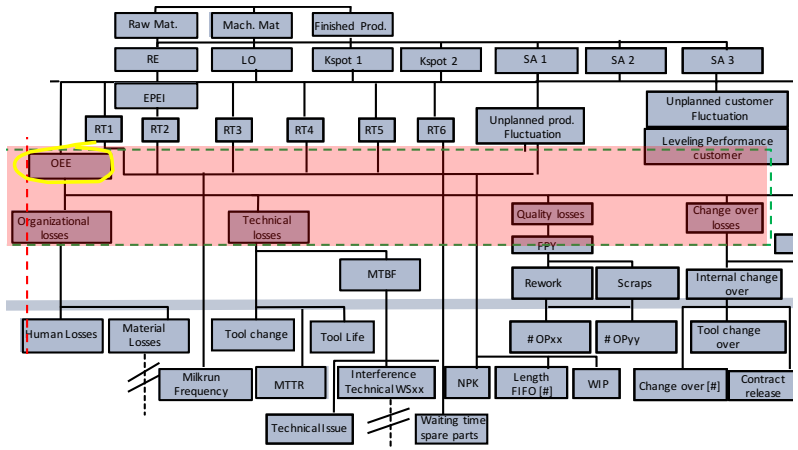
POT = PBT + PDOT

PBT Planned Busy Time (h)
PDOT Planned Downtime (h) (or machine stop)
depends on the non-productive time of the worker spent in indirect activities

PDOT = SCT + TPMT + 6sT

SCT Shift Change Time (h)
TPMT Total Productive Maintenance Time (h)
6st Lean Manufacturing Time (h)

KPR/KPI tree (4/4)



Summary

- A well designed PMS is a crucial need for the MOM of Smart Manufacturing Systems
- Standards for integration (hw & sw) should be improved
- Hierarchical structure of KPIs should be flexible and reconfigurable
- An industrial example of an effective 5–level tree (KPR/KPIs) for lean production environment is given