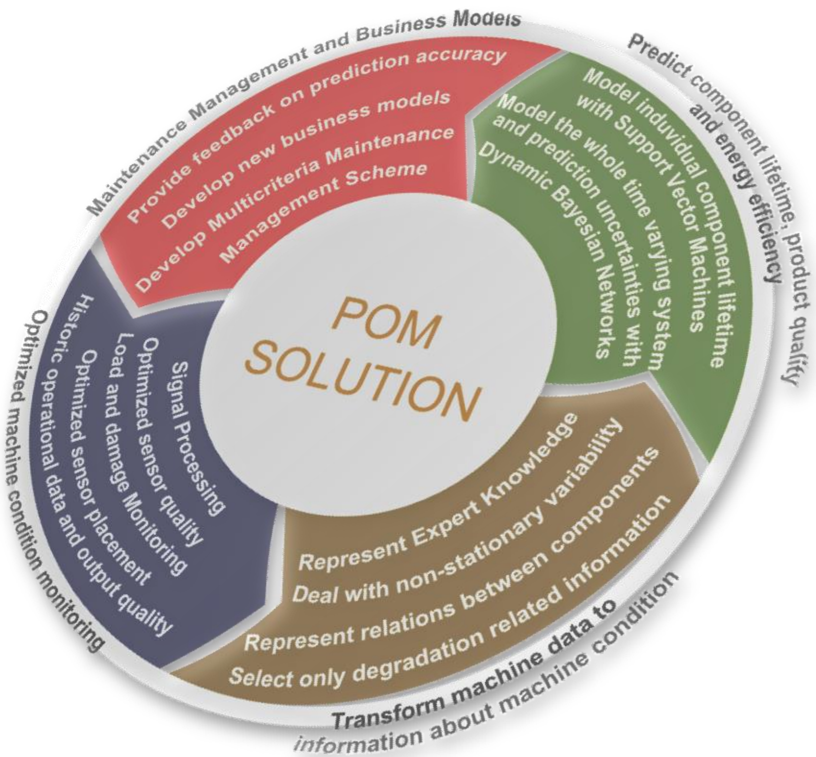


Industrial processes optimisation methodology

POM2 project

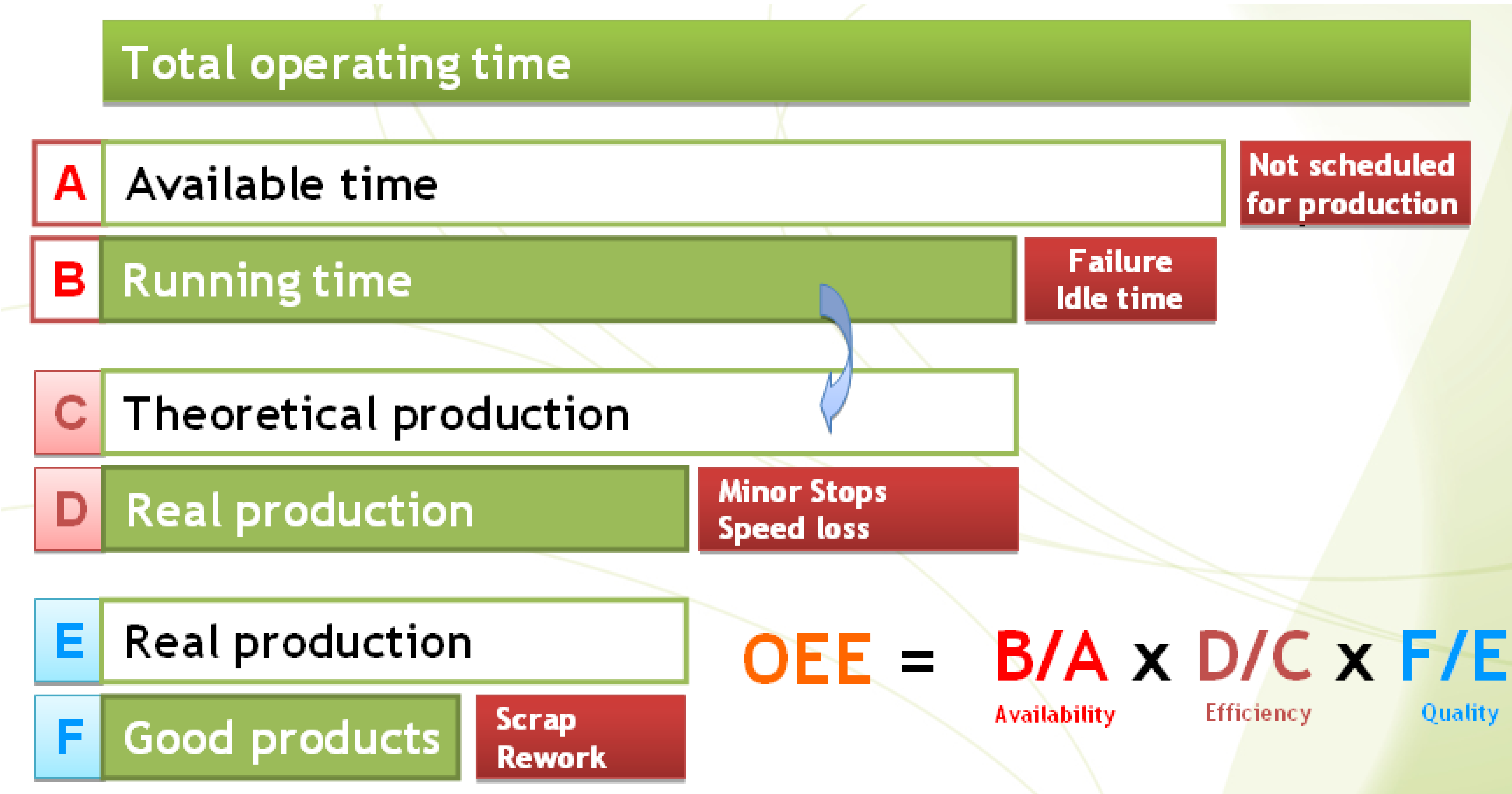
POM2 methodology and tools

- FMTC has develop a methodology for assessing potential OEE improvements against the costs required to achieve the improvement
- Overall equipment effectiveness (OEE) is a hierarchy of metrics meant to evaluate how effectively a manufacturing operation is utilized
- OEE is best used to identify scope for process performance improvement, and how to get the improvement
- Original OEE concepts do not address the issues of cost required to improve OEE

What can be optimized?

- **Maintenance or replacement frequency of components that can fail (predictive maintenance)**
- **Frequency of periodically recurring actions that impact profitability (e.g.: cleaning actions)**
- **Production rate (production speed)**
- **Production yield (amount of good products)**

Overall equipment efficiency - definition



Limitations of POM2 methodology

+ **The methodology can be applied to individual machines operating in a mostly automated way**
  - The number and timing of manual interventions can be optimized but not the duration of the intervention
+ **It cannot cope with defects or faults unrelated to production parameters or maintenance actions (e.g. due to inadequate quality of the raw materials, random failures)**

Prerequisites

- **The methodology is based on data driven models → requires continuous monitoring of:**
  - Input parameters that have an impact on the speed and availability of the machine
  - Output parameters that have an impact on product quality
- **The methodology requires knowledge of the costs associated with the machine operation**

What is in it for machine builders?

+ **Augmenting OEE of the end client through continuous monitoring of the machine**
  - It can be supplied as a one-time development or as a service

What is in it for machine users?

+ **Augmenting OEE of machines through continuous monitoring**

POM2 methodology – steps

Company inputs	Common tasks	FMTC tasks
Feasibility study	**Problem definition**	
	Data collection	
Cost definition		**Data Modeling** Preparation Analysis Feature generation Modeling
		Optimization

Company inputs

+ **Feasibility study**
  - Machines must operate in a mostly automated way (except for periodic servicing: cleaning, raw product input/output)
  - Measure the present value of the OEE
  - Assess if it is possible to increase OEE (by increasing availability, improving yield and production speed)
  - Is OEE increase beneficial (can it be valorized)
+ **Cost modeling**
  - Production costs have to be measured: the cost of maintenance, cost of operation
  - Investment costs have also to be taken into account (e.g.: cost of installing and maintaining a permanent monitoring system)

Common tasks (FMTC + Company)

+ **Problem definition**
  - Define what kind of improvement is possible/desired
  - Assess if the parameters affecting the improvement can be measured by continuous monitoring
  - Define a metric to be improved (e.g.: machine availability, production rate, production yield)
+ **Data collection**
  - Organize measurement campaign or start from existing data set
  - The data has to be representative for the processes that need to be modeled
    - Rule of thumb: the processes that have to be modeled need to occur at least 10 times during the measurement campaign. For instance if product quality needs to be improved each type of defect has to be represented at least 10 times in the measurement set.

FMTC tasks

+ **Machine/process modeling**
  - FMTC will use data driven techniques (machine learning algorithms) to model the machine and its process, with focus on the metric that has to be improved
    - Data models work best when trained on all possible circumstances. They often break down when new, unseen circumstances occur.
  - The model will establish the relation between the metric to be improved and the machine input and output parameters
+ **Optimization**
  - The goal of this step is to find the optimal trade-off between the costs and the metric to be improved
    - This step can be implemented for instance by varying the input parameters and periodicity of manual actions, and measuring the impact on the target metric and the associated costs.

Known challenges

- **Problems are difficult to define**
  - The way of working is to iterate several times through all the steps starting with problem definition, data collection and modeling and optimization
- **Cost estimation is difficult and some organizations do not have sufficiently detailed cost models**
- **Data collection is difficult**
  - Implicit knowledge and textual information (e.g. log books) are hard to abstract
  - Synchronization, sampling rates and compression methods have to be chosen carefully (see presentation on data collection)

Known challenges

- **Data preparation is effort intensive**
  - Data is mostly present in several different formats (e.g. SQL databases, proprietary formats, csv files, text)
  - Data has to be consolidated, synchronized, interpolated, resampled and filtered (e.g. deal with missing data, outliers)
- **Data has to be informative → measured parameters have to describe the machine/process behavior**
  - If essential parameters are not available the model will fail to make good predictions (e.g. some parameters cannot be measured because they are inaccessible or is not economically feasible)
  - Accuracy of the model can be improved iteratively up to the point where missing parameters prevent further improvements

Effort estimation

Feasibility and cost estimation	Precondition
Problem definition	Step 1, 5 – 10 MD
Data collection	Precondition
Data preparation	Step 2, 10 – 15 MD
Data analysis, feature generation	Step 3, 10 – 20 MD
Process modelling – data mining	Step 4, 5 – 15 MD
Process optimisation	Step 5, 5 – 20 MD

EXAMPLES

Optimization of preventive maintenance

+ **Problem definition**
  - Too much preventive maintenance can be costly and will still not prevent or predict machine failures (e.g.: bearing failures, gearbox failures)
  - Perform just enough maintenance → achieve an optimum trade-off between maintenance costs and failure costs
+ **Approach**
  - Design and place continuous monitoring equipment (accelerometers, temperature sensors)
  - Acquire data (minimum 10 occurrences of each type of failure)
  - Build machine model that predicts future failures
+ **Optimize the return on investment**
  - Estimate costs of continuous condition monitoring – acquisition and maintenance costs
  - Estimate losses due to unpredictable machine breakdown

Prevent short, occasional machine stops

+ **Problem definition**
  - Increase machine production rate by avoiding occasional machine stops
  - Reasons for machine stops: overheating
+ **Approach**
  - Design and place continuous monitoring equipment (e.g. temperature sensors)
  - Acquire data (minimum 10 occurrences of the event to be avoided)
  - Build machine model that links the stop event to other machine operating parameters (e.g.: temperature to rotating speed)
+ **Optimize production capacity**
  - Estimate costs of continuous monitoring
  - Estimate losses due to machine stops
  - Develop algorithm that adapts the machine parameters to avoid machine stops and maximize production capacity

Optimize period of short maintenance actions

+ **Problem definition**
  - Increase production rate of good products
  - Product quality changes over time due to dirt accumulation → production rate of good products decreases → need for periodic cleaning actions
+ **Approach**
  - Design and place continuous monitoring equipment (e.g.: accelerometers, camera, pressure, flow, energy)
  - Acquire data (minimum 10 occurrences of the periodic action)
  - Model product quality as a function of monitored parameters
+ **Optimize production capacity**
  - Estimate costs of continuous monitoring
  - Estimate losses due to machine stops
  - Develop algorithm that maximizes profit (trade-off between the losses due to bad products and losses due to production stop

