< Operational excellence >

# Value Stream Mapping in the Chemical Industry

IAMC Toolkit

Innovative approaches for the Sound Management of Chemicals and Chemical Waste

# Introduction

SMEs manufacturing chemical products have challenges reducing waste (time, resources, personnel) which affects the company's profit.

Value Stream Mapping (VSM) is a tool which maps the entire business (including sales, material procurement, production and delivery) and identifies key areas of waste and their root causes.

The reader will learn how to use VSM in the chemical industry to reduce waste, decrease variable and raw material costs and increase business productivity.

# Contents

# Topics

3. Generating the Map
   - Getting Started
   - Steps and Calculation of Key Data
   - Example VSM

4. VSM Good Practices
   - Parallel Equipment
   - Logical Flow versus Geographic Arrangement

5. Key Messages

6. Glossary

# The Value Stream Map

- The Value Stream Map
- VSM Symbols
- Generating the Map
- VSM Good Practices
- Key Messages
- Glossary

# Key Idea (1)

**What is a value stream map (VSM)?**

VSM is a specific type of flowchart used to depict material and information flow throughout a production process.

**What is its objective?**

VSM helps you to:

- Improve your understanding of the processes, inventory flows and causes of waste
- Make decisions to improve your performance on the basis of an idealized “future state” map

# Key Idea (2)

**How is it generated?**

Value stream mapping builds on an existing Process Flow Diagram (PFD) by:

- Drawing a visual representation of every process step
- Asking a set of key questions
- Drawing a „future state" map of optimized processes

This is done using a predefined set of standardized icons.

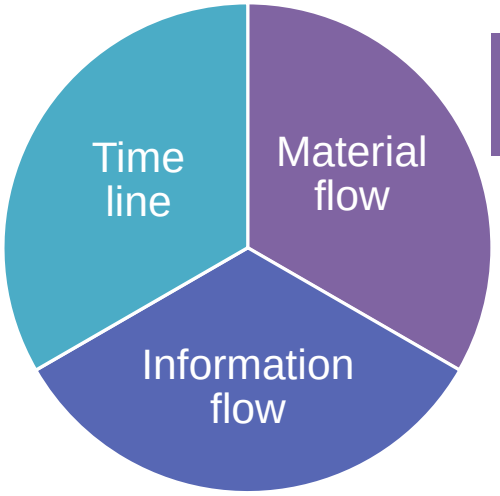
**⇨ A VSM enables you to identify and to plan to eliminate waste in your production process.**

# Key Components (1)

- A Value Stream Map (VSM) is a flow diagram of an entire production process

- It consists of three key components:

Ratio of value-added time (VAT) to non-value-added time (NVAT)

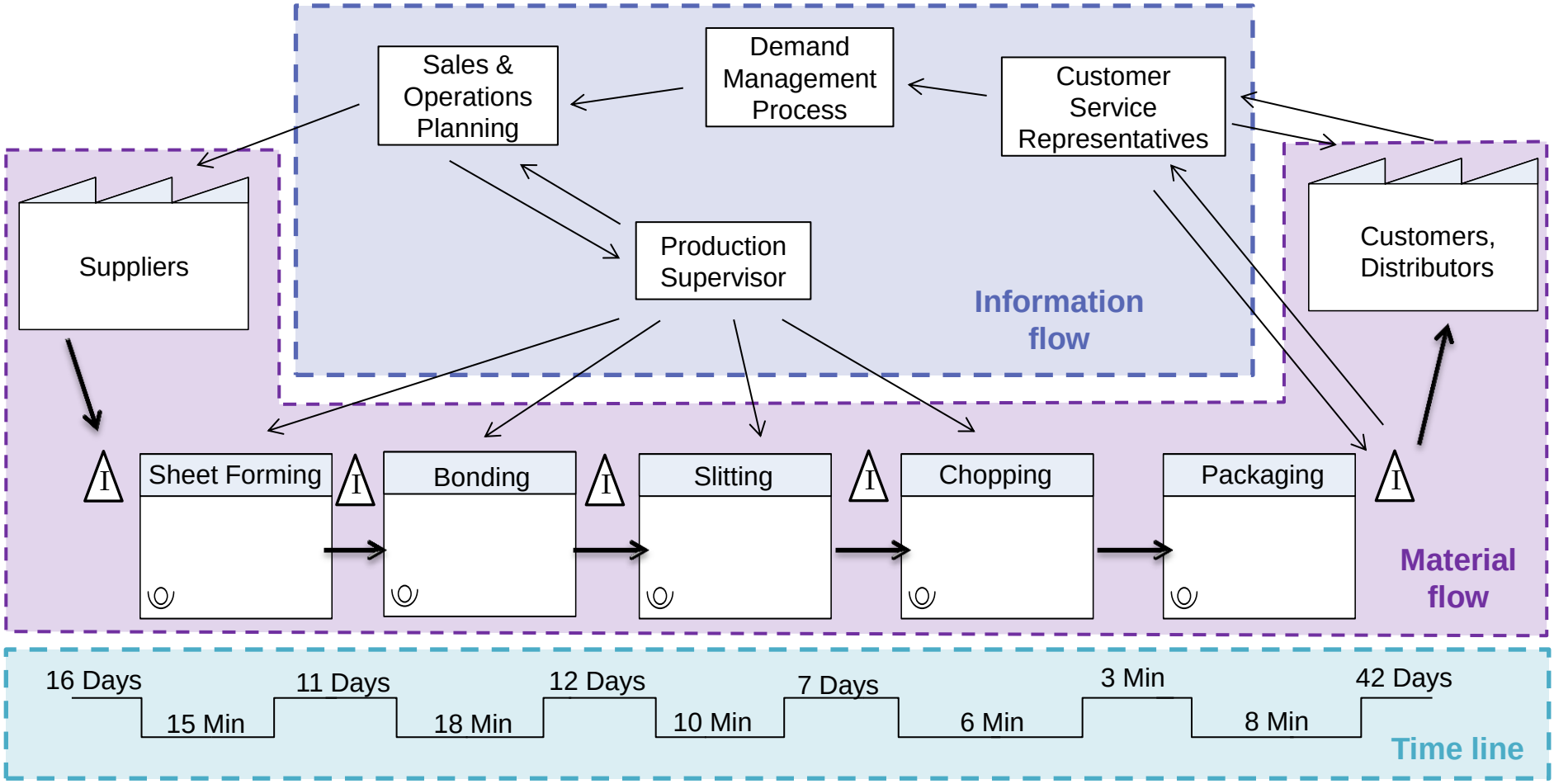



Flow from raw material to finished goods

*Source: ISSPPRO*

What has to be produced and when it has to be produced

# Key Components (2)




*Source: based on King*

# How can VSM help Companies? (1)

VSM and the design of an optimized future state help to:

**Visualise the flow**

- Get a clear overall picture of material and information flow and where they touch
- Develop a sense of flow, inventory and bottlenecks

**Create understanding how**

- Value is created for the customer
- The entire production process operates rather than individual units

# How can VSM help Companies? (2)

VSM and the design of an optimized future state help to:

**Identify waste in all areas of production**

- Identify key areas of waste in the production process
- Identify which and how much waste is generated
- Identify the root causes for waste

**Improve business performance**

- Increase productivity
- Reduce material and energy waste
- Decrease variable and material costs

**→ The "future state" map is essential for this step. Its optimized state serves as a target for all improvement activities!**

# How can VSM help Companies? (3)

*Source: EPA: The Lean and Chemicals Toolkit*

**Example of VSM improving efficiency: Woodfold Manufacturing, Inc.**

- Manufacturer of custom wood products located in Forest Grove, USA.
- Woodfold implemented many of the improvement opportunities identified in the VSM, and achieved the following results:
  - Saved about $44,800 per year, including $34,700 per year from improvements to paint spray transfer efficiency.
  - Found a local recycler for PVC scrap, diverting 6 tons per year of solid PVC waste from the landfill.
  - Reduced volatile organic compound (VOC) emissions by nearly 454 kg per year.

# “Must Knows” for VSM

In order to properly make a Value Stream Map, you should know…

- Units of production
- Takt time
- Cycle time (C/T)

… of all processes in the entire production process.

# Units of Production

**Units of production**

- Express production volume
- Are needed to calculate takt and capacity
- May change from one production process to the next

➲ Also conversion factors between those different units may change during the process

➲ Define takt and capacity with the units most related to throughput capability of a piece of equipment

# Takt Time

**Takt**

- Expresses total customer demand as a time factor
- Reflects the time within which a part or lot is needed
- Means rhythm in German

$$Takt\ time\ \left[\frac{min}{unit}\right] = \frac{available\ work\ time\ per\ period\ \left[\frac{min}{day}\right]}{average\ (customer) demand\ of\ products\ per\ period\ \left[\frac{units}{day}\right]}$$

- ➲ The ideal production process is completely synchronized with the rhythm of customer demand
- ➲ Example: one car per day is produced and the Dealer can sell one car per day → ideal production process

# Cycle Time

**Cycle time (C/T)**

- Expresses equipment capacity
- Reflects the time needed to produce a part or lot

- Indicators such as Uptime or Overall Equipment Effectiveness (OEE) account for reduced equipment capability of different reasons

→ If cycle time equals takt time, production capability is perfectly synchronized with demand.

# Learning Objectives

**Can you list and explain some benefits of VSM?**

- Visualises the flow and helps to develop a sense of it
- Creates and expands understanding
- Helps in the identification of waste and its origins
- Supports improvement activities

**Which parameters have to be known to create a VSM?**

- Production units
- Takt time or takt rate
- Cycle time or cycle rate (=effective capacity)

# VSM Symbols

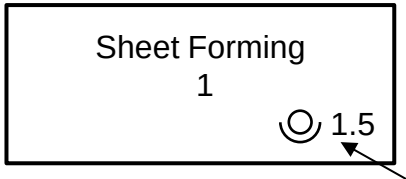
- The Value Stream Map
- VSM Symbols
- Generating the Map
- VSM Good Practices
- Key Messages
- Glossary

# Process Box and Process Step Data Box

**Example:** Sheet forming machine 1

Each major process step is described by a process box

Each process box has a process step data box with numerical information on the step




| | |
|---|---|
| Max Demo Rate | 4 |
| Effective Capac | 3.1 |
| Takt | 2.4 |
| (Master Rolls/h) | |
| Utilization | 77% |
| Lead time | 15 min |
| Yield | 88% |
| Reliability | 90% |
| Uptime/OEE | 78% |
| # SKUs | 12 |
| Batch size | 1 roll |
| EPEI | 9 days |
| C/O time | 45 min |
| C/O losses | < 1 roll |
| Available time | 168 h/week |
| Shift sched | 3 x 8 x 7 |

Number of operators typically working in this step

*Source: based on King*

# Process Step Data Box (1)

- C/T (Cycle time) [min/unit]:Time between releases of parts or batches
- Takt [min/unit]: Time available to produce one unit of product
- Utilization [%]: Measure for how fully utilized a process step is
- Lead time [min]: The time needed for one part or lot to complete this process step
- Yield [%]: Percentage of material entering the step that leaves it with required quality
- Reliability [%]: The percentage of time without any equipment failure
- Uptime [%]: Measure reflecting all sorts of time lost

| Process Step Data Box | |
|---|---|
| C/T | ## [min/unit] |
| Takt | ## [min/unit] |
| Utilization | ## [%] |
| Lead time | ## [min] |
| Yield | ## [%] |
| Reliability | ## [%] |
| Uptime | ## [%] |
| # SKUs | ## [units] |
| Batch size | ## [units] |
| EPEI | ## [days] |
| C/O time | ## [min] |
| C/O losses | ## [units] |
| Available time | ## [h/week] |
| Shift sched | ## [h/week] |

# Process Step Data Box (2)

- Number of SKUs (Stock keeping units) [units]: Number of specific products leaving this process step
- Batch size [units]: Amount of material produced as a single lot
- EPEI [days]: Time span over which all product types are made
- C/O (Changeover) time [min]: Time needed to change from one product to another
- C/O (Changeover) losses [units]: Amount of material lost in the change from one product to another
- Available time [h/week]: Total time this process step is planned to run
- Shift sched(ule) [h/week]: Number of hours per shift, shifts per day and days per week

| Process Step Data Box | |
|---|---|
| C/T | ## [min/unit] |
| Takt | ## [min/unit] |
| Utilization | ## [%] |
| Lead time | ## [min] |
| Yield | ## [%] |
| Reliability | ## [%] |
| Uptime | ## [%] |
| # SKUs | ## [units] |
| Batch size | ## [units] |
| EPEI | ## [days] |
| C/O time | ## [min] |
| C/O losses | ## [units] |
| Available time | ## [h/week] |
| Shift sched | ## [h/week] |

# Process Step Data Box (3)

**The process data box can be complemented by specific environmental data, such as:**

- Hazardous waste generation
- Water consumption
- Energy consumption
- Emissions generation
- Environmental, health and safety hotspots (EHS HS)

**→ Can also be appropriate for inventory data boxes!**

| Process Step Data Box | |
|---|---|
| C/T | ## [min/unit] |
| Takt | ## [min/unit] |
| Utilization | ## [%] |
| Lead time | ## [min] |
| … | |
| **Material and Energy Data** | |
| Hazardous waste | ## [kg/batch] |
| Water consumption | ## [L/batch] |
| Energy consumption | ## [kWh/batch] |
| Emissions | ## [kg/batch] |
| EHS HS | ## |

# Key Metrics (1)

**Apart from takt and cycle time, the following parameters are commonly indicated:**

- Utilisation: Measure of how fully utilized a process step is

$$Utilisation\ [\%] = \frac{cycle\ time\ \left[\frac{min}{unit}\right]}{takt\ time\ \left[\frac{min}{unit}\right]} = \frac{takt\ rate\ \left[\frac{units}{h}\right]}{effective\ capacity\ \left[\frac{units}{h}\right]}$$

- Uptime: Ratio of actual production time to availability time

$$Uptime\ [\%] = \frac{valuable\ operating\ time\ [min]}{valuable\ operating\ time + losses\ [min]}$$

# Key Metrics (2)

**Apart from takt and cycle time, the following parameters are commonly indicated:**

- Yield: Percentage of good parts leaving a process step

$$Yield\ [\%] = \frac{material\ leaving\ a\ step\ with\ acceptable\ properties}{total\ amount\ of\ material\ entering\ the\ step}$$

- Reliability: Measure of the steadiness of a machine

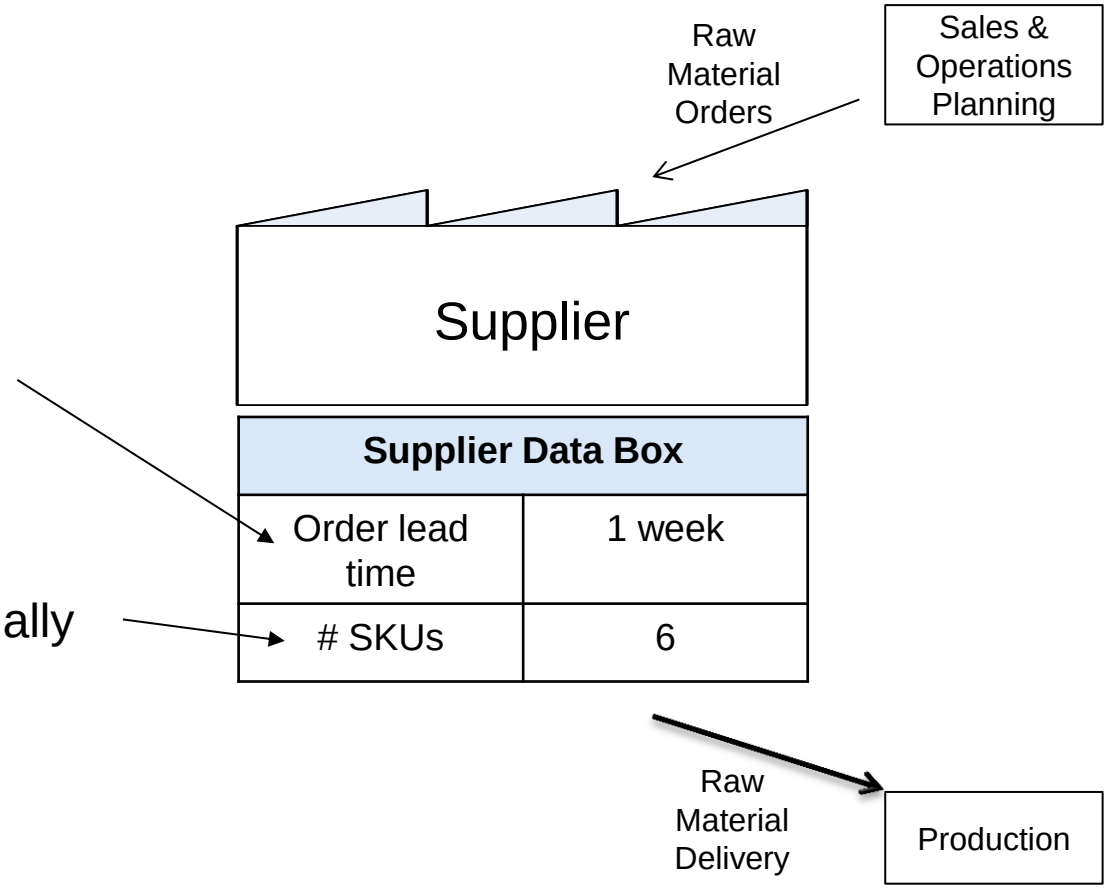
$$Reliability\ [\%] = \frac{time\ equipment\ is\ \boldsymbol{not\ down}\ due\ to\ equipment\ failures}{total\ time\ available}$$

# Supplier Data Box

- Supplier data boxes are normally generated for high-volume suppliers

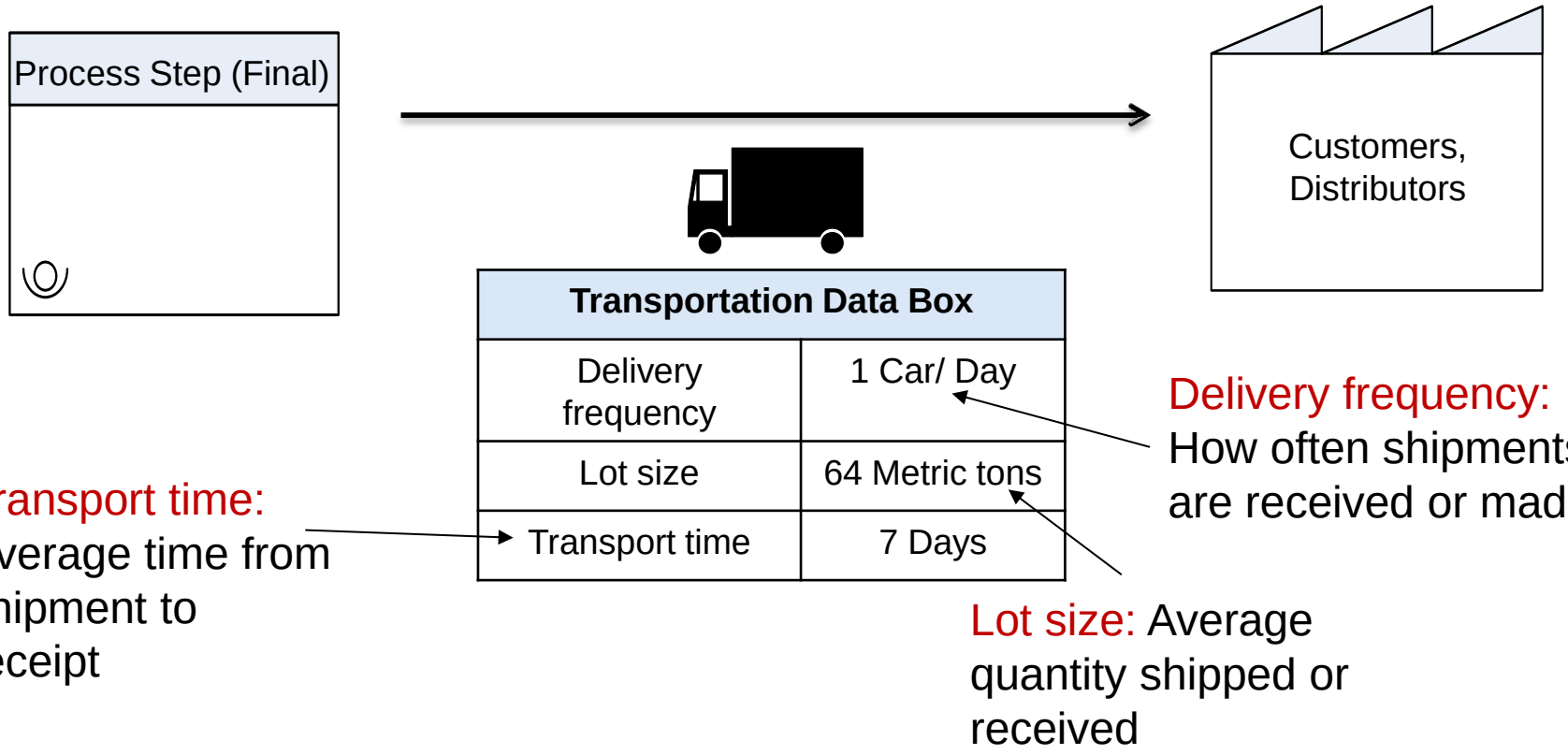
Order lead time: Time from replenishment order until the material arrives

Number of SKUs: Number of material or part types we usually receive from this supplier



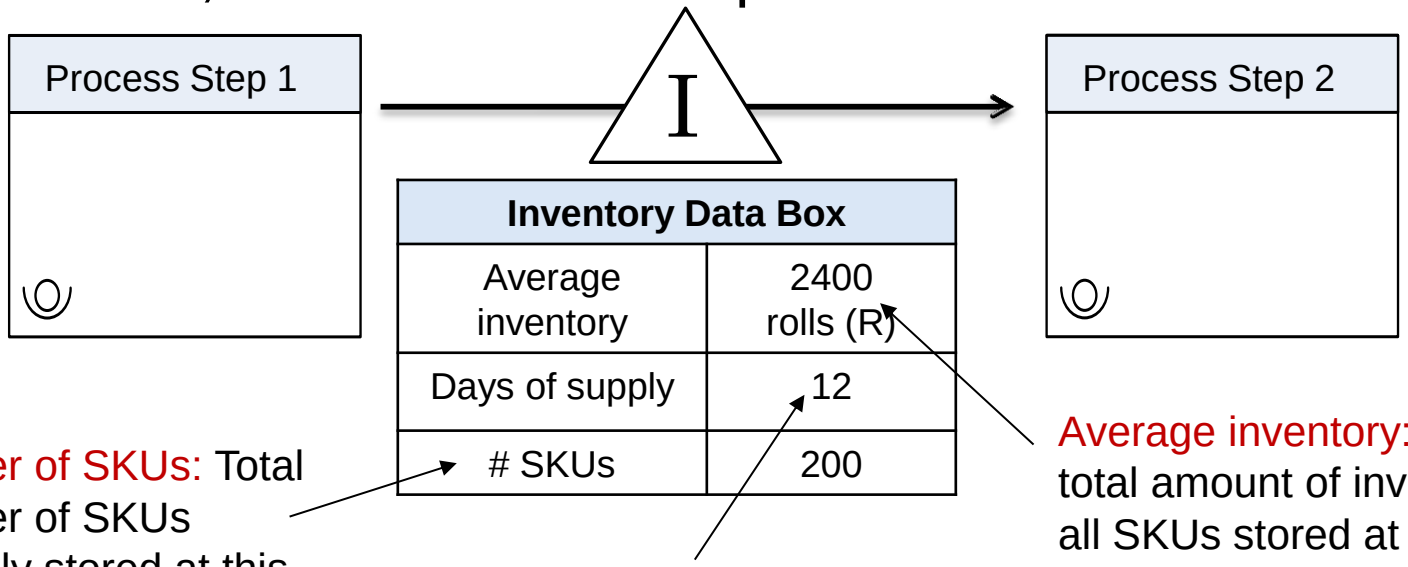
# Transportation Data Box

- Include transportation data boxes for all types of transportation steps



# Inventory Data Box

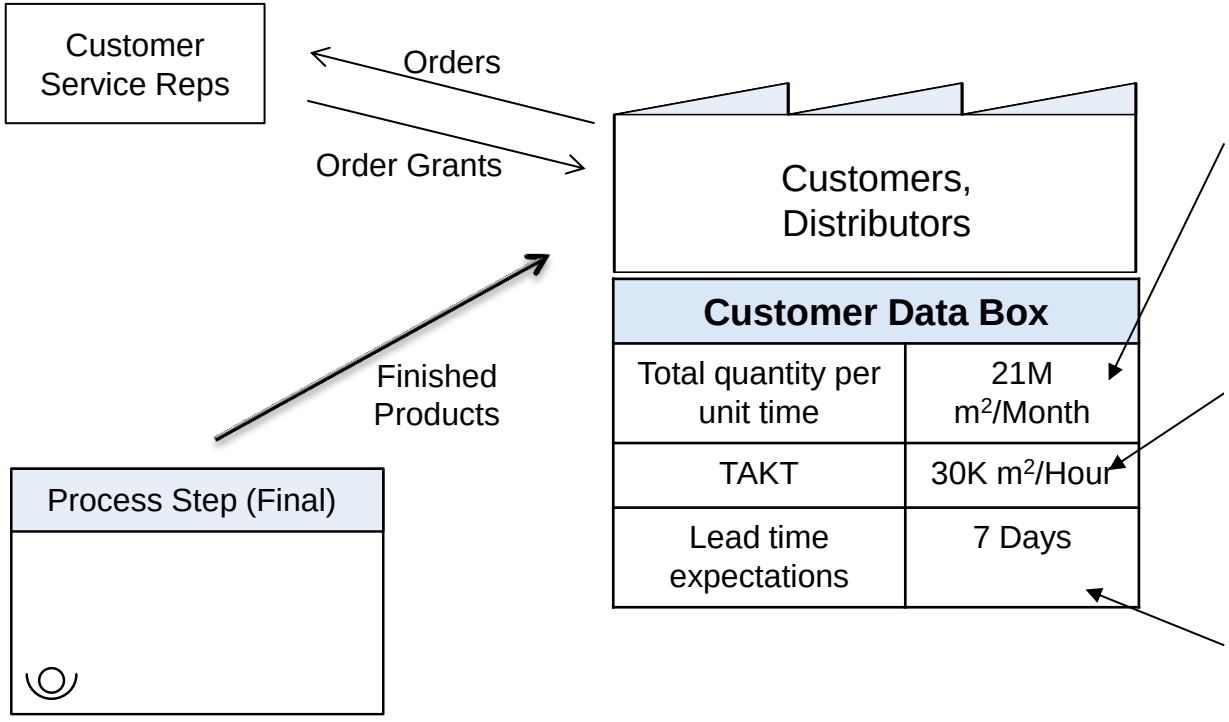
- Use inventory data boxes for all inventories, including raw materials, WIP and finished products




⇨ Environmental data can be reasonable as well!

# Customer Data Box

- Customer Data Boxes tell you how much material customers order and when they expect to receive it

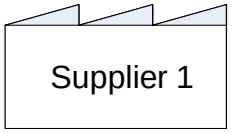



Total quantity: Sum total of all products ordered by all customers

Takt: Time available to produce one unit of product needed to fill customer orders

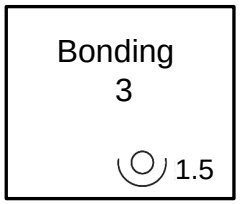
Lead time expectation: Maximum time a customer will accept between order and delivery

# Material Flow

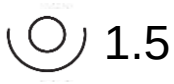



External Supplier

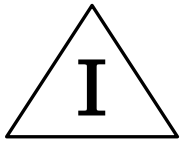

External Customer



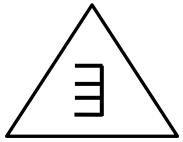

Process Step




Number of Operators assigned to a process step




Traditional Inventory - replenished without regard to current contents



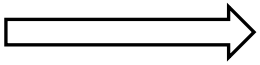
Inventory Managed as a Supermarket – Replenish only what has been pulled


Inventory Managed in a First In – First Out mode

PUSH Material Movement – produce and move based on forecasts

PULL Material Withdrawal from a supermarket

Material flow in a Pull environment



Material to a customer or from a supplier

*Source: based on King*

# Information Flow (1)

- The top half of the VSM contains the flow of all information

→ Communication problems are often the limiting factor!

- Most often and commonly used icons:

Manual Information Flow

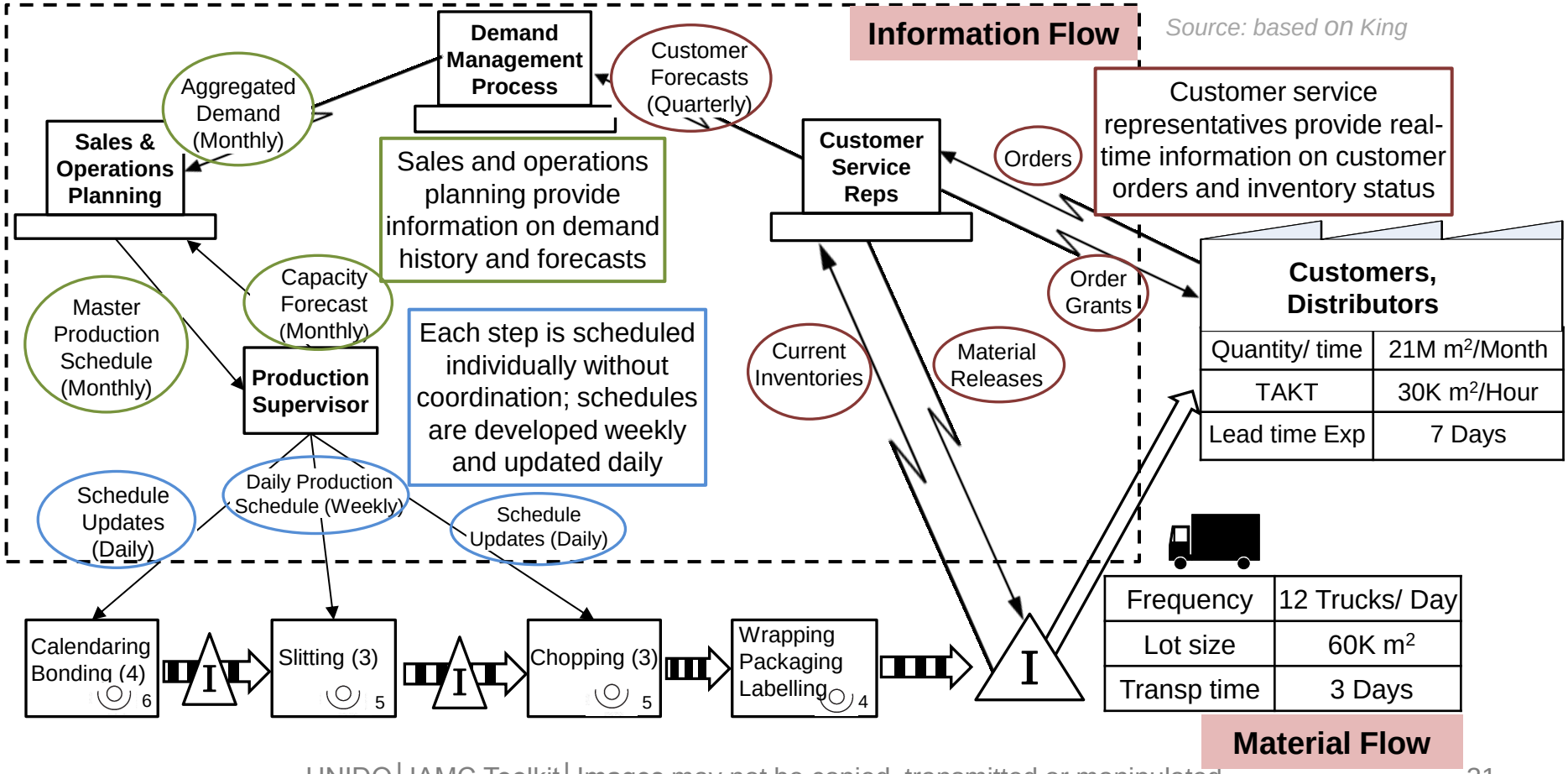
Electronic Information flow


Information Processing Function

„Go See“ Adjusting schedules based on manual inventory checks

# Information Flow (2)

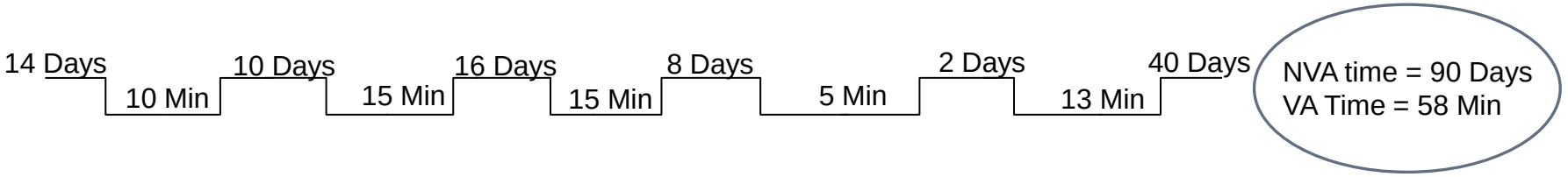
**Example:** Information flow portion, case study process



# Timeline

**The timeline**

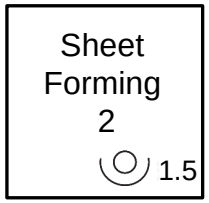
- Is a square wave in the bottom area of the VSM
- Presents the ratio of value-add (VA) and non-value-add (NVA) time
- Is a good indicator of waste, as most of the forms of waste add to overall lead time




Most commonly, NVA time is the top part and VA time the bottom part of the wave

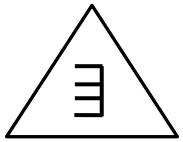
# Learning Objectives

**Can you identify the following symbols?**




Process step with 1.5 operators

Pull material withdrawal from a supermarket



Inventory managed as a supermarket


Inventory managed in a first in – first out mode

Adjusting schedules after manual inventory checks

# Generating the Map

- The Value Stream Map
- VSM Symbols
- Generating the Map
- VSM Good Practices
- Key Messages
- Glossary

# Getting Started (1)

**In order to generate a VSM, you might want to…**

- Establish an interdisciplinary project team

  ⇨ Internal and external experts can be involved!

- Decide to document current (how it works now) or future (how it should work) state of the process

  ⇨ "Future state" maps can be drawn in parallel to current state maps!

# Getting Started (2)

**In order to generate a VSM, you might want to…**

- Map the material flow

⇨ It can be helpful to select product families out of the total product range!

- Take a process walk to observe all process steps and involve people on the floor
- Record the time and amount of materials required for every step

# Getting Started (3)

**In order to generate a VSM, you might want to…**

- Start drawing the VSM by hand or electronically

⇨ Use consistent symbols for all maps!

⇨ Direction of flow should always be from left to right!

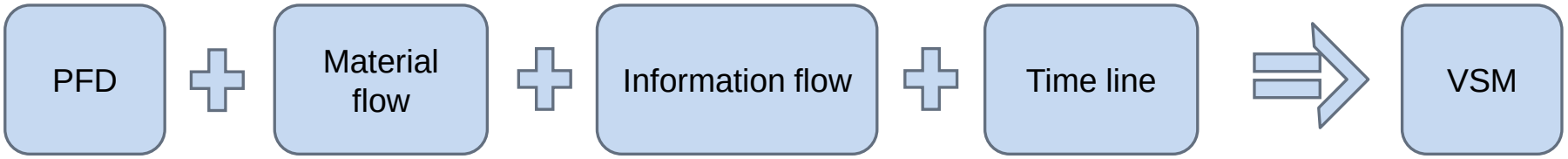
⇨ Find the right level of detail. If necessary, more specific maps can be created for more complex steps!

- Discuss, rearrange, add and modify

# Steps for Generating the VSM

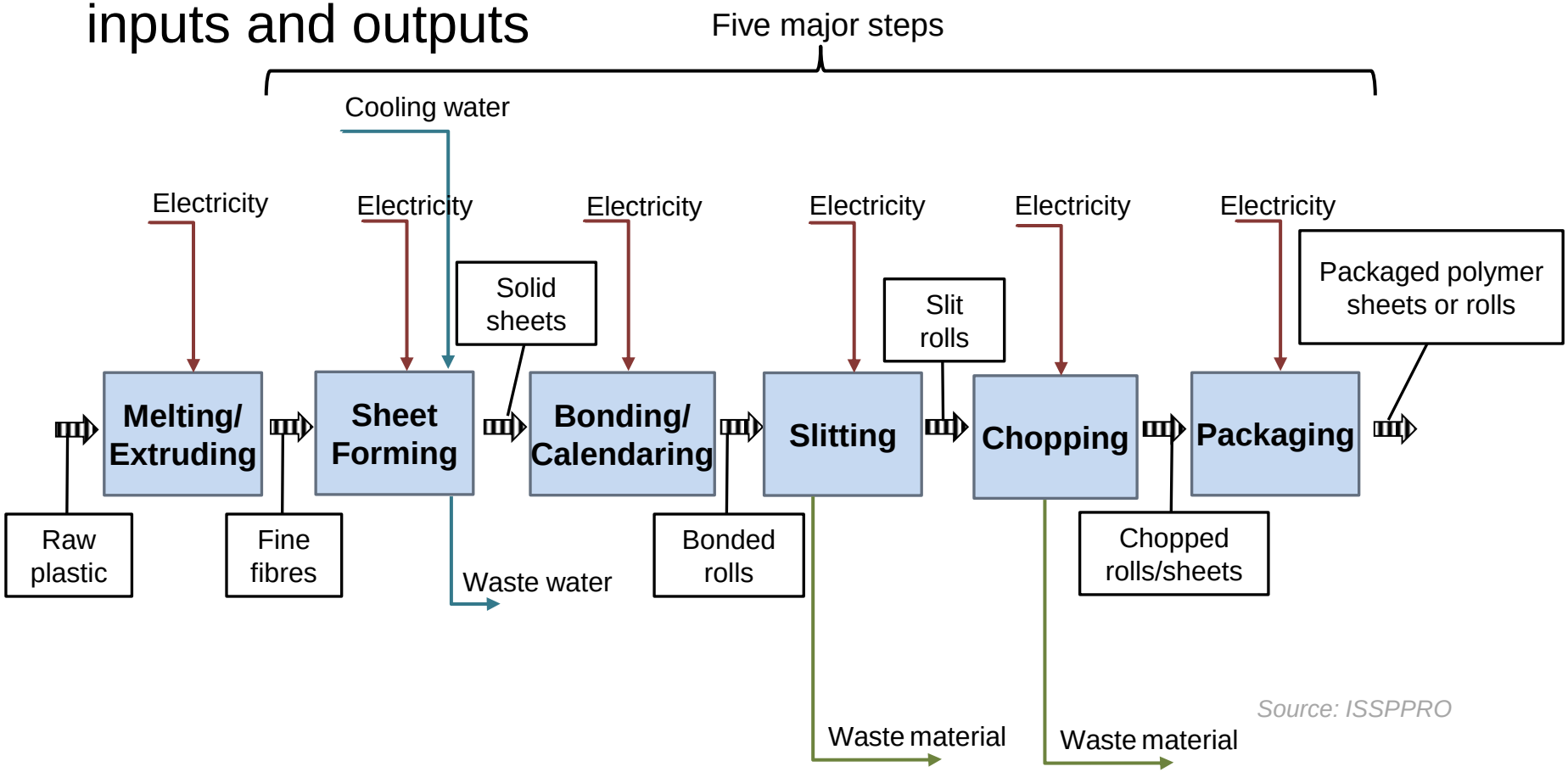
**Elaborate your VSM by**

1. Starting from the PFD
2. Calculating or measuring the necessary data
3. Adding
   - Material flow
   - Information flow
   - Time line



# Step 1: Use a PFD as starting point

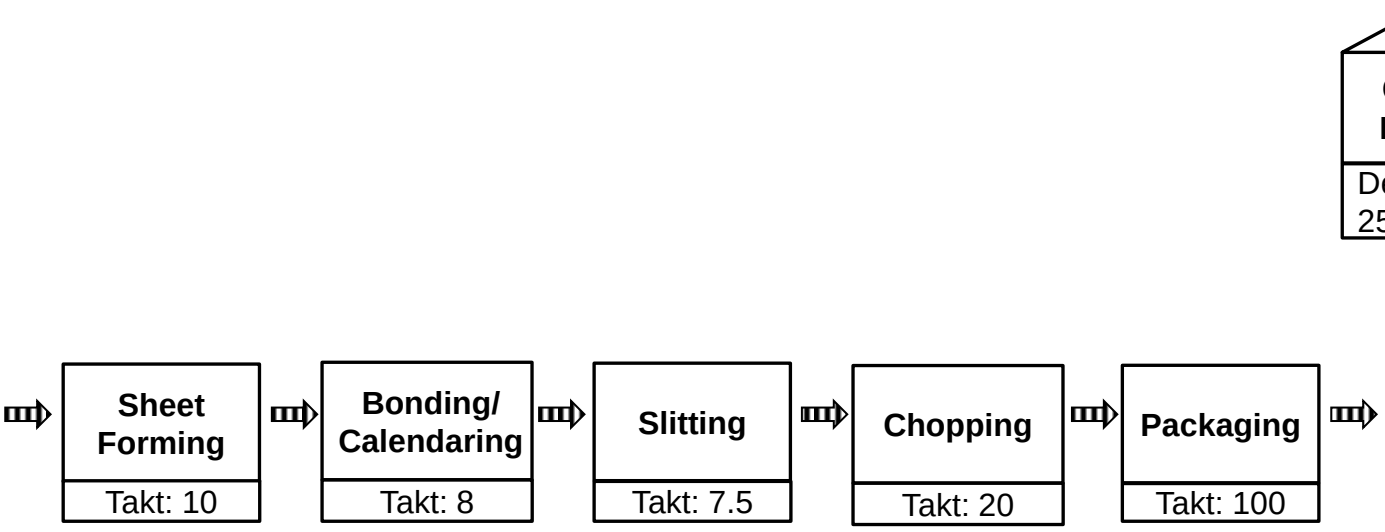
- Start from a well-elaborated PFD with material and energy inputs and outputs




Source: ISSPPRO

# Step 2: Build up the VSM (1)

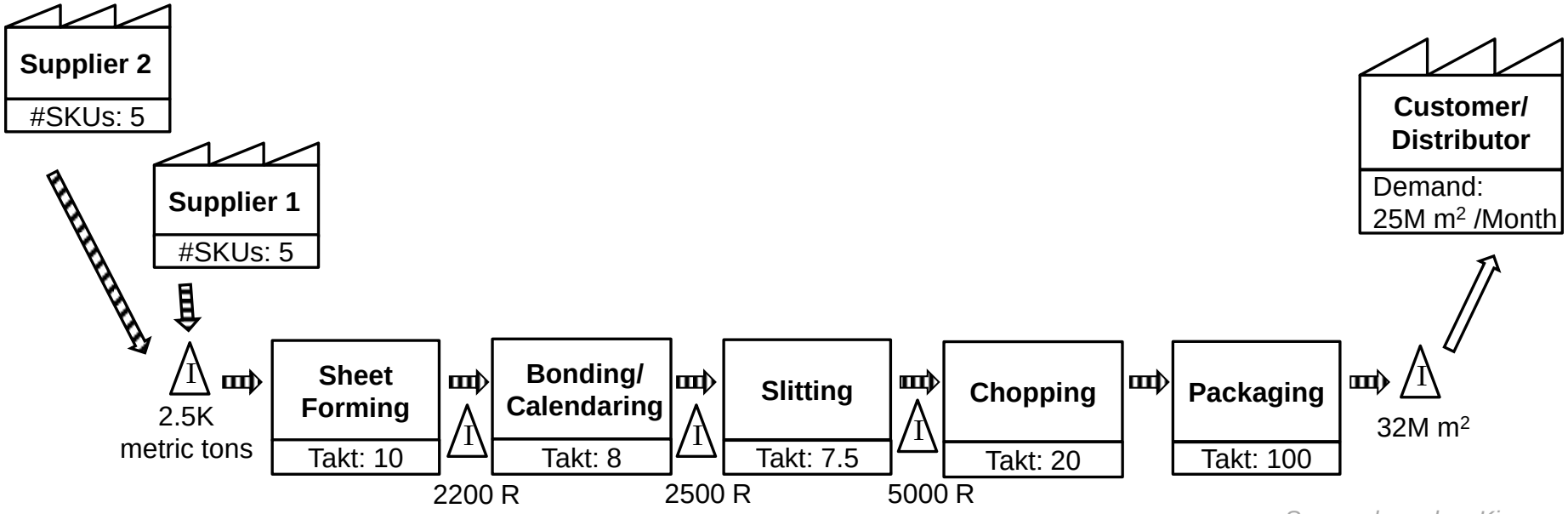
- Focus on the material flow first
- Add the customer box and all process data boxes




*Source: based on King*

# Step 2: Build up the VSM (2)

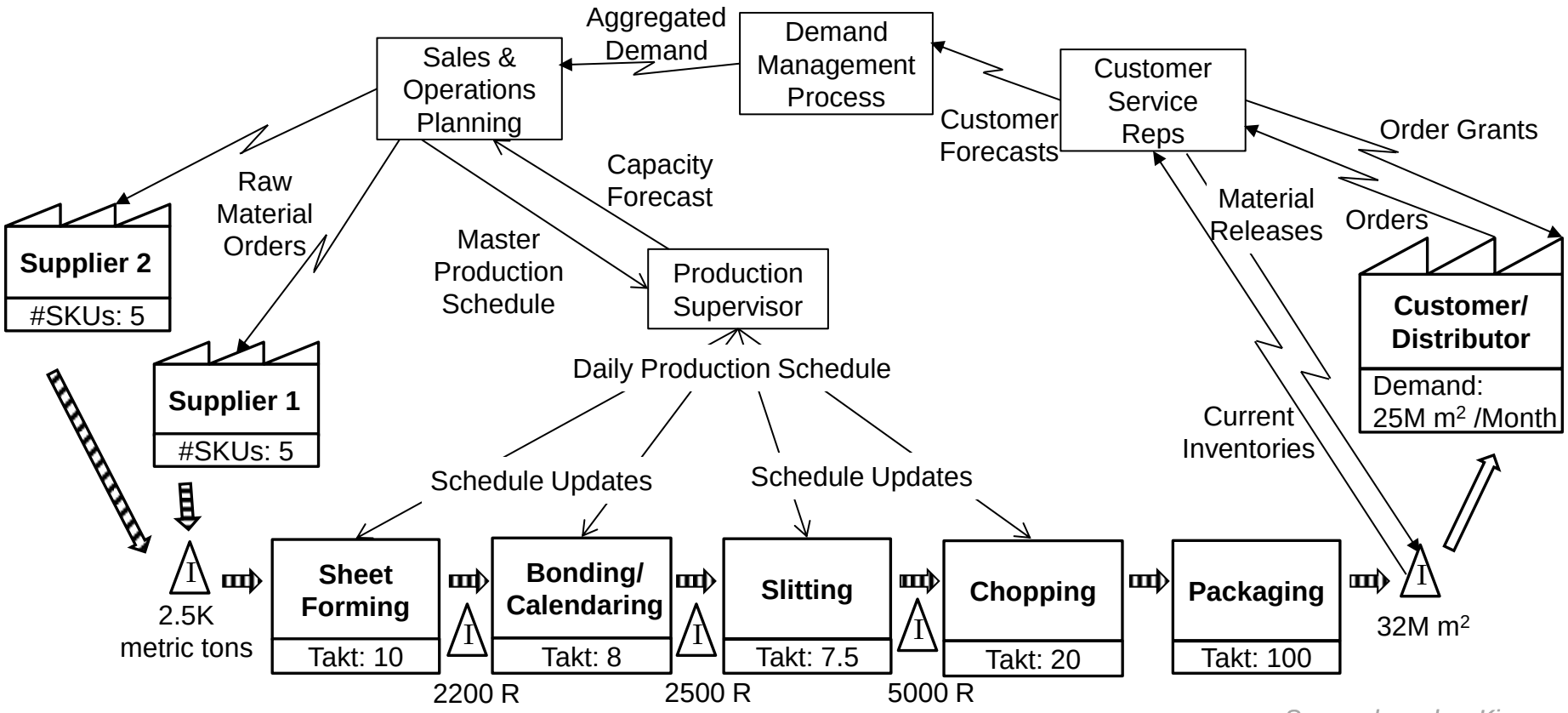
- Add supplier boxes
- Add inventories/ wait times




*Source: based on King*

# Step 2: Build up the VSM (3)

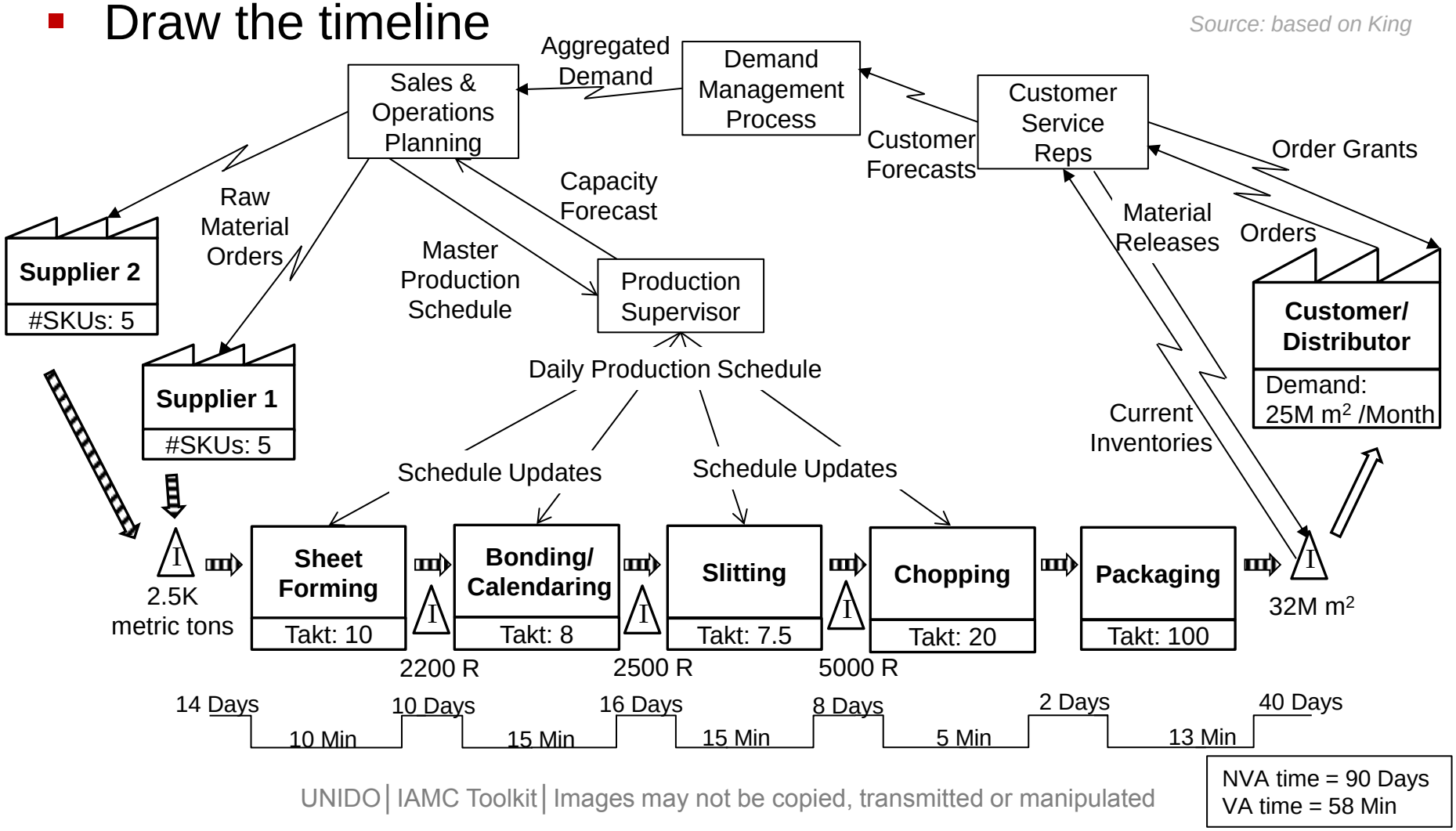
- Draw the information flow




*Source: based on King*

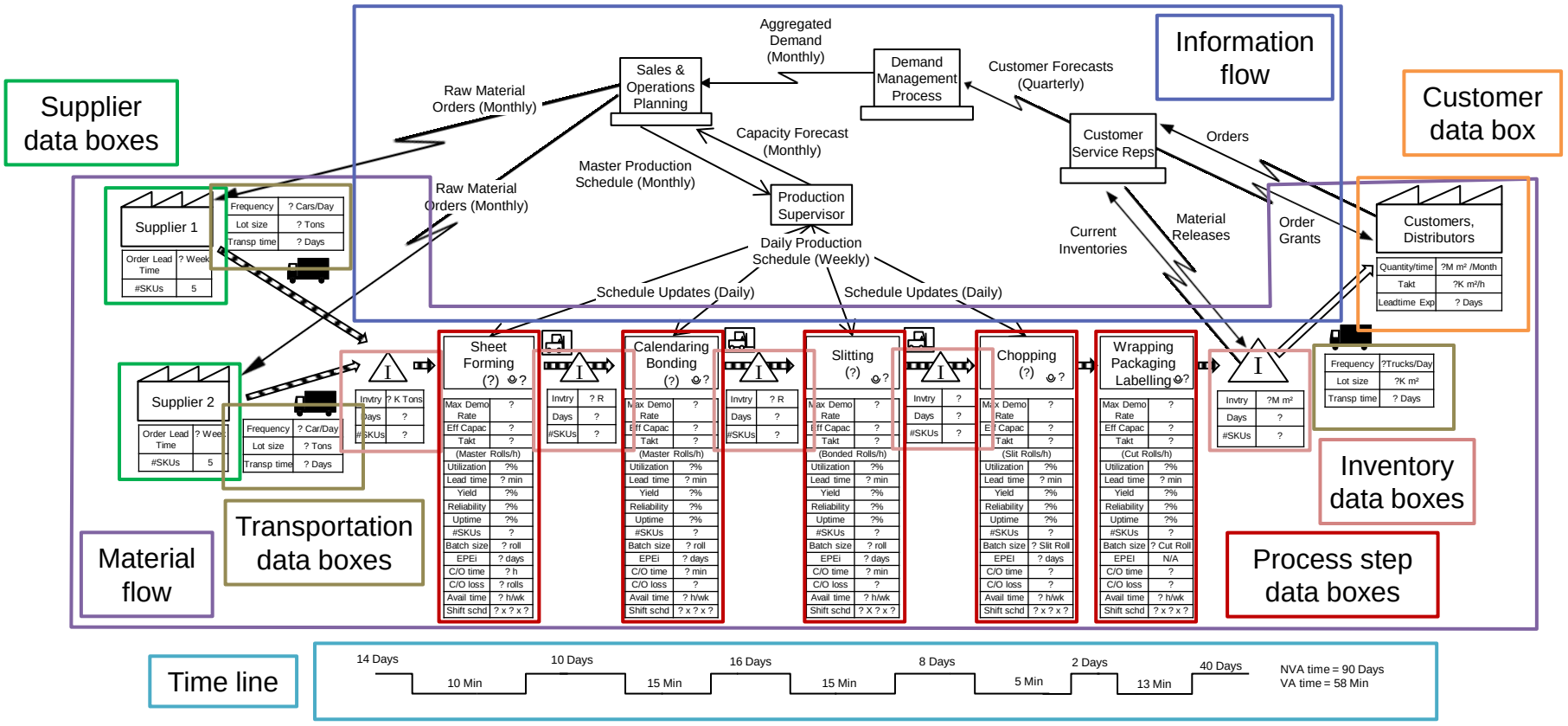
# Step 2: Build up the VSM (4)

- Draw the timeline



# Step 3: Fill in the process data boxes

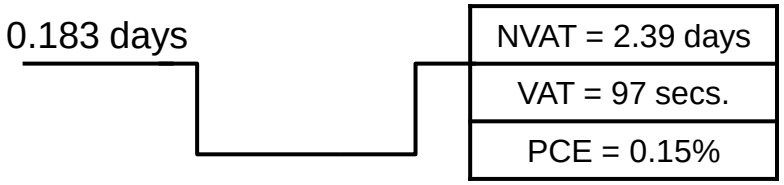
*Source: based on King*



# Step 4: Determine Key Metrics (1)

**For the summary metrics box:**

Sum of individual process metrics




- Total cycle time: Sum of all (process step) cycle times

$$Total\ cycle\ time\ [min] = VAT[min] + NVAT\ [min]$$

*Value-Added Time, VAT:* Total time spent on value-added activities

*Non-Value-Added Time, NVAT:* Total time spent on non-value-added activities

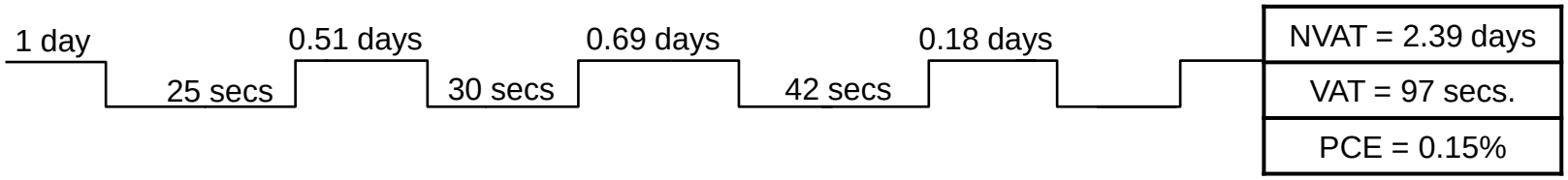
⇨ VAT and NVAT are measured directly from the process

# Step 4: Determine Key Metrics (2)

**Entire process performance indicators:**

- Process cycle efficiency (PCE): Value-added percentage of the process

$$\text{PCE}[\%] = \frac{VAT}{total\ cycle\ time}$$



# Step 4: Determine Key Metrics (3)

**Entire process performance indicators:**

- Overall equipment effectiveness (OEE): reflects all the factors detracting from optimum equipment performance

$$OEE\ [\%] = Availability \times Performance \times Quality$$

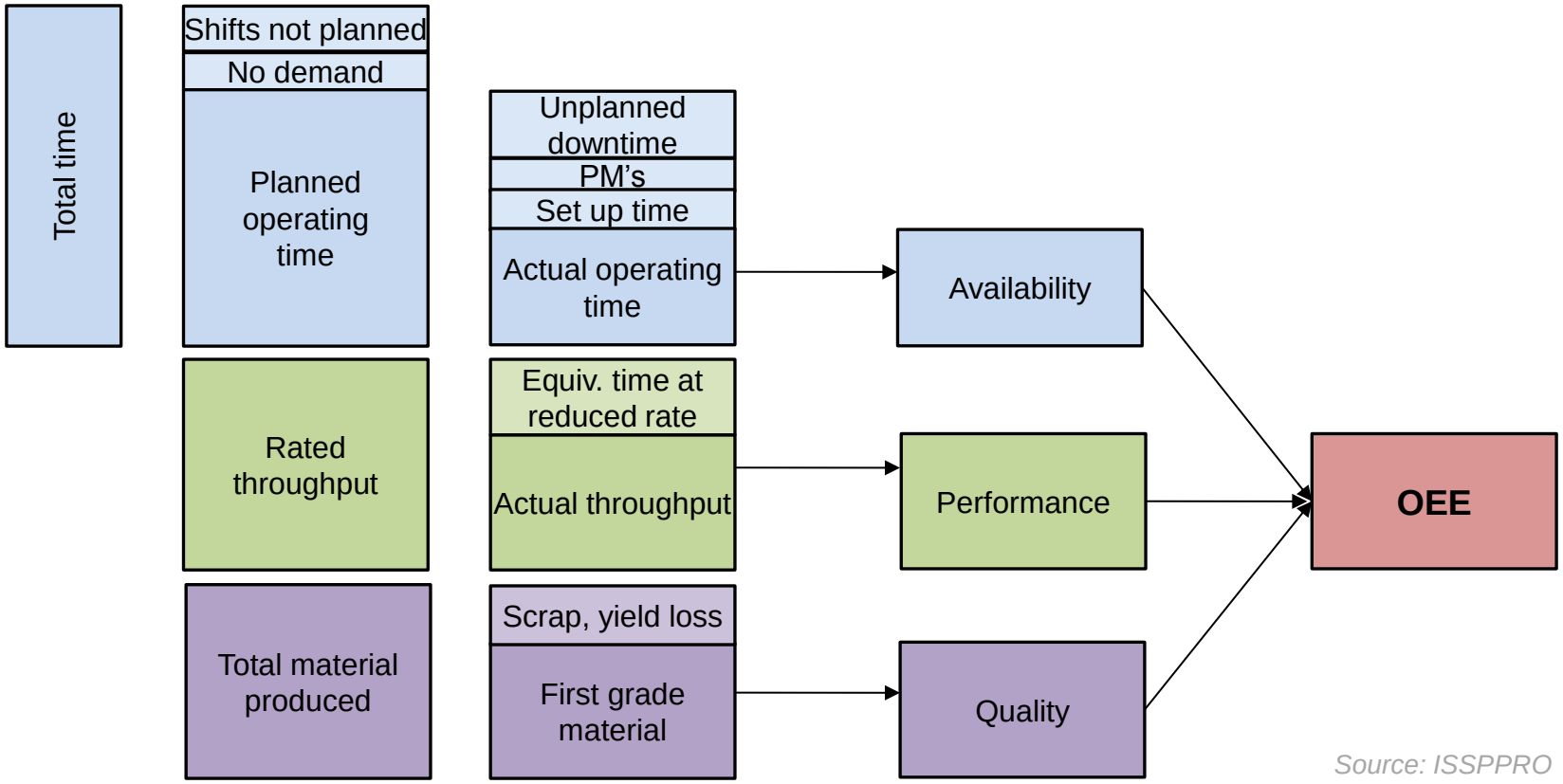
$$Availability\ [\%] = \frac{Actual\ operating\ time}{Planned\ operating\ time}$$

$$Performance\ [\%] = \frac{Actual\ throughput}{Planned\ throughput}$$

$$Quality\ [\%] = \frac{Quantity\ of\ first\ grade\ material}{Total\ quantity\ produced}$$

# Step 4: Determine Key Metrics (4)

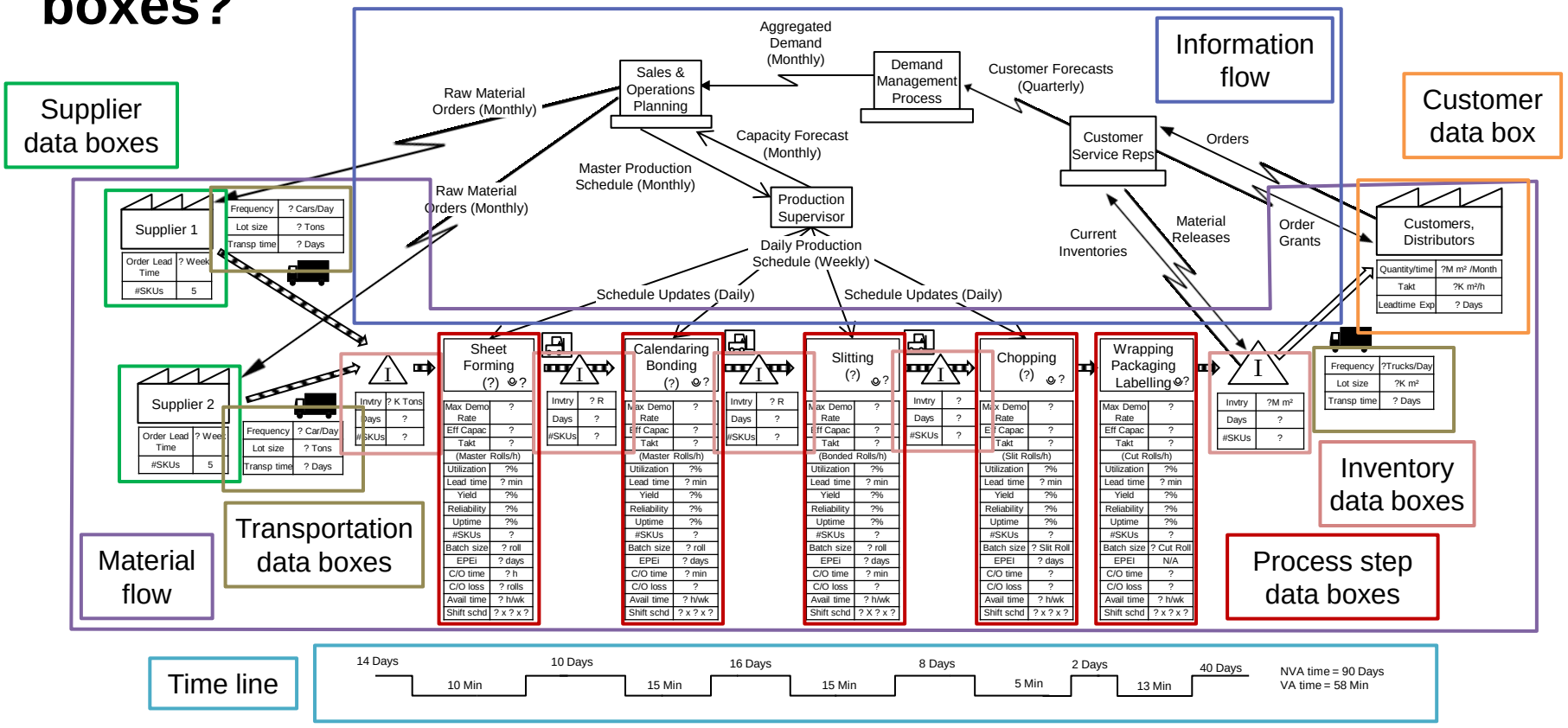
## Overall equipment effectiveness (OEE) components:




*Source: ISSPPRO*

# Learning Objectives

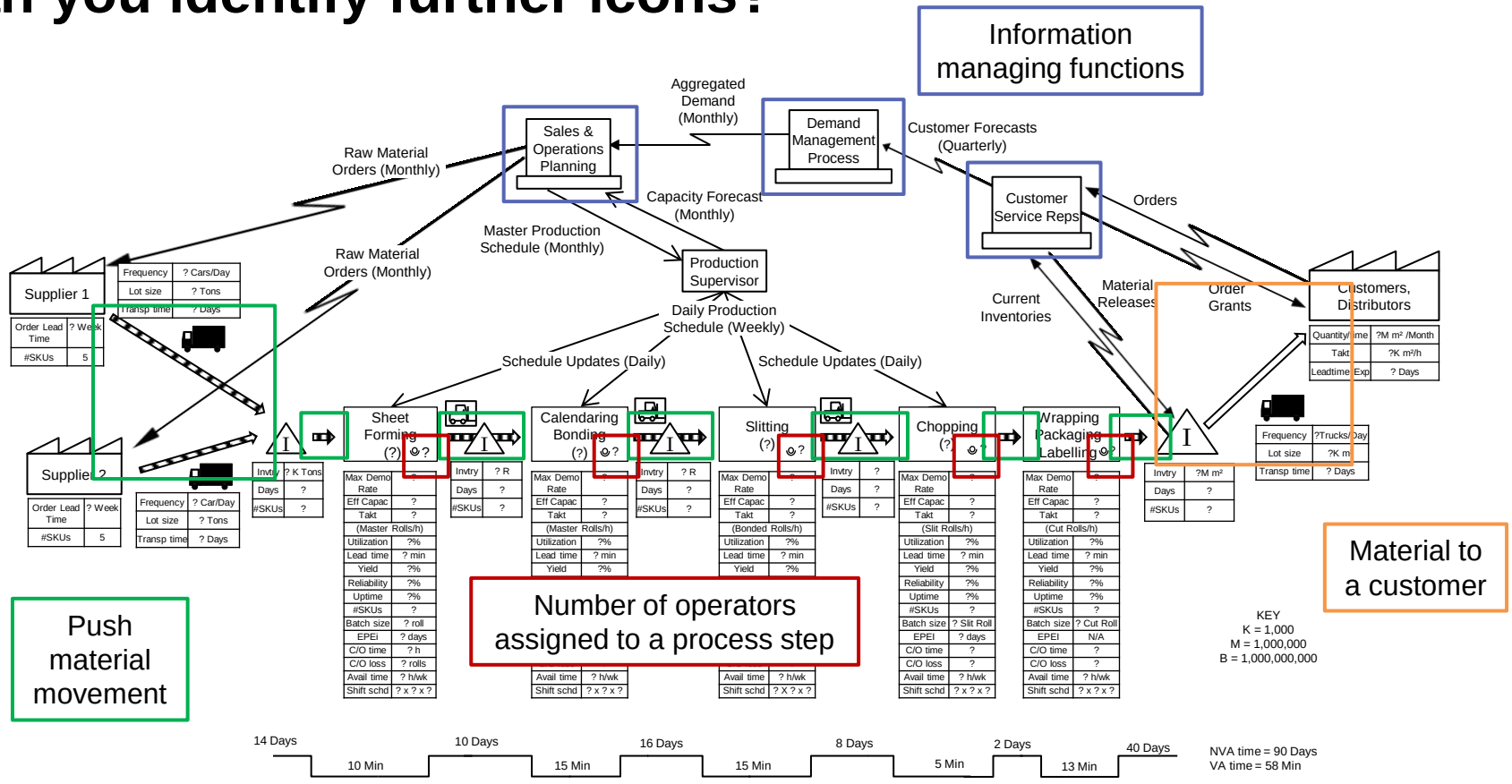
## Can you identify the three components and the data boxes?




*Source: based on King*

# Learning Objectives

## Can you identify further icons?



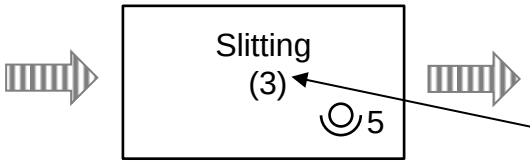

*Source: based on King*

# VSM Good Practices

- The Value Stream Map
- VSM Symbols
- Generating the Map
- VSM Good Practices
- Key Messages
- Glossary

# Parallel Equipment

**Can I describe parallel machines or systems by one single process box? Yes!**




Number of parallel machines indicated in parentheses

| | |
|---|---|
| Effective Capac | ? |
| Takt | ? |
| (Bonded Rolls/h) | |
| Utilization | ?% |
| Lead time | ? min |
| Yield | ?% |
| Reliability | ?% |
| Uptime/OEE | ?% |
| # SKUs | ? |
| Batch size | ? roll |
| EPEI | ? days |
| C/O time | ? min |
| C/O losses | ? |
| Avail time | ? h/week |
| Shift sched | ? x ? x ? |

Different data for parallel machines have to be reflected

⇨ Should be avoided when machines have different characteristics influencing material routing or processing!

*Source: based on King*

# Logical Flow vs. Geographic Arrangement (1)

**Is it more reasonable to arrange process boxes logically or geographically?**

- In general, the VSM should be arranged in a way that the true flow can be seen!

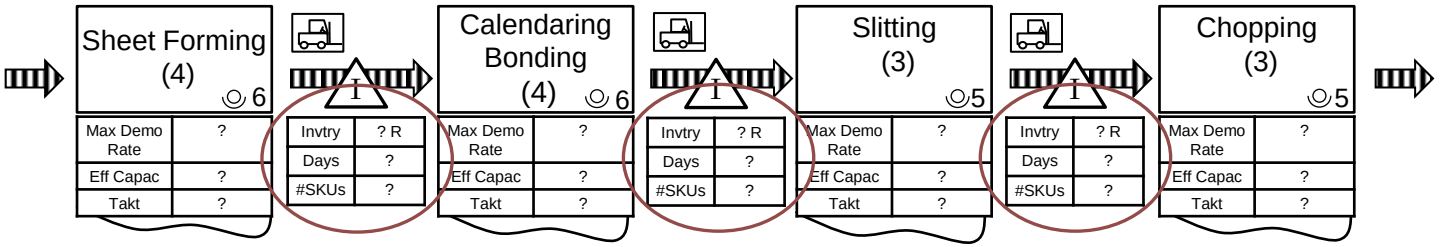
- Geographically accurate VSM can be helpful in some cases, however it should be depicted on a second map.

# Logical Flow vs. Geographic Arrangement (3)

**Example:** Sheet Manufacturing Process

- Logical arrangement:

Inventory stored in the same storage area is depicted several times



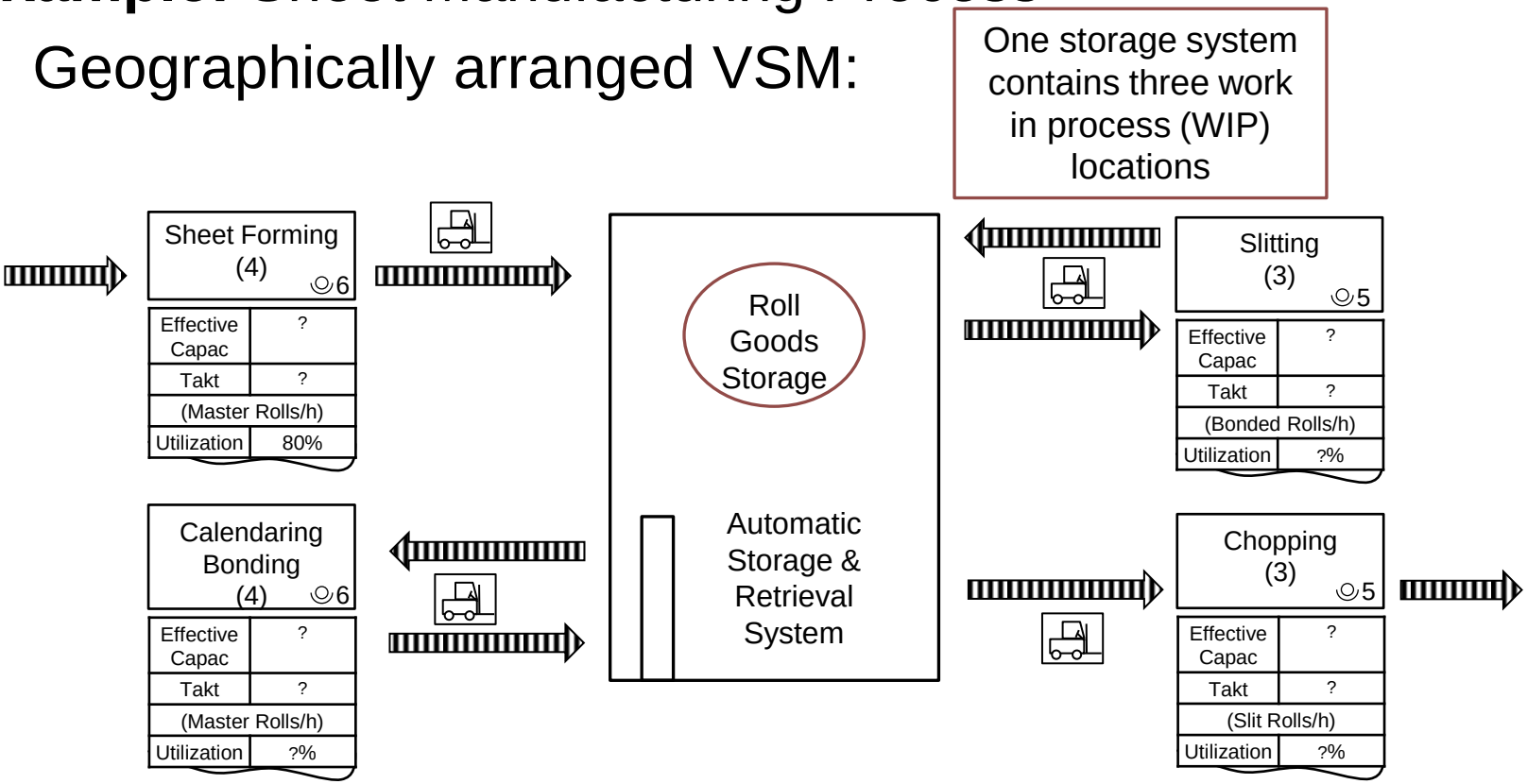

*Source: based on King*

⇨ Sometimes testing labs or storage areas have to be shown several times in order to make the true flow visible!

# Logical Flow vs. Geographic Arrangement (2)

**Example:** Sheet Manufacturing Process

- Geographically arranged VSM:




*Source: based on King*

⇨ This view provides no sense of material flow!

# Learning Objectives

**Summarize VSM Best Practices:**

- When it is reasonable to aggregate/separate parallel equipment?
  - Parallel machines or systems of comparable properties should be summed up in one process box
  - However, if these parallel machines have different capabilities influencing material routing or processing, they should be separated
- Can you explain why a logically arranged VSM should be preferred over a geographically arranged VSM?
  - It helps identifying the real flow, whereas geographically arranged VSM tend to get confusing and should only be as a supplement if needed

# Key Messages

- The Value Stream Map
- VSM Symbols
- Generating the Map
- VSM Good Practices
- Key Messages
- Glossary

# Key Messages (1)

**What is a VSM?**

A Value Stream Map (VSM) is a **flow diagram** of an entire production process, including material and information flow in connection with the required value-add and non-value add time.

# Key Messages (2)

**What are the outcomes of a VSM?**

- Identification of production times that do not add value to the final product
- Identification of production steps that
  - Waste (raw) material
  - Produce (hazardous) waste
  - Produce emissions and pollution
  - Lead to risks for workers' health
- Future state map showing an improved, less wasteful production process
- Development of an implementation plan for further improvements on the basis of Lean activities

# Key Messages (3)

**How can SMEs use VSM to improve their business?**

VSM is a tool which enables you to:

- Improve your understanding of the processes, inventory flows and sources of waste

- Make decisions to improve your performance on the basis of an idealized “future state” map and to reach
  - Higher productivity
  - Lower material and energy waste
  - Lower variable and material costs

# Glossary

- The Value Stream Map
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# Glossary (1)

- A-type process: Converging production process, typically found in assembly plants (starting with a variety of raw materials, producing a small amount of final products)
- Batch size [units]: Amount of material produced as a single lot
- Changeover (C/O) losses [units]: Amount of material lost in the change from one product to another
- Changeover (C/O) time [min]: Time needed to change from one product to another
- Cycle rate/Effective capacity [units/min]: Reciprocal of cycle time

# Glossary (2)

- Cycle time (C/T) [min/unit]: Time needed to produce a part or lot; reflects equipment capacity
- Effective capacity: See cycle rate
- Every part every interval (EPEI) [days]: Time span over which all product types are made
- Future state map: A VSM presenting an optimized state serving as target of all improvement activities
- Lead time [min]: The time needed for one part or lot to complete a specific process step

# Glossary (3)

- Maximum demonstrated rate [units/min]: Maximum production capacity possible under specific process equipment configuration; reciprocal of ideal cycle time
- Non-value-added time (NVA time or NVAT) [min]: Total time spent on non-value-added activities
- Order lead time [days]: Time from replenishment order until the material arrives
- Overall equipment effectiveness (OEE) [%]: Measure capturing all the factors detracting from optimum equipment performance; comprising an availability factor, a performance factor and a quality factor

# Glossary (4)

- PFD / Process flow diagram: Diagram visualizing the flow of plant processes and the major equipment
- Process cycle efficiency (PCE) [%]: Value-added percentage of the process, calculated as VAT divided by total cycle time
- Reliability [%]: Measure of the steadiness of a machine; percentage of time without any equipment failure
- Shift schedule [h/week]: Number of hours per shift, shifts per day and days per week
- Stock keeping units (SKUs) [units]: Product varieties entering or leaving a process step

# Glossary (5)

- Takt rate [units/min]: Rate at which a part or lot is needed, reciprocal of takt time
- Takt time [min/unit]: Time within which a part or lot is needed; calculated by dividing the time available in a period by the average demand of products during this period
- Total cycle time: Sum of all (process step) cycle times; calculated by adding VAT and NVAT
- Uptime [%]: Measure reflecting all sorts of time lost; calculated as net operating time divided by available operating time

# Glossary (6)

- Utilization [%]: Measure for how fully utilized a process step is; calculated by dividing cycle time by takt time or takt rate by effective capacity
- Value Stream Map (VSM): Visual tool used to identify the current flow of material and information throughout a production process
- Value-added time (VA time or VAT) [min]: Total time spent on value-added activities
- V-type process: diverging production process, typically found in process industries (starting from a small number of raw materials, producing a wide range of different final products)

# Glossary (7)

- Work in Progress (WIP, also Work in Process) [units]: all materials and partially finished goods within the production process waiting to be completed
- Yield [%]: Percentage of good parts leaving a process step

# Where to find more information

- VSM Font: http://www.ambor.com/public/vsm/vsmfont.html
- VSM Icons: http://www.lean.org/common/display/?o=866

Books:

- Rother M.; Shook J.: Learning to See: Value-Stream Mapping to Create Value and Eliminate Muda: Value Stream Mapping to Add Value and Eliminate Muda, 2009
- King, P. L.: Lean for the Process Industries: Dealing with Complexity, 2009
- California State University, Northridge Course (Week 7&9): http://www.csun.edu/~shternberg/shternberg-507.htm

# Sources

# Sources


- CSD Engineers, Switzerland / ISSPPRO, Germany, 2015
- King, P. L.: Lean for the Process Industries: Dealing with Complexity, 2009
- King, P. L.; King, J. S.: The Product Wheel Handbook: Creating Balanced Flow in High-Mix Process Operations, 2013
- EPA: The Lean and Chemicals Toolkit, 2009 http://www.epa.gov/lean/environment/toolkits/chemicals/index.htm
- EPA: The Lean and Environment Toolkit, 2007 http://www.epa.gov/lean/environment/toolkits/environment/index.htm

# Images

- ISSPPRO GmbH, Germany, 2015
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