Lean & Green Value Stream Mapping (I)

Training Session 1: A methodology for developing a Lean & Green Value Stream Map for a Virtual Plant
PRESENTATION OUTLINE

1. Value Stream Mapping
2. Lean & Green Value Stream Mapping
3. A methodology for developing a Lean & Green Value Stream Map for a Virtual Plant
4. Designing a Production Line for a Virtual Yoghurt Factory
5. Operational Performance Assumptions
6. Process Diagram
7. Current Value Stream Map
8. Energy Efficiency Comparison for the Operational Scenarios Considered
1. VALUE STREAM MAPPING

• In order to increase the capacity for generating and delivering value to customers and to other major stakeholders, **Lean production systems** focus on both **reducing waste** and **improving material flow** (King and King, 2015).

• But we only can reduce or eliminate waste, if we can understand where it exists in the current production processes.

• A value stream map (VSM) is designed to enable us to see waste and its causes.

• **Toyota** developed its “**material and information flow maps**” specifically to do just that.
Toyota defined seven types of waste:

1. **Overproduction:** making more than the customer needs, or making it sooner than needed.

2. **Unnecessary inventory:** material not currently being processed, including raw material, work in process, and finished product inventory.

3. **Defects:** parts of material that do not meet required specifications.

4. **Waiting:** time that operators or anyone else spend waiting for material or for the equipment to be ready to use.
1. VALUE STREAM MAPPING

5. **Transporting:** movement of material, either from one process step to the next step or into or out of inventory.

6. **Unnecessary motion:** walking around the equipment to get where they are needed, or to get changeover parts or tools.

7. **Inappropriate processing:** Excessive processing, doing more to the material than the customer requires.
1. VALUE STREAM MAPPING

- The first five of these can be readily seen from a well-constructed VSM.

- The remaining two require more detailed analysis, using Lean tools such as motion charts called “spaghetti diagrams”.

- In our VSM exercises, we will focus in understanding the impact of the first four (overproduction, unnecessary inventory, defects, and waiting) not only on operational performance but also on energy efficiency and carbon footprint reduction.
1. VALUE STREAM MAPPING

- An eighth waste is often added to Toyota´s seven:

  8. **Lost people potential:** the waste of human knowledge, creativity and potential.

- This also is something that cannot readily be seen on a VSM; it requires an in-depth analysis of work place culture, attitudes, behaviours, and participation in continuous improvement processes (King and King, 2015).
1. VALUE STREAM MAPPING

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Typical VSM icons. SOURCE: Lean Enterprise Institute
https://es.pinterest.com/pin/298433912781557511/
1. VALUE STREAM MAPPING

• Some typical **Lean metrics** in a VSM:
  
  • **Throughput** or **effective capacity**: The **average output of a production process** (machine, workstation, line, plant) **per unit time** (e.g., parts per hour) is defined as the system's throughput, or sometimes throughput rate (Hopp and Spearman, 2001).

  • **Capacity** or **maximum capacity**: An **upper limit on the throughput of a production process** is its capacity. It is the throughput you could expect from a production process step under “perfect” conditions: i) no yield losses or **defects**; ii) no **rate reductions**, due to mechanical, electrical or control system equipment minor failures; iii) no **unscheduled downtime**, due to breakdowns or to not availability of inputs or operators when needed; iv) no time for **preventive maintenance**; v) no time for **line cleaning and disinfection**; and vi) no time for changing from a product type to another or **changeover**.
1. VALUE STREAM MAPPING

- **Reliability**: The percentage of time that the machine is not down because of mechanical, electrical, or control system equipment failure.

- **Adjusted maximum capacity**: We will define this parameter as the maximum capacity of a machine multiplied by its reliability.

- **Cycle time**: The cycle time (also called variously average cycle time, flow time, or throughput time) of a given routing is the average time from release of a job at the beginning of the routing until it reaches an inventory point at the end of the routing (Hopp and Spearman, 2001).

- **Process cycle time or machine cycle time** \((C/T)\): They can be defined as the inverse of the effective capacity or of the adjusted maximum capacity. The result would be named as the effective cycle time or the adjusted minimum cycle time respectively.
1. VALUE STREAM MAPPING

- **Changeover (C/O) Time:** The time to change from one product type to another, including to get the full rate on the new product and get all properties within quality specifications.

- **Uptime or OEE (Overall Equipment Efficiency):** The percentage of time that a machine or a production line is up and running. For calculating the Uptime or the OEE is needed to take into account:
  - yield losses or defects
  - rate reductions
  - unscheduled downtime
  - preventive maintenance
  - line cleaning and disinfection
  - changeover time
One of the major Lean wastes is **unnecessary inventory**.

However, in most cases, we need to carry **cycle stock** and **safety stock**.

**Cycle stock** is the inventory carried to accommodate the cyclic nature of material delivery or production.

**Safety stock** is the inventory held to satisfy demand in cases where actual demand is higher than expected, or where next cycle is late in starting (King and King, 2015).
• Frequently the **throughput**, the **cycle time** and the **service level** of a production line can be improved by sizing correctly the intermediate or buffer inventories (a combination of cycle stock and safety stock).

• Lean is not about eliminating inventories. The priority of Lean is holding only the inventory needed to reach a very high service level for the current operational conditions.

• Of course, inventory can be reduced by decreasing other Lean wastes such as overproduction, defects or waiting
The Lead Time Ladder or Timeline appears as a square wave at the bottom of a VSM, and it is intended to contrast non-value-add (NVA) time and value-add (VA) time.

Typically, only the processing time (with the machine up and running) is considered value-add (VA) time.
1. VALUE STREAM MAPPING

• MAJOR REFERENCES:

• Peter L. King, Jennifer S. King. 2015. Value Stream Mapping for the process industries: creating a roadmap for a lean transformation. CRC Press Taylor & Francis Group, Boca Raton, FL.

2. LEAN & GREEN VALUE STREAM MAPPING

- **Energy consumption** can be easily incorporated to Lean & Green Value Stream Maps.

- **Machines** will consume energy when they are **up and running**.

- But energy is also consumed for **lighting, cooling or heating** when machines are down.

- **Inventories** are consuming energy all the time in the case of refrigerated chambers.

- In terms of **energy efficiency**, it should also be taken into account the role played by the power installed for the different machines. It has an influence on energy cost.
**2. LEAN & GREEN VALUE STREAM MAPPING**

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- OVERPRODUCTION
- WAITING
- DEFECTS
- UNNECESSARY INVENTORY
- ENERGY CONSUMPTION
- PHYSICAL WASTES
- EMISSIONS
- WATER CONSUMPTION

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Recently, Verma and Sharma (2016) have proposed to develop energy value stream mapping for estimating value adding energy and non-value added energy consumption.

Basically, the energy used by processing equipment and machines when they are running is value adding energy while the energy consumed by lighting and the heating and cooling of facilities is non-value added energy.

The energy consumed for cooling or refrigerating inventories could also be considered as non-value added energy.
Energy Ladder Line discriminating between value adding energy consumption and non-value added energy consumption

2. LEAN & GREEN VALUE STREAM MAPPING

• MAJOR REFERENCES:


While the traditional approach for value stream mapping can be considered as developing materials and information flow maps, we are going to focus on mapping the materials and energy flows.

Water consumption will also be mapped when it is a specially relevant Green waste and information is available.

Since Lean & Green Value Stream Mapping for the different industries has to be completed before visiting the different facilities to be benchmarked in the SCOoPE project, the mapping will be performed for virtual plants with one or more production lines.
3. A METHODOLOGY FOR DEVELOPING A LEAN & GREEN VALUE STREAM MAP FOR A VIRTUAL PLANT

- In the field of engineering, production lines has to be designed when a new industrial plant is being designed.

- The starting point is the products or family of products to be manufactured and the production capacity of the new plant.

- Subsequently, for each product or family of products, the processes are designed and the equipment and machines to carry out the different processes are selected. In the field of engineering, production lines has to be designed when a new industrial plant is being designed.
3. A METHODOLOGY FOR DEVELOPING A LEAN & GREEN VALUE STREAM MAP FOR A VIRTUAL PLANT

- Technical parameters such as the **maximum capacity** (name-plate capacity) and the **installed power** has to be known for each machine and equipment in order to make a basic design of a production line.

- Sometimes equipment suppliers can provide information on **equipment reliability, average time between breakdowns** or **average time for repairing a breakdown**. This information is very useful for designing the preventive maintenance plans but also for a better design of the production line.
• The more sophisticated engineering companies can use discrete simulation techniques or virtual reality for evaluating the operational performance of different production line layouts.

• We are going to design production lines for the major products or families of products being manufactured by the plants to be benchmarked in the SCOoPE project.

• For mapping the materials and energy flows, optimistic and “average” operational scenarios based on a set of operational assumption will be set up.
4. DESIGNING A PRODUCTION LINE FOR A VIRTUAL YOGHURT FACTORY

- For designing this production line, we use as a reference an engineering project for a new factory producing fruit yoghurts and skimmed milk.

- In Spain, food engineers has to defend an engineering project in order to get the engineering degree. Most projects are about the design of new plants in different food & drink industries.

- A similar academic requirement can exist in France for food engineers and probably in Italy.
5. OPERATIONAL PERFORMANCE ASSUMPTIONS

• DAILY WORKING TIME: 24 hours (3 shifts of 8 hours), 7 days per week

• PRODUCTION CAPACITY FOR WORK STATIONS: It will be assumed that the production capacity when the equipment is up and running will be equal to maximum capacity.

• ESTIMATION OF CHANGEOVER TIME: Between 5 (optimistic) and 30 (average) minutes

• ESTIMATION OF CLEANING AND DESINFECTION (AT THE END OF DAY): Between 1 (optimistic) and 2 (average) hours
5) ESTIMATION OF PREVENTIVE MAINTENANCE TIME PER DAY: Between 30 (optimistic) and 60 (average) minutes

6) ESTIMATION OF LINE DOWNTIME PER DAY: Between 1 hour (optimistic) and 3 hours (average)

7) ESTIMATION OF PERCENTAGE OF DEFECTS (AT THE END OF THE PRODUCTION LINE): Between 1% (optimistic) and 5% (average)
6. PROCESS DIAGRAM

MIIL RECEPTION

SANITATION AND BACTOFUGATION

SKIMMING AND ULTRAFLTRATION

HOMOGENISATION

THERMAL TREATMENT (PASTEURIZATION)

COOLING

INCUBATION AND FERMENTATION

FUIT ADDING

PACKAGING AND LABELLING

STORING

Intermediate Product: Skimmed and pasteurized

Final Product: Milk skimmed and pasteurized

Final Product: Skimmed Youghurt with Fruits

PACKING AND LABELLING

STORING
7. CURRENT VALUE STREAM MAP

Supplier

20,000 – 30,000
L / d

RAW MATERIAL

MILK RECEPTION
3 ISOTHERMAL
STORAGE TANKS.
EACH ONE:
MAXIMUM
CAPACITY: 10,000 L
/ 1,5 HORAS
LEAD TIME: 1,5
HORAS
INSTALLED POWER:
5,52 KW

10-04-2018

SANITATION
SANITISER.
MAXIMUM
CAPACITY: 5000 L
/H
MINIMUM C/T: 1 H
INSTALLED
POWER: 6.9 KW.

SKIMMING /
ULTRAFILTRATION
SKIMMING
EQUIPMENT
MAX. CAPACITY:
5000 L/H.
MIN. C/T: 1 H.
INST. POWER: 2.3
KW
ULTRAFILTRATION
EQUIPMENT. MAX.
CAPACITY: 5000
L/H. MIN. C/T: 1 H.
INST. POWER: 11.95
KW

HOMOGENIZATION
HOMOGENIZER.
MAXIMUM
CAPACITY: 5000
L/H.
MINIMUM C/T:
1 H. INSTALLED
POWER: 17.48
KW.
7. CURRENT VALUE STREAM MAP

**HEAT TREATMENT**
- **PASTEURIZER, MAXIMUM**
  - CAPACITY: 5000 L/H.
  - MINIMUM C/T: 1 H.
  - INSTALLED POWER: 5,52 KW.

**COOLING**
- **ISOTHERMAL STORAGE TANK**
  - MAXIMUM CAPACITY: 5,000 L / 1 H.
  - LEAD TIME: 1 H
  - INSTALLED POWER: 5.52 KW.

**INCUBATION / FERMENTATION**
- **EQUIPMENT**
  - MAXIMUM CAPACITY: 2500 L / 3 H
  - LEAD TIME: 3 H
  - INSTALLED POWER: 17.52 KW.

**FRUIT ADDITION**
- **DOSING PUMP**
  - MAXIMUM CAPACITY: 2500 L/H.
  - MINIMUM C/T: 1 H
  - INSTALLED POWER: 2.76 KW.

**MILK PACKING / LABELLING**
- **PACKER**
  - MAX. CAPACITY: 2500 L/H.
  - MINIMUM C/T: 1 H
  - INSTALLED POWER: 2.94 KW.

**COLD STORAGE ROOM**
- INSTALLED POWER: 5.76 KW.
- CAPACITY STORAGE: 48HRS

**FINAL PRODUCT INVENTORY**

**INTERMEDIATE INVENTORY**

**Customer**
8. ENERGY EFFICIENCY COMPARISON FOR THE OPERATIONAL SCENARIOS CONSIDERED

<table>
<thead>
<tr>
<th></th>
<th>PRODUCTION</th>
<th>DEFECTS (1%)</th>
<th>REAL PRODUCTION (KG/L)</th>
<th>TOTAL DAILY ENERGY CONSUMPTION</th>
<th>ENERGY EFFICIENCY (KG OR L PER KWH)</th>
<th>ENERGY EFFICIENCY IMPROVEMENT (%)</th>
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<tr>
<td><strong>DAY PRODUCTION (OPTIMISTIC SCENARIO)</strong></td>
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<tr>
<td>YOGHURTS (KG)</td>
<td>5625,00</td>
<td>56,25</td>
<td>5568,75</td>
<td>1204,97</td>
<td>4,62</td>
<td>36,38%</td>
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<tr>
<td>SKIMMED MILK (L)</td>
<td>20000,00</td>
<td>200</td>
<td>19800,00</td>
<td>1204,97</td>
<td>16,43</td>
<td>21,23%</td>
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<thead>
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<th>PRODUCTION</th>
<th>DEFECTS (5%)</th>
<th>REAL PRODUCTION (KG/L)</th>
<th>TOTAL DAILY ENERGY CONSUMPTION</th>
<th>ENERGY EFFICIENCY (KG OR L PER KWH)</th>
<th>ENERGY EFFICIENCY IMPROVEMENT (%)</th>
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<td><strong>DAY PRODUCTION (AVERAGE SCENARIO)</strong></td>
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<td>YOGHURTS (KG)</td>
<td>3750,00</td>
<td>37,5</td>
<td>3712,50</td>
<td>1095,54</td>
<td>3,39</td>
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<tr>
<td>SKIMMED MILK (L)</td>
<td>15000,00</td>
<td>150</td>
<td>14850,00</td>
<td>1095,54</td>
<td>13,55</td>
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8. ENERGY EFFICIENCY COMPARISON FOR THE OPERATIONAL SCENARIOS CONSIDERED

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<thead>
<tr>
<th>ENERGY LINE (OPTIMISTIC SCENARIO)</th>
<th>Value Adding Energy (KWH)</th>
<th>Non-Value Added Energy</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY LINE (OPTIMISTIC SCENARIO)</td>
<td>282.28</td>
<td>922.68</td>
<td>30.59%</td>
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<tr>
<td>VALUE ADDING ENERGY (KWH)</td>
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<td>NON-VALUE ADDED ENERGY</td>
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<tr>
<td>RATIO</td>
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<tr>
<td>ENERGY LINE (OPTIMISTIC SCENARIO)</td>
<td>190.25</td>
<td>905.29</td>
<td>20.62%</td>
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<tr>
<td>VALUE ADDING ENERGY</td>
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<td>NON-VALUE ADDED ENERGY</td>
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Thank you for your attention!

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