PROJECT NUMBER 2019-1-SE01-KA203-060572

Manufacturing Education for a Sustainable fourth Industrial Revolution

Sustainable Value Stream Mapping

Politechnika Rzeszowska im. Ignacego Łukasiewicza

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

Introduction to Value Stream Mapping

- The concept of Value Stream Mapping (VSM) was introduced by Mike Rother and John Shook in their book, "*Learning to See*".
- The motivation behind the concept was:
  - Many companies suffer from huge amount of wastes related to the non value added activities. This results with the necessity of identification of areas in which the wastes exist and continuous improvement implementation to eliminate the wastes
  - Values stream mapping can help to see the whole of a product flow through different process what allow to see how the wastes existing in different process areas influence the product flow

Rother, Mike, and John Shook. Learning to see: value stream mapping to add value and eliminate muda. Lean enterprise institute, 2003.

Introduction to Value Stream Mapping

- Mike Rother and John Shook presented the concept of Value Stream as:

"A value stream is all the actions (both value added and non-value) currently required to bring a product through the main flows of essential to every product:

1. The production flow from raw material into the arms of the customer
2. The design flow from concept to launch

- The challenge is:

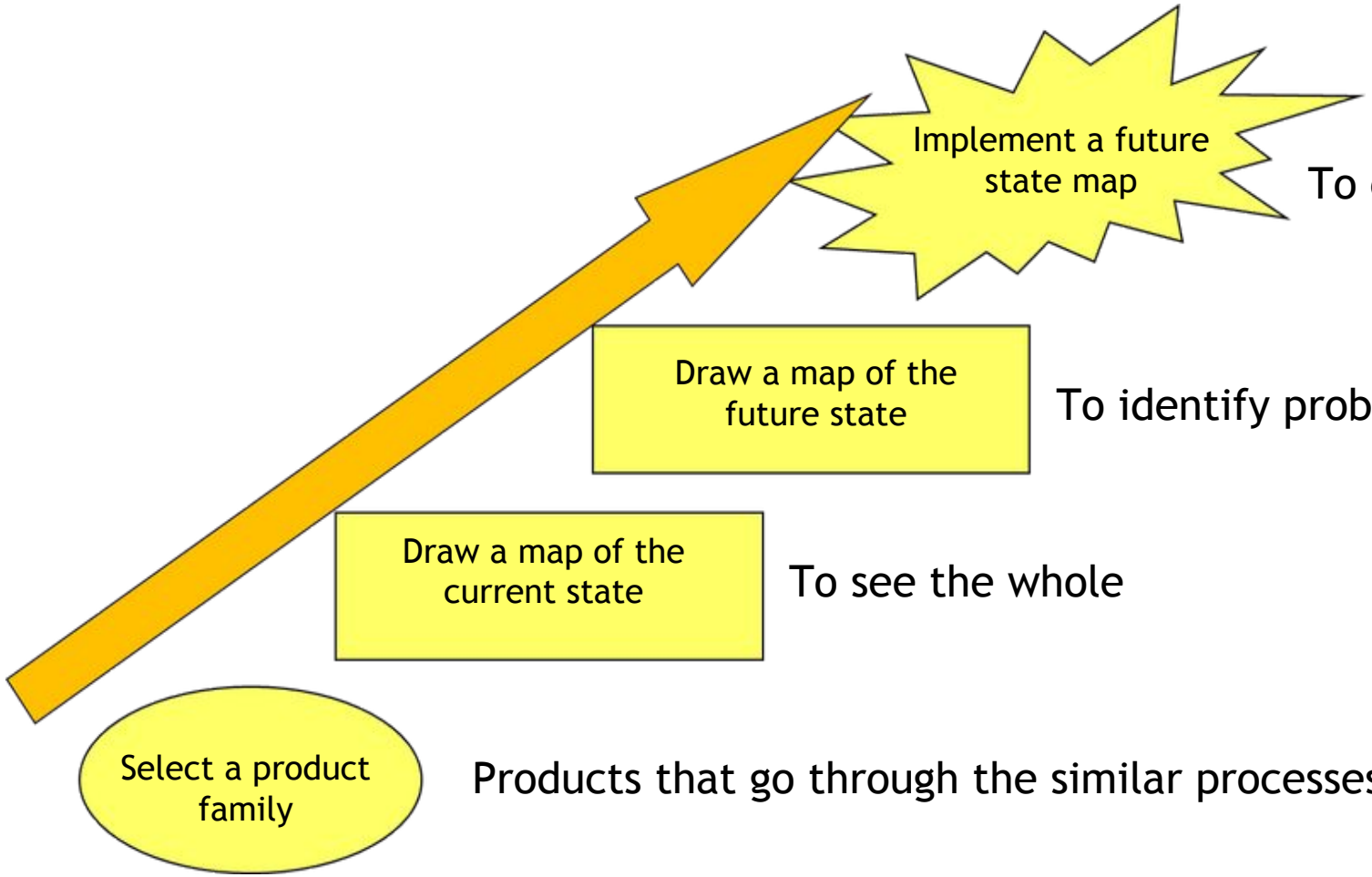
"Whenever there is a product for a customer,

There is a value stream. The challenge lies in seeing it."

1. Introduction to Value Stream Mapping

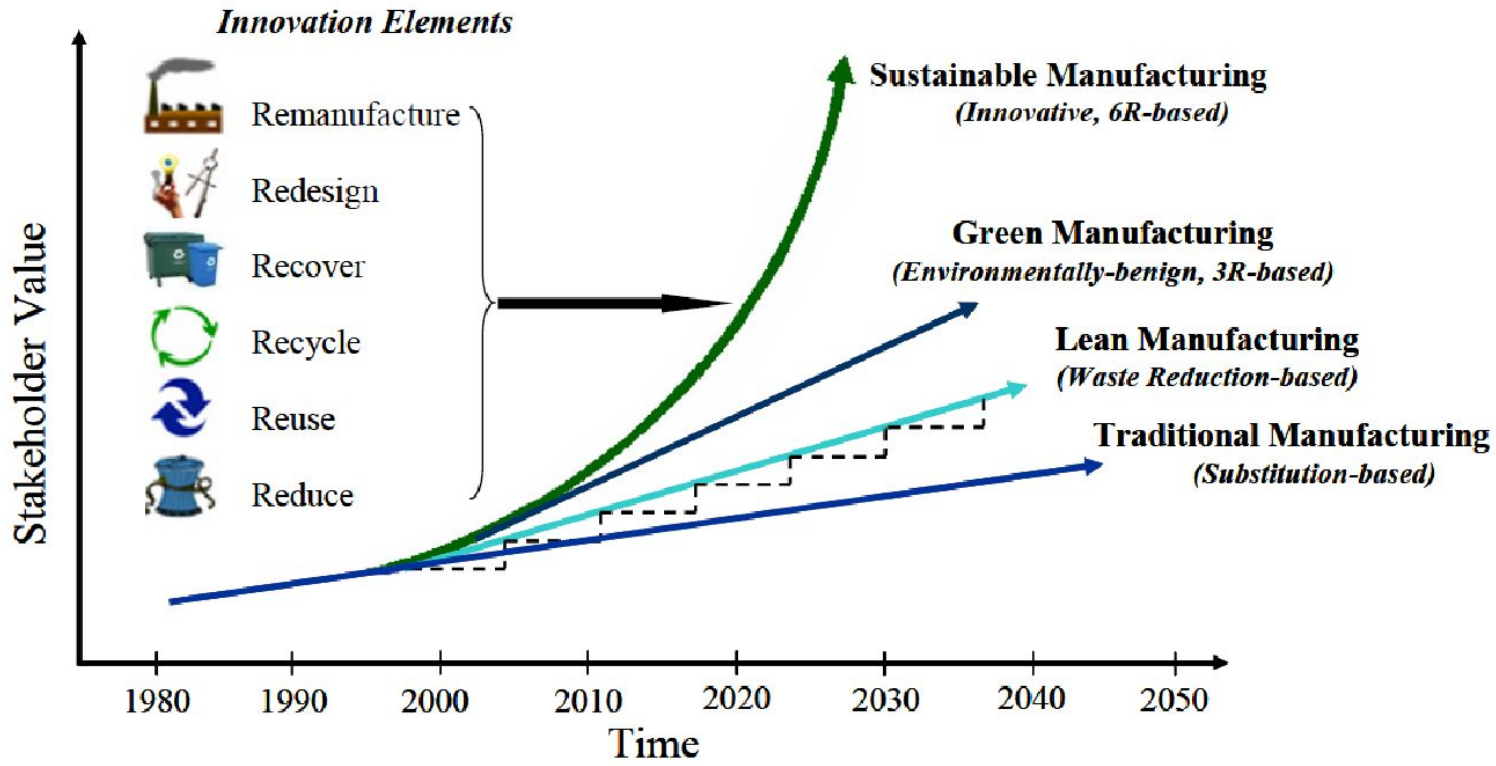
- Phases of the Value Stream Mapping
  - Select a product family
  - Define the value stream manager
  - Draw the current state map
  - Evaluate the current state of the value stream
  - Draw the future state value stream map
  - Plan the implementation of the future state of value stream and assess the achievements

Steps of value stream mapping



Mike Rother, John Shook: "Learning to See - value stream mapping to add value and eliminate muda". Lean Enterprise Institute, 1999

Evolution of manufacturing strategies



Jawahir, I.S., Rouch, K.E., Dillon Jr., O.W., Joshi, K.J., Venkatachalam, A., Jaafar, I.H., 2006. Total life-cycle considerations in product design for manufacture: a framework for comprehensive evaluation, (keynote paper). In: Proc. TMT 2006, Lloret de Mar, Barcelona, Spain, September 2006, 1-10.

Introduction to Sustainable Value Stream Mapping

- The concept of Sustainable Value Stream Mapping (Sus-VSM) was introduced by Faulkner W. and Badurdeen F. in their work „Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance" published in Journal of Cleaner Production in 2014.
- The motivation behind the concept was:
  - In wastes identification the companies take into consideration mostly that wastes that are important from financial point of view,
  - Sustainable development is related to improvement not only financial but also environmental and social aspects,
  - While, identification of the wastes related to environmental and social aspects can also positively influence on economic aspects.

William Faulkner, Fazleena Badurdeen, Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance, Journal of Cleaner Production, Volume 85, 2014, Pages 8-18, https://doi.org/10.1016/j.jclepro.2014.05.042.

Environmental metrics of Sus-VSM

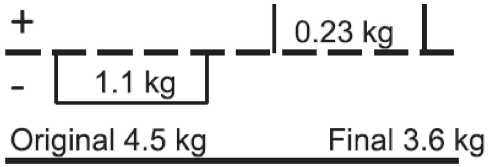
VSM vs. Sus-VSM

Type of waste/issue	Traditional VSM	Sus-VSM	Metric type
Time waste	+	+	Economic
Raw material waste	−	+	Environmental
Process water waste	−	+	Environmental
Energy waste	−	+	Environmental
Job hazards	−	+	Societal
Ergonomics	−	+	Societal

Adam Brown, Joseph Amundson, Fazleena Badurdeen, Sustainable value stream mapping (Sus-VSM) in different manufacturing system configurations: application case studies, Journal of Cleaner Production, Volume 85, 2014, Pages 164-179, https://doi.org/10.1016/j.jclepro.2014.05.101.

Visual representation of environmental metrics in Sus-VSM

Raw material usage



Energy consumption

Process water consumption

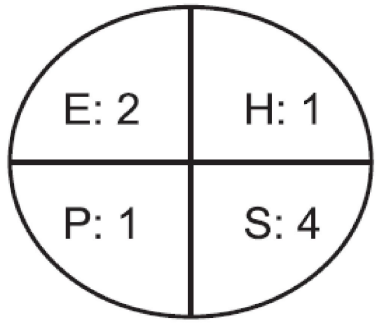
Required	Used	Net
53 L	61 L	23 L

Adam Brown, Joseph Amundson, Fazleena Badurdeen, Sustainable value stream mapping (Sus-VSM) in different manufacturing system configurations: application case studies, Journal of Cleaner Production, Volume 85, 2014, Pages 164-179, https://doi.org/10.1016/j.jclepro.2014.05.101.

Visual representation of societal metrics in Sus-VSM

Work environment:

- Noise (dbA)
- Risk:
  - Electrical systems (E)
  - Hazardous chemicals / materials (H)
  - Pressurised systems (P)
  - High speed components (S)



Adam Brown, Joseph Amundson, Fazleena Badurdeen, Sustainable value stream mapping (Sus-VSM) in different manufacturing system configurations: application case studies, Journal of Cleaner Production, Volume 85, 2014, Pages 164-179, https://doi.org/10.1016/j.jclepro.2014.05.101.

Work environment risk rating description

Potential operator risk - Description

0 - Potential risk does not exist (DNE)
1 - Risk is present but has low impact and probability of occurring
2 - Risk is present but has low impact and high probability or high impact and low probability of occurring
3 - Risk is present but has medium impact and medium probability of occurring
4 - Risk is present but has either medium impact and high probability of occurring or high impact and medium probability of occurring
5 - Risk is present but has high impact and high probability of occurring

William Faulkner, Fazleena Badurdeen, Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance, Journal of Cleaner Production, Volume 85, 2014, Pages 8-18, https://doi.org/10.1016/j.jclepro.2014.05.042.

Key performance indicators in Sus-VSM

- Key performance indicators

1. Total lead time [days]
2. Value-added time [min]
3. Percentage value-added time [%]
4. Process water consumption [L/unit] ([L/unit lost])
5. Raw material usage [kg/unit]
6. Material utilization rate [%]
7. Energy consumption [kWh/unit]

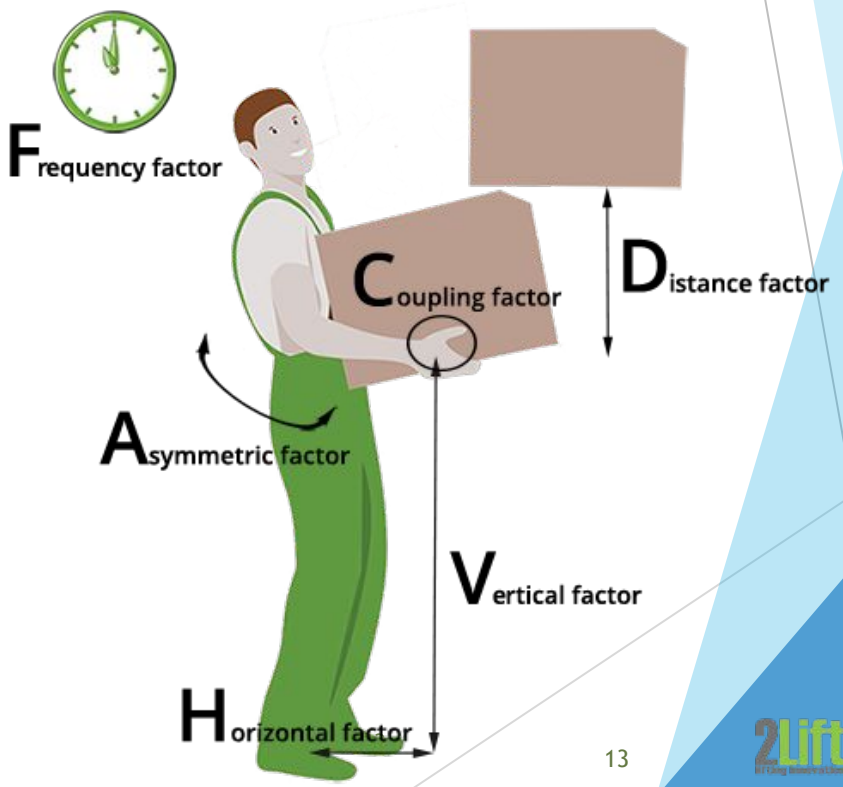
Adam Brown, Joseph Amundson, Fazleena Badurdeen, Sustainable value stream mapping (Sus-VSM) in different manufacturing system configurations: application case studies, Journal of Cleaner Production, Volume 85, 2014, Pages 164-179, https://doi.org/10.1016/j.jclepro.2014.05.101.

Physical work metrics

National Institute for Occupational Safety and Health (NIOSH)

RWL = LC x HM x VM x DM x AM x FM x CM

- **LC - Load Constant**, which is 51.51 pounds (approx. 23 kilograms) is the maximum weight that can be lifted under ideal conditions.
- **H - Horizontal Multiply factor** - horizontal distance from the palm to the center of the body (defined as the midpoint between the knuckles).
- **V - Vertical Multiply factor** - the vertical distance between the hands (holding the load in the starting position) and the floor
- **D - Distance Multiplying factor** - the vertical distance over which the load is lifted, measured from the starting point to the end point
- **A - Asymmetric Multiplying factor** - the angle of asymmetry to the lift force. Degree required to twist the body during a lifting task.
- **F - Frequency Multiplying factor** - the time between lifts and the total duration of the lift during a work shift.
- **C - Coupling Multiply Factor** - load grip quality rated as "good", "fair" or "poor".



https://2lift.com/safe-lifting

Physical work metrics

Physical Load Index (PLI) - is a measure ranging from 0 to 56. The rating is derived from responses to a questionnaire that includes questions about how often (from never to very often) different body positions and coping with different loads.

Index of physical work load = 0.974 × score of T2 + 1.104 × score of T3 + 0.068 × score of T4 + 0.173 × score of T5 + 0.157 × score of A2 + 0.314 × score of A3 + 0.405 × score of L3 + 0.152 × score of L4 + 0.152 × score of L5 + 0.549 × score of Wu1 + 1.098 × score of Wu2 + 1.647 × score of Wu3 + 1.777 × score of Wi1 + 2.416 × score of Wi2 + 3.056 × score of Wi3, where T1 = straight, upright (trunk bent 5 degrees forward), T2 = slightly inclined (trunk bent 45 degrees forward), T3 = strongly inclined (trunk bent 75 degrees forward), T4= twisted, T5 = laterally bent, A1= 2 arms below shoulder height, A2 = 1 arm above shoulder height, A3 = 2 arms above shoulder height, L1 = sitting, L2 = standing, L3 = squatting (trunk bent 15 degrees forward), L4 = kneeling with one or both knees, L5 = walking or moving, Wu1-Wu3 = lifting with the trunk upright, and Wi1-Wi3 = lifting with the trunk inclined 60 degrees. The item scores were coded as follows: "never" = 0, "seldom" = 1, "sometimes" = 2, "often" = 3, "very often" = 4.

Hollmann S, Klimmer F, Schmidt KH, Kylian H. Validation of a questionnaire for assessing physical work load. Scand J Work Environ Health. 1999 Apr;25(2):105-14. doi: 10.5271/sjweh.412. PMID: 10360465.

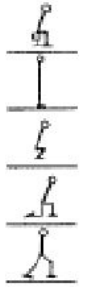
Trunk

	never	seldom	sometimes	often	very often
straight, upright					
slightly inclined					
strongly inclined					
twisted					
laterally bent					

Arms

	never	seldom	sometimes	often	very often
both arms below shoulder height					
one arm above shoulder height					
both arms above shoulder height					

Legs



	never	seldom	sometimes	often	very often
sitting					
standing					
squatting					
kneeling with one knee or with both					
walking, moving					

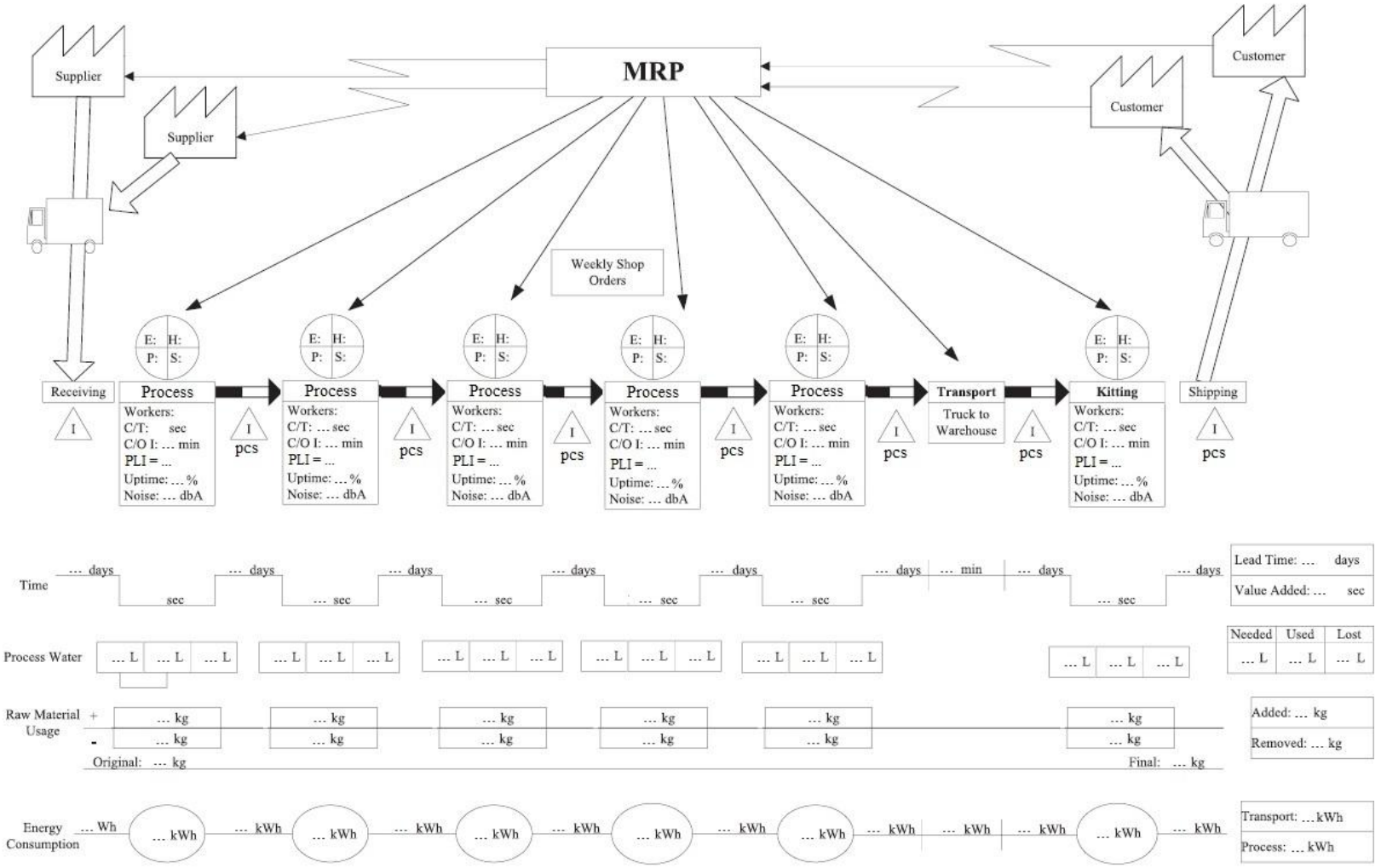
Weight, lifted / carried with upright trunk

	never	seldom	sometimes	often	very often
light (up to 10 kg)					
medium (10 - 20 kg)					
heavy (more than 20 kg)					

Weight, lifted / carried with inclined trunk

	never	seldom	sometimes	often	very often
light (up to 10 kg)					
medium (10 - 20 kg)					
heavy (more than 20 kg)					

An example of a Sus-VS map scheme



References

- Mike Rother, John Shook: “Learning to See – value stream mapping to add value and eliminate muda”. Lean Enterprise Institute, 1999
- William Faulkner, Fazleena Badurdeen, Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance, Journal of Cleaner Production, Volume 85, 2014, Pages 8-18, https://doi.org/10.1016/j.jclepro.2014.05.042.
- Jawahir, I.S., Rouch, K.E., Dillon Jr., O.W., Joshi, K.J., Venkatachalam, A., Jaafar, I.H., 2006. Total life-cycle considerations in product design for manufacture: a framework for comprehensive evaluation, (keynote paper). In: Proc. TMT 2006, Lloret de Mar, Barcelona, Spain, September 2006, 1-10.
- Adam Brown, Joseph Amundson, Fazleena Badurdeen, Sustainable value stream mapping (Sus-VSM) in different manufacturing system configurations: application case studies, Journal of Cleaner Production, Volume 85, 2014, Pages 164-179, https://doi.org/10.1016/j.jclepro.2014.05.101.
- https://2lift.com/safe-lifting
- Hollmann S, Klimmer F, Schmidt KH, Kylian H. Validation of a questionnaire for assessing physical work load. Scand J Work Environ Health. 1999 Apr;25(2):105-14. doi: 10.5271/sjweh.412. PMID: 10360465.

PROJECT NUMBER 2019-1-SE01-KA203-060572

Manufacturing Education for a Sustainable fourth Industrial Revolution

MAESTRO

Thank you for your attention!

Loughborough University

POLITECNICO DI TORINO

KTH VETENSKAP OCH KONST

UNIVERSITÀ DI PISA

POLITECHNIKA RZESZOWSKA im. IGNACEGO ŁUKASIEWICZA

Univerza v Ljubljani

FCT FACULDADE DE CIÊNCIAS E TECNOLOGIA UNIVERSIDADE NOVA DE LISBOA