

**Prof. Ing. Dario Pozzetto**

**Department of Engineering and Architecture – University of Trieste**

**Via Valerio, 10 – 34127 Trieste – Tel: 040.558.3805 / 7982 Fax: 040.558.3812**

**E-mail: [pozzetto@units.it](mailto:pozzetto@units.it)**

# **INDUSTRIAL PLANTS II**

**Chapter one – part 2:**

**Lean manufacturing – Smart Production Factory**

**DOUBLE DEGREE MASTER IN**

**“PRODUCTION ENGINEERING AND MANAGEMENT”**

**CAMPUS DI PORDENONE**

**UNIVERSITÀ OF TRIESTE**

# Lean Manufacturing

## "Smart Production Factory" laboratory

The purpose of the laboratory test is to apply the methods of Lean Manufacturing as closely as possible to a production reality.

The laboratory, built with equipment from LeanProducts S.r.l. of Pordenone, useful for simulating a working environment, takes its cue from an AS-IS configuration consisting of three work points distant from each other and from a warehouse where items for the construction of three specific components of Electrolux Professional S.p.A., LeanProducts S.r.l. and Savio S.p.A.

# Lean Manufacturing

## "Smart Production Factory" laboratory

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The two configurations made it possible to verify the changes in the Key Performance Indicator (KPI) taken as a reference. The simulation involves the installation of a "gadget" product: it is a trolley in the first experience and an economiser in the second.

# Lean Manufacturing

## "Smart Production Factory" laboratory

The goal of the laboratory is to simulate the production of a factory, in which the differences between the following ways of producing are highlighted:

- a) **push logic**: through the management of orders with medium-high lots (round 1);
- b) **pull logic**: introduction of the concept of lean manufacturing (round 2).

# Lean Manufacturing

"Smart Production Factory" laboratory

## **CREATION OF A TRANSPORT TROLLEY - 1st ROUND**

The object to be produced is a trolley consisting of aluminum profiles and four wheels, designed for the transport of containers of materials or pieces, available in two versions: one with a yellow cover frame and a white one. This product could be requested separately from the market.



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 1:** Assembly operation of the aluminum profiles, divided into the following operations:

- 1) withdrawal from the supermarket of a KLT container (storage box with open front with its own label), in which the name of the article, the name of the component, the code of the component and the phase and operation number (for example, 1.1 indicates step number one and step number one).



Supermarket



Container KLT

# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 1:** Assembly operation of the aluminum profiles, divided into the following operations:

2) withdrawal one at a time:

- container for aluminum profiles L = 332; GFF-000L;
- container for aluminum profiles L = 232; GFF-000L;
- metal corner container with screw inside GFJ-A13;
- take the allen key n ° 5;



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 1:** Assembly operation of the aluminum profiles, divided into the following operations:

3) assembly of the materials taken





# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 1:** Assembly operation of the aluminum profiles, divided into the following operations:

The operator must pick up the containers with the necessary components from the warehouse and bring them to the workplace and then, with another movement, take the tool from the toolbox. Subsequently, after inserting the sections into the metal corners, the operator must tighten the 4 screws, one for each corner.

Finally, the lot (consisting of 3 semi-finished products) is brought to the next location.



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 1:** Assembly operation of the aluminum profiles

The following times were noted:

PHASIS	TIMES (s)	ACTIVITIES
A	15	Displacement: supply of materials in the warehouse
B	5	Arrangement of containers on the work table
C	15	Displacement: procurement of tools for assembly
D	240	Processing: assembly of 3 pieces
E	5	Transport of the 3 pieces to the next workstation

The value added activity is D, while the others are non-value added.  
Space covered by the operator 23.6 m.

# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 1:** Assembly operation of the aluminum profiles

The total time to run the batch of 3 components is 280 s, of which 40 s for non-value-added activities and 240 s for value-added activities.

The time taken to make the single piece is:

- first piece 105 s;
- second piece 65 s;
- third piece 70 s.

The time for processing the first piece is greater than the other two: this is due to poor operator training on the operations to be carried out.

# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 1:** Assembly operation of the aluminum profiles

Thanks to practice, the times for the workings of the second and third pieces have, in fact, decreased.

There were two errors during machining: a 5 s error when machining the first piece and a 5 s error while machining the third piece.

Possible causes of the long time for the realization of the pieces can be found in:

- the tip of the Allen wrench got stuck in the head of the screw (inadequate tool);
- poor operator training;
- operator stress due to timing of operations.

# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 2:** Assembly of the trolley wheels, divided into the following operations:

- 1) take one KLT container at a time from the supermarket:
  - wheels with brake, LP-RV002;
  - wheels without brake, LP-RV001;
  - M12 screws, SCREW 061017;
  - dice, 061.018;
  - no. 8 Allen key to assemble.



# Lean Manufacturing

"Smart Production Factory" laboratory

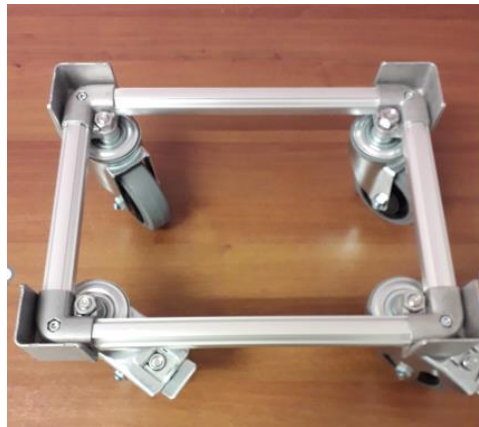
## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 2:** Assembly of the trolley wheels

2) assembly of materials taken



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 2:** Assembly of the trolley wheels

The operator, after having received the batch of frames from the previous position, goes to the warehouse to take the necessary material and the necessary tools. We then proceed with the assembly of the wheels on the trolley by inserting screws in the appropriate housings, screw the nuts to the screws and tighten with the Allen key so that the wheels are well fixed to the trolley frame. Finally, we proceed with the delivery of the lot to the next location.



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 2:** Assembly of the trolley wheels

Bolts must be tightened securely. Wheels with brakes must be mounted adjacent to one of the two short sides of the frame.

The following times were noted:

PHASIS	TIMES (s)	ACTIVITIES
A	89	Displacement: procurement of materials and tool from the warehouse
B	736	Processing: assembly of 3 pieces
C	15	Transport of the 3 pieces to the next workstation

The value added business is B, while the others are non-value added.  
The space traveled by the operator 26.9 m.



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 2:** Assembly of the trolley wheels

The total time to run the batch of 3 components is 840 s, of which 104 s for non-value-added activities and 736 s for value-added activities.

The time taken to make the single piece is:

- first piece 319 s;
- second piece 217 s;
- third piece 200 s.

The time for processing the first piece is longer than the other two: this is due to poor operator training on the operations to be carried out.

# Lean Manufacturing

"Smart Production Factory" laboratory

## **CREATION OF A TRANSPORT TROLLEY - 1st ROUND**

The work phases can be divided into 3 phases:

### **a) batch processing**

**Phase 2:** Assembly of the trolley wheels

During the assembly of the first piece, the operator lost 102 s to remove the Allen key that got stuck in the wheel.

The location was too small due to the size of the frames and material.

# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 3:** Assembly operation of the trolleys covering frames, divided into the following operations:

- 1) take one KLT container at a time from the supermarket:
  - yellow cover frame;
  - gray cover frame.

No special tools are needed.



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 3:** Assembly operation of the trolleys covering frames, divided into the following operations:

2) assembly of materials taken



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 3:** Assembly operation of the trolleys covering frames, divided into the following operations:

The operator picks up the necessary material from the warehouse and places it on the work bench. Subsequently, it passes to the assembly phase, which consists in correctly positioning small plastic protections at the sides of the trolley, thus obtaining the finished product.



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 3:** Assembly operation of the trolleys covering frames:

The following times were noted:

PHASIS	TIMES (s)	ACTIVITIES
A	10	Displacement: supply of materials in the warehouse
B	80	Processing: assembly of 3 pieces

The value-added activity is B, while the other is non-value-added.

The space traveled by the operator 6.6 m.

# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 3:** Assembly operation of the trolleys covering frames:

The total time to run the batch of 3 components is 90 s, of which 10 s for non-value-added activities and 80 s for value-added activities.

The time taken to make the single piece is:

- first piece 29 s;
- second piece 26 s;
- third piece 25 s.

The time for processing the first piece is longer than the other two: this is due to poor operator training on the operations to be carried out.

# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY - 1st ROUND

The work phases can be divided into 3 phases:

### a) batch processing

**Phase 3:** Assembly operation of the trolleys covering frames:

The workstation was not ergonomic: the workbench was too small. Furthermore, parts were missing for the complete realization of the product.



# Lean Manufacturing

## "Smart Production Factory" laboratory

### **CREATION OF A TRANSPORT TROLLEY – 2nd ROUND**

Three ergonomic workstations are used, arranged in such a way as to create the One Piece Flow, the operations are reduced to assembly operations only, therefore they are all value-added: in fact, displacements are avoided for the operators to find the materials, and it is not necessary perform tool placement operations, already assigned and arranged neatly in front of each workstation.

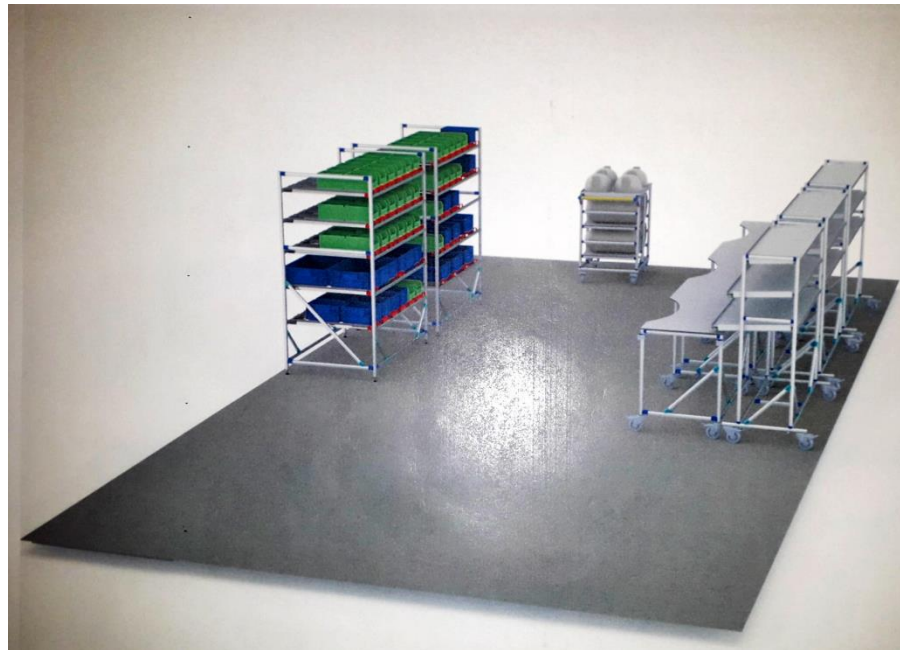


# Lean Manufacturing

"Smart Production Factory" laboratory

## **CREATION OF A TRANSPORT TROLLEY – 2nd ROUND**

Rendering of the "Smart Production Factory" laboratory



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY – 2nd ROUND

The work phases can be divided into 3 phases:

### b) **One Piece Flow processing**

**Phase 1:** Assembly operation of the aluminum profiles, divided into the following operations:

- 1) removal of the components from the KLT containers (storage box with open front with its own label), in which the name of the article, the name of the component, the code of the component and the phase and operation number (e.g. , 1.1 indicates step number one and step number one), which is placed on the workstation rack.



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY – 2nd ROUND

The work phases can be divided into 3 phases:

### b) **One Piece Flow processing**

**Phase 1:** Assembly operation of the aluminum profiles, divided into the following operations:

1) withdrawal from the containers of:

- 2 aluminum profiles L = 332; GFF-000L;
- 2 aluminum profiles L = 232; GFF-000L;
- 4 metal angles with screw inside GFJ-A13;
- the allen key n ° 5;



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"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY – 2nd ROUND

The work phases can be divided into 3 phases:

b) **One Piece Flow processing**

**Phase 1:** Assembly operation of the aluminum profiles, divided into the following operations:

2) assembly of materials taken



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY – 2nd ROUND

The work phases can be divided into 3 phases:

### b) **One Piece Flow processing**

**Phase 1:** Assembly operation of the aluminum profiles

The operator must take the necessary components from the containers on the shelves and the tool from the toolbox.

Subsequently, after inserting the sections into the metal corners, the operator must tighten the 4 screws, one for each corner.

Finally, the lot (consisting of 3 semi-finished products) is brought to the next location.



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY – 2nd ROUND

The work phases can be divided into 3 phases:

b) **One Piece Flow processing**

**Phase 1:** Assembly operation of the aluminum profiles

All activities are value added.

The space covered by the operator is zero.

The time taken to make the single piece is:

- first piece 65 s;
- second piece 60 s;
- third piece 65 s.

The time for processing the pieces is similar and less than that of round 1 since the operator was trained.

There were no errors during the processing.

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"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY – 2nd ROUND

The work phases can be divided into 3 phases:

### b) **One Piece Flow processing**

**Phase 2:** Assembly of the trolley wheels, divided into the following operations:

1) withdrawal from the KLT containers positioned on the workstation shelves of:

- 2 wheels with brake, LP-RV002;
- 2 wheels without brake, LP-RV001;
- 4 M12 screws, SCREW 061017;
- 4 dice, 061.018;
- no. 8 allen key to assemble.





# Lean Manufacturing

"Smart Production Factory" laboratory

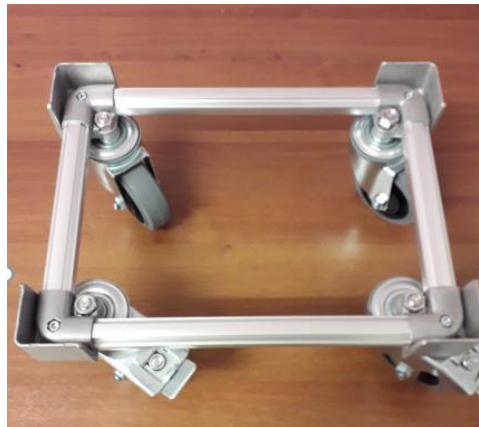
## CREATION OF A TRANSPORT TROLLEY – 2nd ROUND

The work phases can be divided into 3 phases:

b) **One Piece Flow processing**

**Phase 2:** Assembly of the trolley wheels, divided into the following operations:

2) assembly of materials taken



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY – 2nd ROUND

The work phases can be divided into 3 phases:

### b) **One Piece Flow processing**

**Phase 2:** Assembly of the trolley wheels

The operator, after receiving the batch of frames from the previous location, takes the necessary material and the necessary tools. We then proceed with the assembly of the wheels on the trolley by inserting screws in the appropriate housings, screw the nuts to the screws and tighten with the Allen key so that the wheels are well fixed to the trolley frame. Finally, the piece is delivered to the next location.



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY – 2nd ROUND

The work phases can be divided into 3 phases:

b) **One Piece Flow processing**

**Phase 2:** Assembly of the trolley wheels

Bolts must be tightened securely. Wheels with brakes must be mounted adjacent to one of the two short sides of the frame. All activities are value added.

The space covered by the operator is zero.

The time taken to make the single piece is:

- first piece 140 s;
- second piece 60 s;
- third piece 101 s.

The time for the processing of the pieces decreases since the operator has not been trained. There were no errors during the processing.

The space covered by the operator is zero.

# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY – 2nd ROUND

The work phases can be divided into 3 phases:

### b) **One Piece Flow processing**

**Phase 3:** Assembly operation of the trolleys covering frames, divided into the following operations:

1) removal of the components in the KLT containers:

- 1 yellow cover frame;
- 1 gray cover frame.

No special tools are needed.



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY – 2nd ROUND

The work phases can be divided into 3 phases:

b) **One Piece Flow processing**

**Phase 3:** Assembly operation of the trolleys covering frames, divided into the following operations:

2) assembly of materials taken



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY – 2nd ROUND

The work phases can be divided into 3 phases:

### b) **One Piece Flow processing**

**Phase 3:** Assembly operation of the trolleys covering frames

The operator takes the necessary material from the KLT containers and places them on the work bench. Subsequently, it passes to the assembly phase, which consists in correctly positioning small plastic protections at the sides of the trolley, thus obtaining the finished product.



# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY – 2nd ROUND

The work phases can be divided into 3 phases:

b) **One Piece Flow processing**

**Phase 3:** Assembly operation of the trolleys covering frames

All activities are value added.

The space covered by the operator is zero.

The time taken to make the single piece is:

- first piece 10 s;
- second piece 5 s;
- third piece 4 s.

The time for the processing of the pieces decreases since the operator has not been trained. There were no errors during the processing.

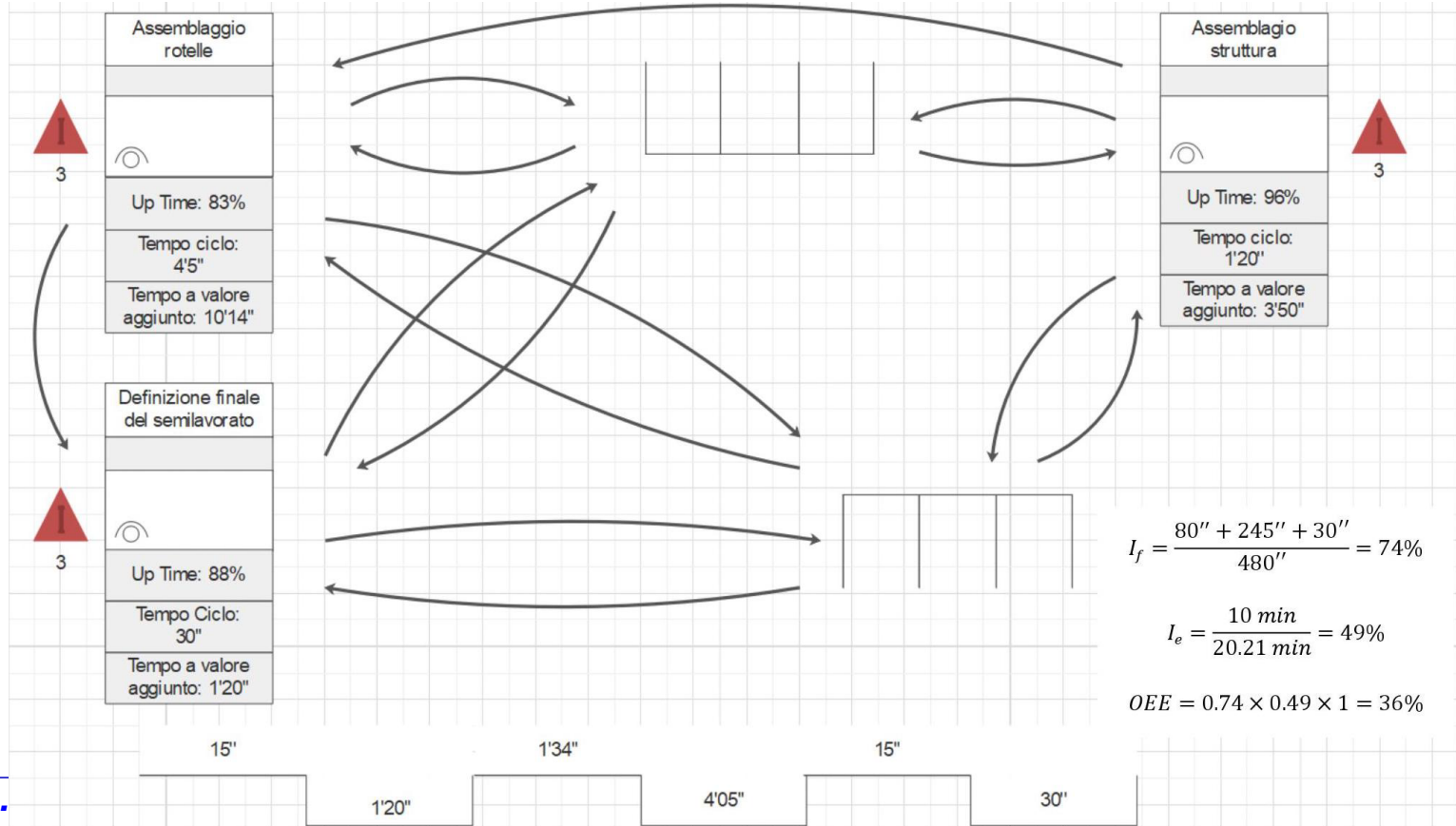
The space covered by the operator is zero.

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## "Smart Production Factory" laboratory

### CREATION OF A TRANSPORT TROLLEY

The Value stream map and the related KPIs of the AS-IS situation is as follows (I apologize if the traditional symbols are not used):



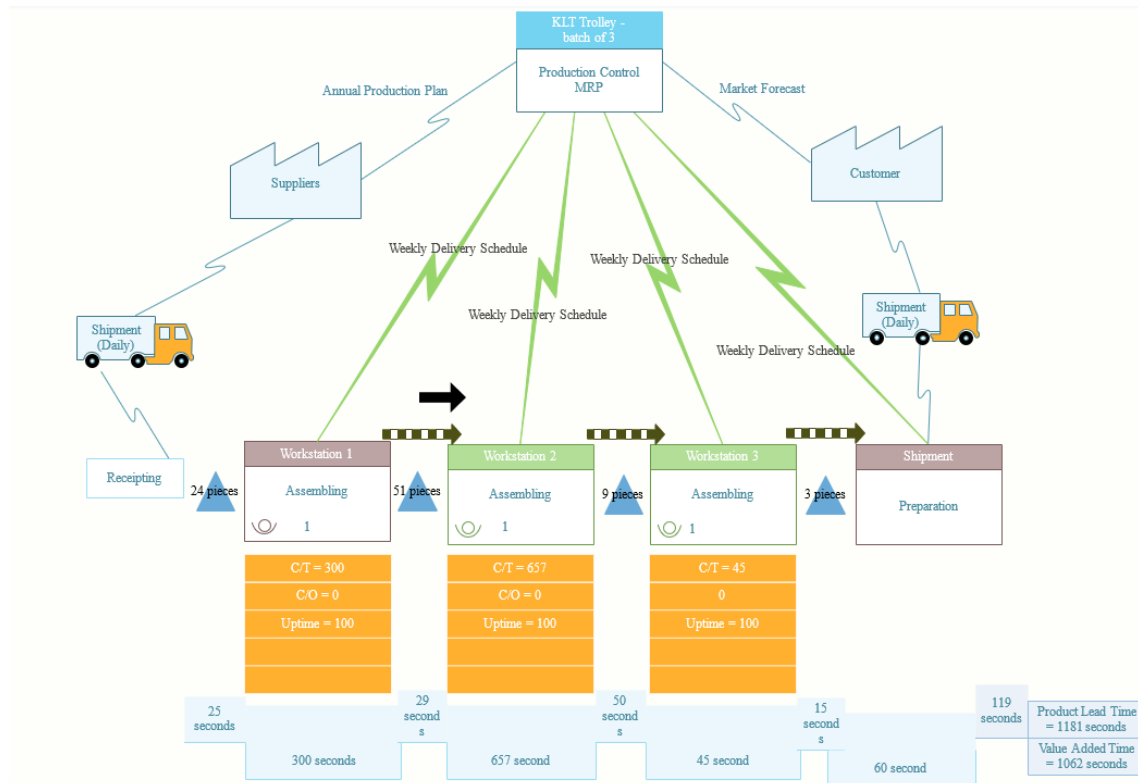


# Lean Manufacturing

## "Smart Production Factory" laboratory

### CREATION OF A TRANSPORT TROLLEY

The Value stream map (using traditional symbology) would be but the data is not real:



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"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY

The spaghetti chart of the AS-IS situation is as follows:

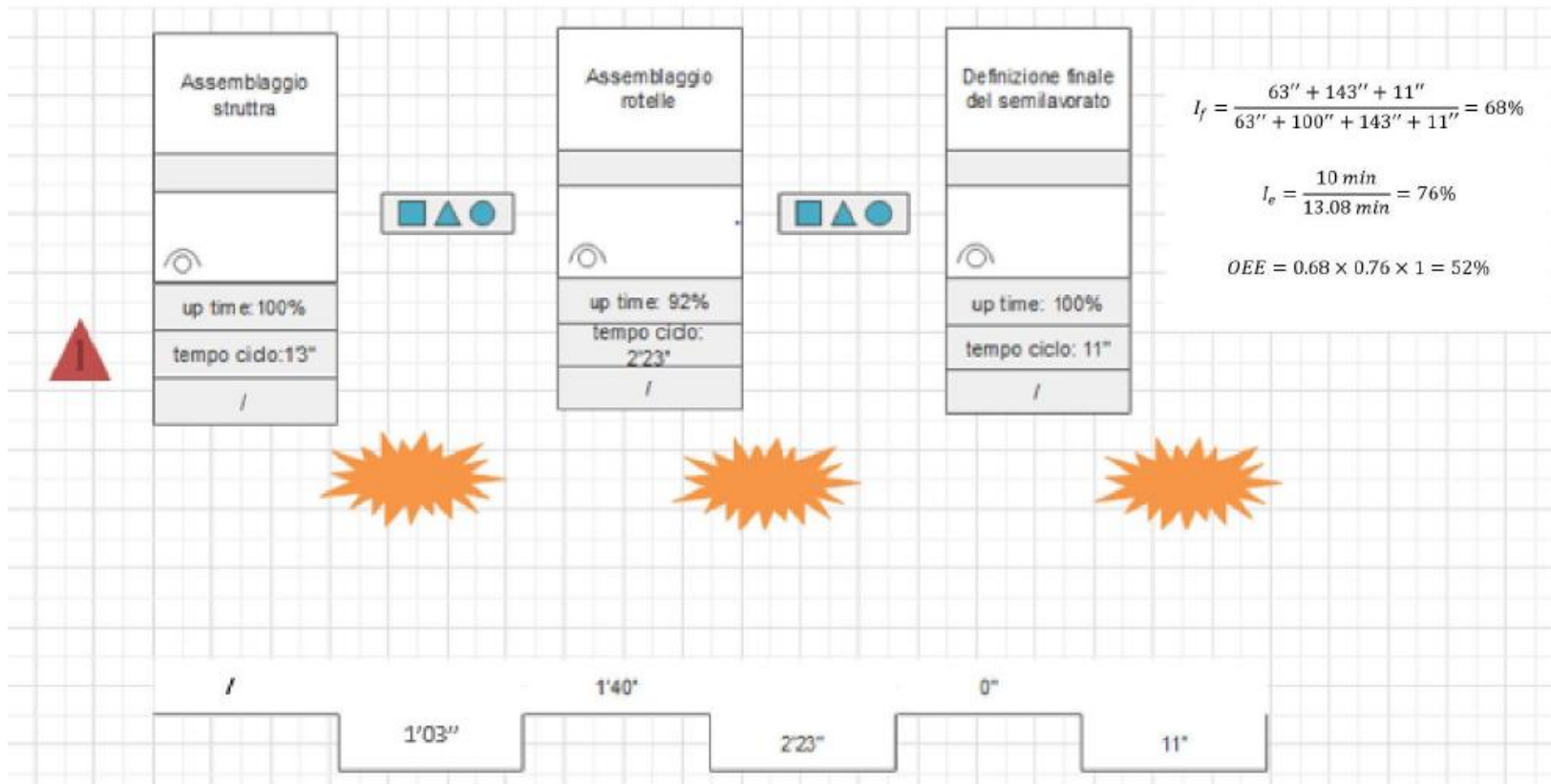


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"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY

The Value stream map and the relative KPIs of the TO-BE situation is as follows:



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"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY

### Conclusions:

In the first phase of the experiment, the following problems emerged:

- waste of time for the transport of tools and material to one's own station: it is too far from the warehouse and at station 1 it took more than one trip to take everything necessary;
- lack of tools suitable for carrying out the operations, especially at station 2, where the operator complains about the inadequacy of the tools for screwing;
- lack of ergonomics of the workstation, in particular of adequate space so as not to hinder movements;
- lack of devices that highlight any operator errors;

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"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY

### Conclusions:

In the first phase of the experiment, the following problems emerged:

- strong disparity in workload and consequently time between the three operations, in particular for the second location, which has the most laborious task;
- inadequate training of operators, who more than once did not know how to carry out certain steps;
- intrinsic complexity of product assembly;
- presence of downtime due to waiting between the respective stations for batch production.

# Lean Manufacturing

"Smart Production Factory" laboratory

## CREATION OF A TRANSPORT TROLLEY

### Conclusions:

In the second phase, where the Lean techniques are applied, the situation has definitely improved with a marked reduction in the lead time and an overall improvement in the efficiency indices, however, the following problems persist:

- inadequate leveling of workload and times between the various workstations;
- intrinsic complexity of product assembly;
- lack of devices that highlight any operator errors;
- lack of suitable tools (station 2).

To complete the experiment, the lines should be balanced and one would be to assemble two wheels in position 2 by inserting a cover frame, while the remaining two wheels and the cover frame in the third position.