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Ermalean

Didactic assembly line for learning Lean Six Sigma and digital technologies of Industry 4.0

Lean 6 Sigma educational workshop

ErmaLean - Didactic assembly line for learning operational excellence methodologies

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AUTOMATISMES

***ErmaLean** in right configuration, with Omron TM5 Cobot & Vision Station*

Visual management area

Shop with Pick To Light

What is Ermalean?

- **ErmaLean is an evolutionary workshop that** allows learners to be confronted with realistic industrial situations (**assembly of a mechatronic unit**) in order to carry out learning activities on the **application of** continuous improvement **tools** and methodologies as practised in an industrial environment
- The learning process alternates between production phases and periods of performance analysis, which are sources of analysis with Lean and Six Sigma tools. The application of these changes enables the objectives expected by the client to be achieved in terms of quality, cost and lead time.
- The deployment of ErmaLean requires a minimum workshop area of 100 m² for the different set-up configurations required for the activities.

Strengths:

- **A management position** with:
  - **Supervision PC** with Wi-Fi link
  - **Whiteboard and** communication **materials**
- **Five assembly stations that can be adjusted according to the** performance being tested:
  - **elements of management and evolutionary steering,**
  - assembly stations allow for **several set-ups** (independent, in-line, U-shaped),
  - **RFID tracking on assembly pallets and transfer between stations.**
- **Dynamic storage system designed for** all the containers required for three product variants
- **Handling**, **component supply** and **inter-station transfers** are designed for the volumes of WIP encountered at the various locations tested with scalable performance levels for the entire process
- **Integrated assembly tools** and **control means,** some of which are linked to the supervision system (measurement of screwing torques, **dimensions, conformity tests, etc.)**
- **The evolution towards the assembly of other products is possible** by the simple adaptation of the pucks and the evolution of the various documentations.

References & Options:

- **LN10:** ErmaLean, Didactic assembly line for Lean 6 Sigma training
- **Option LN11**: Added value for a height adjustable workstation
- **Option EA02:** Sensopart Industrial Vision Case (For parts presence control)
- **Option LN13**: Torque control screwdriver connected to Tulip, with suction system for gripping and "head up" screw dispenser

Associated systems:

- **ON00:** Omron TM5 Cobot & Vision Station: Omron TM5 4kg R900 collaborative robot with on-board camera, on a mobile chassis with height adjustment and work surface
- **ON17:** OnRobot RG2 Collaborative Electric Clamp Option for OMRON Cobot Station
- **AG00**: AGV MiR100 ErmaSmart
- **AG10**: AGV + Cobot " Mir100 + UR5 eSeries " Ermasmart
- **UR17**: OnRobot RG2 Collaborative Electric Clamp option for Cobot UR

Pedagogical approach

Educational activities:

- **Different production sequences with evolving performances**
- **Progressive use of analysis tools leading to the evolution of workstations and procedures to reach the final objective of the customer order rate: the TAKT TIME**
- **Ranges of assemblies** for different performance levels
- Lean and 6 Sigma TP with Excel file for each tool, which can be modified, provided with the course:
  - a tab for each document frame to be used in support of the exercise
  - a instructions tab explaining the chronology of the practical work where the uses of the documents and materials are detailed
- **The computer application allows the display (ranges, instructions, etc.) and feedback (time, measurements, defects, etc.) of each station.** This data is used for analysis and research into improvement solutions.
- Creation and improvement of ranges in the Manufacturing Assistance software "Tulip

- Practical application of the main tools used in Lean 6 Sigma (VSM**, Kanban, Capability, Variability...)**
Conducting projects according to the DMAIC chronology: Implementation of process improvement project management tools and other **teamwork tools**
- Lead time: Highlighting the **impact of balancing items**
-Takt Time: Measurement, analysis and evolution of the flows used: **Material** (batches, part to part) People (implementation) and Information
- Kaizen: Implementation of Kaizen tools (5S, TPM...)
- Quality: Application of Six Sigma tools (Capability; Regression; R&R; ...)
- Workshop management: Consideration of the different parameters of business management
- Ergonomics & Safety: Impacts of ergonomic and working conditions in safety standards

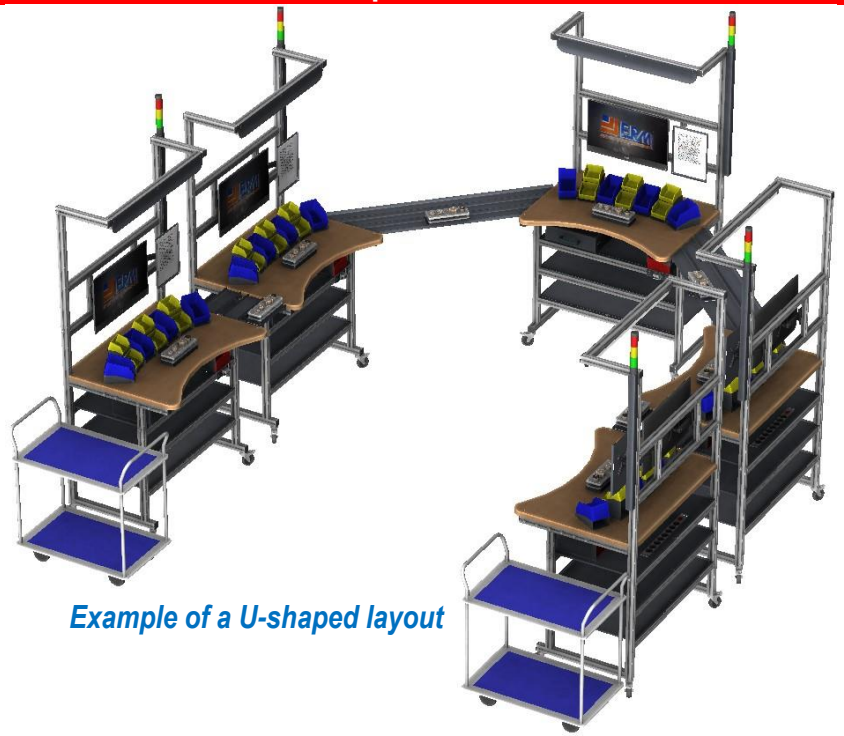
Basic configuration:

The basic configuration comprises the means necessary to **assemble a product** in different configurations:

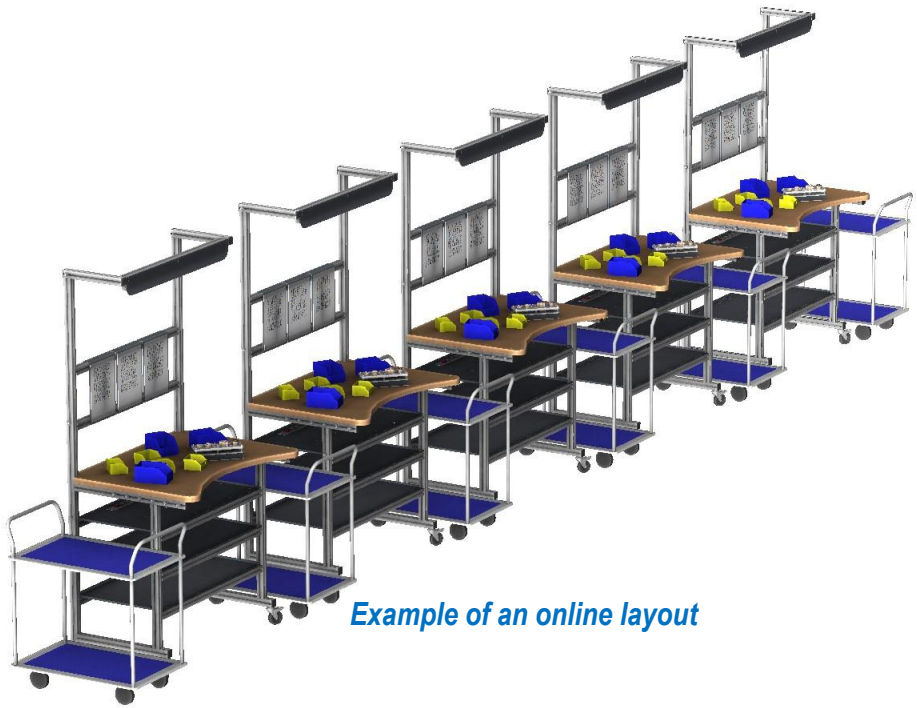
- **Planetary gear motors** (3 product configurations available)

It is also compatible for the integration of other products to be manufactured. Indeed, the evolution of the line towards other products has been integrated from its conception. This is facilitated by a minimum of specific tooling, a totally open software suite and a very intuitive development environment.

Examples of locations



Example of a U-shaped layout



Example of an online layout

Product manufactured

Planetary gear motor :

The selected model is a planetary gear motor consisting of :

- 1x DC motor 2,5W 1,3 - 3Vdc - 6250 to 12200 rpm - Shaft diameter 2mm
- 1x Engine shell
- 1x Motor mount
- 1x Sun gear (gearbox body)
- 1x Inner sun gear
- 4x Satellite
- 1x Satellite holder
- 3x M3x25 mm screws
- 3x CHC screw M3x8mm
- 3x FHC screw M3x8mm
- 3x FHC screw M3x12mm
- 8x M3 nut
- 5x Flat washers narrow M3
- 5x Ball bearings Dint3 Dext8 e4

This package may be subject to change.

This product has a high degree of variability:

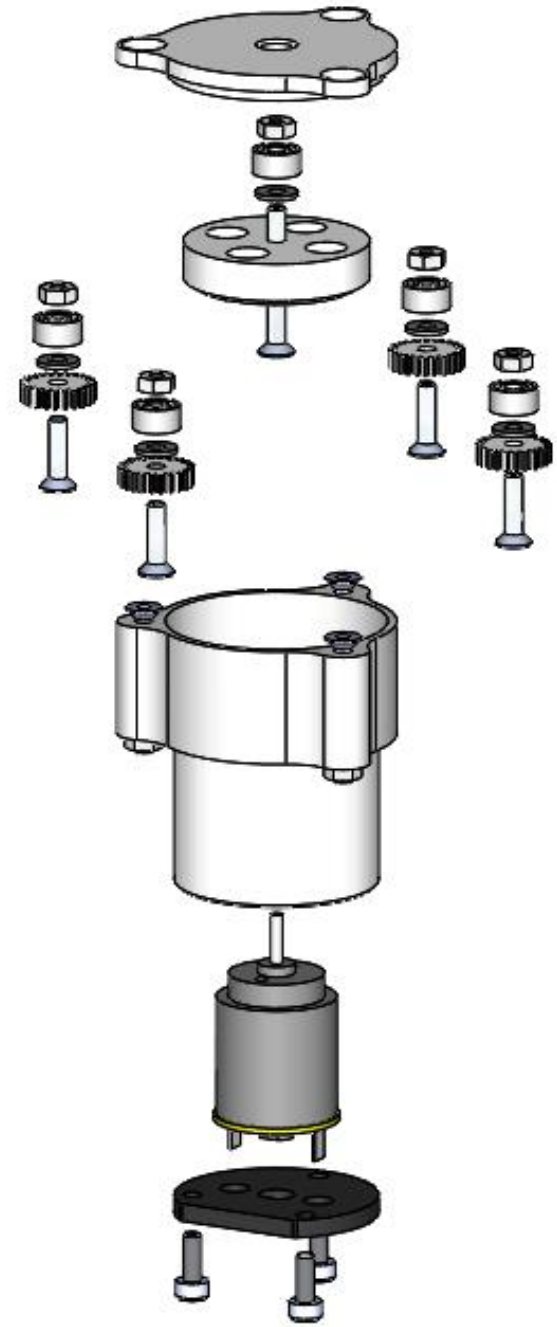
- Reduction ratio
- Housing colour
- Shaft diameter...

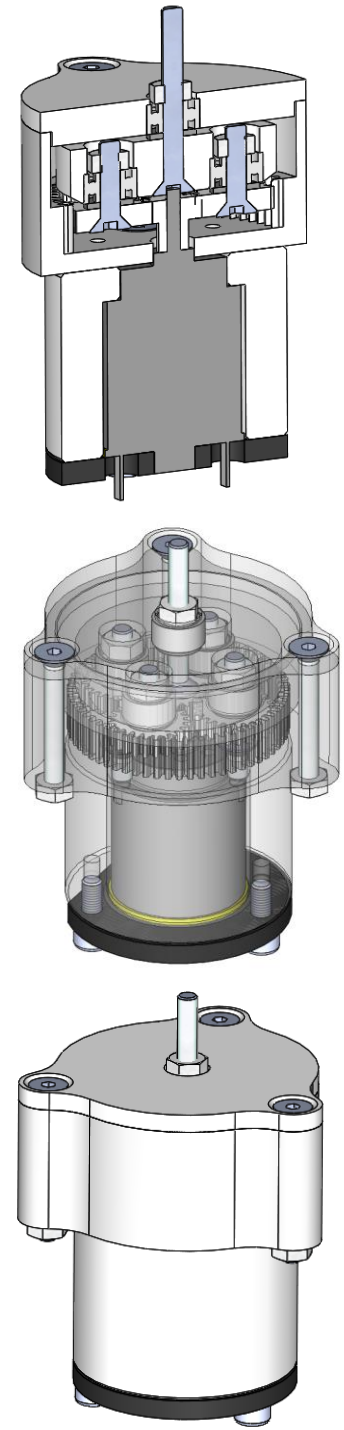
We supply three different models as part of the initial delivery.

The following quality controls can be performed:

- Dimensions (Shaft diameter - Housing thickness...) with caliper connected
- Good mechanical and electrical operation with power supply connected (voltage sent to the motor, current absorbed, speed of rotation)
- Presence of parts during assembly, with connected camera (Option)

Upgrading to other products (e.g. shifters or customer-defined products) is facilitated by a minimum of specific tooling, a fully open software suite and a very intuitive development environment.





Production line equipment and logistics

Five modular assembly stations with :

- **Materialization** => Aluminium profile frame with adjustable work surface
- **Ergonomics** => Set of 5 ergonomic chairs; workstation layout + Height adjustment of worktops (Option LN11)
- **Adaptability to physical flows** => Storage racks and workstation organisation accessories, including removable container supports for ergonomic box positioning
- **Management / Steering** => Paper document holder (removable)
- Signalling => Andon 3-colour controllable beacon (removable)
- Tool drawer => Tool kit for product assembly
- Traceability => RFID reader connected, 1 waste counting sensor
- Connected control => Tulip IoT gateway and IO-Link master
- Management/Digital control => Touch computer (removable)
- **MES and Manufacturing Assistance software** => Tulip giving access to digital procedures on each workstation and feedback from each workstation

Tools for workstations & control integrated and partly linked to supervision :

- **Traditional assembly** => hex keys, screwdrivers, flat keys, plotters, magnets
- **Manual measurement** => 5 Stopwatches and 2 hand counters with ring
- Product performance control under different controlled voltages=> Tachometer
- **Dimensional control connected** => Caliper connected
- **Electrical measurements connected** => Power supply controlled and connected
- **Connected assembly** => Connected screwdriver with torque control (Option LN13)
- **Productivity improvement** => Vacuum system for screw gripping + Head up screw dispenser (Option LN13)
- **Vision control** => Camera connected to Tulip (Option LN12)

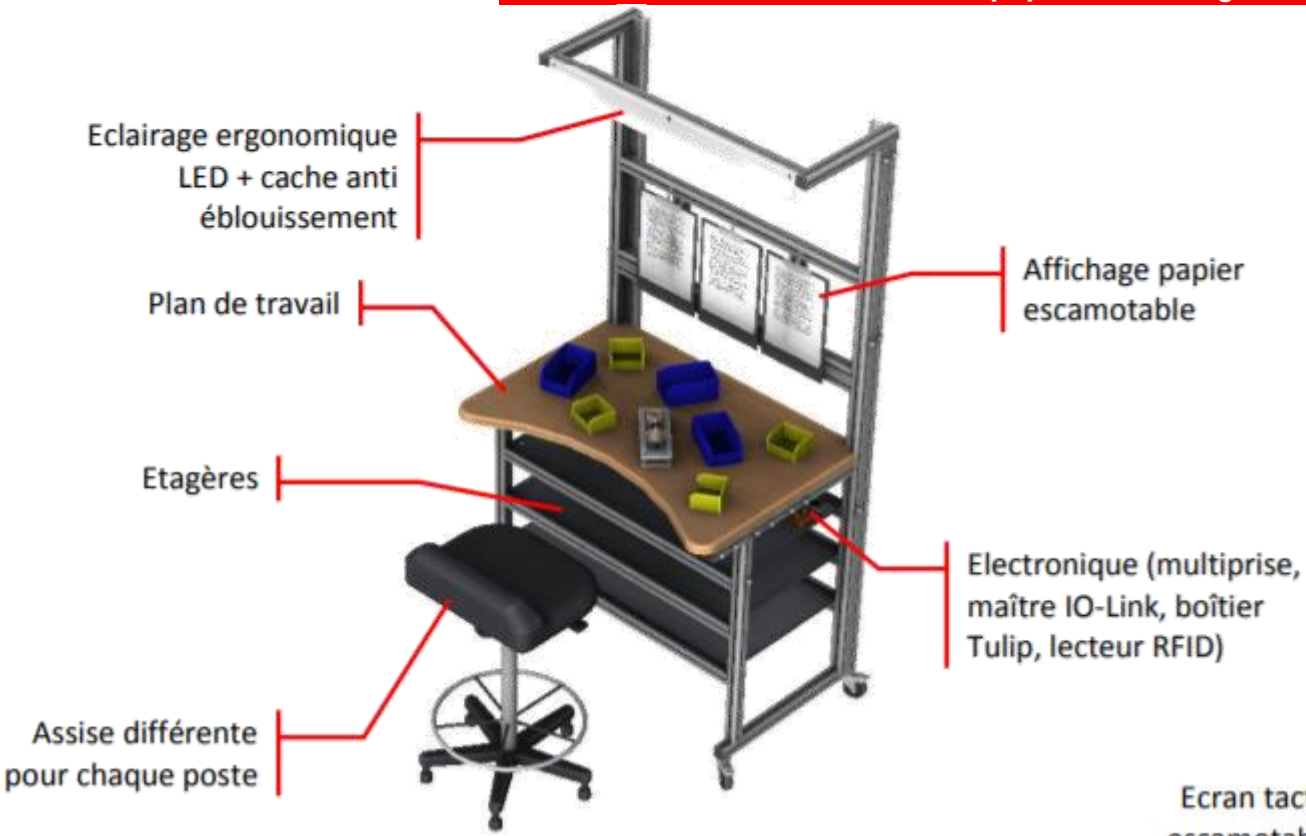
Measurements of torque, dimensions, presence of components, electrical resistance, voltage, current, temperature, humidity, time, and operation of the assembly are connected to the Tulip supervision and can be fed back into NODERED for possible exploitation by other software.

Omron TM Cobot & Vision Station (Option ON00):

- **Materialization** => Robot support frame with height adjustable position
- **Collaborative robot** => OMRON TM5-900, range 900mm, payload 4kg, with on-board camera
- **Safety/collaboration** => 2 laser scanners for the management of collaborative working areas (speed reduction/stop depending on the distance from the operator) and automatic work resumption (Option)
- **Handling** => OnRobot collaborative electric gripper (Option)
- **Software** => Graphical cobot programming environment
- **Programming** => Programming of control and assembly tasks in collaborative and autonomous mode

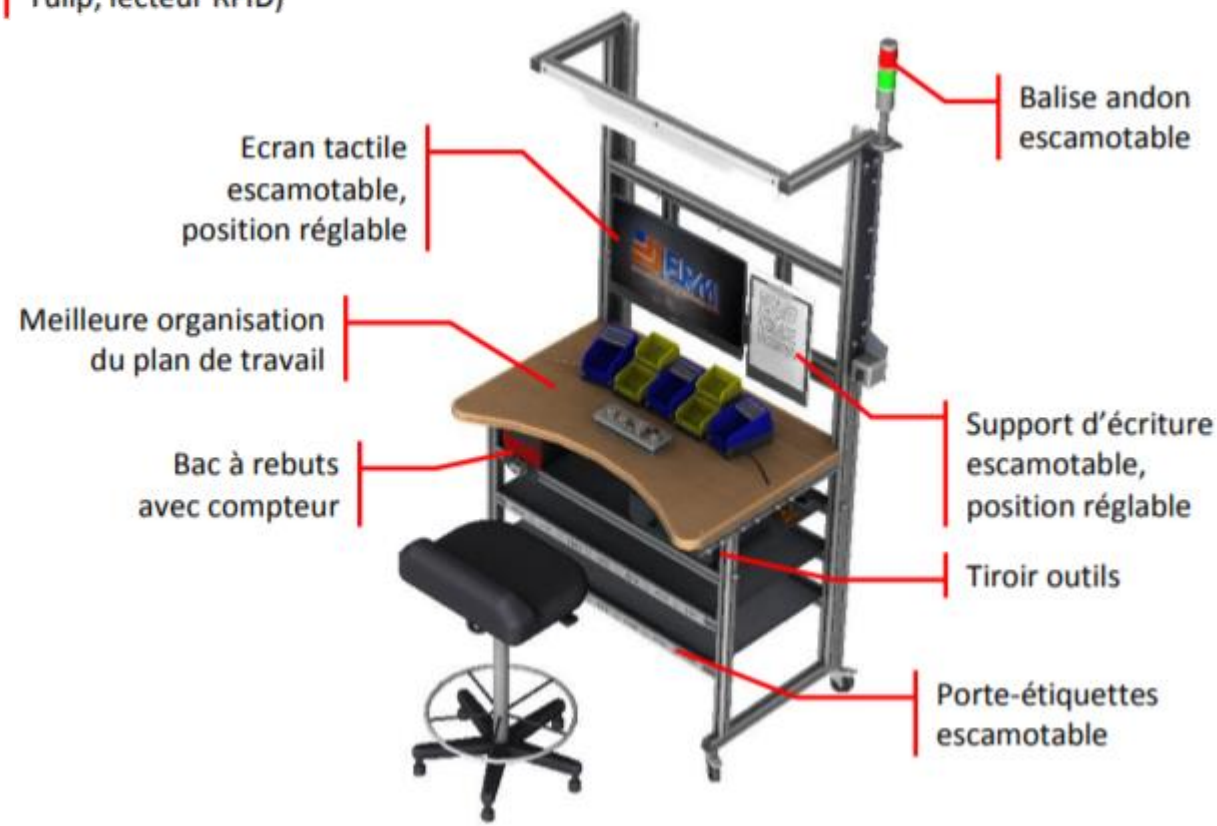
Omron TM Cobot & Vision Station in packaging operation at the end of assembly

Production line equipment and logistics



Workstation Basic Version

Workstation Lean 6-Sigma version



Production line equipment and logistics

Basic and LEAN warehouse (Included in LN10):

- **Storage** => Allows the storage of assembly parts
- **Material**: Aluminium profile frame and gravity racks
- **Management /Steering** => Document support
- **Management/Digital control** => Touch computer
- **Manufacturing Assistance*** => Tulip **software** to assist the order picker in the tasks he has to perform
- **Connected control** => Tulip IoT Gateway, Pick to light, Bar code scanner and QR code
- **Product identification** => Coding and QR Code
- **Storage** => Set of containers required for three product variants and sized to support 3-hour production TPs.
- **Distribution and flow management** => Carried out by manual trolleys

Flow management / Workshop configuration :

- **Supply of spare parts to the stations**: 1 Trolley with 3 trays
- **Station/station flow**: 4 Trolleys with 2 trays
- **Manual conveyors** => 4 straight inter-station conveyors for 1 to 3 product lines, 2 90° inter-station conveyors for 1 to 3 product lines

Specific products/means :

- 10 Basic pucks
- 30 pucks adapted to the product
- 100 RFID chips for pallets and boxes
- Bolt kit for assembly of 60 geared motors
- Spare parts kit for the assembly of 20 geared motors in configuration 1
- Spare parts kit for the assembly of 20 geared motors in configuration 2
- Spare parts kit for the assembly of 20 geared motors in 3-way configuration
- Batch of 0.3L and 1L storage bins, in sufficient quantity to ensure the production of products in the 3 configurations
- Batch of bins for the disposal of finished products
- Adhesive tape for road marking

Production line equipment and logistics (Options)

AGV MiR100 (Option AG00) :

- **A Mir100 mobile robot** (Manufacturer: Mobile Industrial Robots - Origin: Denmark) with an autonomy of 10 hours or 20 Km
- **A wired charger** (100-230Vac 50/60HZ to 24V max 15A)
- **An Intel® RealSenseTM 3D camera** for obstacle detection.
- **A shelf frame** 760x440x700mm with a support for a shelf
- **Two shelves** 700x440x30mm
- **A tablet** constituting the human-machine interface (HMI)

AGV + Cobot "Mir100 + UR5 eSeries" (Option AG10) :

- **A Universal Robots UR5 eSeries collaborative robot**
- **A collaborative gripper** for handling the objects in question (Option UR17)
- **A** 450x420x10mm **tray** for the placement of handled objects (boxes, trays...)
- **A Mir100 mobile robot** with 10 hours or 20 km autonomy
- **A wired charger** (100-230Vac 50/60HZ to 24V max 15A)
- **A second** Li-NMC **battery**, 24 V, 40 Ah
- **An Intel® RealSenseTM 3D camera** for obstacle detection.

Computer hardware and applications

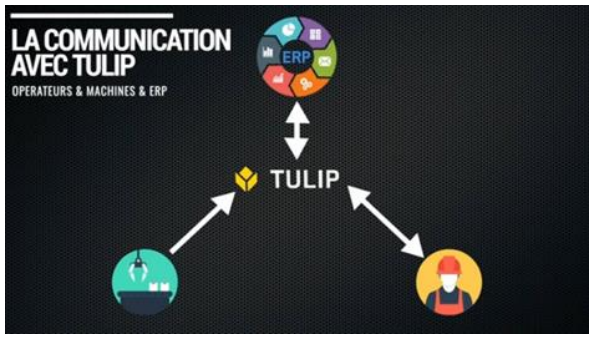
All PCs, monitors and connected tools in the installation are networked through the 4G wifi router provided. Station status and other information is stored in the TULIP cloud and can be accessed on any PC in the line and any other PC you may wish to connect to through your TULIP session.

Each pallet used as an assembly support and transfer of sub-assemblies between stations is equipped with an RFID memory chip and each assembly station has an RFID reader, this equipment allows the tracking of each movement produced by sending information to the database of the supervision PC (Tulip).

For each station, a display dedicated to the function of the station is controlled by the Tulip software.

Presentation of Tulip software (Manufacturing Assistance & MES)

Tulip is a software solution for the digitalisation of production lines and rapid deployment of MES functions.



Tulip is developed in Boston (USA) and used by hundreds of companies in the world to assist production operators and monitor workshops.

Use cases

- **Visual work instructions**: Guide operators through visual procedures instead of those on paper.
- **Training**: Simplify and continuously improve training procedures.
- **Audit & Quality**: Replace paper forms by applications with IoT tools (cameras, scales, ...)
- **Machine Monitoring and Maintenance**: Real-time acquisition of machine data during production
- **Task tracking and visibility**: Import OFs from an ERP (Odoo, etc.), program production indicators (TRS, MTBF, productivity rate, etc.) and display them on dashboards
- **Digital Lean**: Deploying Digital Lean tools and dashboards

The main functions in production management and maintenance

- Creation of digital work procedures
- Monitoring of machine data
- Communication with an ERP (Enterprise Resource Planning)
- Calculation and display of performance indicators (TRS, MTBF, etc.)
- Digitalisation of quality forms
- Digitalisation of audit forms

Tulip's strengths:

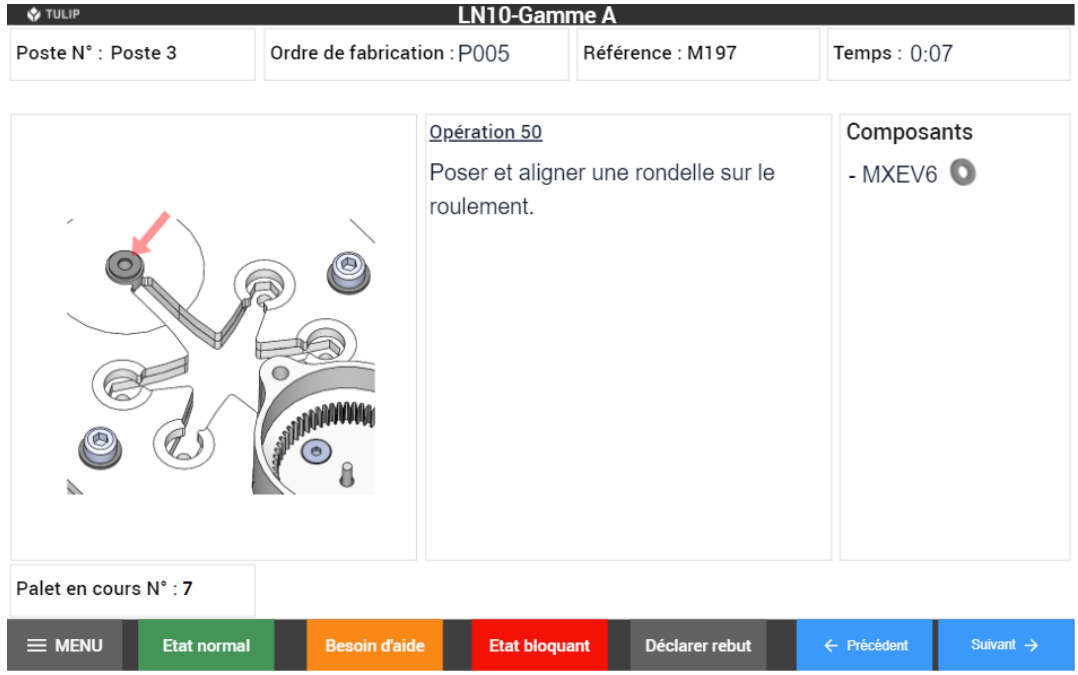
- **Disposal of all paper documents**
- **Easy** and **quick programming of** applications and very simple handling
- **Possibility** to make **mathematical calculations** for the determination of **production indicators**
- Visualisation of all production-related information on a tablet or computer
- Customisation of dashboards: by machine or by production line or by product
- Communication with remote machines through the Kepware communication server and the NODERED platform
- Possibility of using devices connected to the workstations (scales, calipers, cameras, etc.)

- The Tulip software user manual will be provided.

Presentation of Tulip software (Manufacturing Assistance & MES)

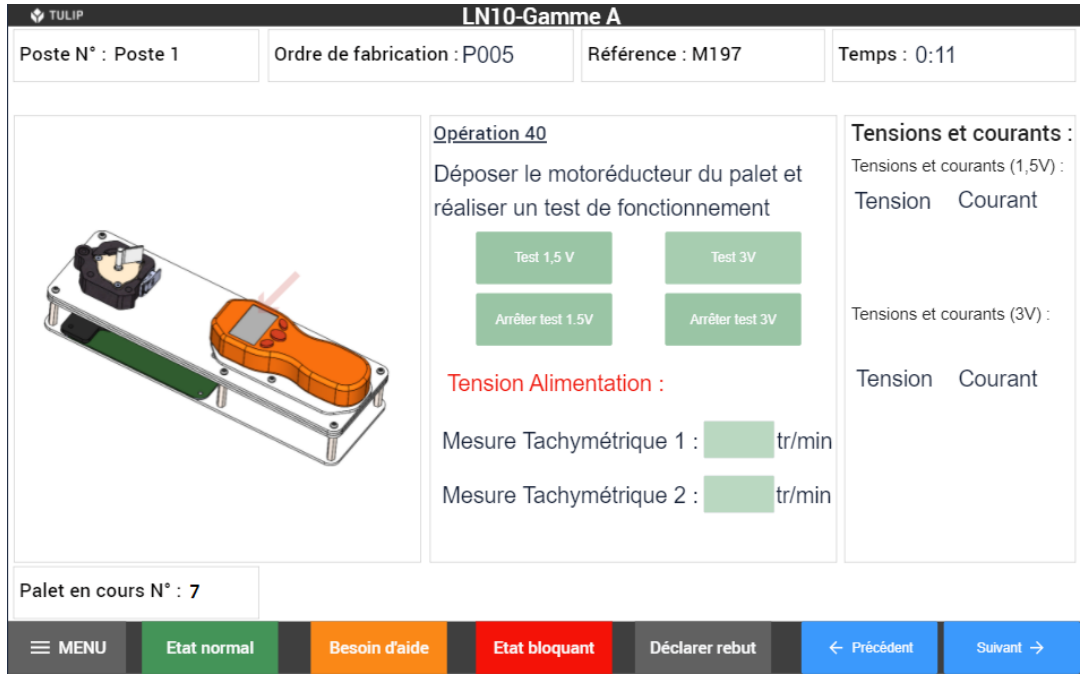
Tulip screen views for push manufacturing (PO: Production Orders)

OF screen Production order



Assembly Step screen

Screen Control step connected (Tachymetry)

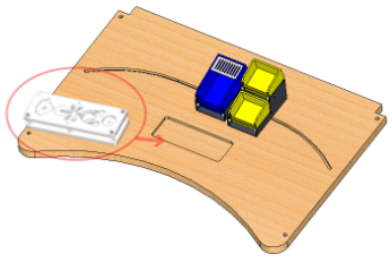


Presentation of Tulip software (Manufacturing Assistance & MES)

Tulip screenshots for lean manufacturing

TULIP — LN10-Gamme B — 0:05

Poste N° : Poste 1	Palet N° : 23	Référence : M 213	Temps : 0:05



Opération 20

Positionner un palet vide sur le plan de travail

Attente positionnement palet sur le plan de travail

Composants

- Un palet vide

- MBII1
- MXEP1
- MXEV2
- MXII4

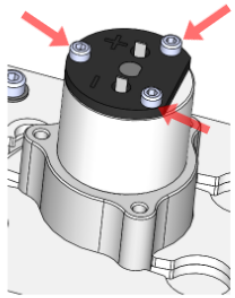
M 197 | M 213 | M 218

MENU | Etat normal | Besoin d'aide | Etat bloquant | Déclarer rebut

Screen Initial step

TULIP — LN10-Gamme B — 0:09

Poste N° : Poste 1	Palet N° : 23	Référence : M 213	Temps : 0:09



Opération 70

Mise en place des 3 vis et serrage

Composants

- MXEV1

Outillages

Clé Allen 2.5mm

M 197 | M 213 | M 218

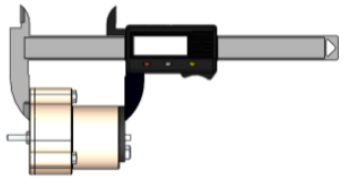
MENU | Etat normal | Besoin d'aide | Etat bloquant | Déclarer rebut | ← Précédent | Suivant →

Assembly Step screen

Connected control stage screen (Dimensions)

TULIP — LN10-Gamme B

Poste N° : Poste 1	Palet N° : 23	Référence : M 213	Temps : 0:07



Opération 60

Extraire motoréducteur du palet, avec pied à coulisse mesurer la hauteur de l'ensemble et valider

Screen Control step connected

Mesure Pied à coulisse : 18.2 mm

Min : 15 mm Max : 30 mm

Produit conforme

Composants

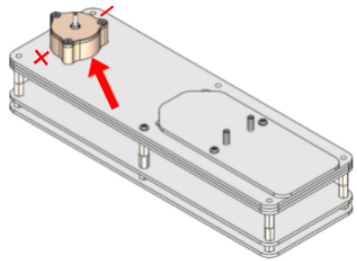
M 197 | M 213 | M 218

MENU | Etat normal | Besoin d'aide | Etat bloquant | Déclarer rebut | ← Précédent | Suivant →

Connected control stage screen (Tachymetry)

TULIP — LN10-Gamme B

Poste N° : Poste 1	Palet N° : 23	Référence : M 213	Temps : 0:14



Opération 80

Réaliser l'opération de contrôle conformité et performance

Test 1,5V | Arrêter test 1.5V

Tension Alimentation :

Mesure Tachymétrique 1 : 1120 tr/min

Min 1 : 1000 tr/min Max 1 : 2000 tr/min

Résultats des mesures

Tensions et courants (1.5V) :

Tension	Courant
1,3V	1,288A

M 197 | M 213 | M 218

MENU | Etat normal | Besoin d'aide | Etat bloquant | Déclarer rebut | ← Précédent | Suivant →

Education through action

Using ErmaLean, students will seek efficient organisation through performance measurements of their work, seek and implement improvement solutions and use Industrial Transformation 4.0 technologies and tools.

A red thread for the animation is available for the trainer, which allows him to have a chronology of the animations and with configuration of the material,

Each production period lasts about 2 hours, followed by a **feedback synthesis**, **deviations from the initial objective are** qualified, a period of **analysis and search for solutions** is initiated in the form of a project using **Lean Six Sigma tools**.
The solutions are implemented and followed by a **new production period**.
This exercise can be repeated up to four times depending on the level of learning to be achieved in the students' programme,

The functions to be performed are assigned and an explanation of the role of each is given to each student.
The different functions are: Customer; Manager; Operator; Logistician; Observers,
Depending on the number of learners in the group, some or all of the functions will be assigned

Different types of flows are foreseen (Push; Pull; Kanban; Product Standardisation), they allow different and evolving levels of performance.

Through the different scenarios, they will be able to :

- Implement industrial developments and innovations as part of **continuous improvement**, in line with the organisation's strategy and digital developments
- **Leading a 4.0 optimisation project** for all stages of the value chain, all stages of the product life cycle
- **Measuring and analysing the performance** of a process/machine/workshop delivering a product or service
- Define the priority areas of progress that contribute to the objectives of Enterprise 4.0
- Supporting the improvement of company performance by putting **into practice and transferring tools focused on and around people**
- Monitor the results of **flow management**, improve the organisation and operation of flow management
- Implementing **knowledge** and skills **management** in a 4.0 environment
- Integrating **occupational health as a strategic lever for the** performance of companies of the future
- Apply **methods of communication and project management** aimed at excellence

Pedagogical proposal

The elements proposed are the bases of practical work with scenario and documentary supports for their development, they are of different levels to meet the different degrees of training to be provided. All the documents are written in French and given in digital format (modifiable).

Adaptation and design of the workshop :

Assembly range :
Several assembly ranges for the three configurations of geared motors on 5 stations are provided, which allow the use of the line to be initiated. The various practical exercises allow the line to be upgraded.

Coding of components :
A codification is prepared for each component.

Identification :
Labels (in a format suitable for the place of use) for the boxes, the in- and outfeed radii of the dynamic storage system, the in- and outfeed for the supply area of each station, and for the trolleys of the milkman's round are provided.

Organisation of the dynamic storage unit
Component box layout plans for each front (inlet and outlet) are provided.
On the input and output side, a "Pick to Light" facility is managed by scanning the QR code included on the label of each component box, this configuration, used at an advanced stage of development (TP related to supply time). A stock management system is updated at each movement of components in or out.

For each of these subjects, paper documents are provided and an Excel file is provided to allow for any necessary modifications to be made as a result of developments in the practical exercises.

Structure of the TP materials:
A digital file is provided with all the documents used for the practical exercises.
For each practical course, an Excel file is provided with a tab for each document frame, an instructions tab detailing the uses of the documents and a scenario explaining the timeline of the course. The timeline includes the hardware configurations to be implemented to start the tutorial and a possible final configuration.
All of these files are 'open' and can therefore be modified by users.

Scalability of the system

The proposed workshop is fully modular and will be upgraded from 3.0 to 4.0 mode by adding removable elements as the pedagogy evolves.

In its initial configuration (3.0)

The workshop will operate in offline mode but with the production tools in non-digital format on the workstations and on the "factory cockpit".
Traditional" tools (chronometer, calliper, etc.) will be used to measure the different stages of production.
A dedicated supermarket/manual shop is planned.

In the advanced configuration (4.0)

The workstations and tools will be connected, and the flow of information up and down will be digitised using connected tools and touch screens at each workstation.

In this configuration, a collaborative robot could be equipped with the final station in order to perform assistance tasks (in collaboration)
The production control and line monitoring station will be digitalised thanks to Tulip and will display, in real time, the information deemed key by the production team.

The entire process is designed for the serial assembly of small components.
The evolution towards the assembly of other products of your choice is possible by the simple adaptation of the poses and evolution of the various documentations.
It will also be facilitated by a minimum of specific tooling, a totally open software suite and a very intuitive development environment (Tulip).

The Tulip computer application allows the display (ranges, instructions, etc.) and feedback (measurements, defects, etc.) of each station according to the performance level used. All the scenarios and displays provided can be modified and reconfigured by the users as the Tulip software is totally open and intuitive. At the end of the training, you will be able to create new scenarios and integrate new ranges and products.

Examples of practical work on production organisation

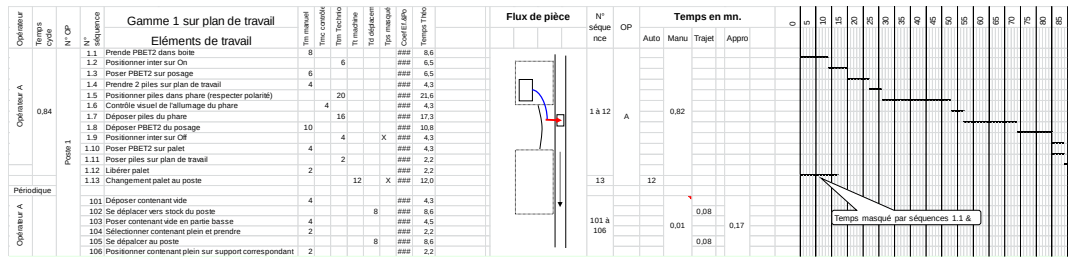
Lead Time

Scenario A/ Inputs :
The line is put into production with the original range and the times at each station are timed.

Teaching aim: To highlight the impact of balancing items.

Document generation :
In a computer file in Excel® a "Standard procedure and time" file:

Example:



Range with, for each workstation, the breakdown of times by category and a diagram of movements on the workstation, then a time simulation graph (highlighting imbalances and NVA).

Output: This tool is filled in on the basis of the measurements made, then analysed and modified for a new production period following the improvements found.

Scenario B/ Inputs :
The line is put into production with the original routing and the output timing of the products is recorded.

Teaching aim: To highlight the impact of the type of flow used. (Pushed / pulled).

Document generation :
In a computer file in Excel® a "Requirements Cadence" file:
The rates of change of the requested references are accelerating, the analysis of the lead time shows a lack of reactivity.

Output: One solution is to use the 3 pucks conveyor (1 per reference) in parallel between each station to match the takt time with mixed references.

Examples of practical work on production organisation

Other common Lean 6 Sigma tools

Document generation :

In Excel®, one file per tool requiring support and with at least one scenario for implementation in the workshop. For example, the following are covered: Purchase order; Production order; VSM; KANBAN; VARIABILITY on product, on time...

Kaizen

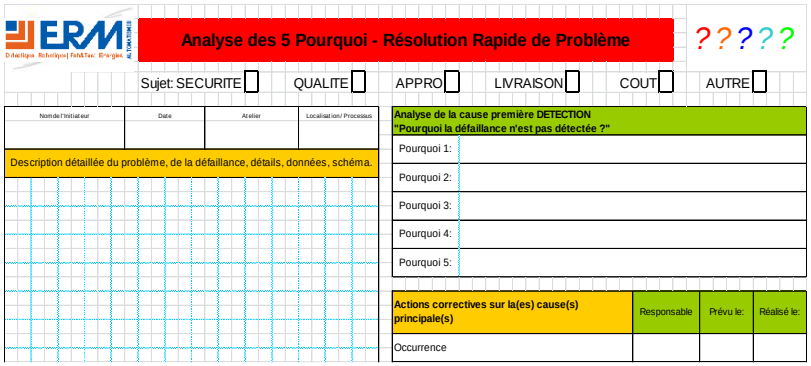
Educational objectives :

Practical application of Kaizen and other teamwork tools.

Document generation :

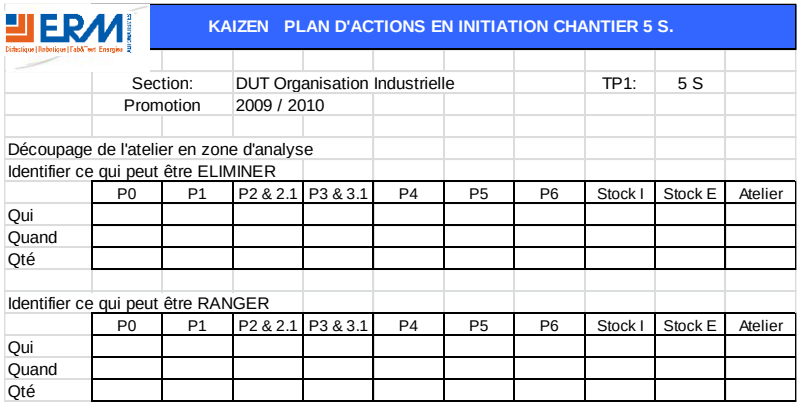
In Excel® one file per tool requiring supports:

- 5 Why : A framework for conducting problem solving

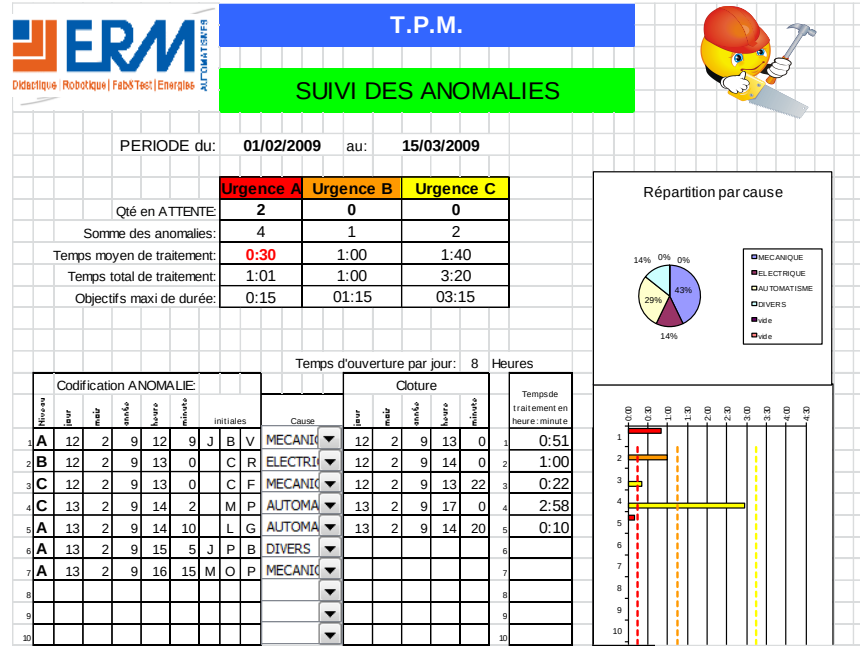


- 5 S: A site management framework adapted to the line

A monitoring schedule during the construction process and an audit schedule



- Anomalies: An anomaly declaration form by degree of urgency and a follow-up of processing times.



- Gemba Walk; Suggestion; TPM are prepared with the same flexibility of use with appropriate documents.

(Partial) tree structure of the teaching pack provided

- 1 Generalités
- 2 Produit
- 3 Matériel
- 4 Implantation
- 5 Conditionnement
- 7 Scénarios
  - 0 Le Formateur
    - 1 Fil rouge du formateur avec conditions de départ
    - 2 Présentation aux étudiants mise en pratique de l'am...
    - 3 Affectation des ressources
    - 4 Indicateurs de performance
    - 5 Mesure stress
  - 1 Le client
    - 1 Rôle du Client
    - 2 Bon de commande
    - 3 Plan de commande run 1
    - 4 Plan de commande run 2
  - 2 Le manager
    - 1 Rôle du Manager
    - 2 Ordre de Fabrication
    - 3 Pointage OF au poste 1
  - 3 Les opérateurs
    - 1 Rôle des Opérateurs
    - 2 Check list de contrôle final
  - 4 La Logistique
    - 1 Rôle du Logisticien
    - Etiquettes chariot
  - 5 Les Observateurs
    - 1.1 Rôle des Observateurs poste
    - 1.2 Rôle des Observateurs ensemble ligne
    - 1.3 Rôle des Chronométreurs
    - 2 Feuille d'observation
    - 3 Fiche de relevé des temps
    - 4 Analyse de déroulement d'un produit
    - 5 Analyse de déroulement + chronométrage vierge
    - 6 Chronométrage feuille d'enregistrement
- 8 Gamme d'assemblage A
- 9 Gamme d'assemblage B
- 10 Gamme d'assemblage C
- 11 Gamme d'assemblage D
- 12 Cockpit usine
- 13 Outils L6S
  - 1 Analyse flux
    - 1 Value Stream Mapping Template
    - 2 Matériel et Etiquettes Kanban
  - 2 Analyses des temps
    - 1 Procédure standard d'analyse des temps run A
    - 1.1 Chronométrage feuille d'enregistrement
    - 2 TRS
    - 3 Mesure des temps par Operation sur vidéo
    - 4 Analyse SMED
  - 3 Gestion des anomalies
    - 1 ANOMALIE
  - 4 Organisation
    - 1 5S
    - Cotation 5S
  - 5 Outils d'analyse
    - 1 LES 5 WHY
    - 2 8 D
    - 3 AMDEC
    - 4 ISHIKAWA
  - 6 Divers
    - Commandes
    - Ordre de Fabrication
  - 7 Personnel
    - Mesure stress
    - Planning polyvalence
  - 8 Conduite projet
    - 1 8 D
    - Fascicule du dirigeant du processus
    - Matrice déploiement stratégie original
    - PDCA
    - Pro Scope projet Lean Six Sigma

Presentation of the Odoo ERP, CAMM & CMMS (optional)

In the context of projects, ERM has developed a connector between Tulip and the open-source ERP Odoo.
Odoo then acts as a CAPM layer on top of Tulip.
The existence of this Tulip connector ⇔ Odoo and our past experience will allow us to achieve this integration, if required, within a limited budget.