A car manufacturing plant (Drof) located in the province of Valencia has capacity to manufacture 2,150 units per day (in 3 shifts of 7.25 hours each) and can assemble 5 different models (800 units of the model A, 450 units of model B and 300 units of the models C, D and E).

Each model has 3 main types of looms (electric cables or wiring sets). The looms connect the engine, instrument panel and other elements of the car. To date, the looms were unique for each car model.

After a cost analysis, the company decided to outsource the production of 2 of the types of looms used for models A & B to a factory in Tunisia. In the new Tunisian facility, the second-tier supplier will manufacture them on 2 production lines. Each line will produce one specific loom type.

The car maker has also decided that it will customize the looms for each car in order to save on costs. This saving is mainly due to a weight reduction (of copper) because only the necessary connections will exist. It can be assumed that each car unit will have its own, unique, and not interchangeable looms.

For this reason, the Tunisian plant will receive the original (expected) sequence (from Germany) for the trim and final assembly line of Drof 7 days in advance.

The two different lines in the Tunisian plant will manufacture the units following the forecasted sequence and the looms will be placed (stored) consecutively in packaging units of type Ford Large Container (FLC) to be sent (according to a strategy *Full Truck Load*) to the first-tier supplier plant (the company that is the focus firm).

Due to disruptive events, the original sequence is almost never fulfilled. That is to say, the sequence that will really occur in the final assembly line never complies with the original "German" sequence. Moreover, there are differences between sequences in the previous plants of the factory (body shops, paint shop, etc.) and they also differ from the final assembly line sequence. There are many reasons that alterate the sequences (quality issues, supply problems, machine failures, order fulfillment strategy, productivity, line balancing constraints, etc.).

For all these reasons, the looms received must be resequenced. After a study of past sequences, approximately 80% of the units are manufactured on the day that was scheduled, 10% are manufactured the day before, 5% two days before, 3% the day after and 1% more than a day later.

Once the first-tier supplier had been selected to perform this resequencing operation, it was determined that the activities can be divided into the following set of areas:

- ✓ **Reception area**: When each truck carrying the FLCs with the looms arrives at the docks, the FLCs must be placed on a conventional pallet racking system. This storing system has a capacity of approximately 400 FLCs (Call it Warehouse1).
- ✓ **Opening the FLCs area**: When a car body enters the paint shop (approximately 15 hours before being sequenced to the final assembly line), a signal (order) is sent to Warehouse1. This information is used to determine the 2 FLCs to pick from Warehouse1 if they have not been emptied yet. The FLC taken will be transported to the replenishment area (before going to the picking area (Warehouse2)).
- ✓ **Replenishment area**: Each loom in a picked FLC must be placed into a bag after a quality control check. Then, the loom in the bag is available to be placed on the picking shelves. Optionally, the rest of the FLC can also be placed in bags and be ready to go to the picking area.
- ✓ **Picking area**: When the painted car (after the AS/RS) enters the assembly plant, Warehouse2 is requested to pick the looms from the picking area and deliver them it to the sequencing desks.

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Jose Pedro Garcia-Sabater & Julien Maheut

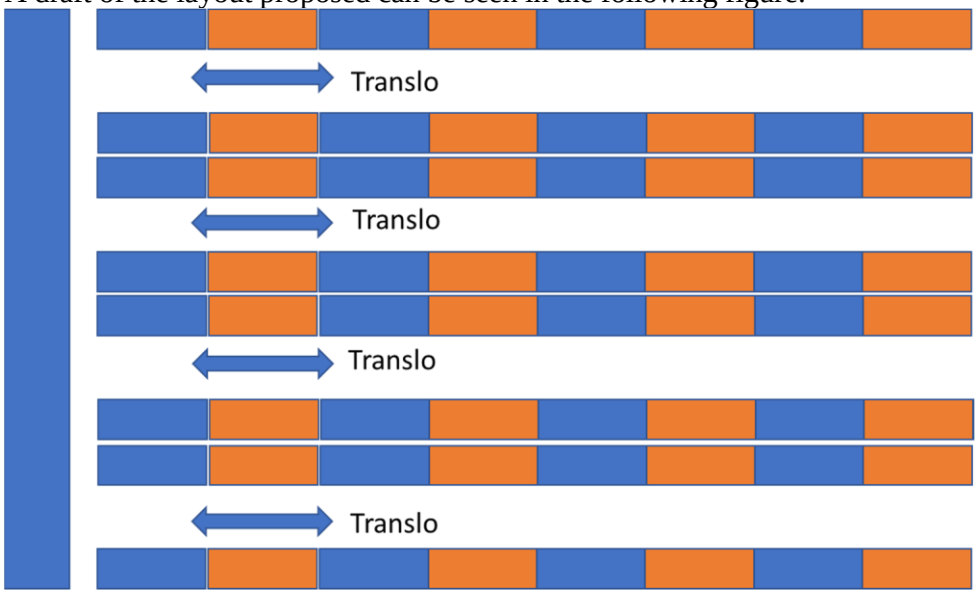
- ✓ **Sequencing area**: The sequencer (worker) checks that the product is correct (right product in the right bag). The product is placed on a sequencing trolley which has a capacity of 12 units. Two trolleys should be filled (one for each loom type).

The maximum duration between the signal reception and placing the product on the trolley must never exceed 25 minutes.

For the design of Warehouse2, several alternatives have been considered.

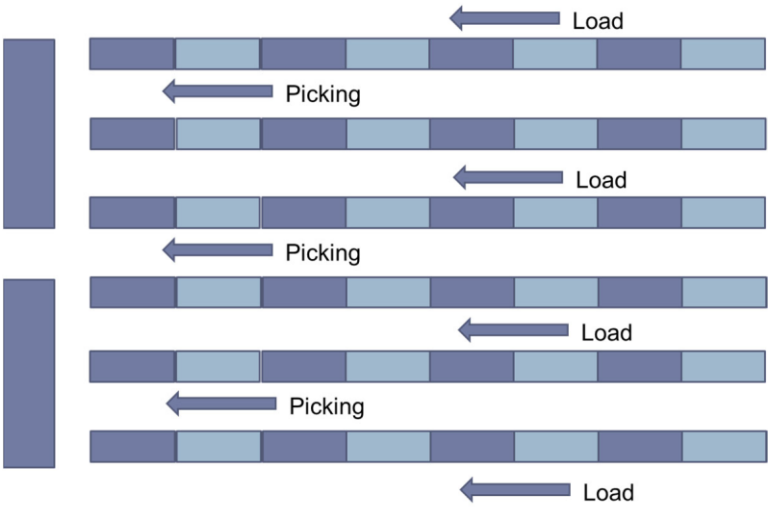
a) An automatic storage system (something like a *miniload)* with capacity for 2,000 looms.
   - ✓ The proposal is to consider 4 aisles of the following dimensions: 10 meters long, 12 meters wide and 6 meters high. In each aisle, an automatic transelevator (*translo)* will load and unload the looms one by one.
   - ✓ Each transelevator costs around 150,000€.

A draft of the layout proposed can be seen in the following figure:



b) A shelving system with lockers with a total capacity of 2,000 looms (2 pick-up aisles and 3 aisles for replenishment).
   - ✓ The picks and the replenishments are done one by one manually.
   - ✓ The two picking corridors are assigned and the worker travels on a picking vehicle with a platform that can reach up to 8 meters.
   - ✓ The replenishment will be made through its assigned corridors with a picker travelling on the same type of vehicle.
   - ✓ The approximate dimensions of the storage area will be 25 meters long and 10 meters wide and 6 meters high.
   - ✓ It is estimated that each picker vehicle costs around 70,000€.
   - ✓ As it is a manual task, it is possible to load up to 6 looms in a row and collect up to 4 looms in a row.

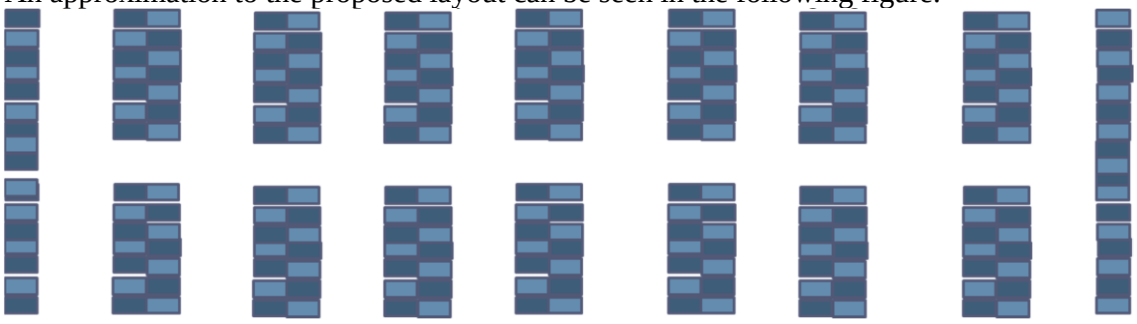
An approximation to the layout can be seen in the following figure:



c) A system of low shelves with lockers with a total capacity of 2.000 looms

- ✓ The replenishment and the *picking activities* are carried out using a customized picking trolley
- ✓ The approximate dimensions of the storage area will be 40 meters long by 30 meters wide and 1.50 meters high.
- ✓ Each loom is placed individually in a box (location).
- ✓ The trolley used to replenish or to pick has a capacity of 4 looms.

An approximation to the proposed layout can be seen in the following figure.



d) No system of picking shelves.

- ✓ In other words, the replenishment-picking operation disappears.
- ✓ The loom is picked directly from the FLC and once picked, it is sent back to the Warehouse1, where it will be stored again.

Some data that may be useful

- 8 looms of model A fit in a FLC.
- 10 looms of model B fit in a FLC.
- 3 workers (one per shift) have an estimated annual cost of 100,000 euros.
- The approximate cost of a forklift is 20,000 euros per unit.
- The horizontal displacement speed of a translo is estimated at 4 m/s.
- The vertical displacement speed of a translo is estimated at 2 m/s.
- A counterbalanced forklift moves at 2 m/s.
- A picking vehicle with a platform moves at 1.5 m/s horizontally and 1 m/s vertically.
- An operator walking and pushing the picking trolley moves at 0.7 m/s
- The time it takes to load a FLC from a conventional pallet racking system at a height of 4 meters is approximately 35 seconds (this is proportional to the height which must be reached).

- The time it takes to unload a FLC from a conventional pallet racking system at a height of 4 meters is approximately 40 seconds (this is proportional to the height which must be reached).
- The time it takes to pick up a loom from a FLC is 15 seconds if you don't have to search for it.
- The time it takes to pick up a loom from a FLC is (on average) 45 seconds if you have to search for it.
- The time it takes to find the right place to drop off or pick up a loom is about 10 seconds.
- The time it takes to check the product (quality control) is 15 seconds. If the product is not correct (2% of the time) it may take up to 5 minutes for repair it or replace it.
- The time it takes to place the loom in the picking trolley is 25 seconds per unit.
- In order to carry out all of these activities, a warehouse of 35 x 45 meters located at 200 meters from the delivery point of the sequenced trolley is available.
- A further 15,000 m^2 are available 1,000 meters from the delivery point.

The project has not gone ahead yet due to the excess of options and has asked you for help.

The design of the system is not complete at this moment and there are many details to be polished. The operating times are an estimation that will obviously affect the learning effect. On the other hand, not only is the cost of operation (OPEX) relevant, but also the cost and the magnitude of the necessary investment (CAPEX).

The issue of safety for workers is a very important issue for the OEM.

It is common knowledge that in the car industry:

- Reliability and quality are vital in delivery.
- If the system cannot serve the correct loom in perfect conditions, it may be impossible to assemble the car... and the car would have to be removed from the assembly line.
- It is also known that the daily mix of car types to be manufactured changes.
- There is a plan to incorporate new models into the installation in the mid-term.
- If the project is a success, other subassemblies of the cars could be sequenced in the same way from long distance sequencers.

Some suggestions to address the assessment

- Information may be missing, incomplete or inexact, so make hypothesis.
- All your hypothesis must be included in your report.
- Although the operational aspect of the system is not fully defined, propose one (the simplest one in your opinion) and do not try to optimize anything.
- Estimate the distances to be covered at each stage of the operation. The time required to move several meters is the distance divided by the velocity.
- Separate the calculations of requirements according to the different operations.
- The maximum saturation level of the resources should be above 85%. The length of the queues should be controlled and limited.
- The ANP method (or its simplified variant AHP) may be useful for assessing/sorting the potential alternative solutions. The weighted factors method is also an alternative method.
- Since no data is definitive, it would be interesting to use a simulation tool based on a MS® WorkBook to build the evaluator (if you need one).