Project no.:	**610917**
Project full title:	**Sustainable and reliable robotics for part handling in manufacturing**
Project Acronym:	**STAMINA**
Deliverable no.:	**D1.1.4**
Title of the deliverable:	**Final public report on use case and experiment specification including evaluation criteria**

Contractual Date of Delivery to the CEC:	**31.05.2015**
Actual Date of Delivery to the CEC:	**28.05.2015**
Organisation name of lead contractor for this deliverable:	**Peugeot Citroën Automobiles S.A.**
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Work package contributing to the deliverable:	**WP1**
Nature:	**R**
Version:	**1.0**
Total number of pages:	**42**
Start date of project:	**01.10.2013**
Duration:	**42 months – 31.03.2017**

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 610917

Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Abstract:

This report is the revised version of deliverable D1.1.3 that was delivered in M6. It provides an updated description of PSA use-case including:

- Specification of the use-case with associated industrial constraints for the targeted application
- List of technological challenges to address for constructing the STAMINA demonstrator
- Definition of performance index and validation methodology

Document History

Version	Date	Author (Unit)	Description
0.1	Jan. 01, 2014	A. CHAZOULE A. LASNIER	Started document
0.2	Mar. 17, 2014	A. CHAZOULE A. LASNIER	Draft submission
0.3	Mar. 25, 2014	All	Modifications during review meeting in Porto
0.4	Mar. 25, 2014	All	D1.1.1 delivered successfully
0.5	April 30, 2015	A. CHAZOULE A. LASNIER	Initializing the refined version of the document. Discussions on what should be updated and modified in the light of the two first test sprints.
0.6	May 22, 2015	A. CHAZOULE A. LASNIER	Preliminary version handed over for internal review
1.0	May 26		Final version

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Glossary

Term	Abbreviation	Definition
Automated Guided Vehicle	AGV	Mobile platform used in industrial applications to move and deliver materials from logistics supermarket to the production line. AGVs are also in charge of returning empty kits to the kitting area.
Takt Time	TT	Maximum time to realize a mission or an assembly task (in this case maximum time to provide a kit)
Large Volume	LV	Type of packaging mainly used for material handling of large items/goods. Large Volume containers are usually handled by forklifts.
Small Boxes	SB	Box-type packaging used for material handling of small items/goods. Small Boxes are usually stored in specific Kanban racks.

***Note** : For understanding purposes, differences between M6 and M20 versions of this document has been marked in blue color.*

1 Executive Summary

This report summarizes the present use-case description proposed by PSA Peugeot Citroën.
Reports D1.1.2 'Final internal report on use case and experiment specification including criteria' and D1.1.4 'Final public report on use case and experiment specification including criteria' are revised versions of respectively D.1.1.1 and D1.1.3.
The purpose of this revision is to update the use-case definition that was initially described in the early phase of the project taking into account the results of the first two tests sprints.

It should be noted that this deliverable is, except for minor changes, the same as D1.1.1. Following the major work efforts on the use-cases and the related technology in the previous year, we do not see the need for a major update of this deliverable. We are still confident that the use-case described in this deliverable is the one we are going to work with in the remaining time of the STAMINA project.

Most objectives seem feasible given the time frame of the project. We remind here that the main idea was to give an ideal specification description from the point of view of the end-user (PSA) that will serve as a benchmark for the STAMINA project to evaluate how far each targeted technology can be pushed in the direction of this ideal use-case.

The goal of the project is considered to be reached if we

(a) push the technology and scientific expertise further into the direction of the use-case
(b) identify problems and challenges that could not have been identified without actually approaching and attempting to solve the use-case
(c) quantify what works and how well it works
(d) identify what does not work and attempt to explain why and
(e) outline next steps to overcome the identified problems.

Minor updates of this document concern mostly:

- Newly available details of the STAMINA robot description and capabilities
- Updated design of the kitting boxes according to the preliminary placement tests
- Discussion on tool changer strategies following the limitations encountered with the chosen gripper
- More details on the STAMINA test area (mock-up of the kitting supermarket)
- Inputs from WP3 and WP4 concerning respectively online calibration requirements and the integration of the logistics planner
- Revised evaluation criteria
- Appendix concerning the manual kitting task description has been removed

Updates with respect to the previous deliverable use blue font.

This deliverable is organized as follows:

- A brief introduction to material supply in an automotive production system
- The expected impact of STAMINA to the organization of logistics
- The specification of the targeted use-case with associated industrial constraints
- The list of functionalities of the STAMINA demonstrator
- A definition of performance index and validation methodology

Note that this document contains sensitive information on PSA industrial processes. Total or partial dissemination of the information contained in this deliverable is prohibited without the prior written consent of PSA. A public version of this deliverable with restricted information removes will also be provided.

2 Introduction

2.1 How material supply works at PSA

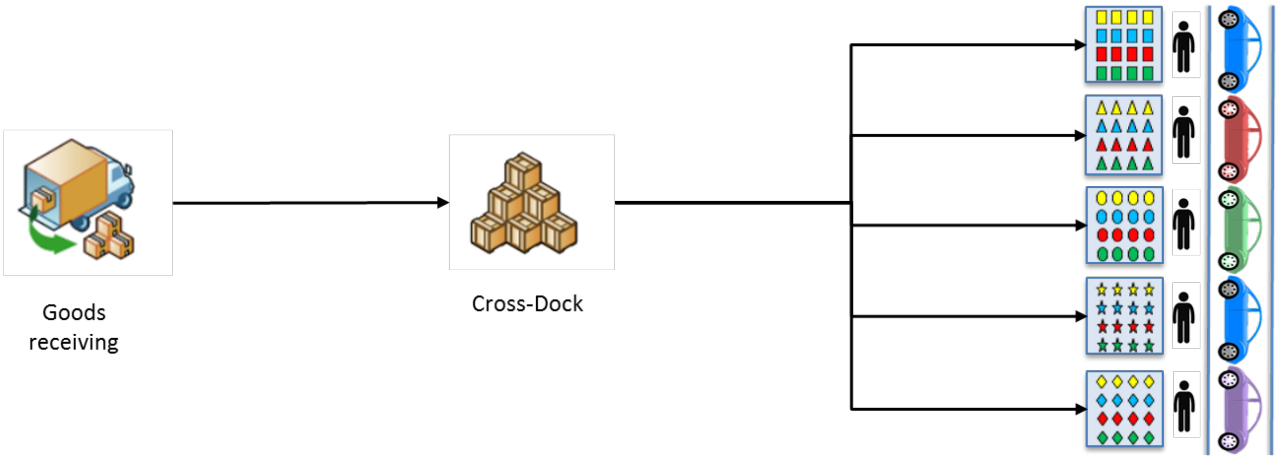
The paradigm of car production has recently shifted from mass production to increased customization of products (build-to-order). While customers are demanding highly customized products and services, **customization** implies fundamental technological changes in manufacturing and reorganization of production and distribution activities within the plants.

More customized products with increased assembly combinations implicitly means more components to store, transport and feed to the production line which leads to difficulties in the management of the supply chain: "providing the right amount of the right material, in the right time".

To remain competitive, most car manufacturers have adopted mixed material supply patterns depending on the cost model. Johansson[1] defines three principles of material supply that are currently well spread in the automotive industry. They are described below.

- *Continuous feeding*

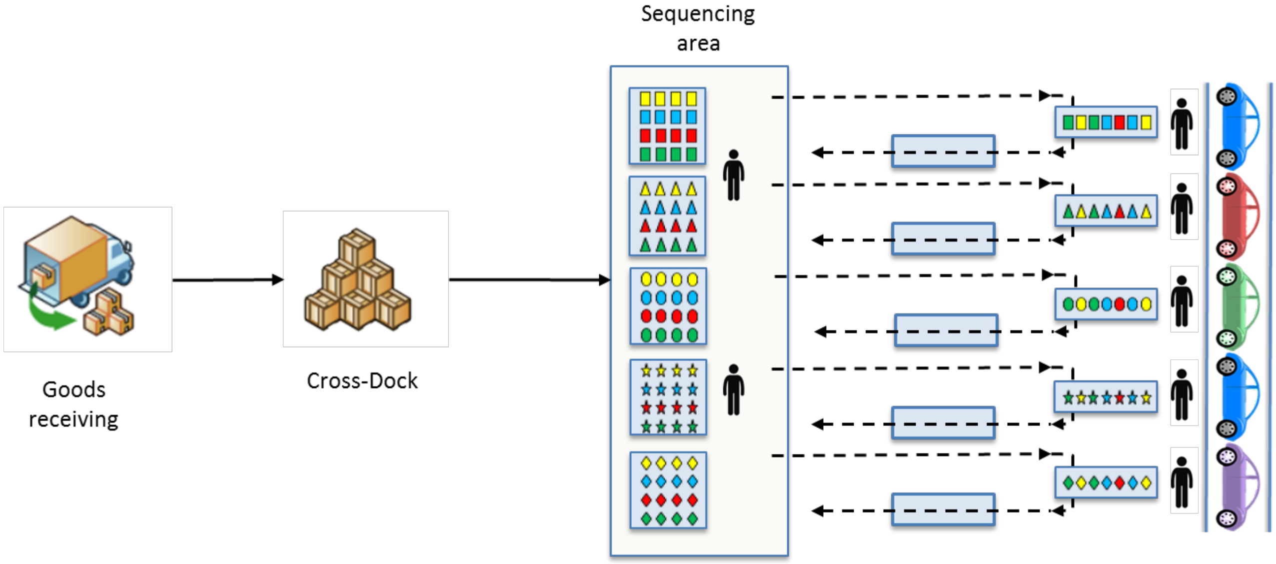
Continuous feeding refers to the case of delivering goods (vehicle parts) directly to the production line. All part variants required for producing the car are available at the workstation all the time. Refilling of each workstation is usually performed by human driven wagons.



[1] Johansson E. & Johansson M.I. (2006). Materials supply systems design in product development projects. International Journal of Operation & Production Management

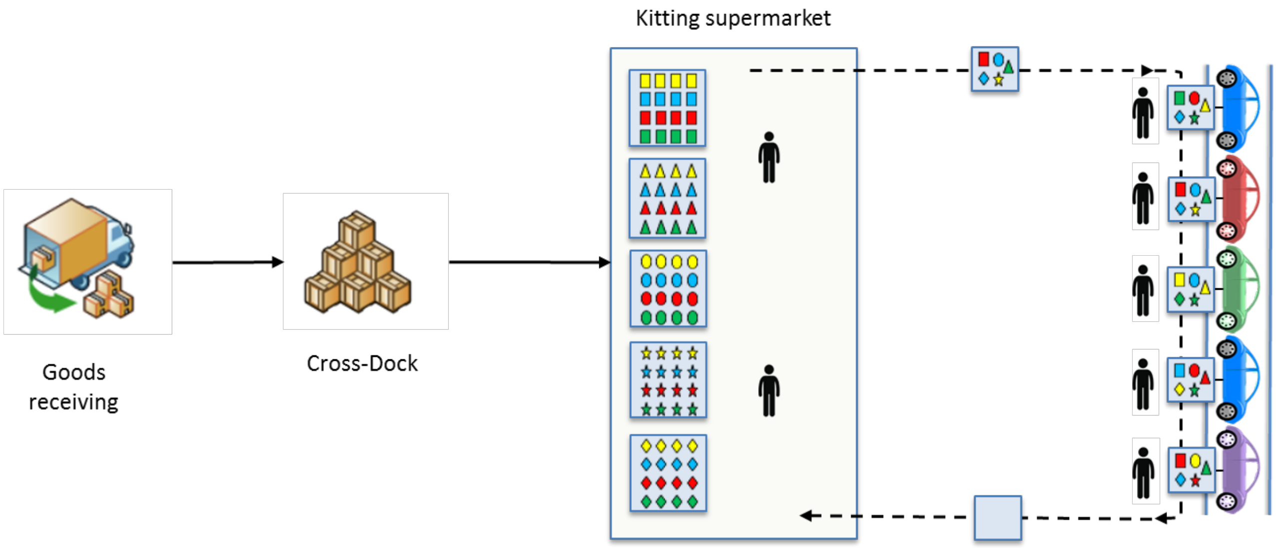
- *Sequential feeding*

Sequential feeding is a feeding principle applied to parts that have a large number of variants. It consists in delivering the parts in the right sequence (defined by production management system). Sequential feeding is space efficient (no space required in the production line to store variants) but requires upstream sequencing operations.



- *Kitting*

With respect to the lean manufacturing principle (just-in-time), kitting is the process where items are grouped, packaged and supplied together in one container (kit). This kit contains parts for one assembly object (one car). This type of feeding principle will be further described in the next section.



2.2 Kitting type distribution

With the impact of growing product variants, kitting type distribution has developed massively in the automotive industry over the past few years. The main idea is to **concentrate the value added on the production line** and decentralize re-packing operations.

As illustrated in the pictures below, kitting operations are usually performed by operators called 'pickers'. Once complete, the kits are delivered to the production line with automated turtle-like AGVs (Automated Guided Vehicle) or manually driven train wagons and synchronized with the car to be produced.

(Left) Kit preparation in the kitting supermarket

(Right) Kits delivered and synchronized with the production line

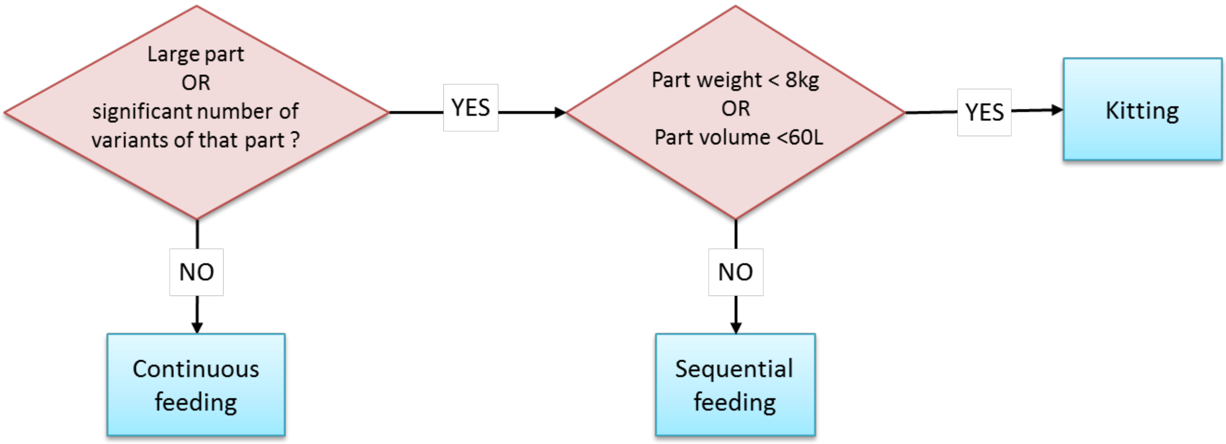
The main benefits of kitting are summarized below:

- Flexibility (easier product changeover and/or fluctuating production rates)
- Reduction of floor spaces (decentralized storage in the kitting area)
- Quality improvements (less damaged parts in open packages, early identification of defects)
- The assembly operator has all the components within reach and can concentrate on the assembly operation
- Improved control over the flow of components, less storage

The appendix of this document **'Kitting principles and its applications in PSA'** provides more information on how kitting is performed in PSA plants. This understanding is crucial to the project partners in order to fully understand the current situation and industrial constraints they will face.

2.3 Benefit of STAMINA to material supply

The three material supply principles defined in section 2.1 are possible distribution strategies; which one to choose depends on the weight, size and variants of the parts and available surface in the production line (see decision tree below).



The current trend in most automotive industries is to deploy the kitting type disribution and extend it to 100% of the parts that are delivered to the assembly line. However, this '**Full-Kitting'** target is currently limited by the fact that kitting operations are performed manually and therefore have to comply with ergonomic rules (part weight < 8kg). This weight limitation of parts, on the other hand, disappears if kitting operations are performed by mobile robotics systems.

In that context, the project STAMINA will investigate the feasibility of **performing standard logistics tasks using intelligent and dexterous mobile robotics system**.

Overall, as kitting distribution is expected to become even more important in the future, STAMINA will, in the long term, bring the following benefits to PSA:

- Explore the use of mobile robotic system under industrial conditions
- Increase the automation level of logistic operations that do not comply with ergonomic rules
- Allow the addition in the kitting standard of new part references that weighs more than 8kg

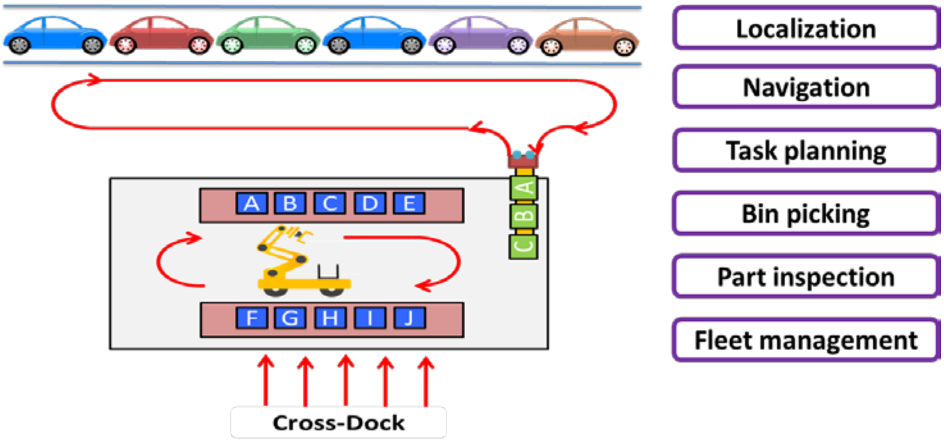
In the remaining part of this document, the reader will find useful information on the selected use-case (namely engine kitting operation) as well as the expected functionalities that the mobile robot is expected to perform in this context.

3 Use-case: description and specifications

3.1 Scenario

In accordance with the arguments highlighted in Section 2, the use-case selected by PSA for STAMINA illustrates the use of a **mobile manipulator** in a **logistics supermarket** performing **kitting/sequencing tasks** with the goal of feeding a production line.

The operating diagram with the macro-functionalities required can be summarized as follows:



3.2 Methodology for selecting the use-case parts

Among the thousand parts that constitute a car, there are unlimited possibilities for selecting the ones that will be proposed to the project partners for robotics kitting and sequencing. It is therefore crucial to **select a representative use-case** with various realistic parts that will demonstrate the **universality** of STAMINA approach.

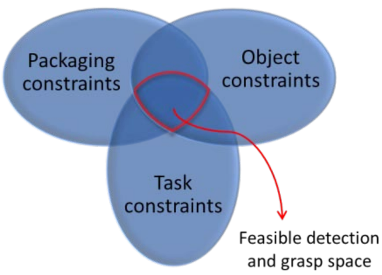
The selection of parts as a study case for STAMINA is based on factory observation of the various parts that are handled in the Logistics and Assembly workshop at PSA. We have conducted a complete survey of the cross-dock and supermarket organization and classified the parts to be manipulated (for kitting or sequencing purposes) according to 3 criteria:

- Part properties (fragile, shiny, transparent, unbalanced...)

- Packaging properties (plastic wraps, cardboard separator, bulk storage, stacking...)

- Task constraints (authorized grasps, part entanglement, placing constraints...)

It is important to be aware that those 3 criteria will influence the choice of hardware (robot, gripper, vision) and grasping techniques to be developed.



3.3 Kit for engine assembly

According to the survey that has been conducted, the 6 candidate parts for STAMINA use-case are taken from the engine assembly line.

- Engine pipe (P)
- Engine support (Su)
- Thermal shield (T)

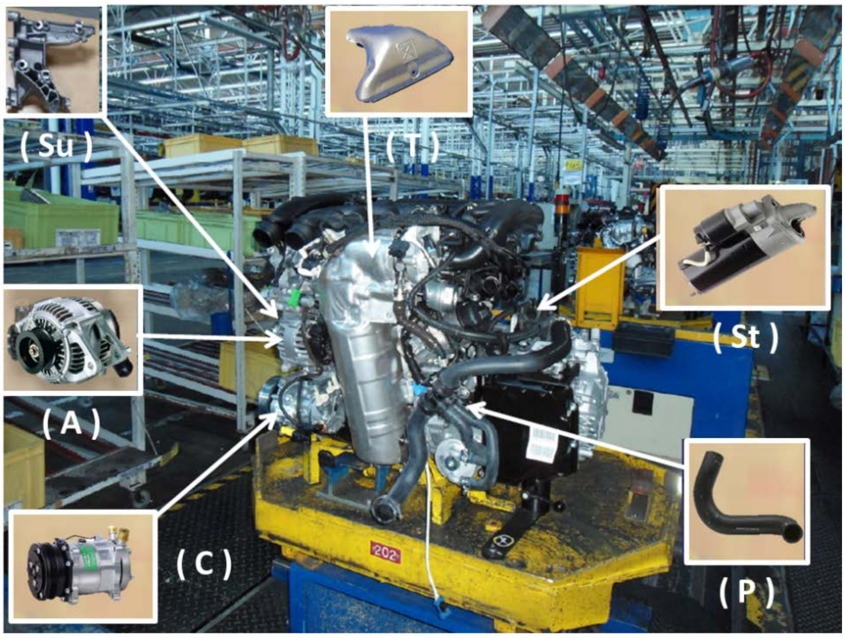
Small Boxes (SB) type packaging

- Alternator (A)
- Starter (St)
- Air conditioning compressor (C)

Large Volume (LV) type packaging

Those 6 parts are components of the **engine kit** that is delivered to the engine production line (see picture of an assembled engine below).

NB: engine kitting has not yet been deployed at PSA and selecting it as STAMINA use-case will serve as a projection towards full-kitting.



Selected parts for kitting in their final configuration

Those parts (described in more details later in this document) have been chosen for the following reasons:

- They represent a **wide variety of properties and constraints** that will have an impact on the hardware and software choices concerning object recognition and grasping
- They illustrate Small Boxes (SB) and Large Volume (LV) packaging constraints (impact on robot reachability)
- They are coherent with the factory needs as they belong to the fabrication process of the same sub-assembly (engine) and can therefore be gathered within a kit that makes sense (see mounted parts in the picture above)

In the following section, each part and its variants will be described in details (properties, packaging, special cautions).

3.4 *Part description*

3.4.1 Part 1: Engine pipe (P)

- Part characteristics:

Engine hoses are light and semi-flexible parts. They are black (shiny or matt) and come into **15 variants**.

The table below gathers useful information on the part variants and their properties. The average daily consumption gives an indication on how often a particular variant is consumed. For Large Volume storage, this information has an impact on the layout (highly consumed references should be arranged so as to optimize the motions of the AGV).

Part designation	*PSA Reference*	*Box type*	*Part weight (kg)*	*Units/box*	*Average daily consumption*
P1	9684566480	06432	0,932	5	66
P2	9686423080	06432	1,11	4	33
P3	9673633180	06432	0,65	5	26

NB: Data on other 12 variants of pipes could not be found but are assumed to be similar to the ones above

P1

P2

P3

- Packaging:

Like most parts that are packaged in Small Boxes, engine pipes are stored in **bulk** (4 or 5 parts per box) which poses the difficulty of being highly **tangled** (difficulties to extract). Below are the box characteristics.

Box type: 06432 (Plastic Box)

Length	594 mm
Width	396 mm
Height	314 mm
Weight (empty)	2,96 kg

- Special caution:

The grasping strategy should be delicate enough to avoid any damage to the part. Especially, the fixation ring is a sensitive zone that should not be deformed. During manipulations, bending the pipe beyond its limits should also be avoided (see picture below).

Finally, the dropping position in the kitting box should be chosen wisely (avoid crushing the part).

3.4.2 Part 2: Engine support (Su)

- Part characteristics:

Engine supports are metal based parts that make the connection between the engine and the alternator or compressor. Their color is uniform (shiny grey) and they come into **7 variants**.

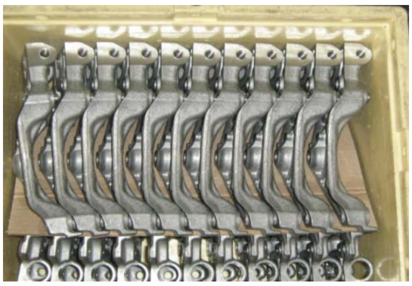
Examples of Engine support parts

Part designation	*PSA Reference*	*Box type*	*Part weight (kg)*	*Units/box*	*Average daily consumption*
Su1	9672950980	04322	0,385	22	35
Su2	9657457980	06422	1,437	4	33
Su3	9674030280	06422	0,729	12	103
Su4	9684613880	BNA20	0,781	14	35
Su5	9675508280	06422	0,773	12	103
Su6	9682776880	04322	1,5	5	40
Su7	V758078180	ANC20	0,265	34	40

- Packaging: *bulk storage*

Box type: 04322 (Plastic Box)

Length	396 mm
Width	297 mm
Height	214 mm
Weight (empty)	1.44 kg



Box type: 06422 (Plastic Box)

Length	594 mm
Width	396 mm
Height	214 mm
Weight (empty)	2,38 kg

Box type: BNA20 (Cardboard Box)

Length	600 mm
Width	400 mm
Height	200 mm
Weight (empty)	0,8 kg

Box type: ANC20 (Cardboard Box)

Length	400 mm
Width	300 mm
Height	200 mm
Weight (empty)	0,5 kg

3.4.3 Part 3: Thermal shield (T)

- Part characteristics:

Thermal or heat shields are aluminium based parts. They are relatively flat and light but can be difficult to manipulate (slightly deformable and fragile parts). They are also shiny and highly reflective.

They come into **3 variants**.

T1

T2

T3

Part designation	*PSA Reference*	*Box type*	*Part weight (kg)*	*Units/box*	*Average daily consumption*
T1	9804088180	06422	0,395	20	139
T2	V759560680	06432	0,748	12	37
T3	V759560580	06432	0,55	12	37

- Packaging:

Unless they have moved during transportation, thermal shields are usually stacked

Box type: *06422 and 06432 described above in 3.4.1 and 3.4.2*

- Special caution:

Thermal shields are fragile and should not be pierced or damaged.

3.4.4 Part 4: Alternator (A)

- Part characteristics:

Alternators are heavy (6 to 9kg) parts that are composed of mixed materials (metal, plastic). They are fragile and difficult to balance due to the inside coil. They come into **9 variants** (i.e. 9 pallets in the kitting supermarket).

Part designation	*PSA Reference*	*Box type*	*Part weight (kg)*	*Units/pallet*	*Average daily consumption*
A1	9803750980	00081	7,12	3 layers of 20	324
A2	9666997980	00081	6,32	3 layers of 20	60
A3	9678048880	00081	7,05	3 layers of 20	216
A4	9678730980	00081	7,2	3 layers of 20	10
A5	9674646180	63396	8,8	3 layers of 20	180
A6	9675753680	63396	8,72	3 layers of 20	12
A7	9809046080	63396	8,83	3 layers of 20	24
A8	V757848880	CCF75	6,2	4 layers of 30	48

- Packaging:

Like most parts that are packaged in Large Volume containers, alternators are stored in cardboard/plastic containers containing 3 or 4 layers of parts. In addition to successfully retrieving the part, the robot should take care about **removing the separators to access the bottom layers** (further developed in Section 4).

Pallet type: 00081

Length	1150 mm
Width	800 mm
Height	730 mm
Type of separator	Cardboard


Pallet type: 63396

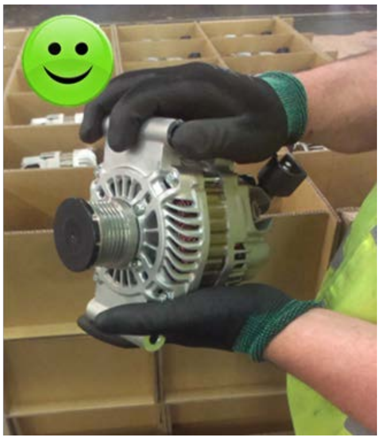
Length	1200 mm
Width	1000 mm
Height	910 mm
Type of separator	Plastic (1 or 6 kg)


Pallet type: CCF75

Length	1200 mm
Width	1000 mm
Height	900 mm
Type of separator	Cardboard

- Special caution:

Sensitive and fragile zones of the alternator concern the axle and plastic connectors. These are forbidden grasping areas. Instead, alternators should preferably be handled by the metal casing (see picture below) without colliding with the environment.



Another important aspect relates to the electrostatic properties of the part: no magnet-type gripper should be used.

3.4.5 Part 5: Starter (St)

- Part characteristics:

Starters are lighter than alternators but illustrate similar constraints (fragile multi-material parts). They come into **6 variants**.

Part designation	*PSA Reference*	*Box type*	*Part weight (kg)*	*Units/pallet*	*Average daily consumption*
St1	9654595680	00081	4,09	4 layers of 21	185
St2	9646694080	00081	3,69	4 layers of 24	39
St3	9647157980	00081	4,02	4 layers of 21	165
St4	9670983080	CAF75	3,25	5 layers of 30	270
St5	9664016880	CCF60	3,13	4 layers of 35	224
St6	V764559080	CCF60	2,8	4 layers of 42	68

- Packaging:

Box type: 00081 with no separators *(see description above in 3.4.4)*

Pallet type: CAF75

Length	1200 mm
Width	1000 mm
Height	900 mm
Type of separator	Cardboard

Pallet type: CCF60

Length	1200 mm
Width	1000 mm
Height	750 mm
Type of separator	Cardboard

- ***Special caution:***

Special handling cautions are similar to the alternator. Starters should not be manipulated by the transmission shaft but rather through the metal housing.

While dropping the part in the kitting box, the started should lie on the metal housing with connectors facing upward.

3.4.6 Part 6: Air conditioning compressor (C)

- Part characteristics:

Air conditioning compressors are middle weight and fragile parts that illustrate specific packaging conditions (see below). They come into **5 variants**.

Part designation	*PSA Reference*	*Box type*	*Part weight (kg)*	*Units/pallet*	*Average daily consumption*
C1	9677824580	16369	5,1	4 layers of 20	32
C2	9678038980	16369	5,8	4 layers of 20	16
C3	9671451180	17306	5,24	4 layers of 20	288
C4	9800840380	17306	5,9	4 layers of 20	256
C5	9678656080	17306	5,33	4 layers of 20	336

- Packaging:

Starters are stored in pallets supporting styrofoam layers. The position of the parts is relatively repeatable due to the imprints in the layers.

NB: Styrofoam layers have to be removed and piled up on an empty pallet.

Pallet type: 16369

Length	1130 mm
Width	970 mm
Height	860 mm
Type of separator	Plastic (5 or 9 kg)

Pallet type: 17306

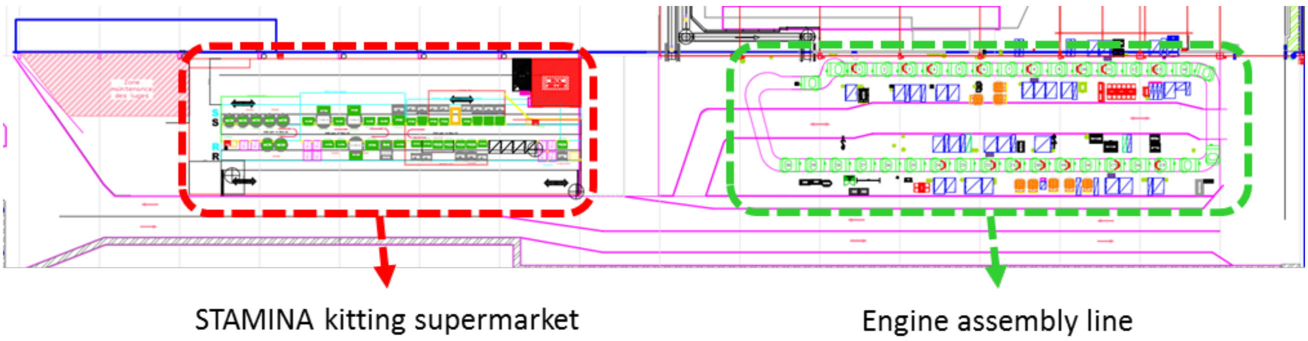
Length	1130 mm
Width	970 mm
Height	700 mm
Type of separator	Plastic (4.3 kg)

- Special caution:

As illustrated below, compressors should not be manipulated by the transmission shaft or the plastic connectors. The design of the gripper should allow a smooth extraction of the part without risks of collision.

3.5 Test zone for the demonstrator

As announced during the kick-off meeting, the final test print for the demonstrator will take place in PSA plant of Rennes. Below is the layout of the testing zone which is currently for alternator and starter sequencing. This area is located close to the engine assembly line (where the kits should be delivered).



This layout has been provided to the project partners and will serve as a reference for building the layout of the STAMINA demonstrator (optimization of the motions of the mobile robot according to parts diversity).

4 Operating mode and required functionalities

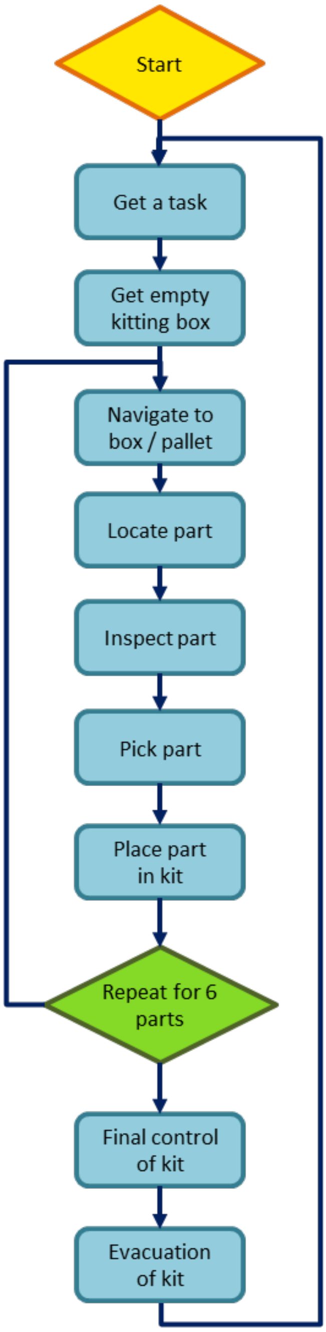
4.1 Mission description

The mission of the kitting robot developed within STAMINA is to collect the 6 parts described above in the kitting supermarket according to production needs (right variant for each part) and constitute a kit that will be inspected and delivered to the logistics transportation device (wagon or AGV).

Ideally, a complete kit should be delivered every **65 seconds** (takt time of the production line).

The evaluation of the cycle time of the STAMINA robot to complete its mission will allow PSA to extrapolate on the total number of mobile robots needed to be compatible with the production needs.

The task decomposition and associated required functionalities are described below.



4.1.1 Task 1: Get a task

<u>Prerequisites</u>:

> *It is assumed that when starting a task, the mobile robot has a prior knowledge of the layout and arrangement of part variants in the supermarket (learning phase).*

In this task, the robot management system should be able to **communicate with the interface layer of the enterprise information** system (ERP/MES) that will deliver in real time information on the production schedule.

From the production data, the decision system will extrapolate, for every kit, the '**shopping list**' for the 6 parts to kit (part variants) and create a robot mission plan accordingly.

In case of anomaly (wrong mission number, unknown part reference, insufficient quantity of components…), the robot should alert the production manager.

- Concerned Work Package WP3 and WP4.

4.1.2 Task 2: Get an empty kitting box

After receiving its mission, the robot goes to a designated area where it will load an empty kitting box on the platform.

4.1.3 Task 3: Navigate to right box / pallet

With the kitting box onboard, the kitting mission task starts.

The first task is to navigate towards the location of the box or pallet that contains the reference of the first part according to Task 1. In order to shorten the cycle time of the overall mission, it is crucial to **optimize the robot path** (shorter itinerary, less manouevers). The positioning of the AGV in front of the pallet/box should be precise enough to be compatible with the reachability of the robot arm.

Ideally, the logistics planner should have some knowledge on the remaining quantity of parts for each variant in the boxes/pallets in order to take the necessary measures if a container is empty (calling forklift driver in advance, removing empty box in the kanban shelf …). If several mobile robots are working together in the supermarket, this knowledge should be shared.

- Concerned Work Package WP2.1 and WP2.2.

4.1.4 Task 4: Locate the part

Prerequisites:

> *In this task, it is assumed that the robot has a prior knowledge of the CAD models of each part variant.*

Once the robot is positioned in front of the designated box/pallet, the sensory system of the robot (to be defined) scans the container in order to **recognize and locate the object**. From the recognized objects, the decision system will **select the best part** to be picked according to its optimization criteria (most graspable object, less collision risks, shorter path). The decision system will then deliver the coordinates of the recognized object that will later be used for collision-free path generation and graping planning.

Depending on the type of container (Small Box or Large Volume), the robot will identify from the scan if secondary actions have to be taken and generate an action plan accordingly.

This involves :
- Necessity to remove a separator (see section 4.2.1 below).
- Necessity to evacuate an empty Small Box (see section 4.2.2 below).
- Necessity to alert the forklift driver if a pallet is empty.

- Concerned Work Package WP2.3.

4.1.5 Task 5: Inspect the part

An added value of the STAMINA handling system is to be able to inspect the handled object and check its compliance with the information stored in memory. By comparing the scanned object with its CAD model, the inspection system will deliver valuable information on the **quality** and traceability of the part. In particular, it should be possible **to recognize possible mistakes made by the logistics delivery system** during the delivery of the boxes/pallets (wrong part variant).

NB: If a defective part is detective, it should be discarded in a specific container

- Concerned Work Package WP2.4.

4.1.6 Task 6: Pick the part

Task 4 delivers the location (coordinates in robot frame) of the most promising object. A **grasp and motion planning** will then be generated and executed by the robot and gripper.

NB: The grasp planner should eliminate grasp poses that are not compatible with the special handling cautions described in Section 3.4.

NB: The grasp planner select in priority the grasp poses that are compatible with the placing requirements (avoid multiple manipulation of the object).

- Concerned Work Package WP2.3.

4.1.7 Task 7: Place the part in the kit

Naturally following the picking task, the placing task will generate a collision-free motion plan for the robot in order to place the part in the kitting box on-board. The kitting box (see image below) follows the standard PSA design rules and is composed of 6 designated compartments (imprints or separators) to avoid any risk of collision between the parts while moving the AGV. The design and sizing of this kitting box has been performed through iterative phases and mock-ups. The kitting box used for the second test sprint looks satisfactory although some minor modifications will be performed in the future iterations to optimize the part placement and esp. regarding the tube support.

Iterative design of the kitting box (2nd iteration)

NB: Both localization and placement skills require precise calibration of the cameras (3 fixed cameras and 1 wrist cameras). To date, the calibration phase is performed manually using a standard calibration procedure. In the next test sprint, AAU will implement an online calibration process that will keep the cameras and the arm calibrated at all times.

- Concerned Work Package WP2.4.

4.1.8 Repeat tasks 3 to 7

Tasks 3 to 7 will be **repeated 6 times** (picking pipe, engine support, thermal shield, alternator, starter and compressor). According to the results of the first test sprints, picking the 6 parts that have different sizes and properties with the same gripper proves to be unfeasible. Therefore, other gripper technologies (vacuum, magnetic) will be investigated. A tool changer will probably be implemented on the robot to allow the exchange of gripper between every part.

NB: As the design of the AGV allows it, the mobile platform now embarks two kitting boxes at the same time to optimize the cycle time.

4.1.9 Task 8: Inspect the complete kit

Manual kitting with human operators does not only consist in placing parts in kitting boxes. There are also implicit control and inspection tasks that the robot should reproduce.

Once the kit is complete, it is thus important to have a **final control** of the parts (right variants at the right spots) and eventually take a picture of the complete kit for traceability and quality insurance.

- Concerned Work Package WP2.4.

4.1.10 Task 9: Evacuate the kit

Delivering the kit to the logistics transportation device (wagon or AGV) is the final task of the mobile robot. After navigating towards the location of delivery, the robot will evacuate a complete kit and load an empty kitting box for its future mission.

NB: The protocol for exchanging kits is using the on-board motorized conveyors on the STAMINA AGV that will drag the kitting box to its final location.

***General remark**:*

Tasks 1 to 9 are performed in human populated environment. It is possible that during the work cycle of the robot, some worker may be located inside the kitting supermarket (e.g. for maintenance purposes). The robot (AGV + arm) should be able to navigate and operate safely and predict human motions. Besides, the shop-floor workers and forklift drivers must feel comfortable when working in close proximity with the STAMINA robot.

4.2 Additional tasks

The STAMINA robot is designed to perform kitting task during standard 8 hours shift (similar to the job shift of a worker). During that time, there will be some infrequent tasks that the robot should be able to handle in order to guarantee a continuous work load. This mainly concerns supermarket organization and waste disposal.

4.2.1 Discard or recycle separators

Depending on the type of Large Volume pallet, the robot will have to deal with the different separators.

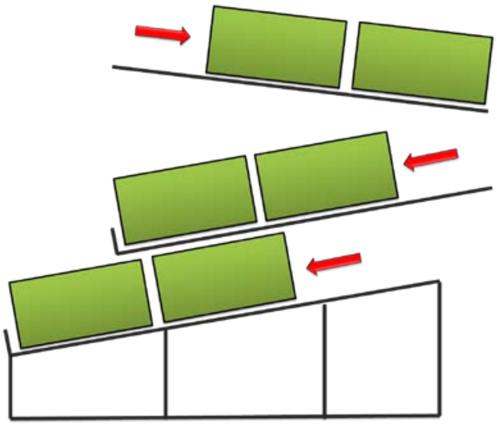
- The cardboard separators will be discarded in specific garbage container located in the kitting supermarket.

- The plastic separators will be gathered in a designated container for recycling.

4.2.2 Evacuate empty boxes

A standard Kanban rack for Small Box storage in the kitting supermarket is illustrated below. This rack generally comprises two layers of full boxes fed by gravity. The layer on the top is the evacuation slope for empty boxes.

When an empty box is detected, the STAMINA robot should be able to **transfer it from the bottom layer to the top layer**.



4.3 Error management

Due to the complexity of the mission, there are a number of reasons why the robot may encounter an abnormal situation. Depending on the diagnosis performed by the intelligent management system, the robot will have to decide on the appropriate measure.

Possible contingency modes are described below.

- Alert and Standby

When the cause of the problem has been identified as quickly solvable by a human intervention, the robot sends a warning signal to the production management system and waits for acknowledgement by the maintenance technician.

Possible reasons could include, but are not limit to:

- Wrong part variant in the box/pallet or defect in the part
- Missing box/pallet in the location
- The robot being behind the production schedule (human intervention needed to compensate for the delay)
- Changes in the layout that have not been notified
- Loss of grasp or contact with the part

Restarting the mission after the problem has been solved should be immediate.

- Alert and shutdown (degraded mode)

When a serious problem occurs (e.g. robot or AGV failure), the robot should send an emergency signal to the production management system and stop immediately its activity. The production of kits is then ensured by a human operator (ergonomic rules need to be respected!)

NB: In both modes, manipulating the robot and/or the mobile platform should be easy and intuitive

5 Setting up the world model and logistics planner

For a more efficient deployment of the STAMINA robots in the automotive industry, a careful attention will be given to the easiness to set-up a new kitting application or modify an existing one.

The procedure to install and set-up a STAMINA robot should be simple enough to be operated by a technician and require no particular programming skill.

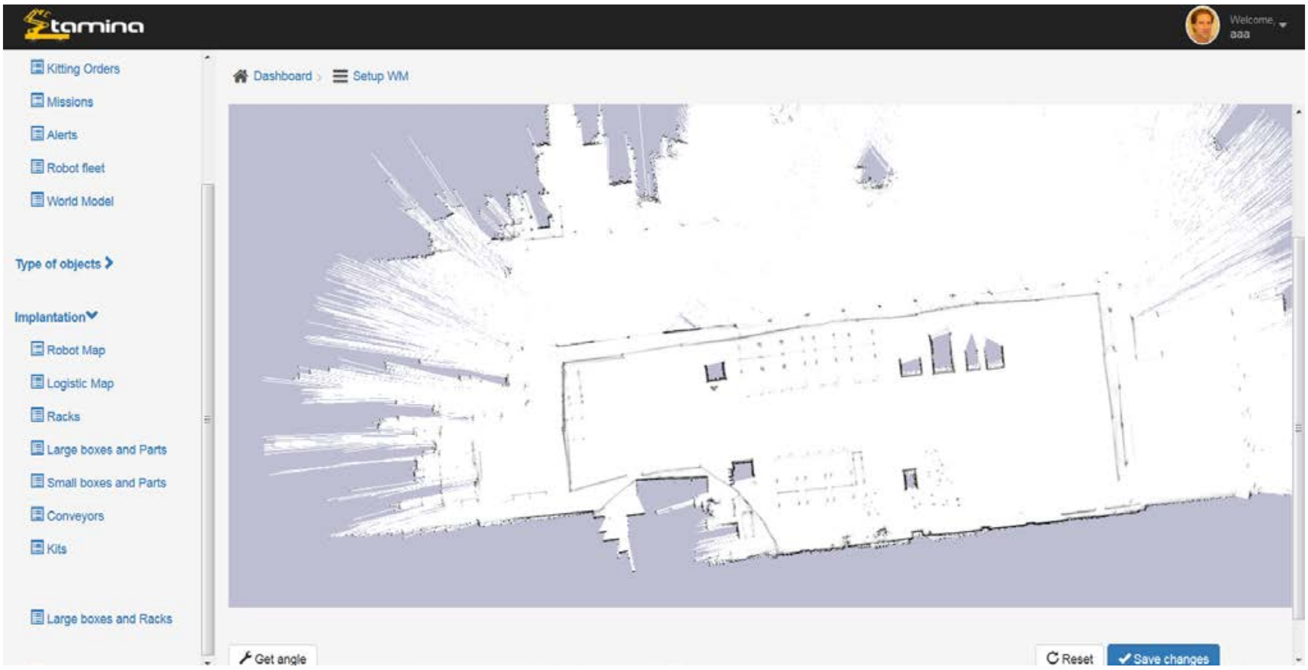
The main interface of the logistics technician will be the logistics planner (WP4). In addition to being the interface between the ERP of PSA and the fleet of robot, the logistics planner also hosts the **knowledge of the world model**, either initially entered manually by the technician and ideally regularly updated by the robots in the fleet. In the following we will give a brief overview of the parts that are relevant for the use-case. For details, please consult the corresponding deliverables (e.g. D4.1.1).

The set-up phase includes the following steps:

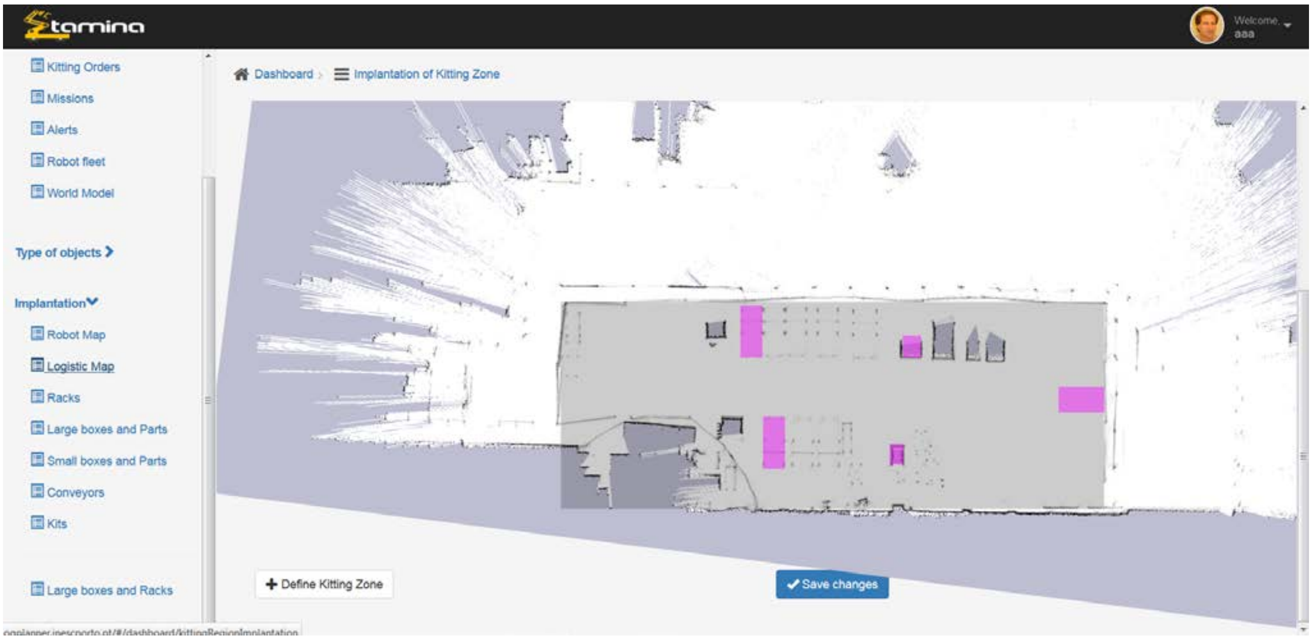
- Mapping of the kitting supermarket

The navigation of the mobile robot requires prior knowledge of the layout and organization of the supermarket. This information is acquired through a mapping phase where the AGV is controlled manually and guided inside the zone of interest.

Once the map is created, it is uploaded to the logistics planner for object identification and placing (manual post-processing).The logistics technician can thus define the **navigation rules** (speeds, directions) and indicate the **expected positions of the different elements of the supermarket (boxes, shelves, containers, trash)** in the supermarket.



Screenshot of the logistics planner interface with the **raw** *map*

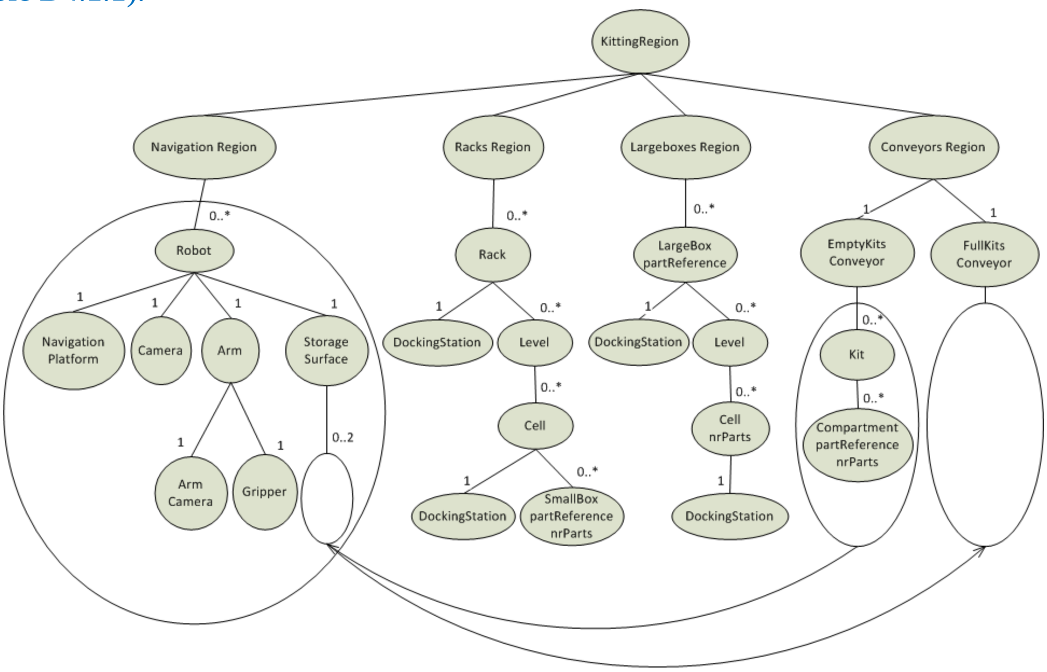


Screenshot of the logistics planner interface with a partially **processed** *map*

- *Knowledge on part and storage characteristics*

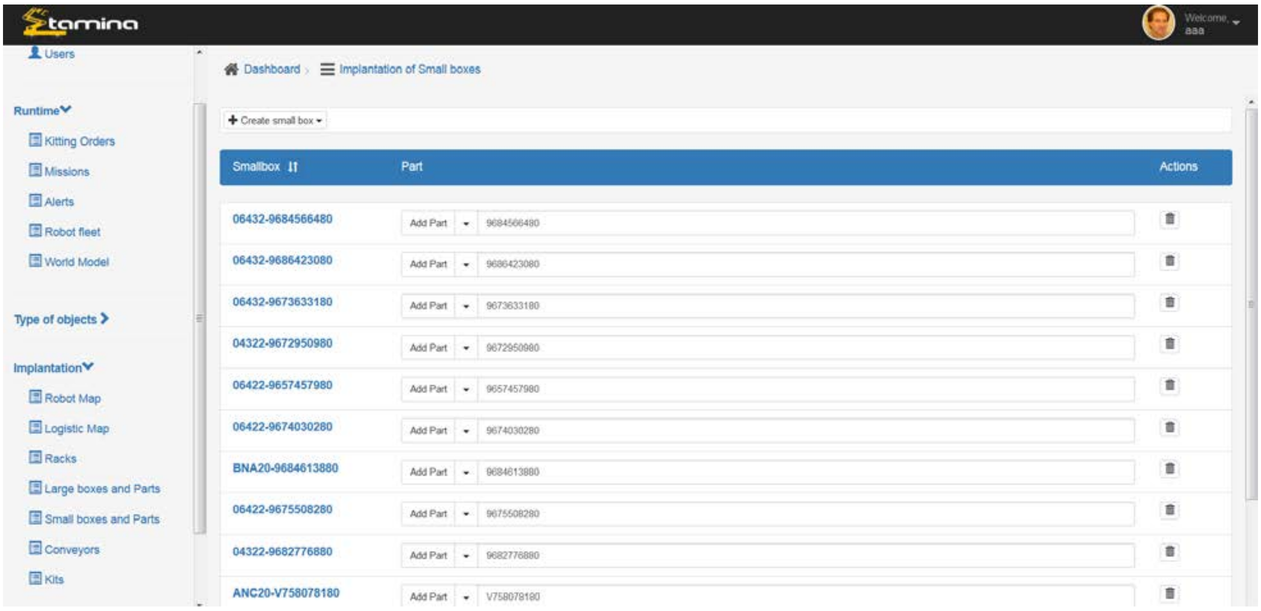
The recognition of the parts inside the bins or boxes to be picked requires prior knowledge of the storage characteristics and part models (**Where should the robot look? What should he look for?**). For that, the technician needs to be able to intuitively feed the robot controller with **CAD models** of the part and inform about **forbidden grasps**.

The world model includes a representation of the hierarchy between shelves, boxes and parts (cf deliverable D4.1.1).



Conceptual representation of the world model.

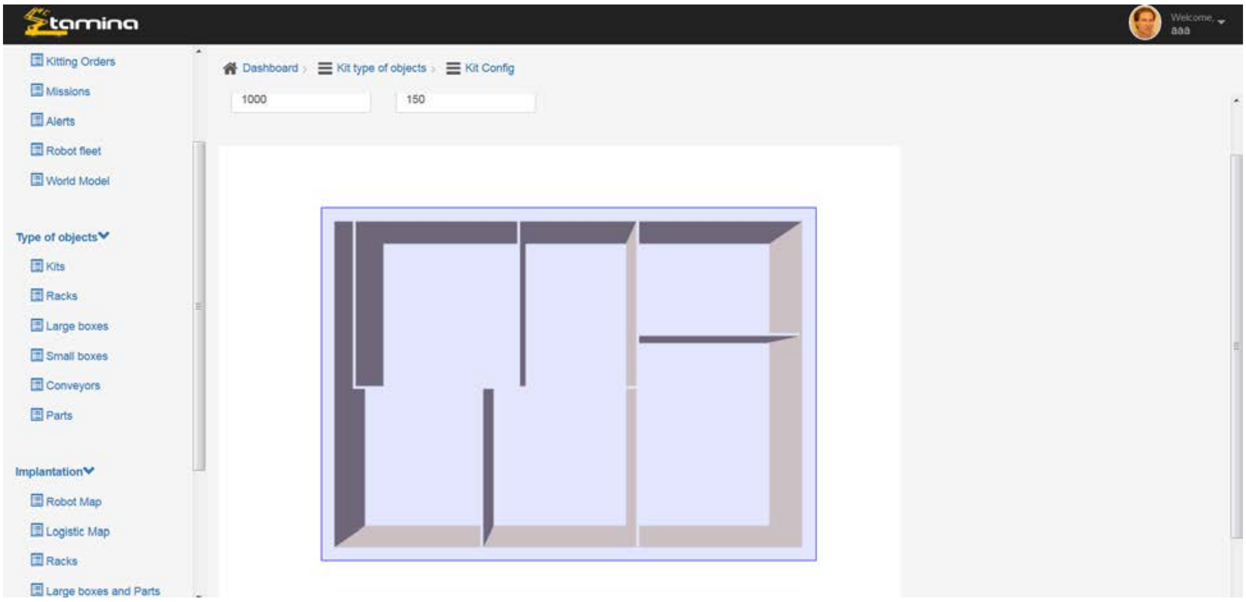
In the logistics planner interface, the logistics technician enters manually this information by filling out the box identification numbers and linking them with the part identification number (see below).
In a future version, the same page will be used to upload the CAD models of the parts that will be pushed to each robot of the fleet.



Screenshot of the logistics planner interface with part and boxes information.

- *Knowledge on kit characteristics*

Similarly, the robot needs to know the characteristics of the kitting box and location of the parts inside the kit. This process is again performed in the logistics planner by the logistics technician. The interface allows loading a top-view image of the kit (from the CAD model) and the user is asked to draw manually the compartments of the kit. The software will then automatically compute the centre of each compartment which will serve for the placement skill.



Screenshot of the logistics planner interface with kitting box definition.

- Connection with factory production system

The last step consists in establishing the connection with the production system according to the chosen communication protocol in order to acquire the so-called ‘kitting orders’ that will trigger the missions and tasks. To this date, the connection with the PSA ERP is only performed in an offline manner (manually pushing the kitting orders to the logistics planner through the network). In the future tests sprint, the online connection with the simulated ERP should be established.

- ***Layout or part modification***

The logistic supermarket is a part of the plant in constant evolution. It is possible that during the exploitation phase, the production manager needs to modify the layout of the supermarket or introduce new part variants.

The logistic planner should allow those modifications in an easy and intuitive way.

NB: The time for setting up or modifying a kitting application is part of the evaluation criteria defined in Section 6.

6 Proposed STAMINA layout and architecture

This section summarizes the current work conducted on:

- the design of the kitting supermarket for the engine kitting study case
- the choice of hardware that fits with the end-user requirements

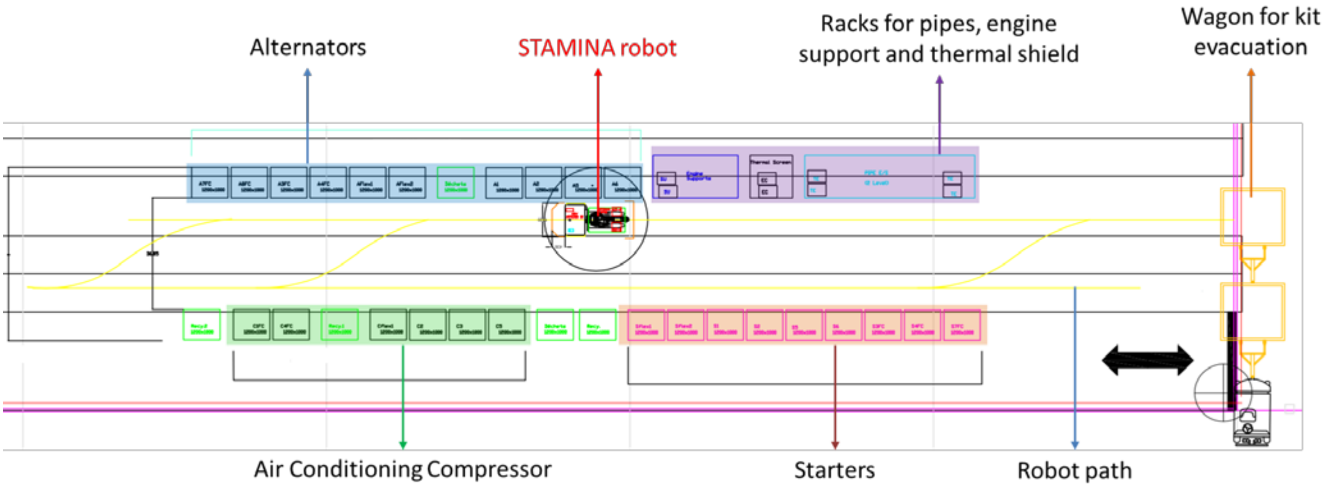
6.1 Proposed layout

When building the layout of the kitting supermarket, the challenge is to propose an **efficient arrangement** of the different containers (boxes/pallets) according the part variants with the view to **optimizing the motions** of the STAMINA robot and the allocated **surface** of the supermarket.

The proposition below is the result of a site meeting that took place on Feb. 12th 2014 with a working group composed of PSA and BA Systèmes experts. Following this brainstorming and given the properties of the proposed AGV from BA Systèmes, we proposed to arrange the supermarket as follows:

- straight line arrangement of the containers
- grouping of containers according to part variants and families
- the less-consumed parts placed further away to optimize motions
- AGV navigation in the aisle performing loops

This proposition allows efficient path management of the AGV (few manoeuvers to perform) and possible multi-robot coordination with reduced interferences.



<u>Particular attention should be paid to:</u>

- Preserve the accessibility and ergonomics for logistics operation (loading/unloading the racks or pallets)
- Take into consideration possible human intervention in the supermarket
- Provide flexibility to modifications and possible adaptations

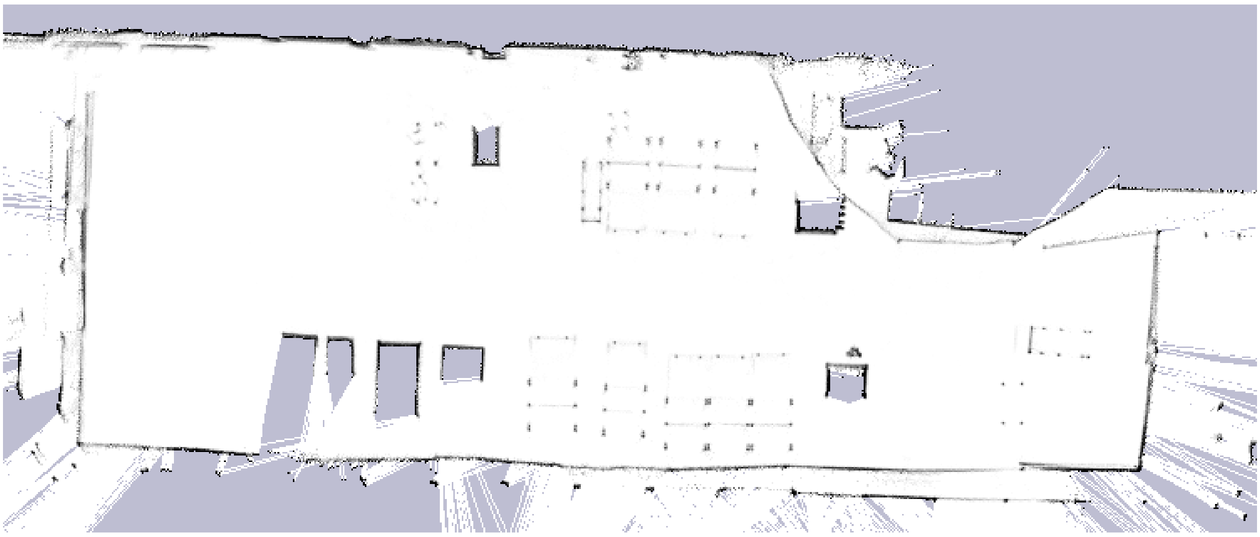
NB: The layout has been provided to the project partners under AutoCAD format and is subject to modifications or evolutions

6.2 Test area for the second test sprint

The second test sprint of the STAMINA project is taking place from M18 to M21. Initially planned at the integrator's location (BAS), the tests are finally being performed at the PSA plant of Rennes as the space available for testing was limited in BAS. For this purpose, PSA has created a replica of a small logistics supermarket (see picture below) with containers and shelves for testing the contribution of the project partners (navigation, part localization, picking, placing). This mock-up, although dismantled every year, will be set-up and augmented for each test sprint until the final demonstration.

Testing environment in PSA Rennes plant

The initial mapping tests of the area using ALU-FR SLAM algorithm allowed the extraction of the map of the supermarket (see below) which will serve both for navigation (WP2) and Logistic planning (WP4).



Map of the kitting supermarket from the SLAM algorithm

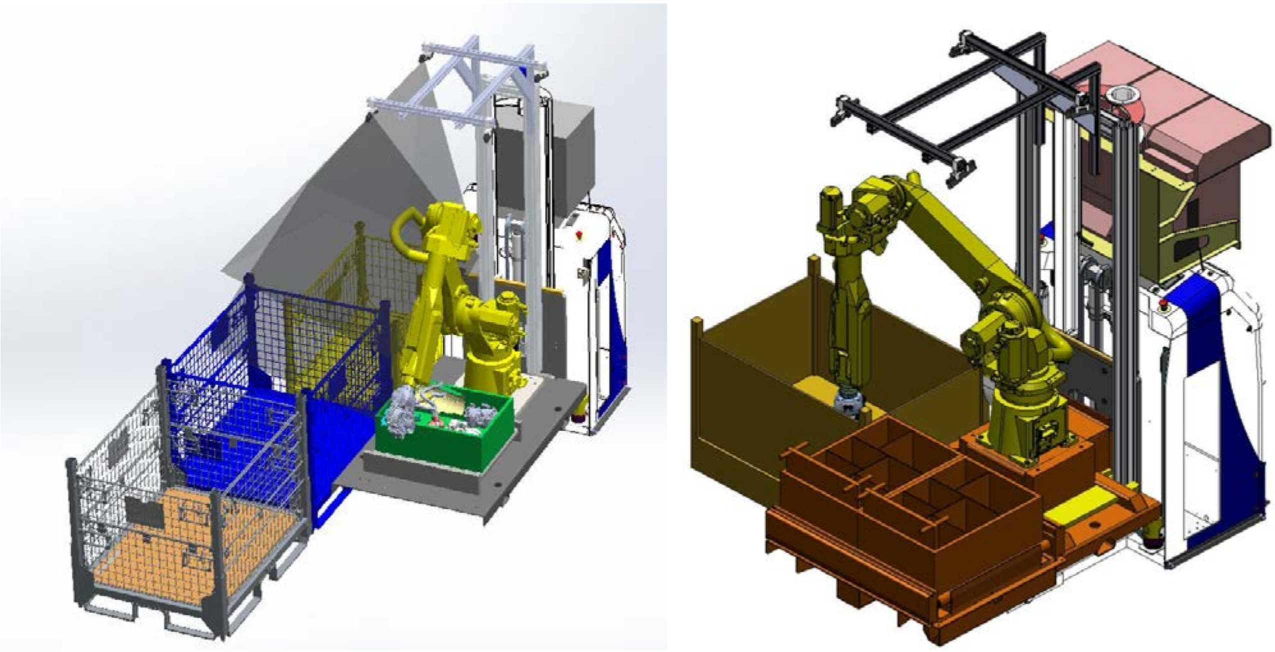
6.3 Proposed hardware architecture

Choosing the right hardware to fulfill the requirement described in this document is crucial. Several attempts have been made to simulate the robot reachability and test different hypothesis (robot morphologies, position on the AGV…).

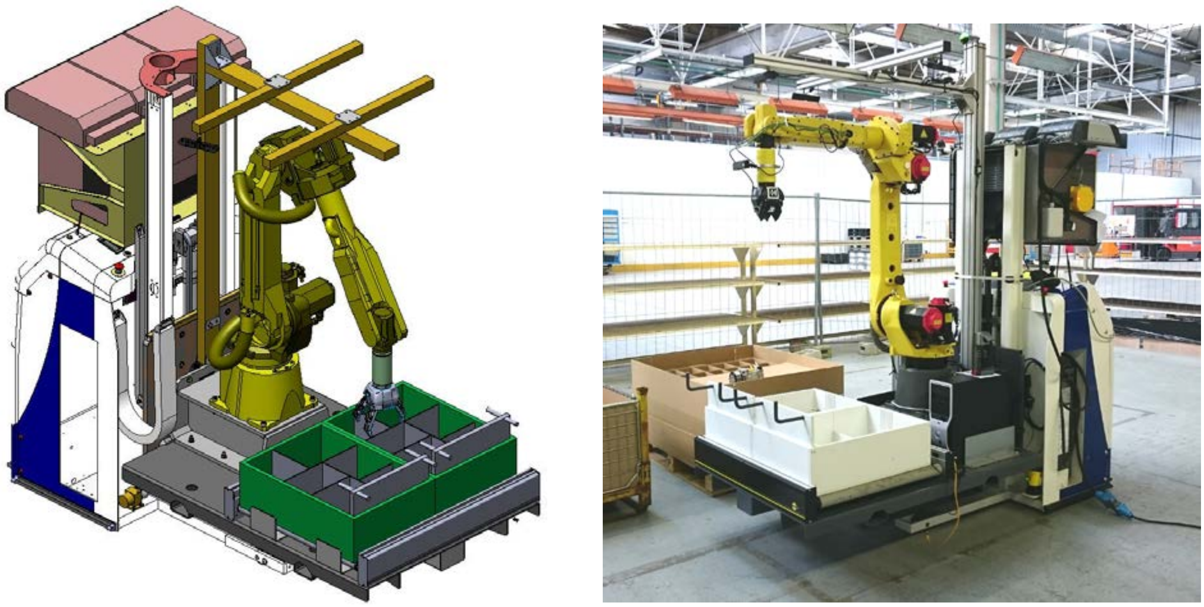
Regarding the choice of the robot arm, the key factors are:

- the reachability envelope (the robot should be able to pick parts from the deepest containers)
- the payload (needs to be sufficient to carry the gripper, the parts and possible sensors)
- the weight and balance of the robot and its controller (in accordance with the maximum payload of the AGV)

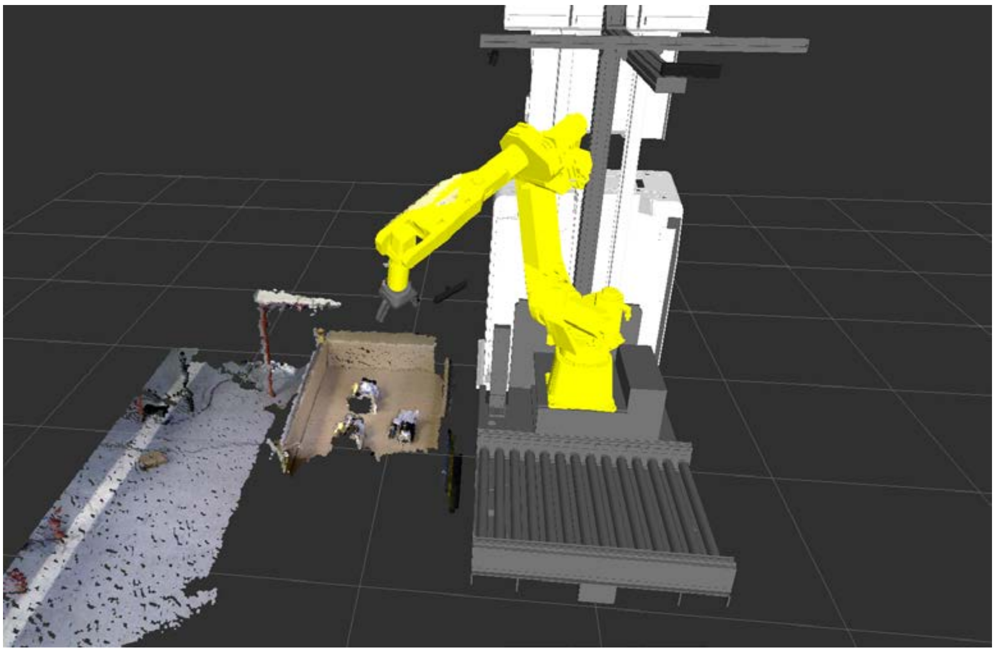
The chosen solution (shown below) is a 6-axis FANUC robot M20iA/35M with a compact controller R30iB. The robot is placed at the center of the AGV platform and able to pick from both sides. The gripper is currently a Robotiq 3-finger hand that allows great versatility but still show some limitations. As mentioned in the previous section, other gripper alternatives will be investigated and a tool changer will need to be implemented on the robot.



Robot simulation for reachability testing



Robot design and realization (M20)



Screenshot of the robot modelling and integration in ROS environment

7 Definition of evaluation criteria

During the project, a series of metrics has been defined to measure how well the STAMINA robot accomplishes its kitting task. Through the use-case proposed by PSA Peugeot Citroën, the performance evaluation will assess the satisfaction of possible clients in the automotive sector to better prepare a future market introduction. This evaluation will help identify the gaps between the industrial need and the actual maturity of technologies.

Obviously, before taking into consideration additional constraints and indicators (throughput, robustness to disturbances etc...), the evaluation of the demonstrator will first address the capability to perform the required tasks:

- The complete system should be able to collect parts
- Without braking
- Meet precision goals (navigation, placing)
- Be effective in terms of start-up time and execution time
- Be reliable (mean-time to failure, amount of human intervention)

Additionally, Key Performance Indicators (KPI) that reflects the end-user goal and defined below.

- Production throughput

The speed of the STAMINA robot in completing its kitting task is a critical indicator of success that will influence the possible deployment of this technology (i.e. how many STAMINA robots are necessary to automate a PSA kitting supermarket?)

After several cycles of work, the average kitting time for the proposed use-case will be measured. This sequence of work will then be decomposed and every task (navigation, localization, grasping) will be timed and optimized through the successive and iterative tests.

- Robustness and repeatability

The STAMINA robot should be autonomous and require no human intervention. For standard industrial processes, the success rate for recognizing and picking the parts is required to be greater than 99%. During the final test sprints, the partners will measure how many human interventions the STAMINA robot needs to complete a standard 8 hours shift.

- Quality

The parts manipulated by the STAMINA robot will be inspected after several kitting operations. No damage should be observed.

- Flexibility

This KPI measures how easy it is to implement/modify a STAMINA solution.

In particular, the following items will be measured:

- the time needed to install and implement a STAMINA robot from scratch (mapping, programming, adjustments)

- the time needed to introduce a new part in an existing installation
- the time needed to modify an existing layout

- Safety

The STAMINA robot should impose no threat to the human workers in the surroundings. In particular, the risk analysis conducted by BA Systèmes will ensure that every measure has been taken in that regard.

- Cost

A cost estimation for the STAMINA prototype and possible serial production will be carried out. This KPI will help refine the business model and assess under which conditions possible clients would be ready to invest in the STAMINA technologies.