PICKNPACK

Flexible robotic systems for automated adaptive packaging of fresh and processed food products

GRANT AGREEMENT Number 311987

2nd periodical scientific report of WP1

Month 19 (April 1st 2014) – Month 36 (September 30st 2015)

Lead beneficiary:DLO

Author(s): E.J. Pekkeriet, all

Dissemination level		
PU	Public	X
PR	Restricted to other programme participants (including the EC Services)	
RE	Restricted to a group specified by the consortium (including the EC Services)	
CO	Confidential, only for members of the consortium (including the EC Services)	

Table of Contents

1 Project objectives for the period

1.1 General objectives of the PicknPack project

The PicknPack project will develop three types of modules that can cope with the typical variability of food products and the requirements of the food sector regarding hygiene, economics and adaptability. It will assess the quality and shape of individual products, will handle the products in a flexible way and will adaptively pack them in an optimized packaging to add maximum value to the quality of the product and provide convenience to the consumer. Information obtained in the process will be transmitted and used upstream and downstream in the chain to optimize performance in logistics ensuring the highest quality for the consumer, minimum waste and full traceability. To ensure utilization of the results of PicknPack, special attention will be given to overcoming barriers and ensuring adoption of the system by the food industry.

These modules will be connected to an adaptive multipoint framework for flexible integration into a production line that optimally makes use of the capabilities of the individual modules. The communication between modules is based on a shared, vendor-independent vocabulary. The system will be designed in such a way that a wide range of fresh and processed food products and packaging concepts can be handled. It will also be able to single out an individual product from a group (bin picking) and correctly orient it for packaging. Tools for fast change-overs and adaption to new products will be implemented to reduce the time required to program the system for new product/packaging combinations (Figure 1 A basic three module adaptive production line).

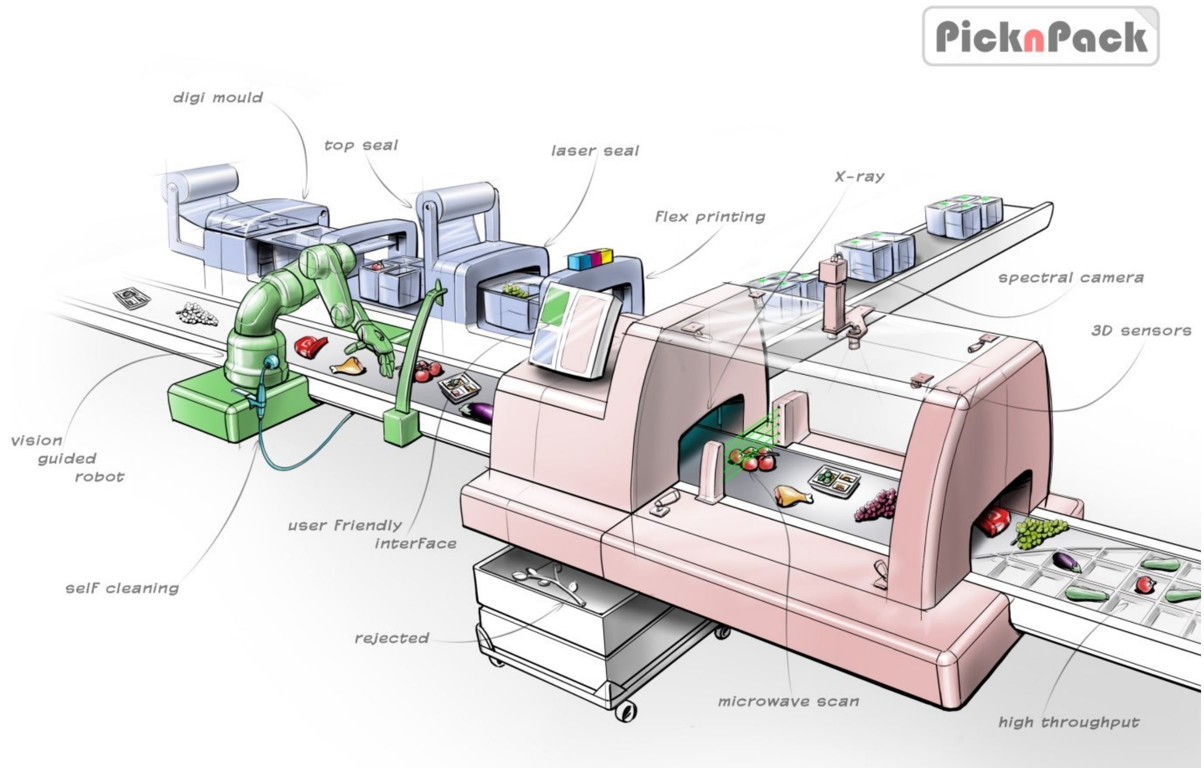


Figure 1 A basic three module adaptive production line

The general objectives are divided in objectives per work package. In the reporting period the following objectives per work package are relevant:

WP1 Coordination

- Manage the project and fulfil all of its goals.
- Organize meetings (including minutes) for governing and management bodies and the Advisory Board.
- Prepare and deliver periodical reports for the Commission.
- Make sure that deliverables are delivered and milestones achieved.

WP2 Flexible Systems Integration

- To make the project's "flexibility" promise a reality, simple enough and generic.
- To decrease the dependency of system builders without compromising on their integration efficiency.
- Development of composability guidelines.
- Development of compositionality guidelines.
- Identification and formalization of all stakeholders involved in the integration aspects.
- Development of a (composable) "ontology" for the domain(s) to be integrated in this project.

WP3 Information, communication and traceability

- To establish a database for upstream food components.
- To establish RFID systems and other common product identifiers such as barcodes for upstream food component tracing and downstream product tracking and vendor managed inventory.

WP4 Quality assessment and sensing

- Development of a module that assesses the shape, position and quality of individual food products.
- Establishment of the relevance of the different sensing principles.
- Combination of the data from the different sensors to derive maximum information on the product to support decision making and traceability.
- Building the module and testing it on different food products.

WP5 Robotic Product Handling

- Development of a food product handling module that is flexible and fulfils the criteria of the food industry regarding hygiene, economy and safety.
- Development of end-effectors that allow handling of a large variety of (non-uniform, delicate) food products.
- Development of a reprogramming method that allows fast change-overs to other products by non-specialized workers.

WP6 Adaptive Packaging

- Development of an innovative mould for forming the primary packaging.
- Development of an innovative packaging integrity system able to extend the shelf life of the food products including a system for auditing the sealing quality.
- Development of an innovative flexible heating system for microwave radiation.
- Development of an innovative decoration system of the packaging ready for supermarket sale.

WP7 Fresh and processed food production line

- Design of a a fresh and processed food production line.
- To develop and evaluate generic concepts and control systems for the production line that can also be used on other products within fresh and processed food applications.

WP8 Hygienic food handling

- Design of a hygienic processing line layout for the PicknPack system.
- Monitor and advise on hygienic design aspects for all product contact parts.
- Design of a cleaning system for the PicknPack system.

WP9 Life cycle analysis and sustainability

- To create a full life cycle picture of the automated systems developed in the project

- To assess the effects of automation of packaging of fresh and processed food products from a sustainability point of view considering aspects like waste minimization, quality increase and logistic optimization
- To base such an assessment on the three pillars of sustainability through a Life Cycle Assessment (ILCD compliant), a Life Cycle Costing as well as a social evaluation.

WP10 Dissemination
- Disseminate the PicknPack results to as many stakeholders as possible
- Maximize the utilisation of the project results by the food packaging industry

WP11 Demonstration
- Not started in this first period

WP12 Acceptance, economics and exploitation
- Analysis of the parameters/factors influencing the acceptability and implementation of an automatic packaging system in the food industry
- Analysis of the economic viability of the robotic packaging systems
- Study of the impact (technical, social, etc.) of the robotic system on the food sector

2 Work progress and achievements during the period

This chapter covers the second period (from April 1st, 2014 until September 30th, 2015) of the activities in the different Work Packages.

2.1 WP1 Coordination

WP1 is part of the Management task and is explained an evaluated in chapter 3.

2.1.1 Use of resources

	Period 1		Period 2	
Cost type	PM	Costs	PM	Costs
Personal	18.1	€ 192,970	18.1	€ 198,000
Subcontracting				€ 1,500
Other		€ 23,739		€ 24,318
Total		**€ 216,709**		**€ 223,818**

2.1.2 Deviations from the DoW

There are no major deviations from the Dow. Little more, but cheaper man months and travel costs were needed than expected at start of the project. It is in line with the overall budget of WP1.

2.2 WP2 Software Systems Integration

2.2.1 Project objectives for the period

- To make the project's "flexibility" promise a reality, simple enough and generic
- To decrease the dependency of system builders without compromising on their integration Efficiency
- Development of composability guidelines
- Development of compositionality guidelines
- Identification and formalization of all stakeholders involved in the integration aspects
- Development of a (composable) "ontology" for the domain(s) to be integrated in this project

This report covers the second project period (from April 1st, 2014 until September 30th, 2015) of the activities in Work Package 2 ("Flexible Systems Integration"). In this period, all Tasks were active, and five Deliverables were produced (D2.1, D2.2, D2.4, D2.5, D2.6). Most of the new effort was spent in the design of a flexible Graphical User Interface, which can be customized to all modules and activities in a food production line, on the basis of the same semantic models that have been developed for the actual production modules itself. The work on system integration started in the first period resulted in a full software implementation of the communication infrastructure ("line controller") that realizes the said integration, for all modules and activities, in a uniform way and with full support for all possible flexibility and tracing requirements set out by the project.

2.2.2 Summary of the work progress and achievement during the period

The challenges posed by the Tasks turned out to be a lot bigger than what could be done with the allocated project budget, but partners KUL and DLO provided *significant* extra man power to the software implementation work. We did not have to give in on the goals that were set out, but the implementation efforts required to bring all ideas into practice turned out to be a lot larger than expected. But what has already been realised concretely also surpasses the expectations, in that the envisaged flexibility and traceability can be supported, systematically, to an extent that has never been seen before. In summary, the goals were reached, but the costs to integrate a new module into the flexible line control is requiring significant efforts, due to the large variation in the capabilities and design of the modules we have in the line. Of course, this integration effort will reduce drastically when a new module is to be integrated that has similar design and functionalities as an already integrated one. Indeed, most of the efforts of such integration are then on changing the *models* and much less of the *software*.

Indeed, the systematic approach of "model driven engineering", introduced in the first period, was consistently continued, leading to a gradual increase in concrete semantic models. to represent the most important data in such a way that (i) modules by different vendors can be connected together without losing interpretability of the data produced by these modules, (ii) minimize the data and knowledge representation primitives while still allowing full capturing of all relevant information, and (iii) the control software of the different modules can be configured with product-specific knowledge, in an automatic way.

This software effort was completely structured on the basis of the design methodology (the "System Composition Pattern") created in the first period, and it has been proven that this methodology can indeed lead to software architectures that can support all envisaged variations of the PicknPack food processing line, and that takes into account explicitly the pragmatic challenges of incorporating "legacy" systems, of various degrees of granularity.

2.2.3 Work progress and achievements during the period

The work reported below was performed with some deviations from the expected work allocation in the DOW, even though KUL and DLO have brought in very significant extra manpower. The deviations are not related to changes in the content or the ambition of the work in WP2, but are fully related to the timing of the execution. The two major objectives of the whole Work Package, however, have been completely reached: (i) we now have formal models (using the JSON-LD language for its representation), of a PicknPack production line, its food processing or quality checking modules, and the production of packages that they generate; and (ii) all modules (physical as well as information processing modules, such as GUIs, the label printer, or the interface to the tracing data base) make use of the same software for self-discovery networking and for flexible event stream communications. Those integrate the formal semantic models for description of the meaning of the communicated data. From the point of view of software implementations, all partners can now make use of a "line simulator" to test the integration of their module or activity with the line controller; the same code is used on the real line too.

This result is without doubt unique in the domain of "cyber physical systems" of the type relevant for Picknpack. All the envisaged objectives are still deemed to be achievable within the foreseen resource constraints, albeit with most probably a lower coverage of new to be integrated modules, with the same depth of implementation as the ones that are already working now. A complete food processing line as designed in the PicknPack project contains a dozen or so modules (quality assurance, sealing, food depositing into packages, printing, etc.) Because of several reasons, not all these modules have reached the same level of completeness and maturity, which means that not all software developed for the integration at the level of the complete line can be deployed on these modules. However, there is a set of fully developed modules on which the integration software has been deployed, and has been proven to work reliably and with more than the expected levels of flexiblity. This subset of modules is very representative for what it means to integrate a food production line with the new software integration approach, so the incompleteness of the line is not decreasing, at all, the integration software results, for the following reasons:

- Integrating a new module requires the modelling of the module-specific configuration parameters, but the software has been designed explicitly to separate this particular, module-specific information completely from the core functionalities.
- The integration of a new module has now been proven in full practice with a handfull of separate modules with very varied feature sets; in each module, the module builder has reused the provided models and software and has been able to let his module discover the others automatically, and start exchanging its own food processing information to the "line controller" module. This sample of modules is more than enough to prove that the project has fully reached its integration ambitions. A very positive observation was that the same models have been implemented in a large variety of programming languages, operating systems and frameworks, with means that our design concepts of "separtion of concerns" do indeed result in the envisaged flexibilty.

In summary, the current partial line of PicknPack is completely integrated with the flexible software infrastructure, with performances as expected in the Description of Work.
Thanks to the very rich set of expertise and variety in modules and features that the software developers could profit from the whole project, from Day 1, even more insights and results than foreseen have been distilled from project.

The following subsections give more details about the realised progress in the above-mentioned areas.

2.2.3.1 Modelling - Ontologies

The "lessons learned" during the first reporting period, that the large *heterogeneity* of modules, functionalities, vendors, programming languages, communication infrastructure, etc., can only be tackled successfully, at the system integration level, if all modules and functionalities get highly formalized "*semantic data models*", was turned into real formal models in the second reporting period. The modelling language chosen for the concrete implementation of the models was JSON-LD, because of several reasons:

- *semantic expressivity*: while JSON has become the number-one formal language on the Web, it is in itself not very well suited for knowledge representation and reasoning, but that gap was filled by the introduction of the "linked data" (LD) extension. This extension introduces core semantic modelling primitives such as: n-ary relations ("graphs"), explicit references to contexts, and systematic support to add unique identifiers to all modelled primitives *and* relationships.

- *availability of software*: since the beginning of the project, there has been a tremendous amount of developments in the domain of web technologies, that can be used at the advantage of the Picknpack project. More in particular, the design, implementation and communication of "event streams" using JSON as meta data language, and with data bases that support such meta data event streams and their processing.

To help the module builders in this difficult task, WP2 has supported them in applying the systematic approach to create concrete semantic models for their modules and/or activities. This has resulted in the availability of JSON models for all modules, with a big emphasis on the ones that are "upstream" in the Picknpack production line, namely the thermoformer, the web of trays, the quality assessment module, and the food manipulation robot module. These modules are the ones that must create all models, at runtime, and provide the most important meta data; the modules later in the line (labelling, sealing, etc.) are mostly consumers of the data produced by the upstream modules, and this requires less effort in the modelling. (But similar efforts in the software implementation, see later.)

2.2.3.2 System Composition Pattern

The project needs to develop software architecture(s) that can support all envisaged variations of the PicknPack food processing line, and that take into account, explicitly, the pragmatic challenges of incorporating "legacy" systems, of various degrees of granularity.
The "meta language" for system architectures, our so-called "System Composition Pattern", was completed with respect to the needs within PicknPack. More concretely, we now have contents for: *line*, *module*, *device* hierarchies of machines; *life cycle state machine* model to coordinate the deployment of machines or software modules; the *stop-light protocol* to synchronize the activities of all modules in a line; the automatic discovery and configuration of communication interfaces for all modules.

2.2.3.3 Implementations

KUL and DLO have continued to work closely together on the concrete implementations of the software for the "line controller", and for individual modules on the line. This implementation work contained two complementary activities: formal modelling in JSON for all modules, implementation of the communication and processing of messages between modules that use the JSON models to formally represent the carried information. This work was (and still is) huge, and took significantly more man power than expected.

2.2.3.4 Support for traceability

KUL and MU have matured the modelling and implementation required to support the envisaged traceability of a PicknPack food production line. Concretely, this means that the progress made in the other tasks (JSON models, communication infrastructure, querying of the "world model") has been turned into concrete SQL models to feed the traceability database.

2.2.4 Use of resources

	Period 1		Period 2	
Cost type	PM	Costs	PM	Costs
Personnel	28.4	€ 263,766	44.3	€ 219,777
Other		€ 37,244		€ 13,647
Total		**€ 301,010**		**€ 233,424**

2.2.5 Deviations from the DoW

There are no major deviations from the Dow. More effort, but cheaper man months and travel costs were needed than during the first period. It is in line with the overall budget of WP2. Other partners with lower costs on personnel contributed a lot in this WP.

2.3 WP3 Information, communication and traceability

2.3.1 Project objectives for the period

The objectives of WP3 for this period are:

- To establish RFID systems and other common product identifiers such as barcodes for upstream food component tracing and downstream product tracking and vendor managed inventory.

The corresponding tasks in the period are:

(1) Task 3.3 RFID System implementation
(2) Task 3.4 Integration
(3) Task 3.5 Testing

2.3.2 Summary of the work progress and achievement during the period

With respect to three tasks above, Task 3.3 and the technical functions of Task 3.4 have been completed. The on-line demonstration of the traceability has not been carried out as a result of the delay in the integration process of the whole project.

During the second period, a UHF RFID hardware system consisting of 2 RFID readers, 4 antennas, a handset reader, and an internet hub has been established. These components form a local area network (LAN) which can be controlled by the traceability application to collect the EPC tags information. The EPC code links the upstream food component information, product information, and downstream logistical and retail information in the food supply chain. The system configuration, control, and data interaction between the RFID hardware system through LAN and the database interface have been successfully implemented. The traceability software has been updated and optimised.

Following the technical solutions for integration proposed by WP2, the communication protocol, data format, and software design model have been implemented in the traceability system. Data interfaces have been provided to share data saved in database with other modules and to request information from other modules in the line. The information is wrapped with Javascript Object Notation (JSON) and communication is made with ZeroMQ, which is now also updated to Zyre. With the cross-platform protocols and tools, the traceability software can communicate to all other modules and understand their messages, based on the agreed WP2 protocol.

The traceability system test work has been done in lab environment, and this will be further verified on the integrated line.

During the second period two milestones, i.e. MS6: RFID Systems in place and MS7: Optimised and Complete Integrated Traceability System, and six deliverables have been made. Deliverables 3.3, 3.5, and 3.7 outline the operation of the traceability software for the PickNPack project. D3.4 describes the RFID system design and implementation, including hardware and software system design, system configuration, event handling, and data management etc. D3.6 describes the integration functions with the proposed communication protocol and data format for inter-module communications and data sharing. D3.8 presents the traceability system for demonstration.

In summary, the tasks in WP3 scheduled for the second reporting period have been largely completed according to the work plan; two milestones have been achieved; six deliverables have been made. Test of the traceability system on the integrated line will be carried out in the coming months.

2.3.3 Work progress and achievements during the period

2.3.3.1 Summary of progress towards objectives and details for each task

The objectives of WP3 for this period are:

- To establish RFID systems and other common product identifiers such as barcodes for upstream food

- component tracing and downstream product tracking and vendor managed inventory;
- To integrate the database, the traceability hardware and the sensing module in WP4 for component-dependent intelligent production management and control;
- To demonstrate the traceability technology in a production line outlined in WP11.

The tasks within the second reporting period are: (1) Task 3.3 RFID systems implementation; (2) Task 3.4 Integration; and (3) Task 3.5 Testing.

To-date the RFID traceability hardware system (Task 3.3) has been established. These RFID devices can be controlled by the traceability application to collect tags information. The system configuration, control, and data interaction between the RFID hardware system through LAN and the database interface have been successfully implemented. The traceability software has been updated and optimised.

Following the technical solutions for integration proposed by WP2, the communication protocol, data format, and software design model are implemented in the traceability system for integration. Task 3.4 and Task 3.5 have been partially completed due to the delay in integration. However, the required functions to be performed on the integrated line have been tested in the lab environment.

2.3.3.2 *Highlight of key results*

2.3.3.2.1 RFID systems implementation

The performance of RFID hardware system is critical to the information traceability in the PackNPack project. Based on the regulations and standards on the electromagnetic devices, the hardware system is established to implement the EPC tags for food product traceability. As shown in Figure 2 Hardware System, the system consists of a maximum of 2 RFID readers, a maximum of 8 antennas, a handset RFID reader, a router, and a PC running the traceability application.

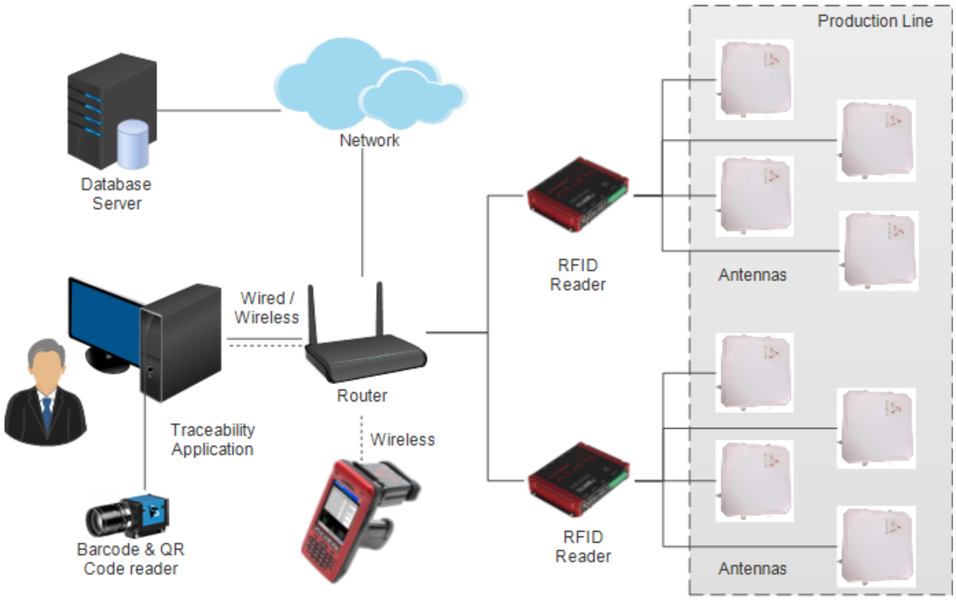


Figure 2 Hardware System

The system configuration, device setting, event handling, and data management of the RFID hardware have been implemented in the traceability software (Task 3.2). The software interface for saving the data generated by RFID device events in database (Task 3.1) has also been built-in. Therefore, the new traceability software by integrating the RFID hardware with the traceability software and database is capable of supporting the information traceability in the project.

2.3.3.2.2 Interfacing RFID hardware system with database

To integrate the RFID hardware to the traceability system, the traceability software needs to be able to configure the hardware, handle the events, and save RFID hardware generated data to database. As shown in Figure 3 Data Interfaces, the traceability software communicates to RFID in TCP/IP with RFID reader commands. It parses RFID reader's messages in XML to obtain the useful data information. A reader listening tread is created to monitor and handle events triggered by the RFID reader. Therefore, all detected RFID tags can be monitored by the RFID reader and events are triggered and observed by the traceability software. In addition, a mobile handset RFID reader can also be used to fulfill the traceability tasks, which is not constrained by cables.

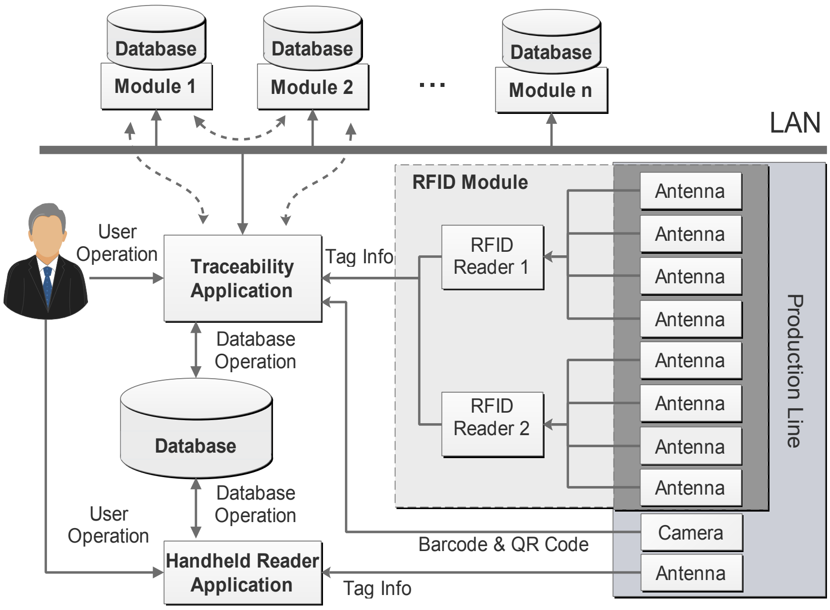


Figure 3 Data Interfaces

2.3.3.2.3 Integration interface of RFID traceability system

Traceability system is not a separate module, and the objective of the intelligent production capability requires the capability of inter-module communication between modules. Open, flexible, and interoperable data interface is important to the success of data sharing and cooperation between modules.

The ZeroMQ, Zyre and JSON proposed by WP2 have been employed to implement the integration interface. With ZeroMQ and Zyre, the traceability module can communicate to the other modules and receive messages from other modules. With JSON to wrap the data, the traceability module can understand messages. These application interfaces are implemented in the traceability system developed with Microsoft Visual C#. Therefore, the traceability system can share the information saved in the database with other modules, and request data from other modules.

Figure 4 shows the ZeroMQ interface for integration, which illustrates the data exchanging between modules with ZeroMQ. Figure 5 gives the model for Zyre communication, which presents the P2P communication and one-to-multiple broadcast in groups using whisper and shout functions respectively.

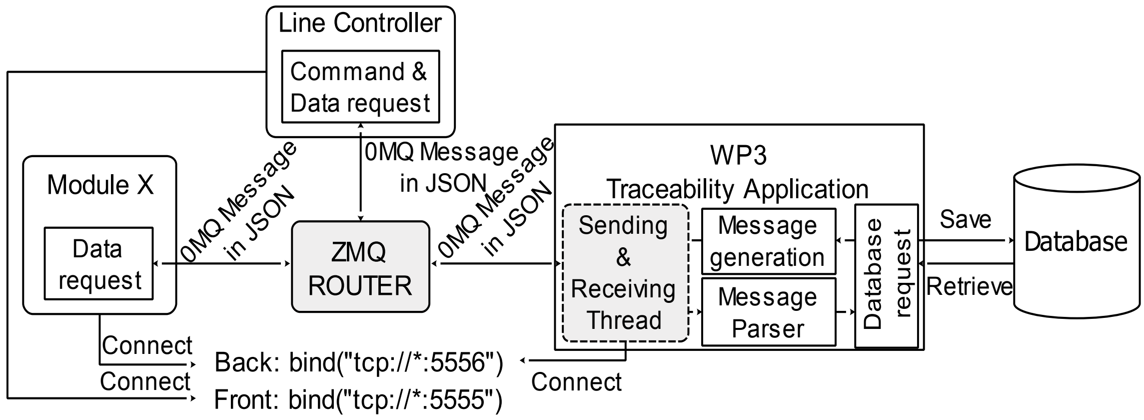


Figure 4 ZeroMQ Interface for Integration

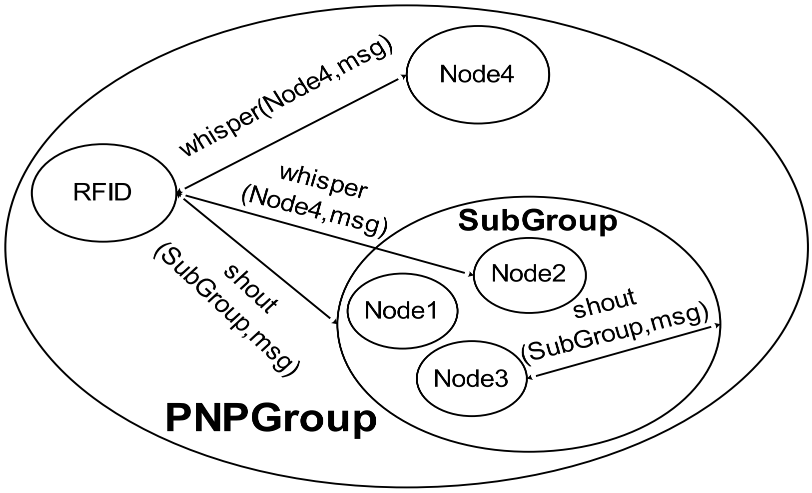


Figure 5 Zyre Communication Model

2.3.3.2.4 Traceability software optimisation

After integrating the database, traceability software, RFID hardware, and inter-module communication interfaces, the traceability software is tested and improved to meet the production line application requirements, which includes the following aspects:

(1) User-friendly operations and interfaces,
(2) Efficient database operation,
(3) Functions to suit the production line application,
(4) Efficient data wrapping and parsing for inter-module communication,
(5) Cross-platform messaging for efficient communication,
(6) The structure of source code

The operation interface of the traceability software and test site are as shown in Figure 5.

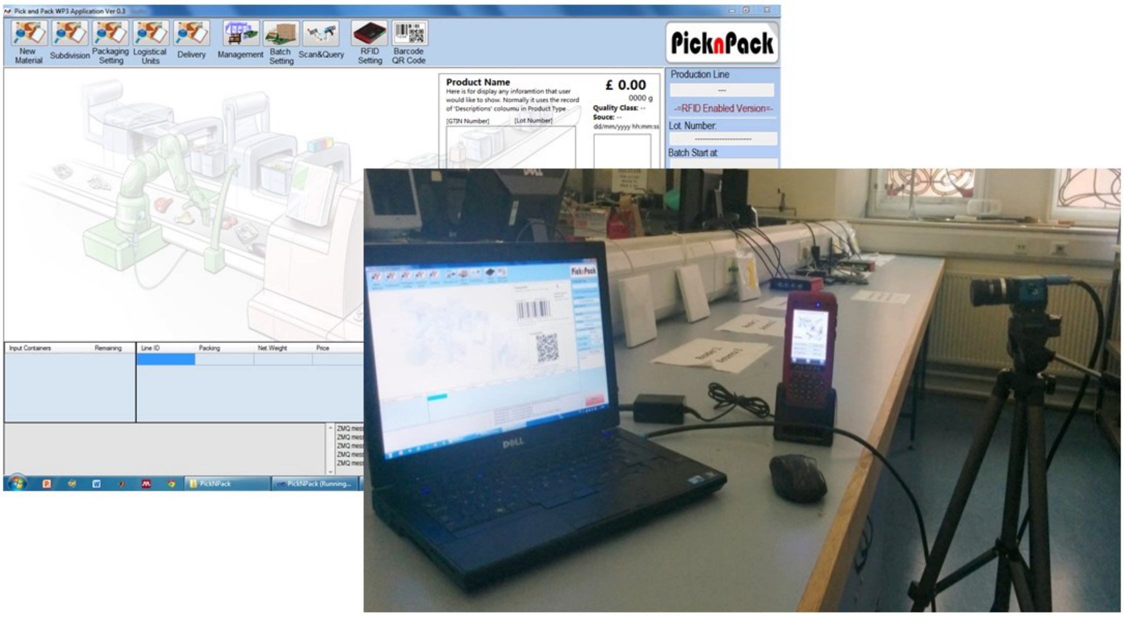


Figure 6 Software Operation Interface and Test Site

2.3.4 Use of resources

	Period 1		**Period 2**	
Cost type	PM	Costs	PM	Costs
Personnel	17.9	€ 122,740	28.3	€ 189,422
Other		€ 41,618		€ 89,912
Total		**€ 164,358**		**€ 279,334**

2.3.5 Deviations from the DoW

There are no major deviations from the Dow. More effort was planned in the second period.

2.4 WP4 Quality assessment and sensing

2.4.1 Project objectives for the period

The project objectives for the second period of WP4, which concern the quality assessment and sensing (QAS) module, center around the design and construction of the QAS module, as well as the integration of the module in the food packaging line.

- Development of a module that assesses the shape, position and quality of individual food products.
- Establishment of the relevance of the different sensing principles.
- Combination of the data from the different sensors to derive maximum information on the product to support decision making and traceability.
- Building the module and testing it on different food products.

This corresponds to the following milestones and deliverables which were due in the second period:

- D4.3: Sensing modules ready for integration in the QAS module (Except X-ray) (Month 24)
- D4.4: Detailed integration plan for the QAS module (Month 24)
- D4.5: First QAS module tested in the lab and ready for integration in the fresh product line, without X-ray imaging module (Month 32)
- D4.6: Second QAS module integrated in the processed foods line, with X-ray imaging module (Month 36)
- D4.8: Development of a self-learning system to insure the end-of-line quality of the packed products (Month 36)
- D4.9: Software development to extract shape-related quality features and colour traits from the 3D model (Month 36)
- D4.11: X-ray imaging module ready (Month 30)
- M16: Algorithm for product clustering based on combined sensor signals validated on data acquired with the QAS module (Month 36)

2.4.2 Summary of work progress and achievements during the period

In the second period of the project, most efforts in WP4 were focussed on the (re)design, construction and integration of the **Q**uality **A**ssessment and **S**ensing (QAS) module. The QAS module comprises of two submodules, one containing the X-ray unit (built by InnoS) and the other containing the remainder of the sensors (RGB, 3D, hyperspectral and microwave, built by KUL).

After the design decision to use the "web of packages" topology, both submodules were (re)designed to be built around the sectional frame transport system that will move the web of packages through the food line. Due to a delay in the construction of these sectional frames, integration of the individual sensors of the KUL submodule was already started on a standard conveying system. This work included hardware (mounting, alignment, triggering) and software (communication, calibration) integration.

After delivery of the sectional frame, the KUL submodule was constructed and subsequently transported to the food hall in WUR for integration into the line. As the communication protocol was changed in the summer of 2015 by WP2 to include the *zyre* library protocol, additional effort has been spent to integrate this library into the Labview software which controls the first QAS module.

Construction of the X-ray submodule by InnoS was delayed due to a delay in the formalization of InnoS as a partner and the transfer of financial resources to them. The X-ray module is currently under construction and is expected to be finished by the end of November 2015 after which it will be shipped to the food hall in WUR for integration and testing.

Besides the module construction and integration, work on the data processing was done as well. All WP4 partners have been developing self-learning algorithms that will allow the inspection system deal with the new products or product classes. DLO has also developed algorithms for sensor fusion with data from 3D and RGB cameras. These will be used in the coming period for improved object segmentation or feature extraction. As WP7 has only recently succeeded in controlling the thermoformer to move the web of packages through the QAS modules, measurements with the QAS module on the line still have to be performed. Therefore, Milestone 16 is delayed by a few months.

2.4.3 Work progress and achievements during the period

As explained in the 1st periodic report, the **Q**uality **A**ssessment and **S**ensing (QAS) module comprises of two physical submodules: The first submodule is designed and built by KUL and contains a hyperspectral imaging unit, a 3D imaging unit, an RGB camera and a microwave line scanner. The second submodule contains an X-ray sensing unit and is constructed by InnoS.
A **detailed description** of each of the sensors in the QAS module was provided in the deliverable report of deliverable D4.3, as well as in the 1st periodic report. Each of the sensor technologies was tested successfully in stand-alone setups in the laboratory of each respective partner.

2.4.3.1 KUL submodule

The first version of the QAS module was designed to be built over a (belt) conveying system. Under the impulse of WP6, it was decided within the PicknPack consortium to alter the transport system used in the food line to the "web of packages" topology. The web of packages is moved in a "stop and creep" motion through the line by custom sectional frames which were designed by WUR (WP7). Therefore, the design of the QAS module had to be updated accordingly to allow for the module to be constructed around a sectional frame.

As the design/construction of the sectional frames was not yet finished at that time, it was decided to first use a standard conveying system to already be able to integrate and test various aspects of the QAS-module. A **detailed integration plan** was presented in the 4th deliverable (D4.4.) which elaborated on hardware integration, software integration, calibration aspects and strategies to introduce flexibility. In Figure 7, the schematic outline of the QAS module is shown.

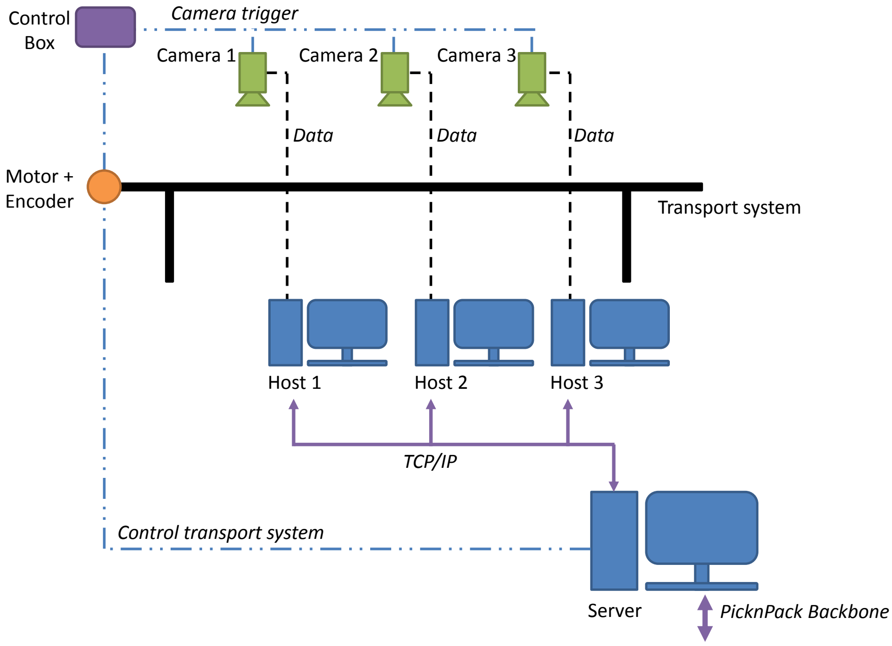


Figure 7 Schematic outline of the QAS module.

Each sensor in the QAS module is controlled by a dedicated host PC which in turn is connected to the QAS module server over an Ethernet connection according to the communication protocol specified in WP2. Furthermore, the motor drive of the transport system (either conveyor or sectional frame) is connected with a control box (A field-programmable gate array, *FPGA*) that translates movement of the transport system to custom camera hardware triggers. In this way, data acquisition is synchronized with movement of the food products.

Each of the components shown in Figure 7 was developed and each of the sensors of the KUL submodule was integrated and tested during various work visits from the WP4 partners in Leuven.

These tests pertained to both software (communication, calibration, self-learning) and hardware (montage, hardware triggering, calibration) aspects of the module.

Due to a delay in the construction/delivery of the sectional frame, the original deadline for the 5th deliverable D4.5. (Month 32) could not be met as the sectional frame is an essential part around which the module had to be assembled. In response to this, the planning for construction and testing of the QAS module was updated and later on approved by the consortium. This planning as well as the preparatory measures for the construction and integration of the module have been described in D4.5.

Following the delivery of the sectional frame in Leuven in March 2015, **construction of the QAS module was finished** in June 2015. The constructed module is shown in Figure 8. All sensors have been mounted over the sectional frame. Following the recommendations of WP8 (hygienic design), a custom designed plastic (PETG) tunnel was integrated which shields the food products from contamination. The QAS module is equipped with wide side doors and detachable side panels to maximize accessibility inside the module and to simplify integration. In July 2015, tests on the functionality of the module were conducted at KUL with fresh tomatoes and various ready meal components. Hereafter, the module was **transported to the food hall in WUR** for integration in the line.

After arrival in Wageningen, the QAS module was inserted into the food packaging line in close collaboration with WP7. For pictures of the QAS module in the line we refer to the section on WP7. Further hardware tests are still required in which the stop and creep motion profile is investigated. Besides this, the software communication protocol has been updated in WP2 by including the use of the *zyre* communication library. As this library was not available in Labview - the programming language in which the software of the QAS module has been implemented – effort has been spent to bridge this gap. The *zyre* protocol is currently being integrated in the QAS software and communication tests are planned by the end of October 2015.

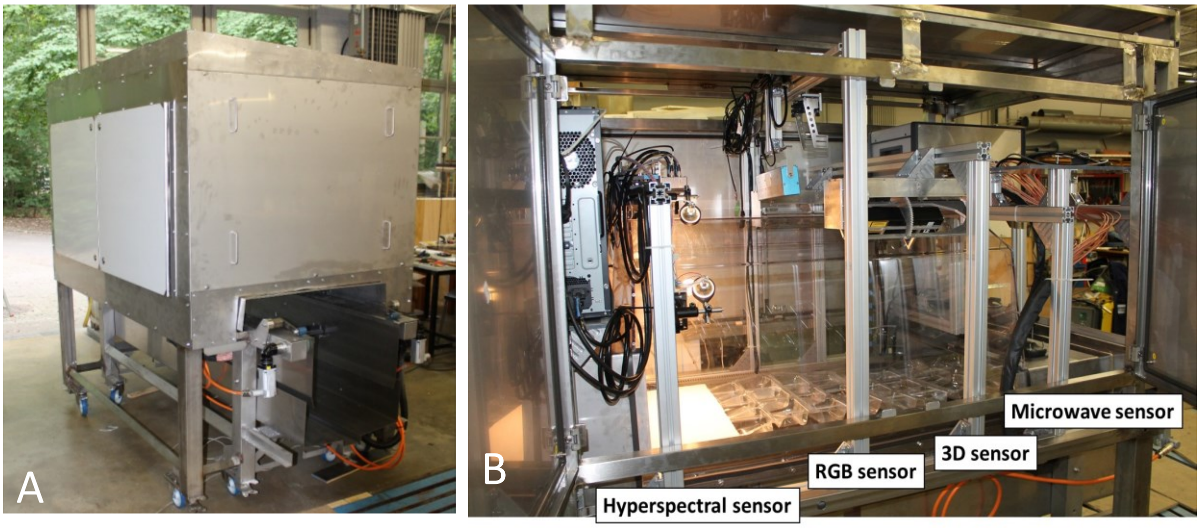


Figure 8 Finished QAS module. (A) Oustide view, (B) inside the module. All sensors are mounted over the sectional frame and shielded by a plastic tunnel.

2.4.3.2 InnoS submodule

Originally, the X-ray submodule was to be built by partner SpectroScan. As this company went bankrupt, it was **replaced in the consortium by InnoSpexion**. This caused a delay in the construction of the submodule and the DoW was updated to take these effects into account.

The **design of the X-ray module** is detailed in the report of deliverable D4.6. The X-ray sensor comprises of stereo pairs of source/detectors which will enable 2.5D vision when combined. To achieve

optimum image quality, the X-ray sources will be placed underneath the web of packages, and the detectors above. Besides the overall design, aspects such as safety, hygienic design and cost price are discussed as well in this deliverable report.
Due to a delay in the formalization of InnoS as a partner and the transfer of financial resources to them, **construction of the X-ray module was further delayed**. The module is currently under construction and it is expected that it will be ready at the end of November 2015 after which it will be shipped to the food hall in WUR for integration into the line. For this reason, deliverable D4.11. is also delayed to the end of November 2015.

2.4.3.3 Data Processing

In the second period, further progress was also realized with respect to the data processing. This concerned the development **of a toolset of self-learning algorithms** which will allow the QAS module to efficiently deal with new products or product classes with minimal operator intervention. The developed algorithms have been described in detail in the 8th deliverable report (D4.8.). Examples include segmentation algorithms that can classify the different components present in an image (RGB, 3D, hyperspectral), internal defect detection (X-ray) and semi-supervised training of the microwave sensor. In a next step, these algorithms will be implemented on the QAS module and tested at runtime.
Besides this, work has been done on the **integration/combination of data** from different sensors (sensor fusion). The 9th deliverable report (D4.9.) describes how this is realized for the RGB and 3D sensor and how this approach is useful for improved segmentation of features and calculation of shape related properties. Further work on sensor fusion is planned in the 3rd period of the PicknPack project. Data from the X-ray unit, hyperspectral camera and microwave sensor will be added to the fusion framework. This work requires that the line is able to move the web of trays through the QAS module, which has only recently become possible. Therefore, the experimental work for this still has to be performed and milestone 16 is delayed to the end of November.

2.4.4 Use of resources

	Period 1		**Period 2**	
Cost type	PM	Costs	PM	Costs
Personnel	44.1	€ 233,310	57.7	€ 249,124
Other		€ 97,947		€ 42,938
Total		**€ 331,257**		**€ 292,062**

2.4.5 Deviations from the DoW

There are no major deviations from the Dow. More effort was planned in the second period.
The work of KUL on hyperspectral imaging runs according the planning. As explained above, some delay in the construction of the KUL QAS submodule was introduced due to the later than expected arrival of the sectional frame system and due to difficulties in implementing the latest communication protocol (zyre library).The QAS module has now been finished and transported to WUR. The software problems are nearly solved as well and testing is planned in the coming months.
Construction of the X-ray imaging unit is still ongoing due to a delay in allocating the finances to InnoSpexion, as reported earlier in this report. Work of DLO and UM are according to the planning.

2.5 WP5 Robotic product handling

2.5.1 Project objectives for the period

The WP5 "Robotic product handling" aims to develop a fast, flexible and easy to program robot and end-effector that complies with the regulations of the food sector regarding hygiene and worker safety, as well as to develop a reprogramming method that allows fast change-overs to other products by non-specialized workers.

The concrete objectives for the second period (from April 1st, 2014 until September 30th, 2015) of the project are:

- **Development of a Pick and Place manipulator for food packaging sector and design of an innovative end-effector for picking variable delicate alimentary products:** Adaptation of an existing Pick and Place robot to perform the manipulations required to package food products and design of the end-effector that takes into account the products variability, fragility and the hygiene constraints;
- **Development of a flexible control for the robot:** Definition of the command scheme and strategies according to the aimed applications and the information exchanged with other modules (vision and packing);
- **Development of a vision system to control the robot to pick and place food components:** Development of 3D vision camera setup and interface for fast real-time control, development of learning algorithms to pick and place a common range of products and user friendly reprogramming solutions;
- **Development and testing of the robotic module on food products (in progress):** assembly, integration, calibration and test of the complete robotic module.

2.5.2 Summary of the work progress and achievement during the period

Development of a Pick and Place manipulator for food packaging sector and design of an innovative end-effector for picking variable delicate alimentary products Two different Pick and place manipulators have been carried out. One will be placed at the beginning of the Pick and Pack line, introducing product from crates to the general line. The second one will be at the end of the line classifying the products into the output crates. Both robots include specific end effectors for food stuff handling. The second one (Cable robot) named Pickable has been patented. Both of them have been certified by CE marking.

Development of a flexible control for the robot: Both robots include different control and user interfaces systems so as to carry out the required task. The delta robot includes a control system based on Marel standards while Pickable includes a system based on C++ programming language running on a RTX (Real Time) operating systems for Windows.

Development of a vision system to control the robot to pick and place food components: Two different machine vision systems have been included. The first one allows Delta robot allocating the foodstuff from the input bin, while the second one is setup in Pickable so as to identify the position and orientation of the packets matrix which come from the thermo- former so as to correctly pick them. Although this second vision system was not included in the task plan the consortium decided to include it avoiding any risk due to the displacement suffered by the packages after the sealing and cutting of the packages.

Development and testing of the robotic module on food products (in progress): Both robots have been assembled, integrated and tested. The setup has not been completed due to different issues and updates required.

2.5.3 Work progress and achievements during the period

Development of a Pick and Place manipulator for food packaging sector and design of an innovative end-effector for picking variable delicate alimentary products

- Regarding Delta Robot (Figure 9):
  - Basis robot produced and delivered to the project.
  - Modifying the construction in order to fit weighing machine in the structure.
  - Changes to the software and control system to accommodate 3 conveyors instead of single infeed conveyor
  - Changes to the infeed aperture and outfeed aperture as the crates to accommodate size of crates
  - Implementing safety light curtains to provide necessary safety.
  - Implementing and building a fixed nozzle system for CIP. Testing done in Holbeach

Figure 9 Delta robot

  - Results positive but some adjustment still needs to take place
- Regarding the chicken breast gripper (Figure 10)
  - The functional tests showed that the gripper worked for the bin picking application. The main issues to be solved from the Fraunhofer hygienic tests were:
    - -metal to metal contact
    - -crevices
    - -bolts
  - The new design is a simplified version of the previous one, with less parts causing pollution and crevices eliminated. Bolts were replaced for food grade bolts with spacers. Also a hygienic FDA approved food grade pneumatic drive was installed, see pictures below.

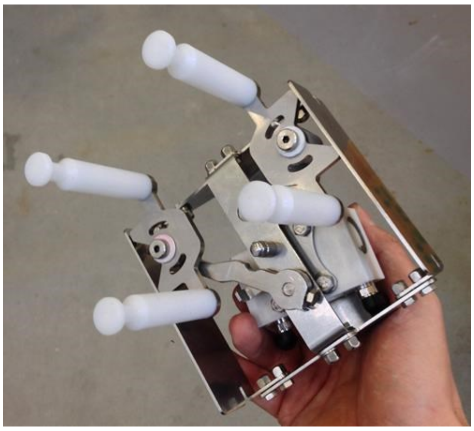


Figure 10 Gripper chicken breast

- Regarding the vine tomato gripper (Figure 11)
    - The functional tests showed that the gripper worked for the bin picking application but required an additional finger placement option. To this end a servo was added. The servo could switch between position mode and force mode, so that the fingers could be placed while placing the gripper, and the pinch force is controlled while gripping. The main issues to be solved from the Fraunhofer hygienic tests were:
        - -metal to metal contact
        - -crevices
        - -bolts/sharp edges
        - -rough surfaces.
    - For this purpose the gripper was redesigned (see picture). The same food grade bolts were applied. The servo is fully encapsulated in a SS shell. The contact areas with the deformable silicone materials are either eliminated (finger tips) or replaced by a more enclosed structure (hinges). The mechanism was simplified to a maximum extend to eliminate crevices and edges.

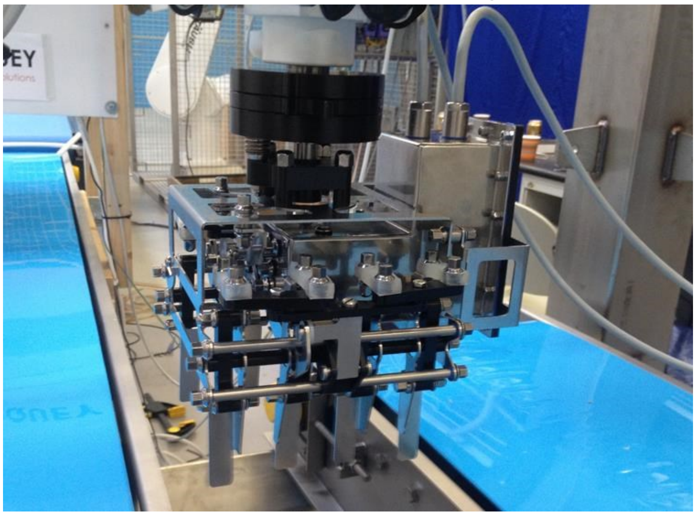


Figure 11 Tomato gripper

- Regarding Pickable (Figure 12)
    - A complete novel concept of Cable robot has been assembled. Due to its invention factor, it has been patented

Figure 12 Pickable

There is a mechanical issue to solve with the behavior (Figure 13) of the chain for a branch of the electrical connection (see image). A more consistent chain will be selected and tested.

Figure 13 end effector Pickable

Development of a flexible control for the robot (Figure 14**):**

- Regarding Delta Robot:
  - The crate sequence software defined , written and tested (will be further tested at WUR)
  - Adapting the infeed control system
  - Defining the path profile for the Grippers.
    - Simulate the path, write the necessary software in the robot, test and debug.
      - Work in Process at this moment.
    - Changes to the path planning system in the robot as pick sequence (tomatoes picking) is different from standard pick and place movement
    - Add extra functionality to the gripper control to accommodate Laquey servo controlled gripper
    - Adapting the Laquey gripper into robotic control system.
      - Preparatory work with Festo control
      - Define communication between Festo controller and Robot system
      - Write and test control sequence
      - (Work in Process)
    - Software for camera calibration
      - Create necessary flowchart diagram, program and test
      - Work in Process.
  - Adapt all software changes into HMI-GUI.
  - Establish communication between all modules.
    - Zyre protocol implemented in robot system
    - Create and define TCP/IP socket connections for internal communication of modules
    - Implement communication between weighing system and Robot
      - Create Heartbeat signals
      - Parsing algorithm in case of data corruption
      - Adapt it to the Zyre protocol (Work in Progress)
    - Implement heartbeat (staying alive signal) between vision system and PLC system in the robot.
    - Create a data bridge between the robot, scale, RFID, conveyor belt and the Line controlling system
  - Regarding Pickable
    - To control de robot, the system requires two industrial PCs (see image)

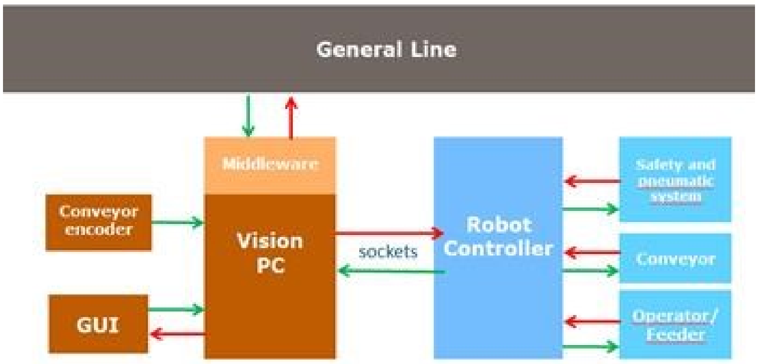


Figure 14 Flexible control

- Vision PC tasks:
  - Communications with the general line and the cable robot
  - Database log for production traceability and arisen events
  - Package detection and tracking
  - Conveyor tracking
  - Safety monitoring
  - Package packing management (box type /package placing)
  - State machine and automation
- Robot controller tasks:
  - Kynematics control (Pick and Place)
  - Conveyor opérate
  - Safety monitoring

Development of a vision system to control the robot to pick and place food components:

- Regarding the vision system for the Delta robot
  - The 3D camera set-up providing RGB (iDS camera) and depth information (Ensenso N20) has been finalized and is mounted to the Marel robot unit. Also a semi-automatic procedure has been developed to calibrate the vision-robot space.
  - Robust vision algorithms have been developed and tested to locate, grasp and place tomatoes, grapes and chicken breasts into a presented package (see deliverable D5.3). The detection of vine tomatoes and grape vines is a combination of detecting the tomatoes/grapes and the stalk (see Figure 15). The detection algorithms use RGB images to derive product properties such as colour, shape and thickness. Depth information is used to detect the chicken breasts. The vision algorithms also determine the grasping order (which product in a crate to pick first), grasping position (where to position the gripper) and grasping actions (pinch grasp, move to free location or full grasp). Figure 15b shows the grasping order (compare top and bottom) and the gripper positions for a pile of chicken breasts.

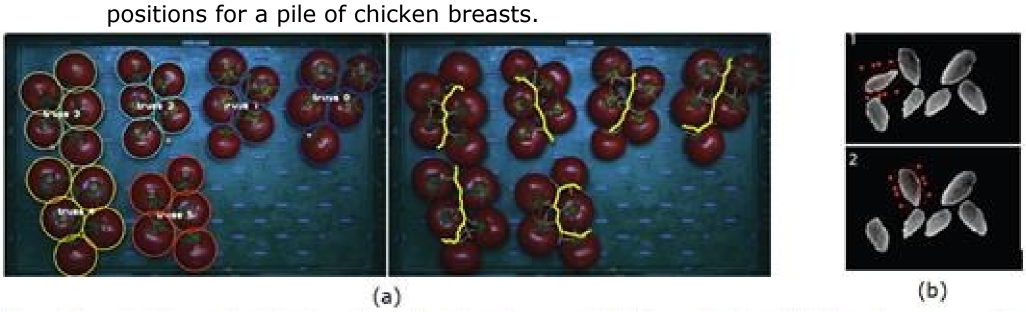


Figure 15 image analysis

- Regarding the vision system for Pickable robot
    - The machine vision for the cable robot is based on a liner camera including a liner lighting system to build the images based on the encoder installed in the conveyor. Successfully tests have been carried out. This system was not planned and has been included due to a further requirement.

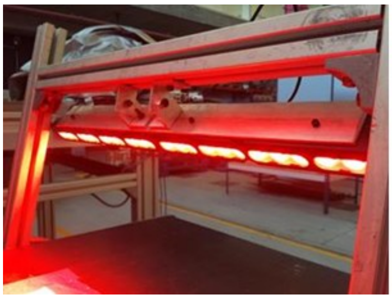



Figure 16 Image system Pickable

Development and testing of the robotic module on food products (in progress):

- Regarding Delta robot
    - 3 FTE are working dedicated on finalizing the Robotic software and mechanics to adapt it to the line located in WUR.
- Regarding Pickable
    - Although functional test have been successful the complete setup of the system is still on going. Two main reasons are the origin of this:
        - The decision of including the machine vision system in this robot when the construction of it had been started
        - The negative after sales and support service of the selected supplier of the control electronics for the motors of the robot
    - To get a successful setup, a task force, including engineers from different Division, has been launched so as to solve the failures in the motion control hardware.
    - In parallel a complete simulation model of Pickable is being carried out so as to develop and offline demonstration if needed. But this is not yet accepted by the project board.
    - Control: Basic communication between PicknPack line and Pickable module was successfully tested using a vpn (between different implementations languages: python, C and a parser of JSON for C#).
    - Diffusion activities were carried out (http://www.tecnalia.com/es/industria-transporte/noticias/pickable.htm)
    - This novel robot has been patented PCT/EP2014/078932
- Regarding the machine vision for Delta Robot
    - The integration and testing of the Pick&Place module is on track. The outline of the Pick&Place components and their communication channels is depicted in following figure. The vision device and the manipulator device exchanges parameters such as *grasp position X*, *grasp position Y*, *gripper opening width*, *product ID*, *next bin*. We demonstrated that the vision system can steer the manipulator and the gripper such that chicken breasts and tomatoes could be grasped successfully (see following figure: Outline of the Pick& Place module devices, GUIs and communication channels)

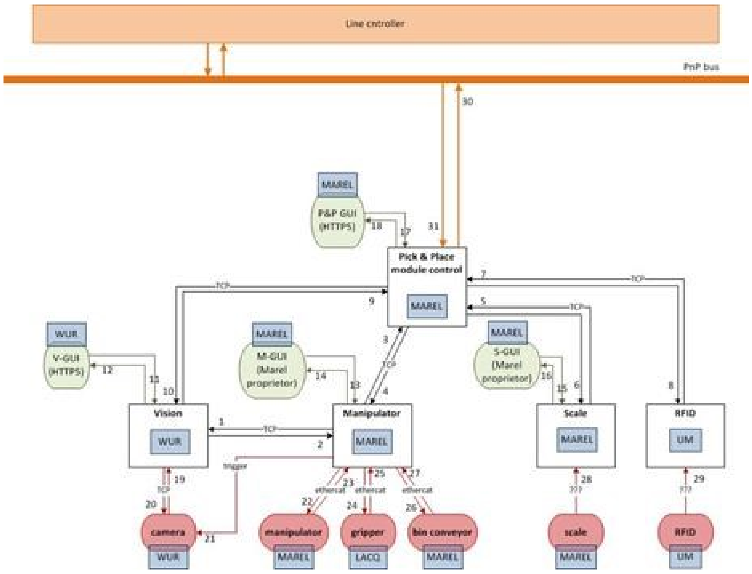


Figure 17 Scheme

- The grippers were successfully integrated in the PicknPack line.

2.5.4 Use of resources

	Period 1		Period 2	
Cost type	PM	Costs	PM	Costs
Personnel	57.7	€ 429,953	96.3	€ 523,397
Subcontracting				€ 15,081
Other		€ 64,661		€ 228,801
Total		**€ 494,614**		**€ 780,591**

2.5.5 Deviations from the DoW

In the second period two robots became available for the project. Most material resources are made in this period. Marel made changes by adding third parties. At comes out that more human resources were needed, but costs are lower. As a result Marel needed more PM's. In the second period two parallel robot innovations were build and started testing. More effort was needed was needed, but financial resources are still available and running according to the plan to achieve project objectives. The Marel robot is deliverred according the DoW, the Tecnalia robot (Pickable) is delayed due to technical failures of hardware. It is expected that Pickable can catch up. Because it is the last module in the line, it will not stop other modules from integration and testing.

2.6 WP6 Adaptive packaging

2.6.1 Project objectives for the period

WP6 had following three deliverables in the second period:

- D6.4) Prototypes: Prototypes of digital mould, flexible integrity system, sealing and integrity checking systems, flexible heating system and decoration system. [month 20]
- D6.5) Integration of prototypes and test of the complete adaptive packaging system: [month 28]
- D6.6) Integration of the adaptive packaging system to the complete PicknPack: [month 36]

The plan was that WP6 had finalised all tasks by month 36 (September 30th, 2015).

2.6.2 Summary of the work progress and achievement during the period

The work of WP6 is almost ready. The thermoformer and flexible mould system produce trays. The printer, the flexible heating system and integrity system also work. The flexible sealing and cutting system are not ready, as WP6 has serious problems purchasing 100% PP films as planned. Two videos document the almost full function of the packaging line. Other components in PicknPack have been integrated in the packaging line such as the robotic system and sectional frames. Other components are still not delivered and will be integrated as these arrive to Wageningen. PicknPack has made a plan to overcome the problems about the PP film, and the last components in this plan is scheduled to work by the end of 2015.

2.6.3 Work progress and achievements during the period

Figure 18 Photo of the integrated adaptive packaging line with brick moulds

WP6 has been delayed, because it was decided in PicknPack in April 2014 to use sectional frames.
The packaging system was shipped to Wageningen in April 2015 in order to be integrated to a complete working PicknPack system. The WP6 packaging line is running with a few exceptions.

2.6.3.1 Digital mould and flexible mould shift

Brick mould system

WP6 has been working on several flexible mould systems. For demonstration, it was decided to use the brick mould system.

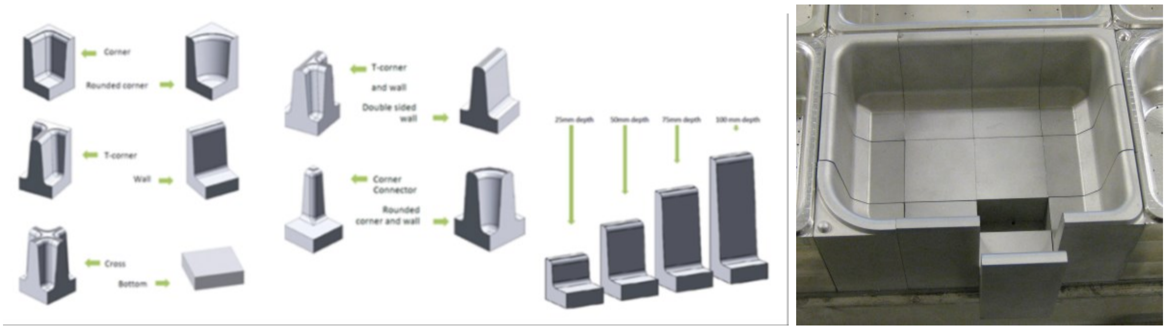


Figure 19 Brick mould system

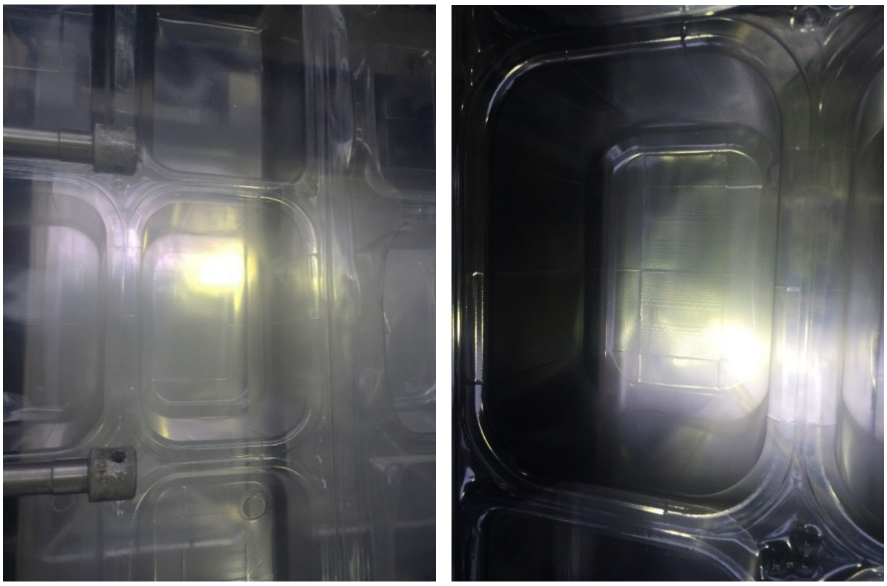


Figure 20 Plastic trays made from the brick mould system

Flexible mould shift

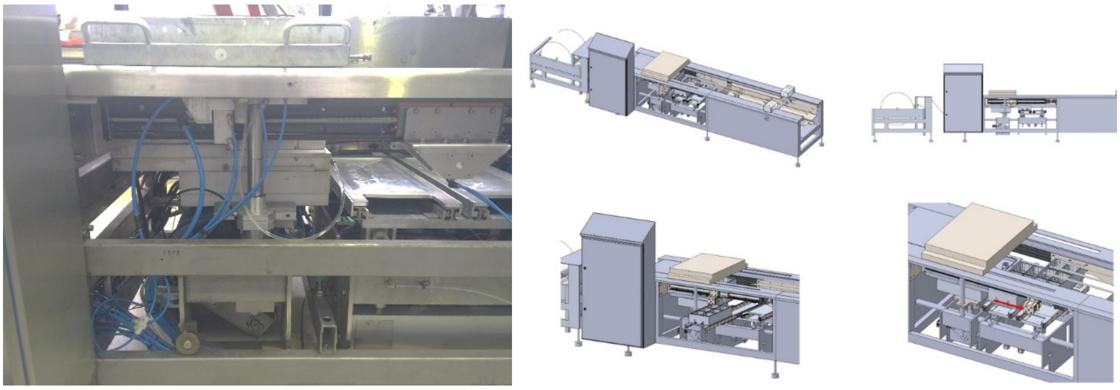


Figure 21 The flexible mould shift system in Wageningen

2.6.3.2 Flexible sealing and cutting

Figure 22 Laser equipment together with printer and cross section.

The CO_2 laser was purchased early in the project in order to seal and cut in PP plastic films. Over the last 2 years these PP films has been replaced by APET. All partners has been working on locating PP in order to make the planned demonstration. The only PP film we have been able to locate is a PP film with a PE welding layer. However, this create a serious problem for WP6, because PE and PP has large differences in melting and crystalline temperatures, the PE is melted when the PP is soft. Under these conditions we are only are able to form with vacuum. The thermoformer can work with both compressed air and vacuum. The best results is performed using both. (First in Mid-November, it has been possible to locate a small leftover web with 700µ 100% PP film. Only about 250 meters is located, so this do not change the decisions made by the Project Board.)

As PicknPack are unable to find resources for another laser system the Project Board has decided that, the line will be split in at least two parts:

1. The combination of thermoformer/delta robot/QAS module working full speed with PET;
2. The combination of cross-sectional and sectional module with the laser/scanner, integrity test, printer and cable robot with RFID applicator working with slow speed.

The problems come together in the laser sealer/cutter. The problems with the laser need to be resolved out of the line. The aim is to demonstrate the second part of the line as an integral system. If we cannot make the laser cut the trays, an additional separation might be necessary between the cross-section and the cable robot.

The second part of the line will be ready to operate by the end of 2015.

2.6.3.3 Integrity system

The integrity checking system is based on a hyperspectral imaging set-up. Two different detectors are used, being a VIS-NIR system (400-1000 nm) and a SWIR system (1000-2500 nm). These detectors are placed together with the laser and can send a message to the laser if the pack is not sealed and the laser can react. Figures 6 and 7 show the set-up and a typical image of an empty package.

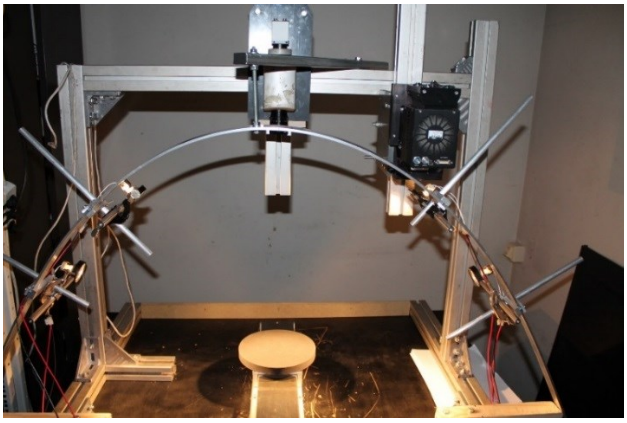


Figure 23 Hyperspectral set-up used for the measurements.

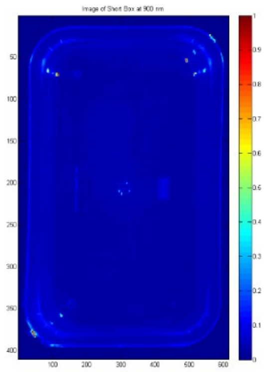


Figure 24 Package image integrity test

The integrity system is working in the laboratory. However, it cannot be mounted on the laser as PicknPack has serious problems, because the practical problems in laser welding and cutting is not solved.

2.6.3.4 Flexible decoration

WP6 has installed the printer for decorating plastic films in different colours.

Figure 25 *Printer build together with the laser welding and cutting*

It has been decided to decorate in two colours for the demonstration unit, which will give an excellent impression of the opportunities in flexible in-line decoration. Extra colours can be added at extra costs. WP6 has discussed the wish to add more colours on the printer. The printer design is made so it is possible to add several extra colours. As the print equipment for four/five-colour decoration in the full 300 mm web width is too expensive for our limited budget, WP6 has chosen to demonstrate in two colours in a high quality.

The flexible decorating system has been in focus every time WP6 has presented the project. It looks like this is the most successful outcome of WP6. DTI has already now commercial requests for flexible printers. These requests is for bag packaging systems as flow packaging, and form-fill-seal-systems. The commercial interest is to purchase a transparent film and decorate small bathes without changing web.

2.6.3.5 Flexible heating system

As already reported in the first period WP6 has developed an innovative flexible heating system based on conductive metallic inks. WP6 has printed samples of metallic inks with the same ink-jet heads as used in the decoration system. The ink create a microwave reflector to be applied on any printable substrate.

WP6 has also demonstrated that these printed reflectors printed in different patterns can have different functionalities in microwave ovens.

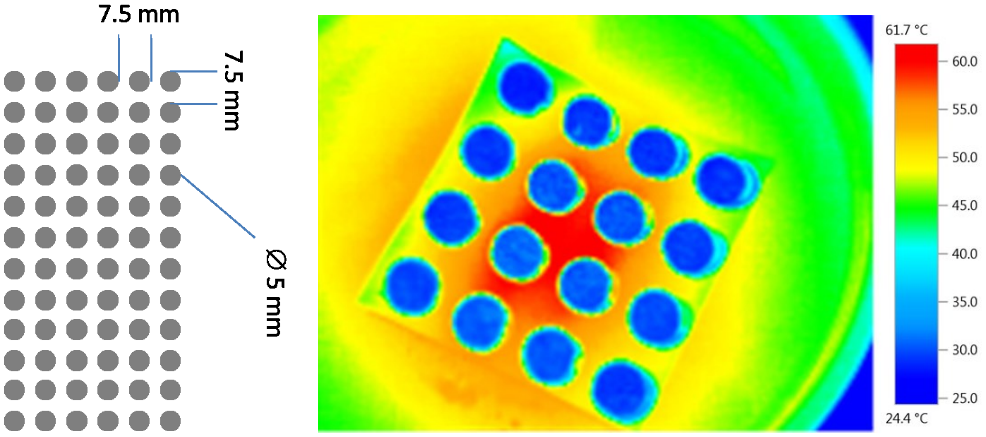


Figure 26 Pattern of totally reflective circular islands allowing heating up to 120-150°C.

In order to have a functional heating system these patterns must be printed on both under and top webs with the ink-jet heads. As WP6 had limited resources for print heads, it was decided to allocate these print heads for two-colour decoration of the top film. It is still the plan to demonstrate the flexible heating system. This demonstration will be done off-line next to the working PicknPack line.

2.6.3.6 Integration to other PicknPack systems

The flexible packaging line is now integrated with the WP7 sectional frames and with most part of WP4 Quality assessment and sensing systems and partly with WP5 Robotic handling system. WP6 do not need any integration with WP3 Traceability system. A number of components is not delivered in Wageningen and these systems are going to be integrated later.

2.6.3.7 Evaluating of the total work in WP6

WP6 has in 2015 several challenges to meet the deadlines for the two last deliveries (D6.5 and 6.6). The main reason for these delays was the decision in PicknPack to introduce sectional frames in our project. At that time, WP6 had purchased the longest possible thermoformer line of more than 12 meters. However, WP7 asked for more than 17 meters. As a thermoformer use chains with clamps it is not possible to make these frames longer. In the spring 2014 PicknPack came up with the idea and decided to use sectional frames.

This decision has given WP6 several problems:

- It was not really possible to make a full integration of all sub-components to a running WP6 line. If the thermoformer had been one big line, this would have been possible for WP6. We write D6.5 and have later upgraded this delivery to compensate for the changed plans.
- WP7 was also late in delivering the sectional frames. Both these delays gave a late installation in Wageningen.
- The partners responsible for the delivery of thermoformer, cross-section and sectional frames have got a serious extra consume in equipment (up to 300%) and also in work hours.

2.6.4 Use of resources

Cost type	Period 1 PM	Period 1 Costs	Period 2 PM	Period 2 Costs
Personnel	49.8	€ 540,959	73.7	€ 623,418
Subcontracting				€ 14,773
Other		€ 155,445		€ 181,244
Total		**€ 696,404**		**€ 819,435**

2.6.5 Deviations from the DoW

Most resources were committed to the second period. Therefore budgets increased compared to the first period. All modules received Wageningen before the end of the second period. Resources are according to the plan to achieve all objectives in the last period.

2.7 WP7 Fresh and processed food production line

2.7.1 Project objectives for the period

WP7 is devoted to develop and test a demonstrator of (1) a fresh food production line, focused on quality assessment, separation of tasks handling and packaging of vine fruits and vegetables (case focus: vine tomatoes and grapes) and (2) a processed food line focused on quality assessment of a variety of processed food components, arranging these components into a package. Both lines will use a subset of the same modules to pick and place food products into adaptive packages that are then sealed and custom printed at the end of the line. Another main objective is to develop and evaluate generic concepts and control within these production lines that can perform on other products within fresh food and/or processed food applications. The major objectives of this work package in the first period are:

- To develop and evaluate generic concepts and control systems for the production line that can also be used on other products within fresh and processed food applications.
  - Get all built prototype modules working.
  - Integrate all the modules into a working line.

2.7.2 Summary of the work progress and achievement during the period

At the beginning of the second period, all module designs were conceptually fixated. Moreover, the order of the modules in the line was known and the line design was chosen. In this final fixated line design, the thermoformer creates a set of packages in a stop-and-go manner. However, in contrast to the old strategy, the sets of packages are not cut and stay connected through all module until the end of the line (the so called 'web'). The sets of packages move in a custom made frame. These sections can be added up to any length as they each have motors to propel the web through the line.

Not all drawings of modules were finished however, so additional efforts by the partners were made to complete the designs. Because the new strategy implied the use of sectional frames, these had to be designed as well. This was a joint effort by the engineers of DLO, DTI and CAM-TECH.

The first modules were ready in month 31, the thermoformer, Marel robot and sectional frames were delivered. The quality assessment module and printer module followed in month 32. The X-ray module and cable robot are still under construction as of month 36.

Because the late delivery of the modules, milestones MS25 and MS26 could not be reached. Although mechanically 85% of the modules are integrated in the line, the individual modules are neither yet operational nor connected with each other through software.

2.7.3 Work progress and achievements during the period

For this period the main task in WP7 was **T7.3: Assembly of fresh and processed food packaging line.** In this task, individual modules should first be assembled and tested. Each module is tested with the specifications delivered in D7.1, focusing on vine tomatoes, grapes and grilled chicken breasts. Thereafter modules are combined into a working prototype of a fresh and processed food production line. For each module, the status of assembly is given at month 36.

Figure 27: Thermoformer

Thermoformer

This module is assembled and was delivered at month 31. However, minor adjustments still had to be made on-site and are ongoing. The thermoformer can already produce packages with the modular mold. The integration of the thermoformer with the rest of the line needed a cover to shield electronic parts for the automatic cleaning. This shielding is now designed. Software to communicate with the rest of the line is under development.

Marel Robot
The Marel robot is assembled and was delivered at month 31. A weigh module was added together with a conveyor to enable the input of a crate with products. Automated cleaning hardware was added. The first tests with picking product was only performed under laboratory conditions are estimated to be applied with the real robot in month 36. Software to communicate with the rest of the line is under development.

Figure 28 Marel Robot

Dispensers
Because dispensers are not a DOW task or part of novel research, this module will be purchased in the third period. Estimated additional costs for second hand dispensers are around 15k. The dispensers are to show that the PicknPack line can work with existing hardware and will provide a good demo experience.

Figure 29 QAS module

Quality Assessment Module
The QAS module was delivered in month 32. Although delayed, it was already integrated with a sectional frame prior to delivery.

X-Ray module
Due to the bankruptcy of the former partner Spectroscan, the new partner Innospexion was delayed in the design and built of the X-ray module. Delivery of the module is expected in month 39.

Printer Module
This module was delivered in month 33. Although delayed, it was already integrated with the fourth sectional frame, which had to be slightly adjusted to accommodate the top foil applicator and to support the laser module. Tests were performed to print to the top foil with success. No tests are performed yet on top foil being applied on the packages, as this depends on the laser module.

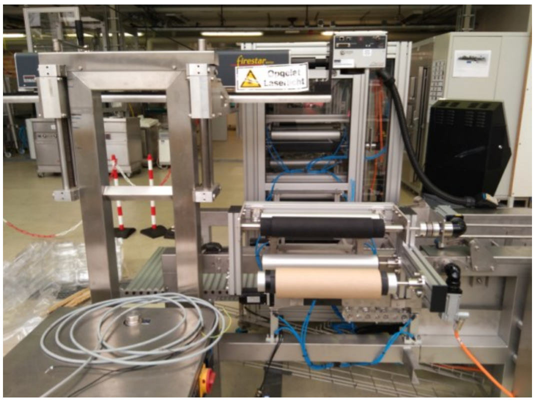


Figure 30 Laser and Printer Modules

Laser Module
In order to seal the packages with the printed top foil and to cut the packages, the laser module is mounted alongside the printer module. The laser module got delivered in month 32. However, integration with the printer and sectional frame is scheduled at month 36. A major concern is the safety of the laser. The protective encasing for this module is not yet ready, which is a dependency for tests to be performed.

Cable Robot

The cable robot is situated at the end of the line and receives individually cut packages. Therefore no integration is required with the sectional frames and it operates to a large extend on its own. Delivery of the complete module is expected in month 42.

Figure 31 a sectional frame

Sectional Frames

The four sectional frames were delivered in month 31 and mechanically installed as the backbone of the line in the following months. The Thermoformer dictates the motion of the web of trays. The sectional frames are now synchronized with the Thermoformer. The cross-sectional frame under the printer module is not yet operational in software.

Cleaning Robot

To clean the majority of the modules automatically, a cleaning robot is designed that moves through the line on the sectional frames. The delivery is expected in month 38 and can only be tested when the whole line is mechanically integrated.

The Integrated Line

Overall, the majority of the modules is delivered and mechanically integrated in month 36. However, some modules are still pending and moreover the deadline for milestone and deliverable for integrating all the modules was at month 36. Hence these are not reached and an overall delay is expected of 4 months.

Figure 32 The integrated line. Top left thermoformer under the Marel IPL robot. Middle quality assesment module. Bottom right printer and laser modules.

Although mechanically integrating modules is one part, the other major part of the work is in software integration. Currently WP7 is supporting this WP2 goal with additional efforts. Regarding the use of resources, WP7 is in its busy period of integration. Partner DLO and DTI are spending more person months than anticipated to integration, mainly because additional software tasks and partner Marel who indicated to withdraw from integration. The budget from Marel is therefore reallocated to DLO and DTI.

2.7.4 Use of resources

	Period 1		Period 2	
Cost type	PM	Costs	PM	Costs
Personnel	39.8	€ 309,295	71.5	€ 528,516
Subcontracting				€ 4,400
Other		€ 12,287		€ 103,565
Total		**€ 321,582**		**€ 636,480**

2.7.5 Deviations from the DoW

The Work package is a few months behind schedule, according to the resources end effort. Modules arrived, but late. A small delay is possible by shifting the demonstration more to the end of the project This is agreed so achieving all objectives should be OK by the end of the project,

2.8 WP8 Hygienic food handling

2.8.1 Project objectives for the period

The objectives of WP 8 for this period were the following:

- Design of a hygienic processing line layout for the PicknPack system.
- Monitor and advise on hygienic design aspects for all product contact parts.
- Design of a cleaning system for the PicknPack system.
- Sub-objectives in the second period:
    - Cleanability Tests with the relevant modules of the PnP-Line (product contact surfaces),
    - Detailed development of the automated cleaning system for the line,
    - Review of equipment regarding proper hygienic design and suggestions for revision and improvement.

2.8.2 Summary of the work progress and achievement during the period

During the first part of the project most of the designed modules which are in direct product contact were reviewed regarding proper hygienic design to guarantee that they are completely cleanable. But during the design process of all modules also compromises had to be made between hygienic design and functionality. Therefore it was necessary in the second part of the project to make cleanability tests with all relevant modules. The aim of those tests was to find areas which are not cleanable and also areas which are not easy to clean. Depending on the relevance of the determined critical areas design changes have to be made.

Cleanability tests were performed with the following modules:

- Delta Robot (WP 5),
- Chicken gripper and Tomato gripper (WP 5),
- Sectional frame (manual version, WP 2, 6 and 7).

To determine critical areas the modules were soiled with a test model soil which was then cleaned after drying with a practically relevant cleaning method. Areas which could not be cleaned were declared as not cleanable or hard to clean.

The most critical areas were detected on the grippers which were still in a prototype phase at this moment. Lacquey already proposed crucial design changes which should improve the hygienic design of the grippers significantly what is essential in the case of the grippers, because they are in the closest contact with the products. Also on the Delta Robot and the Sectional Frames critical areas were determined. For relevant areas design changes were proposed.

In addition to the cleanability tests the cleaning system of the line was brought from the conceptual design to a detailed design, ready for manufacturing. The work mainly contained the finalization of the Mobile Cleaning Device (MCD) which will move through the line and clean it module by module. Since the conveyor belt was replaced by the sectional frames it was necessary to make the MCD completely autarkic so that it can move by itself. So therefore the MCD was equipped with a stepper motor. There are three types of nozzles implemented on the MCD which can be controlled by magnetic valves. The nozzles were selected by means of a spray shadow simulation with the 3D CAD models of the modules and practical cleaning tests with mock-ups of the modules. The stepper motor and the valves are connected to a central control unit which can be triggered via Wifi.

2.8.3 Work progress and achievements during the period

2.8.3.1 Cleanability Tests

<u>Test Method</u>

For all cleanability tests the several modules were coated with a model soil. Different soils were used:

- RET medium (Figure 33): easily removable soil which is mainly used to detect areas that are completely not cleanable because of poor hygienic design or spray shadows.
- Food model soil (Figure 34): application-related soil which is mainly used to detect areas that are hard to clean because of insufficient hygienic design. Soil is fluorescent to make it visible under UV-light.

For bigger modules especially the critical areas of complex geometry or potential spray shadows are soiled.

Figure 33: Machine part (Sectional Frame) coated with RET medium before cleanability test.

Figure 34: Machine part (Sectional Frame) coated with food model soil (sour milk) before cleanability test.

The soiled modules were cleaned after a defined time of drying with a reproducible application-related cleaning method which is described in detail as part of the results of the cleanability tests with the different modules. After the cleaning of the modules areas of insufficient hygienic design are detected by checking for residual soil on the different critical parts of the module (Figure 35 and Figure 36).

Figure 35: Machine part with insufficient hygienic design (Sectional Frame) coated with RET medium after cleanability test.

Figure 36: Machine part with insufficient hygienic design (Sectional Frame) coated with food model soil (sour milk) after cleanability test.

Cleanability Results for the Grippers

The cleanability tests with the chicken gripper and the fresh fruit gripper were performed with prototypes in an early phase of the design process when also functionality still was tested. Therefore complexity of the grippers was still pretty high and a significant number of areas with insufficient hygienic design could be detected.

The cleanability tests were performed with the RET medium (general cleanability) and custard as a food model soil (quality of cleanability). Because of the complex geometry of the grippers it was decided to clean them in a washing machine. The cleaning fluid was water at 40 °C.

The cleanability tests revealed several areas of insufficient hygienic design for both grippers (Figure **37**). The most crucial issues were metal-to-metal-contacts, sharp edges, crevices, small gaps and rough material. A lot of those issues are based on the high complexity and the high amount of parts in the gripper which were necessary in this phase to test the functionality with different setups.

Figure 37: Examples for areas of insufficient hygienic design on the grippers, determined with the fluorescent food model soil (bright areas).

With regard to the cleanability tests Lacquey proposed several measures to reduce the parts and the complexity of the grippers. Two proposed design changes are shown exemplary in Figure 38 and Figure 39.

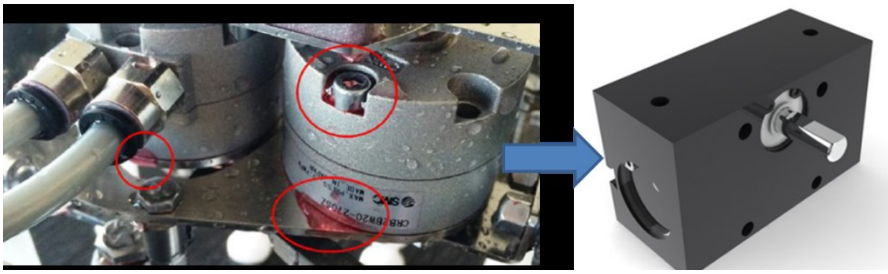


Figure 38: Design solution with an FDA approved pneumatic motor for the Chicken Gripper.

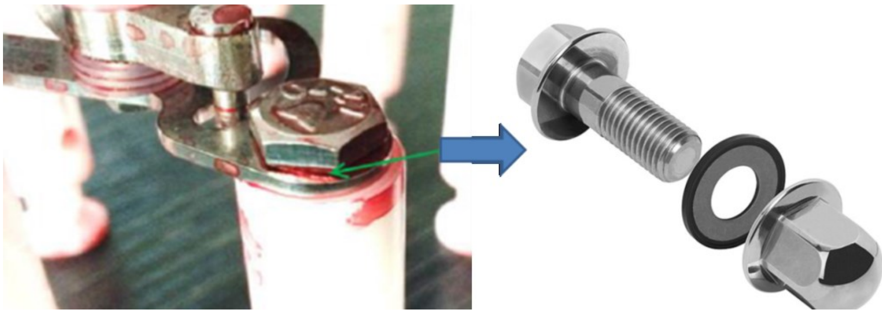


Figure 39: Solution with sealed hexagon bolts to avoid metal-to-metal-contact.

<u>Cleanability Results for the Delta Robot</u>

Cleanability tests have been performed to find critical areas within the Delta Robot and to compare the proposed cleaning concepts. As model soil the RET medium was used. Since it is easily removable, it can be used perfectly for finding out spray shadow areas in an open cleaning system. It can be also used very well to compare the cleanability of a module with different cleaning systems, in this case the cleaning with the fixed nozzles (Figure 40) and the Mobile Cleaning Device. The two cleaning concepts were developed based on spray shadow simulation (Figure 41). Based on the test results the design of the module and the cleaning system can be improved.

For the cleaning with the fixed nozzle system, the robot module was completely sprayed with the RET medium. The cleaning process was started with the two rotating spray heads. After several time steps the process was paused and photos were taken of the critical areas which didn't get cleaned within this time.

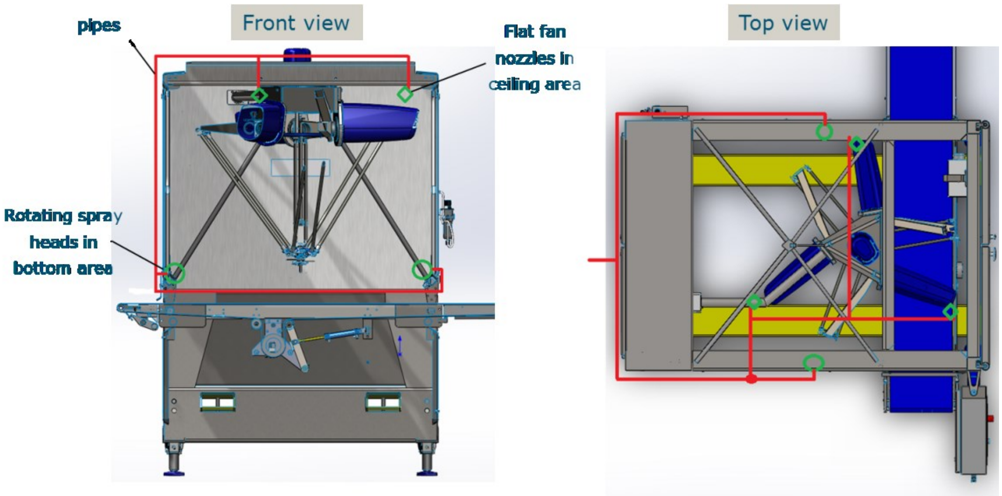


Figure 40: Nozzle arrangement in the Delta Robot with flat fan nozzles in top area and rotating spray heads in bottom area.

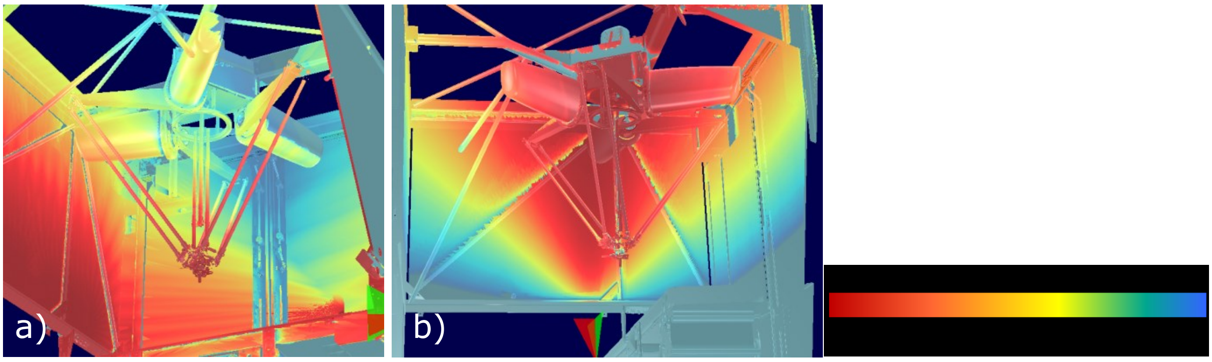


Figure 41: Spray shadow simulation with a) fixed nozzles and b) Mobile Cleaning Device.

For the last cleaning step also the three full cone nozzles were used to see if they are able to clean the areas which the rotating spray heads were not able to reach. For the cleaning with the Mobile Cleaning Device the robot was completely soiled again. For the cleaning the Mobile Cleaning Device was pulled from one side of the robot to the other and then back. The pulling was performed at different speeds. After each run the cleaning was paused and photos were taken.

The tests revealed several spray shadow areas especially in the ceiling area of the robot. Most of them were caused by additional stability structures within the ceiling and sensing units which were not part of the design which was the base for the simulation and development of the cleaning system. To solve this issue it would be necessary to implement additional nozzles in the ceiling area of the robot. It has to be discussed and decided if this is necessary with regard to the hygienic importance of those areas or if occasional manual cleaning is sufficient within this demonstrator.

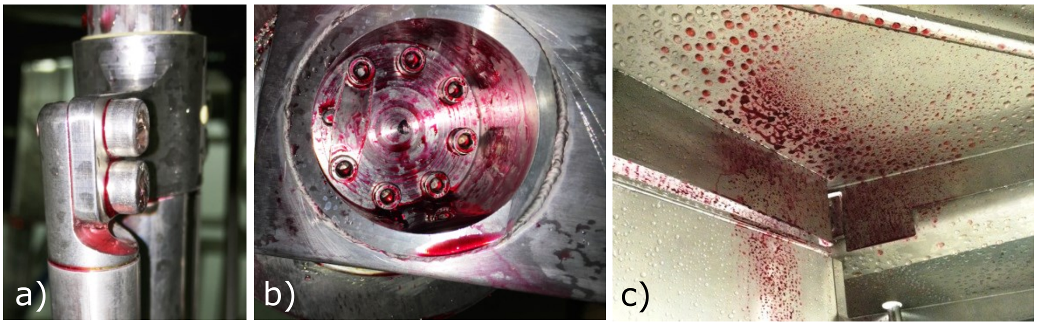


Figure 42: Examples for areas of insufficient hygienic design (a and b) and spray shadows (c).

Also some critical areas with insufficient hygienic design could be detected. Examples for areas of insufficient hygienic design and spray shadows are shown in Figure 42. The tests also showed that the cleaning with the Mobile Cleaning Device has some advantages in comparison to the cleaning with the fixed nozzle system. Due to the movement of the MCD e.g. some spray shadow areas can be eliminated because the spray angle is changing the whole time. An example for the improvement of the cleaning result is shown in Figure 43.

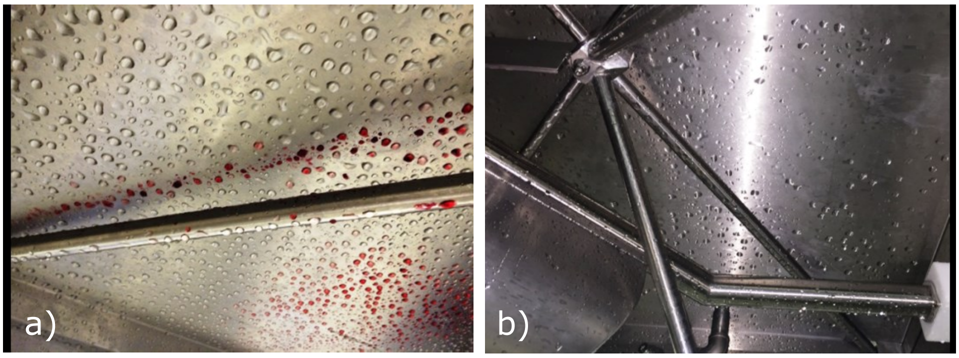


Figure 43: Improved cleaning behind crossbars in the top area due to the movement of the cleaning device: a) fixed nozzle system, b) Mobile Cleaning Device.

Nevertheless, the MCD alone is also not able to reach all areas, especially at the ceiling. The support by the flat fan nozzles in the top area is necessary to reach as much parts of the Delta Robot as possible.

<u>Cleanability Results for the Sectional Frames</u>

The cleanability tests with the Sectional Frames were divided into two parts: tests within the product contact area and tests within the non-product contact area.

The tests within the non-product contact area were performed only with RET medium because they are not of high hygienic importance. Nevertheless, these areas have to be cleaned manually from time to time, so therefore they also need to be cleanable. After soiling and drying the sectional frame was cleaned manually with a spray lance. The tests revealed that there are several areas which are hard to reach for an operator. Also on some parts metal-to-metal contacts, sharp edges and welded seals are making those areas not cleanable (Figure 44). It has to be decided if it is necessary to redesign those areas or if the current state is sufficient for the demonstrator.

Figure 44: Red coloured areas are hygienically critical (non-product area of the Sectional Frames).

Within the product contact area the cleanability tests were performed with RET medium as well. In addition the tests were done also with a sour milk food model soil in order to determine the quality of the cleanability. For the cleaning a mock-up of the Mobile cleaning Device was used. For the cleaning tests with RET medium only water was used as cleaning fluid. For the tests with the food model soil the cleaning method was adapted more to the real process. In this case the sectional frame was foamed at first with mild alkaline foam. After an exposure time of 10 minutes the rinsing step was done with the mock-up of the MCD and with water as cleaning fluid. Figure 45 shows exemplary areas within the product contact area which are not cleanable due to metal-to-metal-contacts, sharp edges and open threads. Those areas should be minimized or redesigned completely, especially in areas of direct product contact.

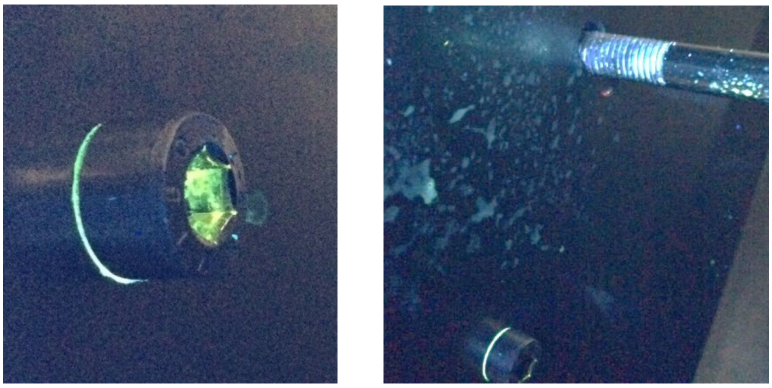


Figure 45: Examples for critical areas in the product contact area of the sectional frames. Non-cleanable areas are marked by the green soil residuals (soil: sour milk with tracer).

2.8.3.2 Design of the Mobile Cleaning Device

The Mobile Cleaning Device (MCD) is the central module of the cleaning system. It moves through the whole line cleaning module by module. Figure 46 shows the final design of the MCD.
With the magnetic valves the several nozzles can be activated and deactivated at any time. With the stepper motor different speeds are possible. Both components increase the flexibility of the Mobile Cleaning Device significantly. Motor and valves are connected to a central control unit on the MCD which can be triggered via Wifi. The MCD is connected to a supply hose which is leading to a stationary hose drum. The hose drum itself will also be automatically unrolled by a stepper motor. It is placed at the beginning of the line over the Thermoformer. On this point the MCD is also put into the line before cleaning. From there it starts the movement through the line. The cleaning method contains a pre-rinse, a foaming step and a final rinse. The cleaning fluid will be supplied by two mobile Ecolab Typhoon systems.

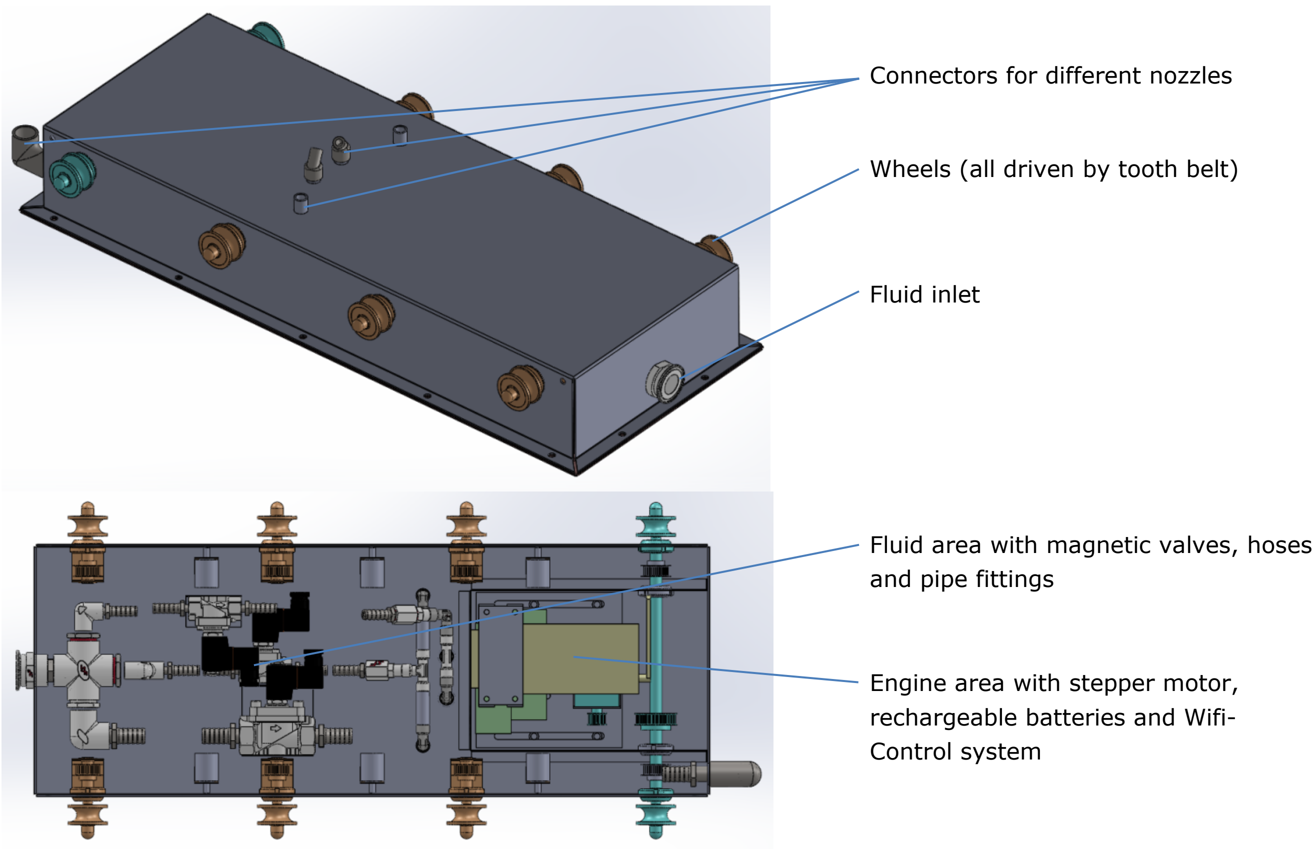


Figure 46: Design of the Mobile Cleaning Device.

2.8.3.3 Statement on the use of resources

The work and all travelling expenses were necessary and in accordance with the planned resources. There are no significant deviations between the actual status of the work package and the planned schedule.

2.8.4 Use of resources

	Period 1		Period 2	
Cost type	PM	Costs	PM	Costs
Personnel	16.8	€ 131,596	19.4	€ 128,983
Other		€ 13,349		€ 18,103
Total		**€ 144,945**		**€ 147,086**

2.8.5 Deviations from the DoW

The work package is running according to the plan.

2.9 WP9 Life cycle analysis and sustainability

2.9.1 Project objectives for the period

Main objectives for WP9 in PicknPack project includes:

- To create a full life cycle picture of the automated systems developed in the project
- To assess the effects of automation of packaging of fresh and processed food products from a sustainability point of view considering aspects like waste minimization, quality increase and logistic optimization
- To base such an assessment on the three pillars of sustainability through a Life Cycle Assessment (ILCD compliant), a Life Cycle Costing as well as a social evaluation.

Objectives relate to the following tasks:

- Objective 1: Development of full life cycle picture of the automated systems developed in the project (Task 9.1)
- Objective 2: To assess the effects of automation of packaging of fresh and processed food products from a sustainability point of view (Task 9.5)
- Objective 3: To base such assessment on the three pillars of sustainability through ILCD compliant Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and social evaluation (Tasks 9.2, 9.3 and 9.4, respectively).
- Objective 4: Demonstrate the sustainability advantages of such automated systems in comparison with current manual operations for the packaging of fresh and processed food products (Task 9.5).

The main objective during this second reporting period has been the completion of the Objective 1 as well as the Objective 3.

2.9.2 Summary of the work progress and achievement during the period

The main work progress within WP9 during this second period of PicknPack is summarized below:

1) Life cycle diagrams and LCA data collection for benchmark packing lines has been achieved. Data from two thermoformed packaging manufacturers and one foodstuff packer (coupled with these two packaging producers) has been collected, treated and by Sep 30th was under modelling with LCA software.
2) Real power measurements in benchmark packing lines were possible by using three-phase electric power measurement devices purchased for such purpose.
3) With regard the PicknPack lines (fruit/vegetables and ready meals) it has also been possible to define the final life cycle diagram together with WP7.
4) Most of the data has been collected for the PicknPack packaging materials, although the power measurements and quantification of packaging materials use, water and cleaning agents have not been made yet because of the delays on the assembly of the whole line. WP7 responsible will keep ITENE informed as soon as the PicknPack line is ready in order to begin with such measurements.
5) A series of preliminary LCA results for the packaging formats in PP, A-PET (amorphous), C-PET (crystalline) have been also obtained. However, these will be modified in accordance with the latest specifications on materials and dimensions (final trays will have less depth than initially expected, changes on material types are also expected too).
6) Life cycle costing has been started with the search of prices about electricity and packaging materials, although this work still depends on the completion of the LCA, especially for the PicknPack packing line.
7) A similar situation occurs in case of the packer acceptance studies which has not been started yet because require of the demos with the whole PicknPack line to be developed within WP11.
8) The timing on the assembly of the whole PicknPack line has not allowed yet the development of the sustainability assessment since this is the combination of the quantitative data of LCA and LCC with the semi-quantitative data from packer's acceptance studies.

Consequently, main actions for the success of the work within WP9 depends on the assembly of the PicknPack line in WP7 as well as the development of the demos in WP11. Therefore, if such tasks are speed up, ITENE will be able to complete the WP9 tasks in due time.

2.9.3 Work progress and achievements during the period

As pointed out before, during the first reporting period (Apr 2014 to Sep 2015), work has been mainly focused on Task 9.1 (Life Cycle Definition) as well as in Task 9.2 (LCA). Even though Task 9.3 (LCC), Task 9.4 (Social Evaluation) have been started by March 2014, and Task 9.5 (Sustainability assessment) has also started in October 2014, only some significant achievements have been reached for Task 9.4 (Social Evaluation) based on the cooperative work developed within WP12 and WP4 on technical parameters related to the Quality Assessment and Sensing (QAS) module and possible added value to packers and consumers. More precisely, the following activities have been carried out during this 2nd reporting period:

Task 9.1. Life Cycle Definition:

Subtask 9.1.1. Description of the life cycles of current manual operations and conventional equipment: This work started with a search of equivalent conventional packing equipment capable to meet the functionalities of the PicknPack line. After such search ITENE contacted several packing equipment manufacturers and users within Spain. It was assumed that the operational parameters and performance are independent of the location where the packing equipment is placed. Finally, three companies accessed to provide data which was used for the development of Task 9.2 (LCA), as summarized in the table below. The names of these companies are omitted because of confidentiality issues since these are outside the PicknPack consortium:

Company	Activity	Location	Date of measurement
1	Production of thermoformed packaging	Alicante, Spain	March 2015 (electric line) September 2015 (pneumatic line)
2	Production of thermoformed packaging	Valencia, Spain	March 2015
3	Foodstuff packaging and sealing based on previously thermoformed packaging (coupled with companies 1 and 2). This packer works with chicken meat and ready meals based on chicken	Navarre, Spain	June/July 2015

As a result of that, it was possible to build the following life cycle flow diagrams for conventional thermoforming equipment. Such diagrams shows also the packaging material and power consumption obtained during the measurements. Next figure shows the flow diagram for Company 1.

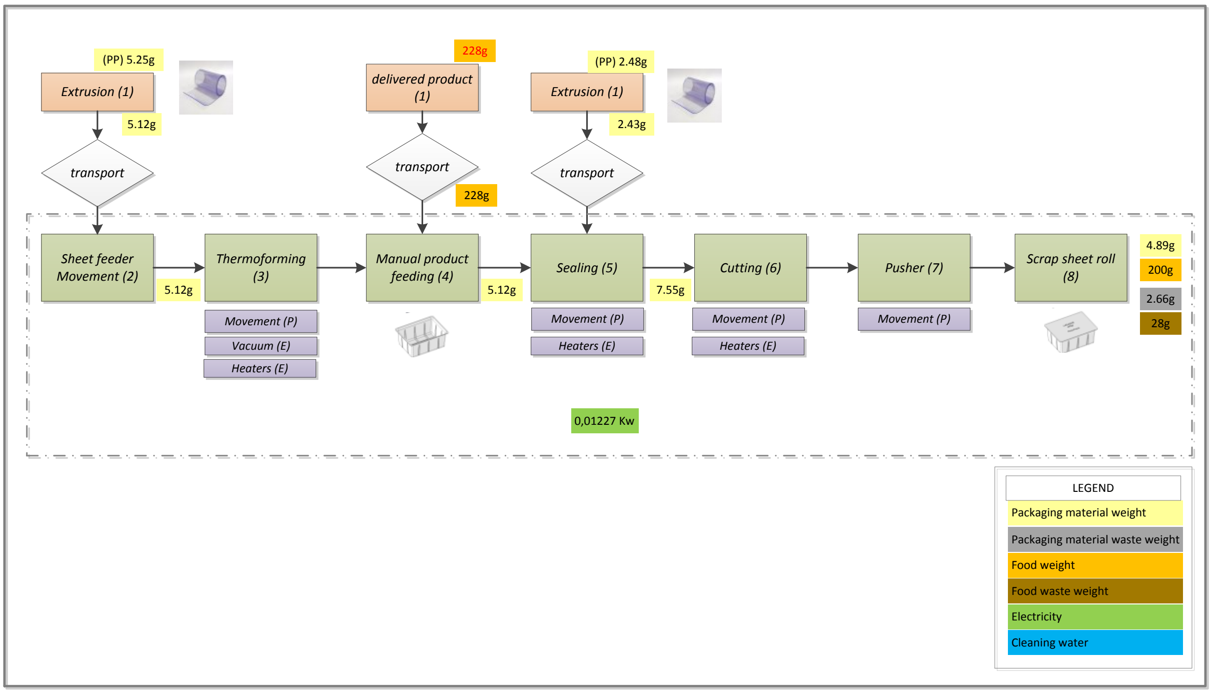


Figure 47 Scheme

Subtask 9.1.2. Creation and continuous update of a process life-cycle map of the PicknPack system: This subtask has also continued from the former period by a continuous exchange with WP7 leader. For a more effective communication, several Skype and phone meetings were made from September 2014 to July 2015. Next figure shows the outcomes of the September 2014 Skype meeting with Bart van Tuijl (WP7).

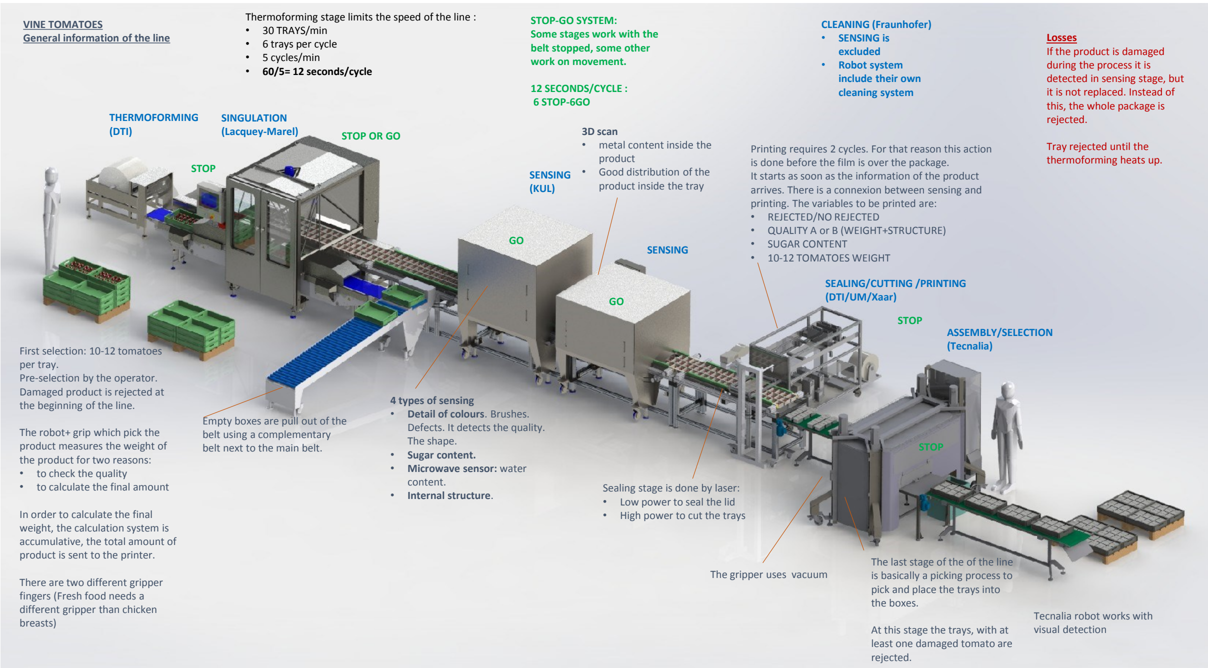


Figure 48 Lay out line

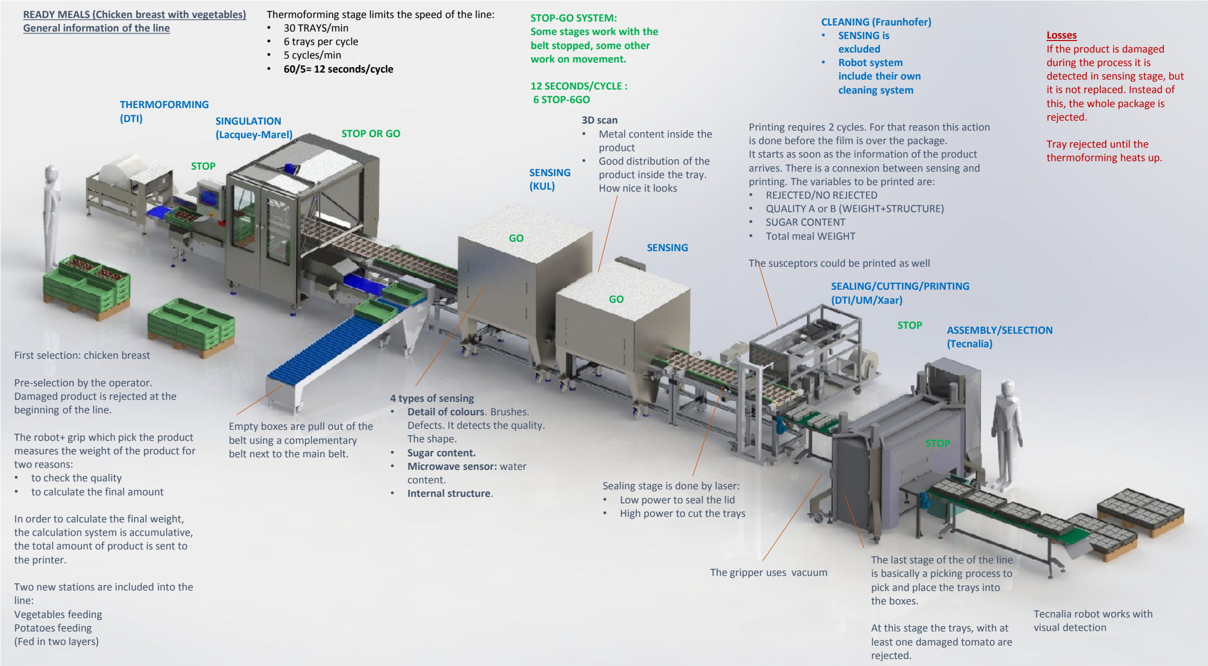


Figure 49 Lay out line

These diagrams have been used as a basis for the data collection about PicknPack line, which is expected to be made as soon as the whole line is assembled and ready for tests. Several e-mail exchange with WP7 was made in July and September 2015 in order to arrange the measurements and carry out measurements with individual modules by the end of 2015.

In accordance with the latest conversations in July and September 2015, it was agreed with WP7 leader to train people in charge of the integration of the line at Wageningen University on the use of power measurement devices (expected for the next General Assembly in Leuven, Belgium).

Subtask 9.1.3. Data collection for LCA and LCC analyses: The data collection about LCA (environmental impact) and LCC (life cycle costing) has continued from the first period. Different types of data have been collected. It has to be pointed out that, for the time being, data collection about LCC has not been started (Sep 2015) except for the prices of three-phase electricity (medium voltage) and prices of plastic raw materials for packaging. The following table summarizes the current status of data collection to date of Sep 30th 2015.

Data	Conventional current packing equipment	PicknPack line	
		For fruit and vegetables	For ready meals
Power (electricity) consumption	✓ (3 companies)	✗	✗
Packaging materials	✓ (except sealing film)	✓ (except sealing film)	✓ (except sealing film)
Water	✗	✗	✗
Cleaning agents	✗	✗	✗
Contained product	✓	✓	✓

It is worth to note the significant breakthrough in Subtask 9.1.3 achieved after the meeting in Dresden (October 2014) with regard the approach considered for the data collection about the PicknPack line. The initial approach based on direct data collection from the partners was finally discarded because of the difficulties of the partners to provide a reliable reply since power/material/cleaning agent/water consumption were not measured individually by each one of the partners. This was especially critical in case of power consumption which is expected to be the one of the most relevant contributions to environmental impact of the packing line. Based on these issues, this approach was modified in order to estimate the power consumption from technical specifications and nameplate/factsheets from the components that use electricity (motors, actuators, sensors, pumps, etc.) in the line. After several discussions, it was decided in Dresded to change the approach again by performing directly such power measurements using electrical power measurement equipment coupled to input powerlines. Below it is described in detail the actions made for data collection during this second reporting period of PicknPack project:

- *Power (electricity) consumption data*: Data has been collected from conventional thermoforming packing lines in Spain by using small electric power measurement devices for three-phase medium voltage electricity (see figure below). These devices are simply attached to the cables in the electrical panel, providing average and peak power consumption in kWh at periodic intervals, by integration of instantaneous measurements. Such data power measurement is still pending for the PicknPack line as soon this is integrated and ready for the test.

		
Figure 50 Receiver, current clamp and transmitter	**Figure 51 A receiver showing power consumption data**	**Figure 52 Installation in the machine fuse box**

- *Packaging materials*: Based on the outcomes from WP6, the different packaging materials expected to be used within PicknPack packing line have been modelled including: PP trays, A (amorphous)-PET trays and C (crystalline)-PET trays. A-PET and C-PET trays were modelled with a welding layer of PE for sealing. LDPE sealing film was considered only for A-PET trays. Data was still pending about the sealing film used for PP and C-PET trays as well as for those trays intended to be in contact with ready meals. After the discussions in Manchester meeting (April 2015) it was decided to focus on PP for ready meals, because of the difficulties of welding PE by Mike Dudbridge (University of Manchester), although PET was also considered a good thermoforming material. By Sep 30th 2015 ITENE was still discussing with DTI about the final selection of materials (PP and maybe also A-PET only for fresh produce) as well as the dimensions (75 mm deep for fresh produce and 35 mm for ready meals).
- *Water and cleaning agent consumption*: This data was not supplied/found both for the conventional packing equipment and the PicknPack line. Some contacts have been made with WP8 in order to know these data for PicknPack line, although this was not still possible to measure the amount required. For the conventional packing lines considered such information was not available because this is usually a manual operation, so it is intended to make an average assumption based on literature search and consultation to industry experts.
- *Contained product:* During this second period the models for both vine tomatoes and table grapes have been completed. The model for pizza (for ready meals) has been finally discontinued and a new model for chicken breast with vegetables has been prepared. All the three models on contained products (tomatoes, grapes and chicken breast with vegetables) are currently under revision in order to consider the most up-to-date data.

Task 9.2. ILCD compliant Life Cycle Assessment (LCA):
Subtask 9.2.1. Life cycle inventory analysis including data analysis: This subtask was directly related to the activities within Task 9.1. During this second reporting period, the data already collected has been modelled appropriately using the LCA software SimaPro. Several assumptions have been made to carry out the LCA, which are:

a) The LCA only considers the impacts related to the operation of the PicknPack packing line. The main reason for that is that usually the impacts of machinery use usually exceed the impacts caused by the raw materials/construction of the equipment (e.g.: cars, laptops, mobile phones, etc.). In case of industrial equipment this situation is even higher, because of the large functioning hours and the number of units produced per hour. Moreover, payback of these kind of equipment is long, so the life of the machinery can be longer than 10 years. On the other hand, data collection about the materials and components of the machinery is a very challenging task, which cannot be provided easily by the partners.

b) It has been assumed that the behaviour of the PicknPack packing line is independent on the place where is located. Therefore, the same amount of electricity, materials, packaging, etc. is consumed. Additionally, the same amount of waste and product units are expected. Therefore, the models will only change the type of electricity consumed, for which three scenarios have been considered: UK, Spain and The Netherlands.

c) The measurements from conventional packing equipment (benchmarks) are based on current technologies within industries. Differences between the type of packaging materials, packaging dimensions and production speed are assumed to be weighted by the use of scale factors and extrapolation rules as function of the specifications of the PicknPack packing line. The scale factors and the extrapolation rules are currently under development by ITENE.

The status of modelling by Sep 30th 2015 in SimaPro is summarized in the table below:

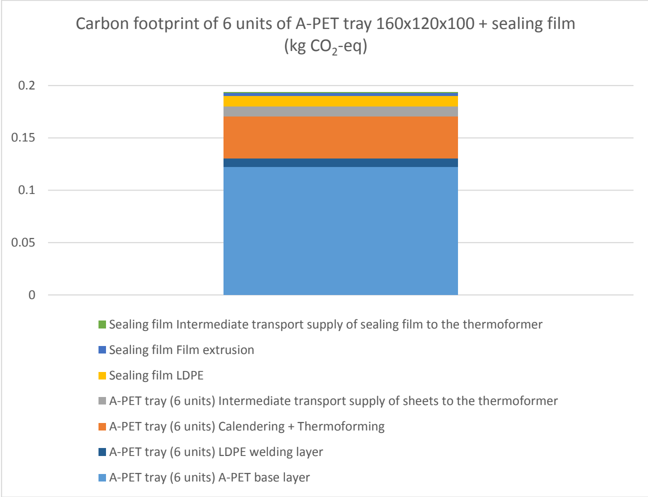
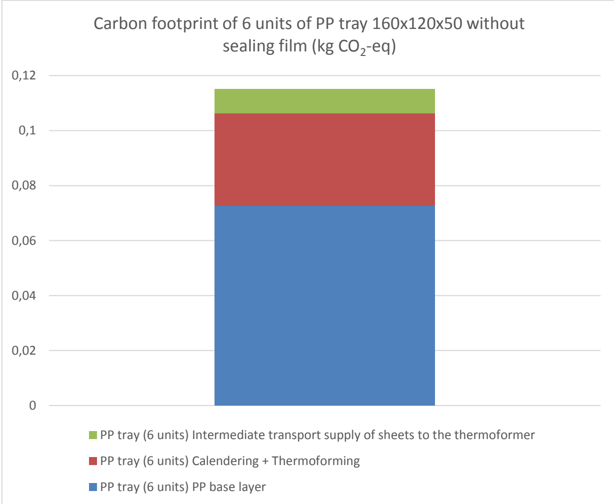
Model	Conventional current packing equipment (benchmark)	PicknPack line	
		For fruit and vegetables	For ready meals
Packing line operation (power & packaging material consumption, water and cleaning agents)	Φ (2 thermoformed packaging producers coupled with 1 foodstuff packer)	× (looking forward to the assembly of the line)	× (looking forward to the assembly of the line)
Packaging materials	Φ (new packaging formats)	✓ (former A-PET format with sealing film and PP format except sealing film) Φ (new packaging formats)	✓ (former C-PET and PP formats except sealing film) Φ (new packaging formats)
Contained product	✓ (to be further revised and improved)		
✓ Modelling ready Φ Modelling on-going × Modelling not started yet			

Because of the complexity of the LCA of energy-using systems and the substantial changes on electricity models made in the most recent versions of Eco-invent LCA database included in SimaPro, a training course was attended in Barcelona in July 2014. The training course was provided by the Spanish dealer of SimaPro LCA software.

Subtask 9.2.2. Life cycle impact assessment & Subtask 9.2.3. Interpretation of life cycle impact assessment results: Life cycle impact assessment has been completed for certain parts of the PicknPack LCA assessment, including impact assessment results and their interpretation: (1) Table grapes, (2) Vine tomatoes, (3) Chicken breast with vegetables, (4) Pizza (discontinued) and (5) Packaging trays for fruit and vegetables & ready meals (see figures below).

Next figure shows some examples of the results obtained for the packaging trays. In accordance with them, the PP trays are those with the lowest carbon footprint. However, by Sep 30th there was still not decided the type of packaging material to be used. Indeed, the dimensions of the packaging have also changed from a depth of 100 mm to 75 mm for fruits/vegetables as well as from 50 mm to 35 mm for ready meals. Changes for the calculation of the impacts of the packaging formats are therefore on-going, although final results have not been extracted yet until a final decision on the packaging materials is made by DTI.

Graph 1

	
LCA results (carbon footprint) for vine tomatoes A-PET packaging format	*LCA results (carbon footprint) for ready meals PP packaging format*

It is also worth to note that the results for the above-mentioned two benchmark packing lines (2 thermoformers coupled with 1 foodstuff packer) are also ongoing. However, results for the PicknPack line have not been obtained yet since the power (electricity) measurements in the whole PicknPack line has not been started by Sep 30th 2015.

Task 9.3. Life cycle costing:

Subtasks 9.3.1. Life cycle costing of benchmarks & Subtask 9.3.2. Life cycle costing of PicknPack lines: During this second period, work in LCC has been limited to the search of costs for electricity and plastic packaging materials. Main reason for that is because of the need of a completion of the LCA data (based on mass and energy units) prior to calculate the LCC of benchmarks and PicknPack packaging lines. Therefore there is an urgent need for data collection in the PicknPack line in order to know how much energy and materials are consumed in this line.

Task 9.4. Social evaluation: packer acceptance studies

In this task the most relevant results have been those related with the exchange with WP12 and WP4 about the quality parameters measured by the QAS module. In that sense, added value points for both food packers and consumers have been identified and were still under discussion by Sep 30th 2015.

However, this a small part of the scheduled work in this task, which necessarily requires of the demos with the whole PicknPack packaging line. This is only possible if the line is totally assembled. Therefore, it is suggested to begin with the packer acceptance study as soon the two scheduled demonstrations of the PicknPack line within WP11 are planned. Therefore, the integration with WP11 is crucial for the success of the acceptance study.

Task 9.5. Sustainability assessment

This task is based on the outcomes of previous tasks. However sustainability parameters cannot be calculated until the completion of the LCA, LCC and packer acceptance studies. Even though LCA and LCC is ongoing, the packer acceptance studies have not been started yet, so therefore sustainability results have not been obtained yet.

2.9.4 Use of resources

	Period 1		Period 2	
Cost type	PM	Costs	PM	Costs
Personnel	22	€ 65,888	22.9	€ 135,193
Other		€ 5,818		€ 9,004
Total		**€ 71,706**		**€ 144,197**

2.9.5 Deviations from the DoW

In the second period other partners started to contribute to the project. Main effort and outcome is expected in the last period of the project. This is according to the plan.

2.10 WP10 Dissemination

2.10.1 Project objectives for the period

1) To organise 2 project workshops at different venues. (10.1)
2) To develop and upgrade the website with links to social media. (10.2)
3) Maintain links with the IAB and organise one formal meeting and an associated social event. (10.3)
4) Expand the communication network within the UK and Europe with a bias towards industrial links for ultimate exploitation opportunities. (10.4)
5) Plan education and training events to be held in association with project demonstrator activities. (10.5)
6) Pursue all possible patent opportunities. (10.6)
7) Establish links with other projects and initiatives. Establish relationships and organise joint events. (10.7)

2.10.2 Summary of achievements

- Two workshops were organised with extensive industrial exhibitions. Average attendance was 50 registrants mainly from industry. (10.1)

- Website completely revamped and updated with enhanced interactive capability and social media links. Network now has 147 registered users. (10.2)

- A meeting of the IAB was organised at Dresden in October 2014. (10.3)

- Communication links greatly expanded within the UK and Europe which will lead to enhanced industrial involvement and cosponsoring of events. (10.4)

- Two training events are now planned for the spring and summer of 2016 in association with planned project demonstrator events. (10.5)

- Patent opportunities have been identified and progressed for the cable robot. Patent opportunities have also been identified for the software constructs developed for data processing in Wp2, WP3 and Wp4. (10.6)

- Formal links have been established with E.C project Smart-E, the UK's Food Manufacturing Engineering Group and a group of companies in Belgium for the organisation of joint events.

  (10.7)

2.10.3 Work progress and achievements during the period

2.10.3.1 Workshops

THIRD PROJECT WORKSHOP

The third workshop was held in Kortrijk in Belgium on 7th May 2015 at the Expo centre in Kortrijk in association with the large biennial Indumation Fair and Exhibition of industrial automation (100+ exhibitors). With the strong support of the University of Leuven we liaised with the regional Food Factory of the Future project and its partners Flanders FOOD, Sirris and Angoria to organise a joint workshop which we could present to their wide network of regional industrial companies in the food industry.
The event attracted about 50 attendees who apart from some of the presenters were exclusively from regional industry.

An overview of the PicknPack project was given by Gert Kootstra and detailed presentations given on aspects of novel instrumentation, data processing and traceability. Peter Weyn an Economist from Fevia (The Federation of the Belgium Food Industry) gave an overview of the impact of automation on the food sector and Sybraam van Breem from Friesland Campina described in detail with video presentations the installation of an innovative automated production line for chees processing.

There were two industrial panel debating sessions the first focussing on sensor technology and the second on robotics and automation. A key feedback factor was the increasing importance of data acquisition and management (industry 4.0 and IOT) which emphasised the relevance of current outputs from WP2 and WP3 and WP4.

On the advice of the local organiser all presentations (bar one) and debates were delivered in Dutch. A comprehensive report on the event has been provided in English by Agoria and is available on the PicknPack website.

At the conclusion of the workshop a series of guided tours was arranged to take attendees around the adjacent industrial exhibition each tour being themed on specific topics such as automation, packaging and sensors.

Fourth Project Workshop

The 4th workshop took place at the MediaCity exhibition site in Salford UK on 4th September 2015 in association with the launch of Innovate UK's Robotics and Autonomous systems Special Interests Group's Northern Robotics Network. This was a large industrial event with an attendance of about 300 registrants and over 40 industrial exhibits of robotic systems applications including ABB, Festo, Siemen's, Kuka, Shadow Robots and MOOG Automation.

The programme of the event covered a range of industrial sectors including aerospace, nuclear, transport smart cities and food manufacturing. The inclusion of a food manufacturing stream was considered relevant because of the strategic importance of this economic sector in the region.

Apart from regional and central UK government support the event was cosponsored by a number of major UK and international manufacturers, trade associations and professional engineering institutions.

The food manufacturing stream was co-sponsored by the UK's Defra Food Manufacturing Engineering Group (FMEG) which is a partner in the Northern Robotics Network and the E.C project Smart-E. The morning session was concerned with advances in general manufacturing with presentations being given by speakers from Siemens, ABB, Festo, Rolls Royce and the UK's advanced manufacturing research centre. The Siemens presentation focussed on the impact of industry 4.0 on manufacturing which had a resonance with the later PicknPack presentation on WP2.

The afternoon session included a detailed overview given by Erik Pekkeriet, a presentation on project instrumentation given by Wouter Saeys, an overview of future manufacturing trends in the sector given by Mike Dudbridge and a review of developments in data processing and traceability given by Zhipeng Wu.

In accordance with suggestions form the Commission the scope of the workshop was broadened to include the outputs of another relevant large E.C project. In this case presentations on soft robotics which are very relevant to the processing of fragile pliable food products were given by Steve Davies and Samia Nefti-Meziani from the current E.C Smart-E project.

The PicknPack workshop had some 50 attendees which was close to room capacity with registrants from a range of companies including PepsiCo, Heinz, OMRON and the OAL and IML Groups.

A PicknPack stand was established in the exhibition zone and featured our new PicknPack pop up banner. This is now available for other colleagues to use.

2.10.3.2 The Website
The University of Manchester was instructed in April 2014 to develop an entirely new website to communicate to the public whilst the old site would continue to be used for unloading and sharing internal documents.

The new website was created on Joomla 3.4.1 and went live on 18th September 2015. The home page has been structured to enable visitors to access information at ease (minimal mouse clicks), the template was created to make sure that each page is consistent in design and function using the same template throughout has ensured the site has a professional and consistent look and feel. It took several weeks to build the additional pages, content and images were placed on pages and code was written. All pages include a main menu, basic information i.e. contact information, sitemap, social media links and a feature to sign up to the Mail Chimp newsletter.

The website is fully compatible to view on mobiles and tablets. The most noticeable changes include image slider, videos, participant logos, progress reports. The website now delivers project developments clearly and is easy to navigate.

Two comprehensive and informative newsletters have been issued concerning the project and its progress.

2.10.3.3 Social media
Twitter, Facebook and YouTube have been set up to disseminate the technical outputs of the project. The pages are continuously maintained however many partners are not connected to social media so they cannot join the PicknPack channels.

We have asked Project Leaders to include links within their email signature to promote the PicknPack social media channels.

All workshop Leaders can now access the website directly and input data and videos on their individual outputs.

2.10.3.4 Industrial Advisory Board
An Industrial Advisory Board meeting was held in Dresden during 27-29th October 2015. Three members were present. Feedback from the Board meeting has proved valuable and comments from this meeting prompted a significant review of how we were organized our work and the issues raised were rapidly addressed and a follow on meeting arranged to confirm proposed solutions. The minutes of this meeting are available on the website.

2.10.3.5 Communications
Links have been established with:

- The UK's Food Manufacturing Engineering Group who co-sponsored the second and third workshop and link with our website.
- The Flanders Food, Sirris and Agoria Groups who co-sponsored the third workshop and plan to cosponsor the 5th workshop.
- The large UK industrial Northern Robotics Network who co-badged the fourth workshop.
- The IML Publishing Group who hosted a PicknPack stand at their annual Appetite for Engineering event and plan a series of articles on the project in the food journal.

- Editorial office of the New Food who are liaising with partner AZTI to publish an article on their outputs and plan a special issue featuring the PicknPack project in late 2016 or early 2017.

- The E.C project Smart-E which co-sponsored the third workshop will provide dissemination to a wide group of their industrial partners.

- A growing range of companies that wish to be associated with the project and informed on its outputs including ABB, Festo, Kuka, Siemens, PPMA, Mitsubishi (robotics), Rittal, Nestle, Omron, Pepsico, Bakkavour and Unilever.

- The UK's Food and Drink Federation who plan to be involved in our training events through the UK's National Centre for Excellence for Engineering.

- The UK and Ireland IEEE Robotics and Autonomous Systems Chapter co-badged the 4th workshop and is interested in being involved in future PicknPack events and in dissemination information and our outputs.

2.10.3.6 Training events

A programme of training events has been planned for 2016 in association with the planned programme of project demonstration events.

a. Training event 1 – Wageningen May 2016
b. Training event 2 – Lincoln September 2016

Target audience will be young industrial workers and students who are focused on a career in manufacturing. We are currently working with local academic and training groups to identify collaborating companies and student cohorts.

2.10.3.7 Patent applications

Current patent applications are being submitted by Technalia on design aspects of the cable robot. It is also clear that the software structures for the decentralised control of large data sets developed in WP2, 3 and 4 are of great commercial interest to companies such as Unilever and patent protection will be sought where feasible. It is now certain that this work will be one of the major industrially relevant outputs from the project.

2.10.3.8 Liaison with other partners

As indicated in 4 above liaison with other projects and initiatives include:

- E.C Smart-E
- The FMEG series of colloquia and workshops
- Flanders FOOD, Sirris and Agoria
- IML Groups Appetite for Engineering series of events

2.10.3.9 List of recent publications and video presentations

Magazines:

De grote ambities van PicknPack
Janssen, A. (2013) VMT Magazine 2013 nr 10, p18-p19
Van kas tot kassa
Zedde, R (2014) Magazine Vision & Robotics 2014, Year 8 nr 8 p20-p22

Food websites:

Wageningen UR test flexibele voedsel verpakkingslijn in project PicknPack
Pekkeriet, E.J. (2015) www.groentenieuws.nl publication date: October 26, 2015
Waiting for the horticulture robot
Vliet, M (2015) Greenhousetechnology.international publication date: August 28,2015
Waar blijft de robot
Vliet, M (2015) www.greenhow.nl, publication date: August 20,2015
PicknPack
Verdouw, C (2015) www.tuinbouwdigitaal.net, publication date March 11, 2015
Één productielijn voor meerdere producten
Pekkeriet, E.J. (2015) www.hortivalley.nl, publication date October 27, 2015
Food Processing http://www.fponthenet.net/article/97394/PicknPack--Flexible-Robotic-Systems-for-Automated-Adaptive-Packaging-of-Fresh-and-Processed-Food-Products.aspx
Food & Drink Federation https://www.fdf.org.uk/events/Flexible-Automation-in-Food-Manufacturing
FMEG http://fmeg.org/fmeg-is-sponsoring-the-4th-picknpack-workshop-on-4th-september-2015-at-media-city-uk-salford/

Webinars:

Agrofood Robotics and Automation: From Farm to Table
Zedde, R (2014) IEEE RAS TC on Agricultural Robotics and Automation Webinar. Date September 26, 2014.

Events:

Soren gave a presentation of PicknPack at the June IAPRI Symposium in Valencia, Spain. See following:
http://iapri.itene.org/
https://www.flickr.com/photos/itene/sets/with/72157654635611658
Richard van de Linde gave a keynote on IROS in Hamburg 2/10/201, food agro workshop.
keynote about Lacquey, with 1 slide mentioning PicknPack.

Also, at the visit of Yukri Katainen, Vice President European Committee, in Delft, April.
Richard mentioned PicknPack during this visit (picture, you can see the picknpack logo on the background)

Figure 53

Appetite for Engineering 21 October 2014 http://www.controlengeurope.com/article/82188/Appetite-for-Engineering--the-UK-s-annual-food-processing-industry-forum.aspx

Media:
IET film

Other:
North West Aerospace Alliance
Automation Magazine
IET http://mycommunity.theiet.org/communities/events/item/67/15/10099#.Vks5unbhCUk

2.10.4 Use of resources

	Period 1		Period 2	
Cost type	PM	Costs	PM	Costs
Personnel	29.7	€ 119,443	20.3	€ 186,647
Other		€ 18,299		€ 19,869
Total		**€ 137,742**		**€ 206,516**

2.10.5 Deviations from the DoW

The project is running according to the plan.

2.11 WP11 Demonstration

2.11.1 Project objectives for the period

WP11 Demonstration first starts all activities in M18 (1 April 2014).

Objectives:

- Demonstrate the viability of the PicknPack results in the food packaging business
- Reduce resistance to adoption of robotics in the food packaging industry
- Solicit feedback from potential users of PicknPack results

The overall objective of WP11 is the demonstration of the PicknPack system in the food business. The demonstration will be conducted in food companies or companies related to the food industry. It will be done in the following kinds of food companies:

- Packaging of fruits and vegetables in the Netherlands
- Ready meal producer in another EU country (most likely UK)

Task 11.1. Liaise with interested companies (DTI, WUR, UM, Tecnalia, Marel, Fraunhofer, MS)

- Identify companies that could be interested in PicknPack results (in collaboration with WP11)
- Establish contact with selected companies
- Draw up agreements with companies
- Prepare for demonstrations

2.11.2 Summary of the work progress and achievement during the period

The work is still just started as demonstration mainly is planned for the last project year. We have now a written agreement (D11.1) on a plan to demonstrate:

- Packaging of fruits and vegetables in the Netherlands performed at WUR.
- Ready meal producer in UK performed in University of Lincoln, Holbeach.

WP11 will cooperate with WP10 in order to combine the demonstrations with dissemination activities.

2.11.3 Work progress and achievements during the period

2.11.3.1 General situation

In the second period only Task 11.1 was planned.

Task 11.1. Liaise with interested companies (DTI, WUR, UM, Tecnalia, Marel, Fraunhofer, MS)

- Identify companies that could be interested in PicknPack results (in collaboration with WP11)
- Establish contact with selected companies

We work just now on a plan to demonstrate:

- Packaging of fruits and vegetables in the Netherlands performed at WUR.
- Ready meal producer in UK performed in University of Lincoln, Holbeach.

As food companies are typical negative to have visits from competitors and PicknPack need to demonstrate the innovative system to all the industry we had a challenge.

Another challenge for WP11 has been the changed status of the two industrial partners Marel and Marks & Spencer. The largest challenge was Marel with a first budget of 24 PM did not want to demonstrate PicknPack. The coordinator (WUR) has together with the relevant partners made a new budget proposal transferring resources from Marel and Marks & Spencer to the partners taking over these demonstration tasks. This proposal need first to be approved by first the Project Board and second by European Commission. Both approvals did not happen before the end of the second period.

2.11.3.2 Demonstrations

Figure 54 *Photos of the integrated adaptive packaging line*

PicknPack will in the first half year of 2016 perform two demonstration events:

- Fruits or vegetables (NL) at WUR in Wageningen
- Ready meals (GB) in cooperation with National Centre for Food Manufacturing (University of Lincoln) in Holbeach. National Centre for Food Manufacturing will be included in marketing.

Both demonstrations will have two different practical demonstrations and a workshop.
Workshop with partners presenting results from PicknPack

1. Inline demonstrations using food products
2. Off-line demonstrations from side booths with:
   - Physical demonstrations
   - Video demonstrations
   - Demonstrator samples/prototypes
   - Posters

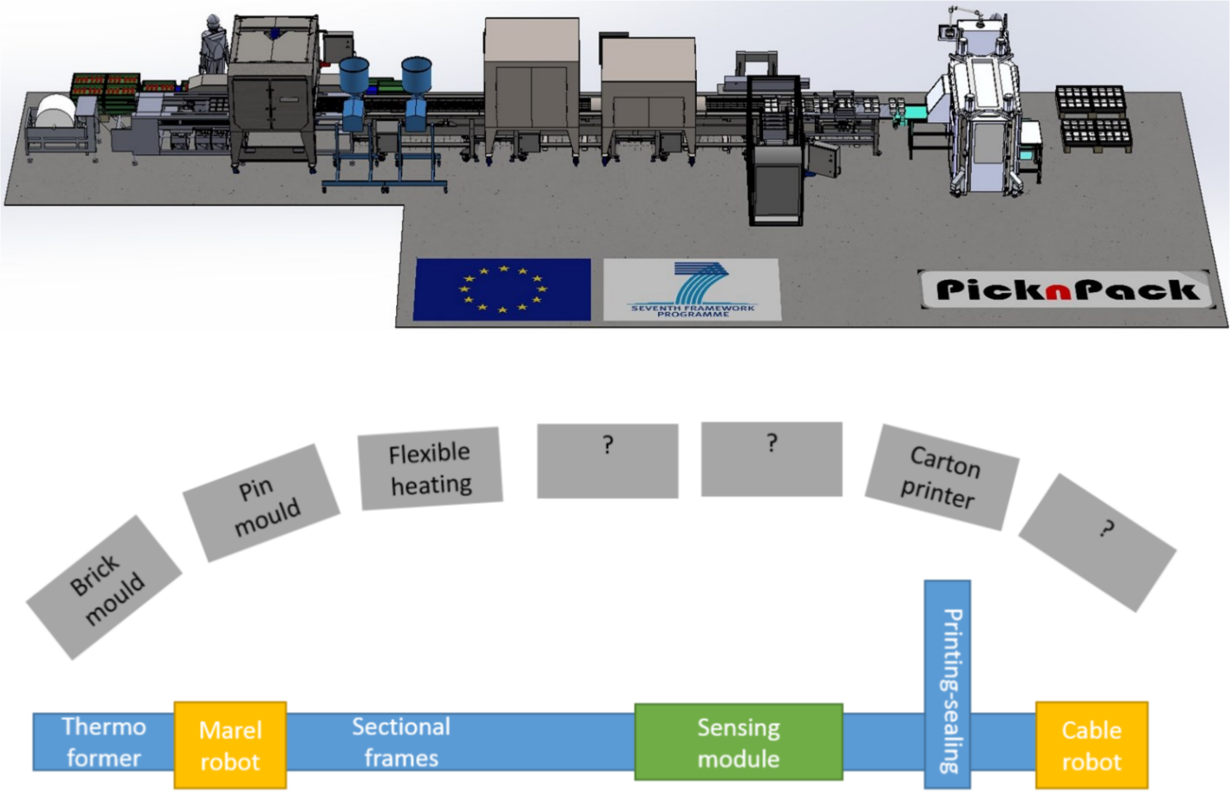


Figure 55 *Demonstration lay-out*

The off-line demonstrations will be:

- Design and production of brick moulds
- Pin moulds and plaster moulds
- Flexible heating systems
- Carton printer
- MAP
- Etc.

2.11.3.3 Timing

It is the plan to perform these two demonstrations:

1. Fruit, vegetables and ready meals at WUR in Wageningen in May, 26, 27, 2016
2. Ready meals in National Centre for Food Manufacturing, Holbeach, UK in September 2016

2.11.3.4 Resources

The PicknPack line is under installation in WUR at Wageningen. After the finalisation of the packaging line the line will be used for the demonstration of fruits and vegetables on this location. WUR has a conference room for about 50 persons for 1-2 workshops and space for off-line demonstrations between the conference room and the PicknPack line.

Costs for the Wageningen demonstration is included in WUR's budget. All other partners shall be ready to install, run and demonstrate within existing budgets.

DTI organise transport from Wageningen to Holbeach in two 20’ ISO-containers.

The National Centre for Food Manufacturing (University of Lincoln) in Holbeach is not a partner in PicknPack. The annexed cost calculation equal to € 24,000 will be invoiced and paid by DTI for different services under the demonstration in UK. The National Centre for Food Manufacturing has excellent facilities for the demonstration including test halls and conference rooms. All partners in PicknPack will also participate in the demonstration in Holbeach within already allocated budget.

This agreement is only valid on the condition that the EC accepts the reallocation of the budget as suggested in the email from coordinator of 14 September 2015 or better for DTI.

2.11.4 Use of resources

	Period 1		**Period 2**	
Cost type	PM	Costs	PM	Costs
Personnel	1.2	€ 11,395	7.1	€ 51,951
Other		€ 778		€ 12,122
Total		**€ 12,173**		**€ 64,073**

2.11.5 Deviations from the DoW

The Demonstration is scheduled in the last period of the project. The work package is running according to the plan.

2.12 WP12 Acceptance, economics and exploitation

2.12.1 Project objectives for the period.

Objectives relevant for the second period were:

- Analysis of the parameters/factors influencing the acceptability and implementation of an automatic packaging system in the food industry
- Analysis of the economic viability of the robotic packaging systems
- Study of the impact (technical, social, etc.) of the robotic system on the food sector

In this period WP12 focussed on the objectives to **complete and have ready the different tools to face the development of the exploitation plans** in an optimal way. Moreover, the objective was also to get a **first preliminary overview of the exploitable units** of the project and their potential. For that reason in this period the inputs of the technological developer partners were required for developing this preliminary picture.

To achieve this general target, the objectives of the different task were the following ones:

- To **finalize the acceptance study**, in order to make the **global interpretation of the results** regarding investing intention and drivers and barriers towards implementation. The purpose of this study was to have the information required to perform a reliable exercise to **find the opportunities and threats of the post-harvest and food industry** towards the implementation of automatic equipment. Thus, the aim was to achieve an updated and reliable tool to help **finding the right strategies for exploitation** of the different modules in the exploitation plans, (i.e. a tool to develop the further SWOT analysis for the exploitable units).

- To **explain to the partners** of the project **the developed tool to simulate the economic viabili**ty of the exploitable units and the way to work with the selection of different scenarios of the food industry and how to get a valuable inputs for the strategy development of the different modules.

- **To develop a tool for the evaluation of the impact of the Picknpack modules** or line on workers welfare in terms of **occupational risk assessment** (impact on the safety and ergonomics of the workplace and of the whole food process line). For that issue a theoretical identification of the efforts and tasks to be done along the line were studied and suggestions for improvement of critical points were described.

- To **define a first overview of the different exploitable units** to be integrated in the line. For each module/unit, problems, solution, description of the technology and benefits of it, TRL and expected IPR was asked in order to start having the whole picture of the project outputs.

2.12.2 Summary of the work progress and achievement during the period

Under the **first task 12.1 the acceptance** study was finalized. Finally, **81 answers** were achieved from different decision makers from the industry. An equilibrated distribution of answers for both target sectors was obtained, 56% post-harvest industry and 44% for the processed food industry. With this information, **a context analysis** of the industry regarding automation and the most important **factors and perceptions (drivers and barriers)** towards implementation was done. Finally, a **cross analysis was** done to correlate the investment intention of the surveyed companies with the different barriers and drivers mentioned. This exercise gave a more reliable and defined view of the **opportunities and threats** appeared in **this industry towards the investment on new automatic equipment**.
Regarding the task **economics 12.2., during this period the explanation and presentation of the developed tool was done to the partners**. The aim was to explain to the partners the mechanism to perform the further analysis of the economic viability in the PicknPack project. The developed tool to simulate economic viability was explained.
Under **task 12.3.societal impact,** the tool for assessing the impact of the PicknPack line in the workers welfare in terms of o**ccupational Risk Prevention (ORP)** was done, focusing mainly on the ergonomic aspects of the manual labor done by the workers. The objective of this period was to define the strategy in order to check the line design, identify and reduce the ergonomics hazards presents in it and minimize their effect on the workers' health. For that issue a theoretical identification of the critical points was

studied and suggestions of improvement were described. Moreover the methodology to follow was defined and explained to the partners.
Concerning **the task 12.4. "Exploitation plans**", a first planning was started. The concept, objectives and exploitation plans description was done to the partners. To have a preliminary overview of the exploitable units, some information was requested for brief description by the technology developer partners. The gathered information was focused on a brief technological description of the technology, strong points and weak points of the modules, benefits or added value of the results, current and expected TRL at the end of the project, owners and possible IPR for the solution and potential flexibility of the solution. All this information was collected and shared with all partners for all to have the overview of the whole project.

2.12.3 Work progress and achievements during the period

Task 12.1. Evaluation of the acceptance of the robotic products in the food packaging sector.

Under the first task the **acceptance study was finalized**. This was accomplished thanks to an important dissemination of the survey via email and by telephone. The surveys obtained were from Netherlands, Italy, Germany, France, Spain and UK. In a fist stage only 35 answers were obtained, even if all partners involved in the project also did efforts for dissemination and contact of different companies for the survey, the main responses were from Spain (country of the partners leading the study) and from post-harvest industry. In order to correct this deviation and to lessen the risk of not getting a balanced distribution of responses in all countries for achieving a reliable study, a new update of the survey was done to simplify it and a subcontracting of professional interviewers was done to obtain a minimum number of answers in the different countries.
Finally the acceptability study was finished and **81 answers** from industry decision makers were achieved. Thanks to this a balanced distribution of answers for both target sector was obtained, **56% post-harvest industry and 44% for the processed food industry**. Thus, an equilibrate study between countries and sectors (post-harvest, and processed food sector) was reached.

Table 1. Structure of the companies surveyed (n=81)

	Distribution of companies	Distribution by sector		Distribution by size		
		Post-harvest	Food (excluded post-harvest)	SME	BIG	Other (cooperative, etc.)
SPAIN	*n=23*; 28%	70%	30%	43%	22%	35%
FRANCE	*n=13*; 16%	46%	54%	77%	0%	23%
UK	*n=6*; 7,5%	0	100%	33%	67%	0%
GERMANY	*n=8*; 10%	13%	88%	50%	0%	50%
NETHERLANDS	*n=25*; 31%	79%	21%	76%	12%	12%
ITALY	*n=6*; 7,5%	50%	50%	100%	0%	0%
TOTAL	***N=81***			***63%***	***15%***	***22%***

With this information, **a context analysis** of the industry regarding automation and the most important **factors and perceptions (drivers and barriers)** towards implementation were analysed. These results were presented to the partners in Manchester *(April 2015)*.

For defining the context, structure of the companies (big, SME, cooperative or others), **type of products**, **number of processed products**, **automation level** of the different sorting attributes, **productive weeks**, **interest on quality sorting** parameters and **problematic issues** on sorting and packaging , among other questions, were asked to the decision makers of the contacted industries. This information gave an updated view of the industry and its current interest and problems regarding automation in sorting and packaging.

Finally, a **cross analysis was** done to correlate the investment intention of the surveyed companies with the different barriers and drivers mentioned. This exercise gave a more reliable and defined view of the **opportunities and threats** appeared in **this industry towards the investment on new automatic equipment** and it gave the possibility of detecting differentiation details between the different perceptions in both sectors.

Table 2. Opportunities and threats (economical and technological) concluded from the study

	OPPORTUNITIES	
	POST HARVEST	FOOD
Economical	1. **IMPROVE THE PROFIT MARGINS** OF THE PRODUCT 2. **SAVING IN LABOUR COST** 3. AVAILABILITY OF **PUBLIC FUNDING** 4. INCREASE PRODUCTION **VOLUME** 5. IMPROVE PRODUCTION **EFFICIENCY** 6. **DIFFERIENTIATE** FROM COMPETITORS	1. **IMPROVE PROFIT MARGINS** OF THE PRODUCT 2. INCREASE PRODUCTION **VOLUME** 3. IMPROVE PRODUCTION **EFFICIENCY** 4. **SAVING IN LABOUR COST**
Technologicals	1. **STANDARIZATION OF THE PRODUCT QUALITY ATTRIBUTES** BY HIGH ACCURACY DETERMINATION OF **EXTERNAL** PROPERTIES (DEFECTS, FOREING MATTERS, COLOR, SIZE) AND **INTERNAL** PROPERTIES (FIRMNESS AND COMPOSITION AFFECTING TO THE ORGANOLEPTIC CHARACTERISTICS) 2. **FLEXIBLE SYSTEMS** FOR IMPROVING THE HANDLING OF THE PRODUCTS TO AVOID QUALITY DETERIORATION 3. **USER FRIENDLY** EQUIPMENT 4. IMPROVE OF THE **FLEXIBILITY OF THE PACKAGING** (MANIPULATION FOR **FILLING, ACCURACY OF WEIGHT, LABELLING, TRAZABILITY**…)	1. BETTER QUALITY **CONTROL OF PARAMETERS** AFFECTING **THE PROCESS EFFICIENCY**, I.E. DOSAGE (SALT AND OIL CONTENT), OR PRODUCT STABILITY/SHELF-LIFE (MICROBIOLOGY, GASSES, PH) OR RISK (FOREING MATTERS) 2. IMPROVE OF THE **FLEXIBILITY OF THE PACKAGING** (MANIPULATION FOR FILLING, ACCURACY OF WEIGHT, LABELLING…) 3. **USER FRIENDLY EQUIPMENT** 4. FLEXIBLE SYSTEMS FOR **IMPROVING THE HANDLING OF THE PRODUCTS (CUTTING, MIXING, ASSEMBLING ETC.)** FOCUSED IN INCREASING THE **SPEED** AND PRODUCTION **VOLUME**

	THREATS	
	POST HARVEST	FOOD
Economical	1. **INVESTMENT COST** 2. MAINTENANCE AND EQUIPMENT UPDATING **COST** 3. **TECHNICAL SERVICE**: COST AND RELIABILITY	1. **INVESTMENT COST** 2. **STRUCTURE AND SIZE OF THE COMPANY** 3. MAINTEANANCE AND EQUIPMENT UPDATING **COST**
Technological	1. TECHNICAL COMPLEXITY OF THE TECHNOLOGIES 2. LACK OF FLEXIBILITY OF THE AUTOMATION WHEN DEALING WITH A LARGE VARIETY OF PRODUCTS OF VERY DIFFERENT CHARCTERISTICS	1. BATCHES/VOLUME NOT LARGE ENOUGH FOR AUTOMATION 2. TECHNICAL SERVICE FAR/UNAVAILABLE

In summary, the present study has investigated the acceptability of innovative automatic systems by the FOOD and POSTHARVEST industry. It has analyzed the investment intention by companies of both sectors and the factors that push them to declare a positive or negative intention. The study has also provided a context to these factors. Thus **the knowledge of the particular and common characteristics of both sectors will orient, in next months, the approaching strategies to design the adequate exploitation plan, for automation suppliers to facilitate a greater implementation in the food industry of today.** The conclusions of the whole study was summarized and shared with the partners *in Manchester project meeting (April 2015)*. The main results will be gathered and redacted as a publication in the following weeks.

Deviation:

Problem: The low success in the response of the survey made the partners and WP leader to dedicate a lot of effort on its dissemination and in contacting companies. The efforts resulted in receiving answers from 30 companies, mainly Spanish and from the post-harvest sector. However, it was considered that this didn't give an equilibrated view of the industry in Europe. The main problem was to obtain responses from other European countries than Spain (mainly non-English speaking countries).

Solution: In order to reduce the risk of not reaching a minimum amount of answers to perform a balanced study, it was decided to carry out an initially not foreseen subcontracting of a professional European interviewer company. For some weeks, a training plan took place including the purpose of the *study, the database to be used, the terms used in the survey and the aim of the different questions in the survey. Thanks to this subcontracting, finally the contribution of 80 companies was obtained, which has been considered adequate for the performance of the whole study.*

Task 12.2. Economics.

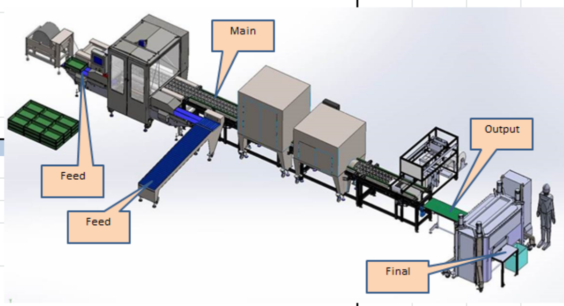
During this period the **explanation and presentation of the developed tool for assessing the economic impact of the PicknPack modules, was done to the partners** (*Iceland project meeting in April 2014*). The aim was to explain to the partners the mechanism to perform the further analysis of the economic viability of the exploitable units in the PicknPack project. The developed tool to simulate economic viability was explained. Moreover the way to work with different scenarios or hypothesis was showed in order to estimate the future return of investment of the potential PicknPack exploitable units.

Task 12.3. Evaluation of the societal impact of robotics systems in the food packaging sector.

Under **task 12.3.societal impact,** the tool for assessing the impact of the PicknPack line in the workers welfare was done in terms of o**ccupational Risk Prevention (ORP) and focused in the ergonomic improvement of the labour work**. For defining and identifying the factors affected by the PicknPack line regarding workers welfare the following actions were carried out:

Data collection: In order to get the more accurate technical information about the different modules and equipment that are part of the PicknPack line, a questionnaire was done and sent to Wageningen UR, TECNALIA and DTI technicians. The inquiries were about measures and distances between objects, heights of working surfaces, weights of the boxes , types of loads and grips, line speed, movements frequency and need for attention to the task.

DATA REQUIRED TO MAKE AN ESTIMATE OF THE MAGNITUDE OF ERGONOMIC RISK OF PACKAGING LINE		
ISSUES	DATA	COMMENTS
RAW MATERIAL FEEDING		
Maximum and minimum heights of raw material crates on pallet	minimum = 120 mm, maximum is unknown, not decided	
Maximum and minimum heights of empty crates on pallet	minimum = 120 mm, maximum is unknown, not decided	
Is there buffer areas in the crates input and output?	Yes	
Type of crates: are the crates foldable?	Not foldable, document is enclosed in email. Fresh food crate: https://eshop.plastibac.eu/en/logistics-industry/euronorm-stacking-containers-coloured/pb-6412-spv Chicken breast crate: https://eshop.plastibac.eu/en/logistics-industry/euronorm-stacking-containers-coloured/pb-6412-scv	
Weight of raw material crates full	max 6 kilo	
FINAL PRODUCT PALLETIZATION		
Is there buffer area in the final product output?	Yes	
Type of trays (size, grips, etc.)	See line 28, same crates will be used	
Weight of the finished product tray full	max 0.75 kilo	
Is there an area or table to put the trays in boxes? - Table height - Table width	No table as of yet, not decided	
Type of boxes: - Boxes size - Open or closed handles?	open handles see line 28	
Weight of the final product boxes empty and full	max 6 kilo	
Maximum and minimum heights of final producto boxes on pallet	Not decided yet	



CASTELLANO | Ergonomics in PnP | VALORACIÓN TAREA 1 ALIMENTACIÓN | VALORACIÓN TAREA 2 FIN DE LÍNEA | VA

Figure 56 Data collection for estimation of ergonomic risks in PnP line

Tasks identification and description: Based on the current design of the line, there were identified three tasks where it was necessary to take into account the human work intervention. One of them was raw material feeding, other was final product palletizing and the last one was general operation control. It was defined that there will be 2 workers in the line, therefore, the general operation control task must be shared between both, so this will increase the need for attention to the line.

Identification of body movements and theoretical magnitude estimation was done, in order to relate them to the most usual/probable ergonomic risks and compare these data with the optimal ergonomic conditions.

Preliminary preventive measures: Although the study was being conducted on the basis of theoretical data, it was recommended some preventive measures that can be done with the information of the preliminary data. For example, using crates with open handles to improve the grip of the boxes, including a buffer area in the inlet conveyor to minimize the dependence of the speed of the line, using auxiliary elements for palletizing, etc.

In addition to the above described, in the following period a guideline will be proposed to follow it when integrating this process line in a real production plant. The activities carried out for the estimation of the ergonomic hazards presents in PnP line were based in the theoretical information of the design of the line because PnP line was not yet built so far, so this estimation will have to be confirmed during the test runs.

Task 12.4. Promoting exploitation of the project results and stimulating new applications.
With regard to task 12.4.- "Exploitation plans", **a first planning was defined**. The concept, objectives and exploitation plans **description and explanation was done to the partners**, in order to give and translate to them the main ideas of this task. The aim was to put in common the different concepts and to make them understand the importance of the plans. Even if still not having, during this period, final results for the different modules, a **first check of the preliminary results** was done. To have this preliminary overview some **information was requested** for brief description by the technology developer partners. The gathered information was focused on a brief **technology description** of the technology, **product specifications**, **strong points and weak points** of the modules, **benefits or added value** of the results, **current and expected TRL** at the end of the project, **owners and possible exploitable channels or IPR** for the solution and **potential flexibility** of the solution. All this information was collected and shared with all partners for all to have the overview of the whole project. This information was also useful to make a workshop during a project meeting, for checking and developing the **flexibility** concept. That is, for defining other potential applications or performances of the modules, which could be assessed, demonstrated or explained to the industry at the end of Picknpack project.

Table 3. Exploitable results developed in the project divided by the respective modules or work package

Traceability	1.	*Traceability System with the capability of M2M inter-module communications*
Cleaning module	*2.*	*Mobile cleaning device*
	3.	*Sectional frames with drainage*
Packaging module	*4.*	*Flexible moulding*
	5.	*Laser sealing*
	6.	*Flexible decoration*
	7.	*Printed Susceptor and reflector*
Robotic module	*8.*	*Robot cell with integrated cleaning system*
	9.	*Cable robot "Pickable"*
Sensor module	*10.*	*Quality assessment module*
	11.	*Microwave sensor application*

After evaluating the inputs from the partners, it was concluded that the level of definition for the different exploitable units at present was very variable, probably due to the lack of the results, differences on the technical progress level and/or lack of common language regarding exploitation. A workshop was decided to carry out in a next project meeting in order to make clear this last point.

At the end of this period ProBio **B3O (Bio-Based Business Opportunity)** project experts contacted the project leader to offer the support in this task. The work package leader of exploitation plans task took over this contact in order to perform the necessary steps to achieve this coaching. A draft submission was requested by B3O project with the preliminary exploitation plans, in order to evaluate the current results and possible coaching for this task. A preliminary draft was send with the general results and with detailed information of the most developed module so far. However, according to the ProBio project contact, the variable progress level of the different modules didn't allow us to send a coherent draft in order to be possible to evaluate it on time for the first submission deadline. Nevertheless AZTI attended the first workshop on "The first thematic FP7 Results Presentation Event by ProBIO" in Brussels, where several exploitation plans of different EU projects were presented, in order to listen and learn how other exploitation plans are being designed and to contact different coaches expert in this field.

During this period three project meetings were hold: In ICELAND (April 2014), in Dresden (October 2014) and in Manchester (April 2015) where the current progress and results of the WP12 were explained and discussed with the rest of the partners.

2.12.4 Use of resources

	Period 1		Period 2	
Cost type	PM	Costs	PM	Costs
Personnel	15.2	€ 126,778	22.4	€ 173,668
Subcontracting				€ 6,190
Other		€ 11,967		€ 7,566
Total		**€ 138,745**		**€ 187,425**

2.12.5 Deviations from the DoW

The work package is running according to the DoW.

3 Project management during the period

3.1 Consortium management tasks and achievements

According to the consortium agreement the coordinator fulfils the following tasks:

- Monitoring compliance by the Parties with their obligations
- Keeping the address list of Members and other contact persons updated and available
- collecting, reviewing to verify consistency and submitting reports and other deliverables (including financial statements and related certifications) to the European Commission
- Transmitting documents and information connected with the Project to and between Sub Project Leaders, as appropriate, and any other Parties concerned
- Administering the financial contribution of the Union and fulfilling the financial tasks described in Article 7.3
- Providing, upon request, the Parties with official copies or originals of documents which are in the sole possession of the Coordinator when such copies or originals are necessary for the Parties to present claims.

The coordinator is on schedule with most of the submission of all deliverables and other tasks. Project meetings are scheduled every 6 months according to the plan. The coordinator has continued a quality check on all deliverables to provide feedback on deliverables and improve the quality of the project. Deliverables are checked by the coordinator and two other Project Board members.

The coordinator started the procedure for scientific and financial reporting and advised all partners where relevant information about financial guidelines can be found, three months before the end of the reporting period. Assistance by Wageningen UR is offered.

3.2 Problems which have occurred and how they were solved

During the second period relevant problems occurred where the coordinator took action to resolve them

1. At the Dresden meeting (M24) it became clear that partners were not heading on the same planning and keeping track on the agreed specification. There were differences in progress. The specification was also divided over several Work Packages. A few major decisions were needed to refocus on the same goals and planning. Also from the IAB advise we scheduled a series of conference call meetings with the project board to achieve a sharpened project document on the goals from the DoW. This document is called The Promise (the promise we need to make towards each other). This is a two A4 document that covers our goal to achieve a working line and to achieve a defined level of flexibility. The promise is agreed upon all partners. Two months after the Dresden meeting.

2. Innospexion replaced Spectroscan due to the bankruptcy of Spectroscan. The acceptance of this amendment took a long time. Innospexion was unable to participate with the required effort. Together with WP4 we made a schedule to the deliver the module later than other modules and ensures the delivery on time to achieve all the objectives of the project. This is according to risk and contingency plan nr. 16.

3. The CO_2 laser was purchased early in the project in order to seal and cut in PP plastic films. Over the last 2 years these PP films has been replaced by APET. Also other risks are involved with the laser: 1. The laser is also the bottleneck in speed (capacity is low) and the laser needs perfect quality of the formed PP-trays, which is not yet achieved in the research phase of the thermoformer. Also a lot of modules are coming together in this part of the line: 1. Sectional

frame, 2. Cross-sectional frame; 3. seal test, 4. Printer and 5. The laser seal and cut. All modules have their own prototype failures and integration is therefore difficult.

To avoid difficult dependencies and risks, the laser will not be part of the line any more. The remaining line will consist the modules and functionality of:

- the thermoformer, bin picking delta robot, QAS module, sectional frames, tracking and tracing devices and antenna's, printer, cross-section. This part will run at the required speed with PET-film to assure that we have an integrated line with a packaging module, robotic module and quality assessment module as agreed in the contract. All modules are connected to the t&t-software and novel line control.
- The laser is moved out of the line and will be demonstrated as a standalone demonstration together with the seal integrity camera system. The seal integrity systems checks the closure of the seal. If the seal shows defects, it will be possible to seal in a second attampt controlled by the seal integrity system.
- Because packages are not closed by the laser also the Pickable robot (cable robot) will be demonstrated as a standalone module. In a video will be explained how all modules coud work together in the future.

Other advantages of this split of the line are:

a. Research on other modules can continue immediately (they were a bit waiting until the whole line was running), because the first part of the line is already connected and tested.
b. Less failures to be expected because of the use of less prototype modules and functions connected to each other (the line will always run on its weakest pint). This will insure a more reliable demonstration.
c. Separate important functions from the line into parts of the line will also provide more focus on the achievements of the individual modules/achievements.
d. Provides full focus on solving the issues with the laser sealer and not sharing the focus with integration and tests of connected modules.
e. It is still possible to do a full software integration between the modules.

This decision was made also on the advice of the Industrial Advisory Board and made on the project meeting in Leuven. This is in line with the risk and contingency plan nr. 1 and 3.

4. Most modules arrived late at Wageningen. Developing and testing of modules took more time because of the novelties that were in it and in most case a few iterations were needed. The whole project followed a tight schedule on research and development of the modules and a long demonstration period with only two demonstration events. This long demonstration period allows the project to shift a little in the planning. After all modules arrived Wageningen we rescheduled all the effort that was needed to achieve good integration steps and a successful demonstration. This is according to the risk and contingency plan nr. 14 in the DoW

5. Timely achievements
After the decision to move the laser out of the line. All other modules could start integration tests in the line. The X-ray module was delayed, but installed and already tested in the line, February 2016. Integration of the X-ray module was not too complex because no moving functions needed to be integrated. It is not expected that the X-ray influences overall objectives of the project. The laser is moved out of the line but will be demonstrated as a standalone module with the capability of sealing and cutting with a laser. This will also not affect the overall objectives of the project.

3.3 Project meetings

Three project meetings were organized during the second period:

1. April 28-30, 2014 Reykjavik (Iceland)
2. October 28-30, 2014 Dresden (Germany)
3. April 21-23, 2015, 2015 Manchester (United Kingdom)

During integration many project members visited Wageningen

3.4 Project planning and status

The project is running according to the DoW. A delay occurred in integration due to later arrival of modules. This is within the risk and contingency plan nr. 14. The demonstration is rescheduled to late May in Wageningen and early September. It is expected that the project can achieve all objectives of the project. A special plan is made for the integration of the X-ray module of WP4. As part of the Risk and contingency plan nr. 16.
Also the cable robot of WP5 is delayed due to technical failures. This is currently handled by the coordinator to achieve a faster integration or another solution.

3.5 Impact of possible deviations

Deviations of the project are within the milestones of the project. Only the robot Pickable is behind schedule which occurred short before the end of the second period. The coordinator will visit Tecnalia at the end of November to find a solution that will meet all objectives of the project.

3.6 Changes in the consortium, if any

3.6.1 Bankruptcy Spectroscan and replacement by Innospexion

After the first period it became clear that a relevant and large partner Spectroscan had to face bakruptcy and could not fulfil any of its tasks. Together with WP leader 4 (KUL) we found a new partner and added the party (InnoSpexion) as a beneficiary to the project. This was part of the first amendment.

3.6.2 Marel ehf and Marel Ltd added as third Parties and establish electronic submission of financial reports

Marel HF transferred work to Marel ehf and Marel Ltd, which are a 100% subsidiaries of Marel HF. Because of the different legal entities Marel HF requested to add Marel ehf and Marel Ltd as a third party.

The coordinator proposed these changes to the Steering Committee. After they agreed the coordinator started the change of the DoW and officially activated the request for amendment to the European Commission. These steps where achieved within the second period.

3.6.3 Changes of positions of Work Package leaders and Project Board members

Project Board member Patrice Guery of Spectroscan is replaced by Jörgen Rheinlander of Innospexion.
Project Board member Richard Seager is replaced by Adalsteinn Viglundsson.