EUROPEAN COMMISSION
Community Research

SEVENTH FRAMEWORK PROGRAMME

PICKNPACK

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

GRANT AGREEMENT Number 311987

3rd periodical scientific report of WP1

Month 37 (October 1st 2015) – Month 48 (September 30st 2016)

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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)	

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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).

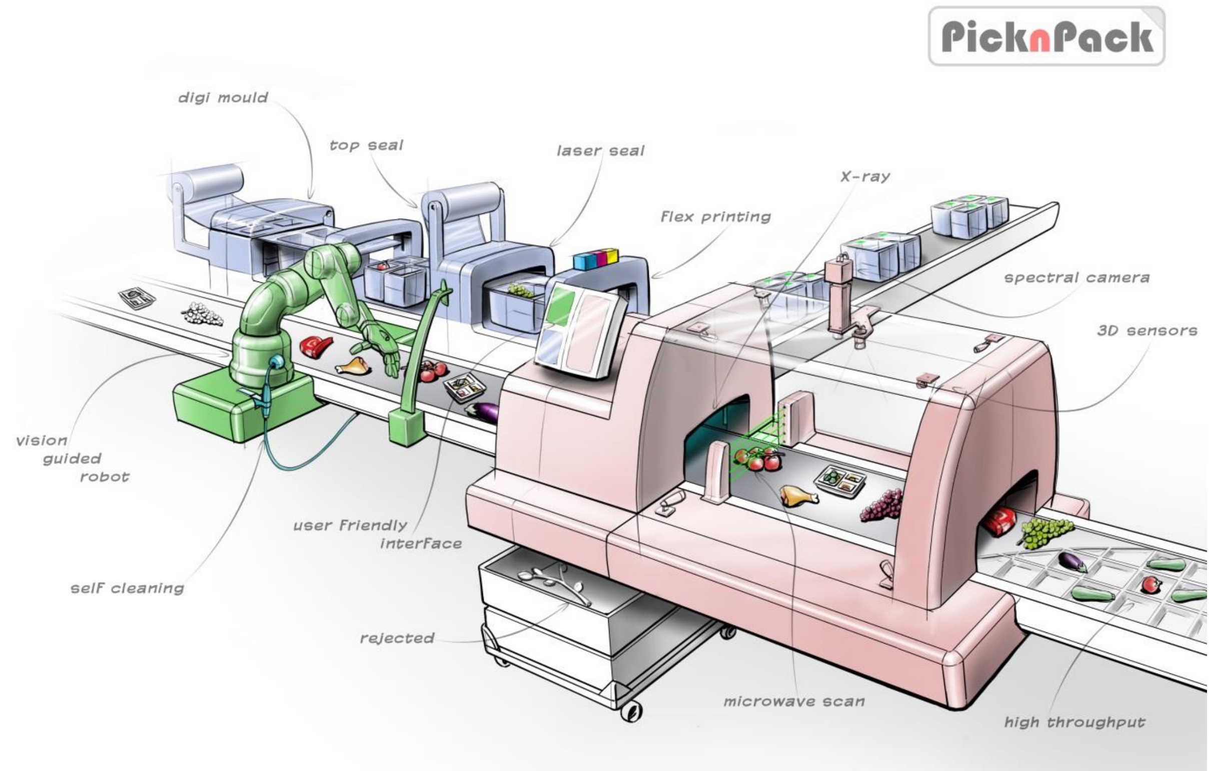


Figure 1 A basic three module adaptive production line

The general objectives are divided in objectives per work package. In the 3rd 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.
- 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 RFID systems and other common product identifiers such as barcodes for upstream food component tracing and downstream product tracking and vendor managed inventory.
- Integration of the database, traceability hardware and the sensing module in WP4 for component-dependent production management and control
- Demonstrate the traceability technology in a production line

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.
- Integration of these systems

WP7 Fresh and processed food production line

- Design of 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

- Monitor and advise on hygienic design aspects for all product contact parts.
- Development 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.
- To demonstrate the sustainability advantages of such automated systems in comparison with current manual operations used for packaging of fresh and processed food products

WP10 Dissemination

- Disseminate the PicknPack results to as many stakeholders as possible
- Maximize the utilisation of the project results by the food packaging industry
- Ensure follow up on results by the industry to create new economic activity
- Patent those results that can enhance the economic impact of the project

WP11 Demonstration

- 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

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
- Ensure exploitation of the project results with committed exploitation plans

2 Work progress and achievements during the period

This chapter covers the third period (from September 30th, 2015 until September 30th, 2016) 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

The use of resources was according to the plan of the last amendment (2015-09-01). There were no significant deviations to the plan.

2.2 WP2 Software Systems Integration

2.2.1 Project objectives for the period

The focus of WP2 during this period (from month 37 until month 48) was on Task 2.3 Modular Graphical User Interfaces (GUI) infrastructure and Task 2.4 Data and information integration. The objectives were respectively to develop a GUI infrastructure which is self-descriptive and vendor or OS independent (Task 2.3) and develop a semantic database and design a communication architecture to distribute the data (Task 2.4).
These tasks have following overall objectives:
provide a structured methodology that is (i) simple enough for all project partners to realise the ambitious integration and flexibility goals in the project, and (ii) generic and powerful enough to be reusable as a general methodology also beyond the scope of this project, in similar large-scale integration projects.
decrease the dependency of system builders on specific vendors, middleware, hardware and software platforms, etc., without compromising on their integration efficiency
the development of customized and configurable workflows and GUIs for each of the stakeholders, but all connected to the same (distributed, noSQL) database of data, models and domain knowledge.

2.2.2 Summary of the work progress and achievement during the period

In the third period the focus was on integration with all the different partners in order to succeed with the demonstration of the Pick-n-Pack line at Wageningen in May 2016 and at Holbeach in September 2016. Additionally, much development effort has gone into the flexible graphical user interface, which was also demonstrated at both events.
The integration with all partners was challenging due to the different hardware and software configurations each partner had running. To facilitate this integration network sockets were used and both a Windows compatible DLL and Linux compatible library were developed and disseminated among module developers. If required, individual workshops were organised to setup the use of the communcation infrastructure. This library encapsulates local discovery on the Pick-n-Pack databus, setup of connections between all modules on the Pick-n-Pack line and a communication mechanism for transferring data or sending queries, both one to one (whispers) and one to many (shouts). In addition, the implementation of the Line Controller, following the models and designs defined in Task 2.1, was completed and successful integration was achieved on time for the demonstrations at Wageningen and Holbeach.
The graphical user interface uses the same communication infrastructure to talk to the line controller or individual modules. This also allows to deploy it anywhere, while still visualising data from different modules in the Pick-n-Pack line. In order to achieve a vendor and operating system independent GUI, a web-based GUI was developed in Javascript and running on MeteorJS, a framework for web applications. For demonstration purposes, several views on the data were developed, both at the line level to highlight messages being passed around, as well as at the module level to display, for instance, the set of labels that needs to be printed or a history of inspected trays. A live version has been deployed on Heroku, a cloud application platform, and is reachable at . It runs both on desktops and mobile devices and integrates data from all modules communicating to the Pick-n-Pack databus. The visualisation framework, that was developed to showcase the Pick-n-Pack data, defines a generic structure in which you are able to display content and define hierarchies. This way it can be used for any other application and is flexible in what you want to display at a particular time and given particular events on the databus.

2.2.3 Work progress and achievements during the period

2.2.3.1 Fulfillment of Task 2.3 objectives

The main objective of Task 2.3 was the **development of a modular graphical user interface** which uses the same database and listens to the same Pick-n-Pack databus as the individual Modules. This was achieved by designing a **flexible web application** running partly on a web server and partly in the client's browser. The motivation for this choice is twofold: firstly, technological advances in the domain of web development have increased tremendously the last five years, especially in the availability of **open-source** javascript frameworks and libraries, improvements with respect to **3D rendering in the browser** with webGL and ways to connect to code or programs running on the server or on the local network. Secondly, and equally important, web developments are vendor and operating system independent and provide the **flexibility** to run on virtually any platform. The **MeteorJS** framework was used to implement the web application and the visualisation is designed in a hierarchical and modular way.

2.2.3.2 Fulfillment of Task 2.4 objectives

The first objective of Task 2.4 was to realise **integration between all project partners** by means of a methodology usable beyond the scope of this project. This was achieved by introducing the network socket communication and accompanying data models. The underpinning methodology is what we defined as the **Mediator Pattern**. This defines a software entity that has knowledge of two or more independent other software entities and couples them through "mediation". As result the other software entities remain decoupled. In the Pick-n-Pack project this is demonstrated both in the way Modules communicate through the **Pick-n-Pack databus** and how the data they communicate is visualised in the flexible graphical user interface. This same pattern is applied **hierarchically**, at line level, module level or device level, keeping the knowledge about data locally but allowing to connect to other peers on the network and share this data. All this data is also saved into the **semantic database** for traceability purposes.

The other objective of Task 2.4 was to **efficiently integrate between partners without having to depend on specific vendors or platforms**. This was achieved by defining network socket interfaces on which data was communicated following custom data models and a communication protocol. This "**Pick-n-Pack language**" was adopted by all partners and resulted in much easier integration. Since we had to cope with integrating software written in many different programming languages and running on different operating systems, not only a network socket interface was chosen, since it enables both legacy software and newly developed software in any programming language to communicate information, but open-source networking library **ZeroMQ** was chosen which offers a message queue interface. On top of ZeroMQ, the open-source project Zyre, offers local discovery and network setup and allows for one to one and one to many messaging. KUL developed a **wrapper library** which can be used to call the specific Zyre functions. This significantly increased the adoption of the communication middleware and sped up the preparation of the Pick-n-Pack line demonstration.

2.2.3.3 Flexible graphical user interface

At the Wageningen workshop in May 2016, we demonstrated **Version 1** of the flexible GUI, which collected data from the different Modules in the Pick-n-Pack Line (by listening on the Pick-n-Pack databus). During the Summer of 2016, this flexible GUI was further improved and new functionality was added, which resulted in the demonstration of **Version 2** at the Holbeach workshop in September 2016.

Demonstrations of both Version 1 and Version 2 with recorded data from the Pick-n-Pack Line have been deployed on Heroku and are available at http://pick-n-pack.herokuapp.com and http://pnp-v2.herokuapp.com respectively.

The **architecture** of the web application is depicted in Figure 2 Architecture of Web applicationFigure 2. This shows how the flexible GUI, running partly on the Web-app server and partly in the browser, receives data from the Pick-n-Pack databus, which uses the "Zyre network". This is done using the **Mediator pattern**, which listens to the databus, converts this data to useable data for the web visualisation and adds this data to the **semantic** realtime database.

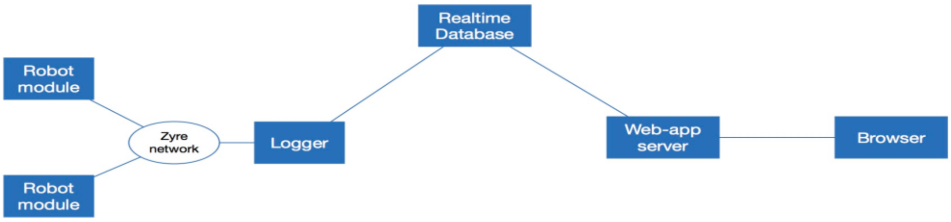


Figure 2 Architecture of Web application

The user interface itself is built in a **modular** way, meaning that it will visualise active Modules on the Pick-n-Pack databus and **dynamically update** events it receives from them through the Mediator.

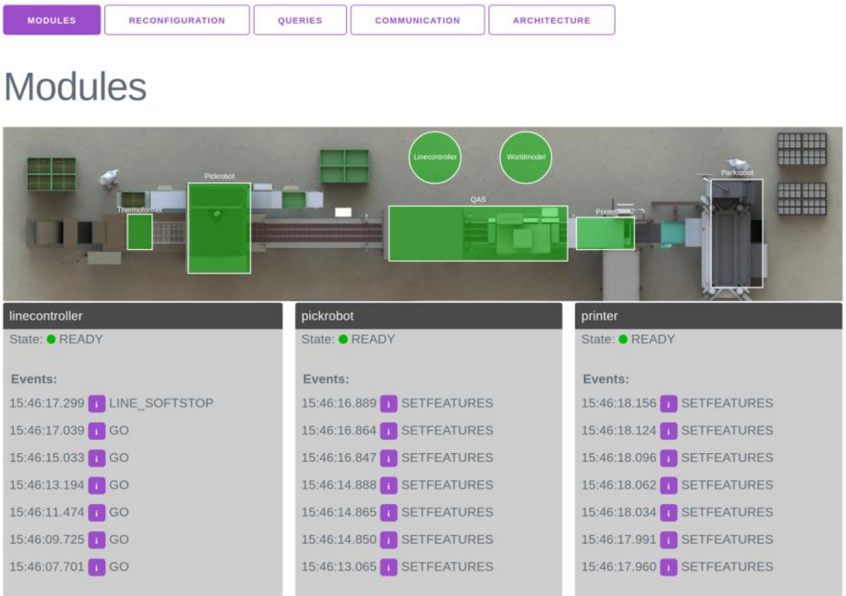


Figure 3 User interface

Figure 3 provides an overview of the active Modules during the Wageningen demo. The status of each Module is visualised by a green (ready) or red (not ready) colour and different messages by the different Modules in the Pick-n-Pack Line are displayed below. You can also see the Line controller sending GO signals to all the Modules.

For demonstration purposes, the Flexible GUI also includes an interface to **reconfigure** the line. This is shown in Figure 4. The visualisation indicates the states of the modules that need to reconfigured, in this case the QAS, and displays the underlying **Life-Cycle State Machine** that each Module implements to achieve this behaviour.

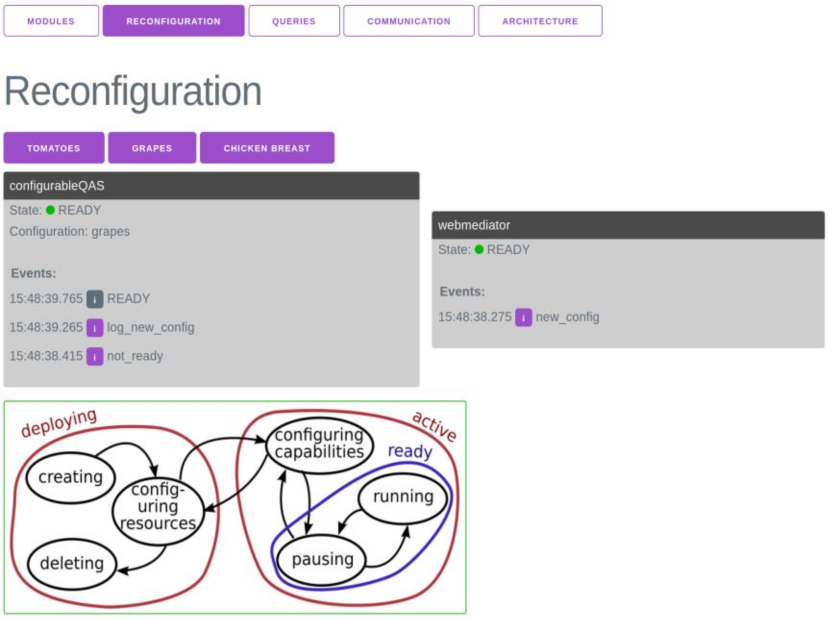


Figure 4 Configuration of the line

In addition, a **Query interface** was made availabe, to query the **semantic database** and visualise statistics on the quality assessment or generate labels for the Printer Module. An example is given in Figure 5.

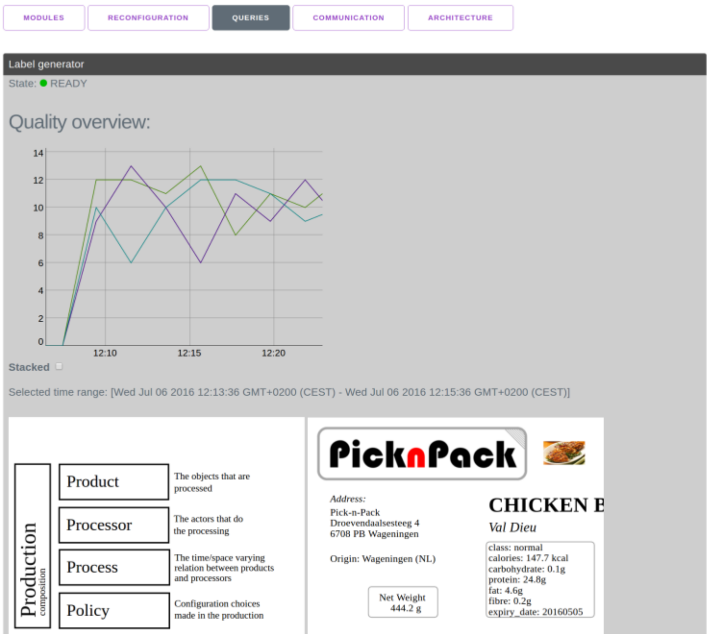


Figure 5 Query interface

In Version 2, the design of the web application was further **modularised** by adding a hierarchy and creating a **generic visualisation framework** which can be reused **independent of Pick-n-Pack**. The same functionality was provided as demonstrated in Version 1, but visualisations where improved and regrouped in an intuitive way. Also an **additional 3D view of analysed tomato trusses** by the QAS Module was developed. Figure 6 demonstrates the modularity of the Flexible GUI Version 2.

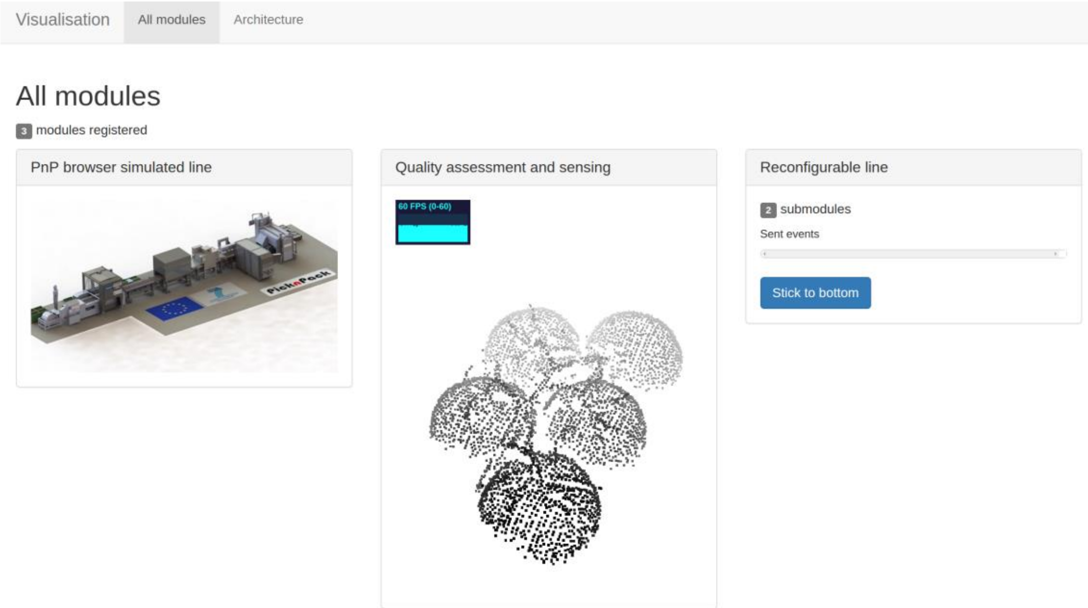


Figure 6 Flexible GUI

2.2.3.4 Mediator pattern and wrapper library

The Mediator pattern was developed to decouple software entities which share data but not necessarily need to be aware of each others knowledge domain. An example is the visualisation of data collected on the Pick-n-Pack databus and visualised in the Flexible GUI. The **Mediator** has **knowledge** about both the agreed data format on the Pick-n-Pack databus and data format used by the visualisation framework.

Another way of mediation was done at the Module level, where internal specific knowledge of the Module developer needed to be converted to comply with the agreed **Pick-n-Pack language**.

Complementary to the Mediator pattern, the Zyre wrapper, developed by KUL, offers the technological solution to Module developers to share data and send events on the Pick-n-Pack databus. More concretely, it provides following functionality:

- int **start**(char* name, char* model_uri);
  This will start a Zyre node and let it listen on the network for other nodes while broadcasting its own ID.
- int **verbose**();
  Switch to verbose mode to print out debug messages.
- int **shout**(char* group, char* message);
  Shout a message to specific group on the network. This equals the one to many communication mode.
- int **whisper**(char* peerid, char* message);
  Whisper a message to a specific peer on the network. This equals the one to one communication mode.
- int **send_msg**(char* message);
  Shout a message to the default Pick-n-Pack group on the network.
- int **stop**();
  This will stop the Zyre node by sending an EXIT message on the network. It will also delete all the allocated memory.
- int **recv_msg**(char * buffer);

This is a blocking message that polls the message queue, while supplying its own buffer. As a result, the buffer will be filled and the size of the message is returned.

- int **register_callback**(MessageCallback messageCallback);
  This registers a callback function to enable non-blocking communication. The callback will be executed whenever a message has been received.

The adoption by all partners of both the Mediator pattern and the Zyre wrapper, or connection to the Pick-n-Pack databus directly, allowed for faster integration and easier data sharing and contributed to a succesfull demonstration of the Pick-n-Pack Line at Wageningen and Holbeach workshops.

2.2.4 Use of resources

The use of resources was according to the plan of the last amendment (2015-09-01). There were no significant deviations to the plan.

2.3 WP3 Information, communication and traceability

2.3.1 Project objectives for the period

The work of this stage focuses on system integration, optimization, and demonstration. The objectives of the RFID based information traceability module of this period are:

(1) To integrate the module with the PicknPack line to perform a comprehensive online and offline product data tracking and tracing, and demonstrate the concept,
(2) To improve the software function, database model, data structure, and communication protocol, and optimize the overall performance of the system,
(3) To prepare for the demonstrations in Wageningen and Holbeach and demonstrate at these two sites.

The work progress and achievements during this period are detailed in the followings sections.

2.3.2 Summary of the work progress and achievement during the period

Progressing from the work in previous two periods, the work during this period is on the system integration, improvement and optimization of the RFID information traceability module. The RFID traceability module can collect the data generated by its own hardware and all other modules in the PicknPack line, and save the data in database for tracing and other further uses.

Firstly, the RFID traceability module is integrated to the PicknPack line with the software architecture and the selected communication protocol. The traceability software is updated so that it can communicate with peer modules using Zyre. With the software, the RFID traceability module can present itself and discover all available machines for communication. It can collect data from all other modules, parse the messages and save the data in database for further uses.

Secondly, a custom-designed database model is finalized for data management of PicknPack line for online and offline data collection and tracing. Focusing on the food manufacturing process, the source material information, online generated product information, and outgoing information are integrated with the identification of input crates, product units, and output crates, etc. Acomprehensive product information traceability software is developed with the RFID technology.

Thirdly, versatile methods for product information tracing technologies are integrated to the RFID traceability module, such as fixed reader and mobile reader for RFID tracing, and video camera for QR code tracing.

Finally, improvement and optimization of the traceability software including GUI design, correct observation of RFID labelled objects, operational efficiency of the software, data structure optimization for machine collaboration, etc.

In the final demonstration, the following functions have been achieved:

- The RFID traceability module can monitor the input crates with raw food materials in place;
- The RFID traceability module can receive, parse, and save in the database all the message information created by peer modules.
- Production information can be traced back with RFID tags and QR code in real-time using both fixed and mobile RFID readers and video camera.

The demonstrations of the module took place in Wagenigen and Holbeach in May 2016 and September 2016 respectively.

2.3.3 Work progress and achievements during the period

The main work of Workpackage 3 during the third period is the final integration and optimization of the RFID traceability module with the new line communication protocol. The module includes the RFID hardware (readers, antennas, computers, tags, applicator, camera, handheld reader) and traceability software (GUI, database, settings, management).

By applying the cross-module communication technology, the online generated data of each module in the line are integrated with a Universal Unique Identity (UUID). Then, the online generated data and pre-registered data can be integrated with the application of RFID. Associated with the custom-designed database model, the data of products at all stages of manufacturing is integrated and stored in database with the RFID traceability module.

2.3.3.1 Integration with PicknPack line

Process modeling and system architecture

Different from other peer modules in the line, the RFID traceability module does not generate data. It consumes data generated by peer modules and builds connections in the database. Therefore, the construction of PicknPack line and production strategy determines the functionality of the traceability software as a module.

The functionality of the traceability module is finalized according to the updated requirements of of the PicknPack line. One RFID antenna is integrated in the 'pickrobot' to monitor the RFID labeled input crates with raw food materials; one RFID antenna is installed after sealing and cutting to monitor the individual product units; one is installed after 'packrobot' to monitor the RFID labeled output crates. A management antenna is used for registration of RFID labeled items or product information tracing. In addition, a handheld RFID reader and a video camera are integrated as an interface for product information tracing. The RFID traceability module as a module in the system is shown in Figure 7.

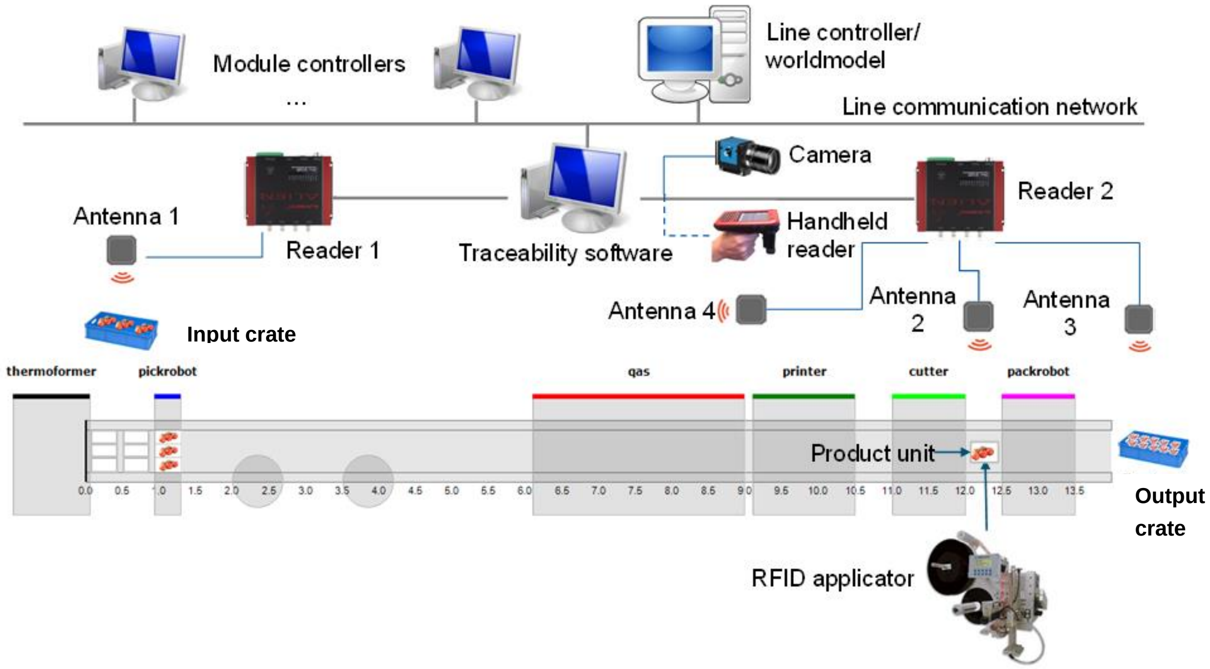


Figure 7 System architecture

Flexible communication for data integration

The communication and data integration are critical issues for an automated digital manufacturing system such as the PicknPack line. The RFID traceability module communicates with the line using Zyre communication protocol. The traceability software can initiate a peer-to-peer(P2P) message and broadcast messages as shown in Figure 8.

There are two essential communication tasks for the traceability software in terms of communication: (1) to identify the current valid RFID labelled input crate and send the RFID to 'pickrobot'; (2) to listen to 'linecontroller/worldmodel' and collect online generated information.

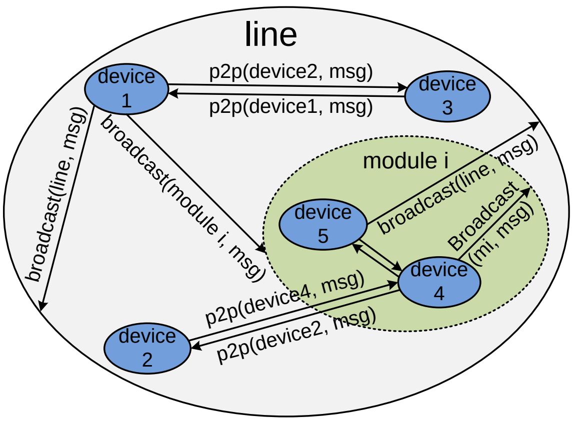


Figure 8 Line communication protocol

Flexible database model and data structure

Since flexible food manufacturing is an objective of the PicknPack line, the traceability module needs to be adapted to different food categories andproduction strategies. This system combines the strengths of relational database and markup language. Both structured data format and variable structure are integrated to achieve flexibilityand data interoperability.

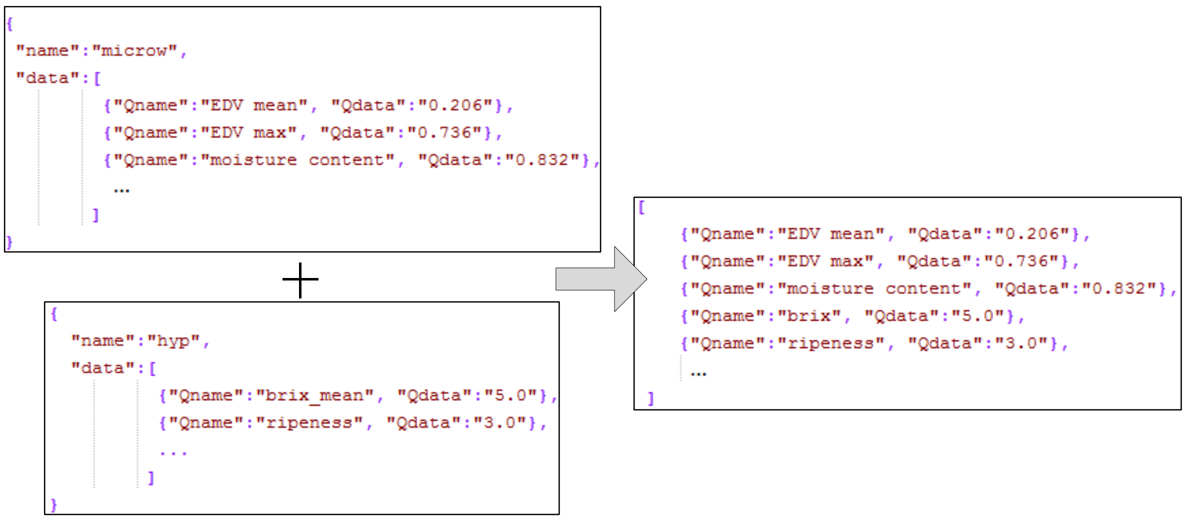


Figure 9 Flexible data structures

As shown in Figure 9, in order to make the system format independent and support dynamic number of features and sensor systems, a JSON array is used to store the parameters. The GUI data presentation is also designed to support dynamic number of parameters.

This open data format has largely enhanced the flexibility in maintenance and update of the traceability module. When new devices are added, the traceability software and database can support the new system as long as the data it created follows the design rules.

2.3.3.2 Improvement and optimization of RFID traceability module

Software functionality and GUI

Software functionality and GUI are improved and optimized according to the progress of line integration. For simplicity and operational efficiency, the layout of interface is designed as shown in Figure 10.

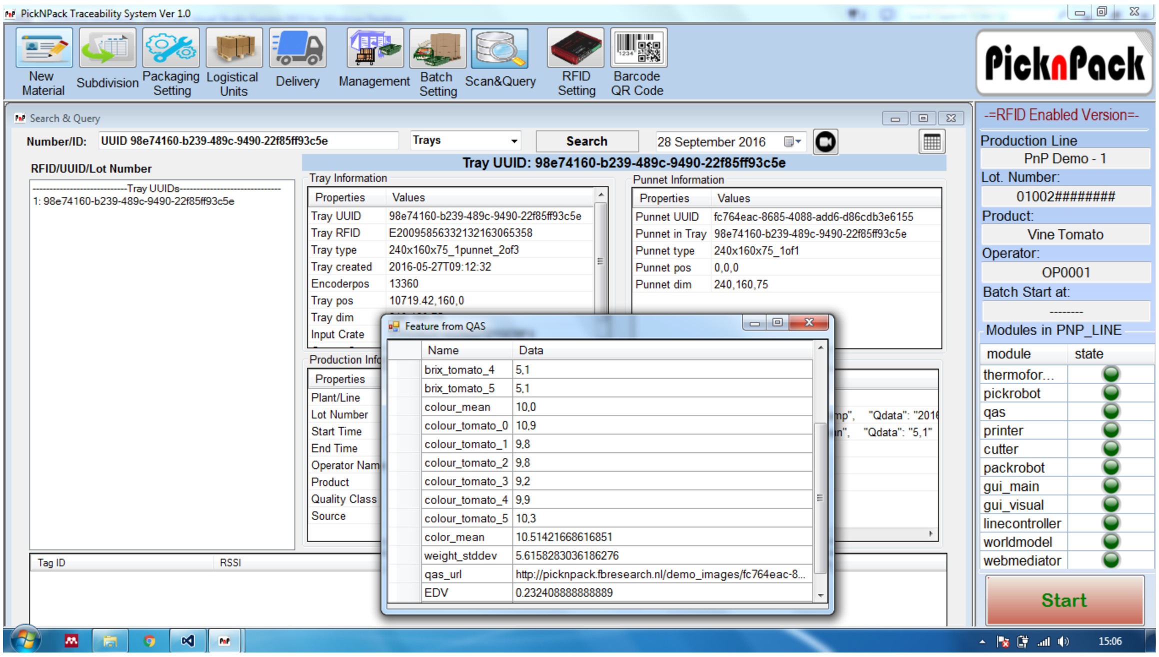


Figure 10 GUI of RFID Traceability module

On the top are the functional buttons, which can navigate to settings, configurations, and individual steps of the food manufacturing process. On the right shows the current running production job batch and states of peer modules in the line. On the bottom-right is the message area, where hardware events and communication with peer modules are displayed, and the detected RFID information is displayed on the left. Then, in the center is the main workspace of configuration, setting, and process functions that are navigated by top area buttons. This GUI design makes the functionality of the system clear to users.

Accurate identification of RFID labeled products

An important task for the RFID traceability module is to observe the current valid input crate and output crate in workspace in order to determine the raw material and where the products go. The RFID system read RFID tags with the backscattering of radio waves. Therefore, it can read RFIDs in all directions within a distance.

In order to identify the current RFID in workspace, this RFID system filters other ambient tags with the Received Signal Strength Indicator (RSSI) of the RFID reading. For example, when a crate moves in the feed in the tunnel from 50 cm away in front to the antenna position (0 cm), and then to the workspace of ‘pickrobot’ which is 50cm away at back, the RSSI increases from a nominal value to its peak value 2.93×10^4 at 0 cm and decreases again. We set the RSSI value to 2.25×10^4 (when the tag is at 10 cm away from the antenna position) as the threshold ‘RSS_TH’. If the received RSSI is greater than ‘RSS_TH’, it means a new input crate passes the tunnel, which will be the next one in workspace of ‘pickrobot’. Those with RSSI less than ‘RSS_TH’ are filtered and ignored by the software. The recognized RFID is considered the current valid one until a new one is found.

With this method, a new input crate can be detected when it goes through the tunnel. The crate can be correctly detected at the correct place and time.

Flexible product information tracing approaches
The product information tracing is an essential task for the RFID traceability module. This system provides four approaches to trace information of a product: (1) Fixed RFID reader/antenna; (2) Video camera for QR coder reading; (3) Handheld device RFID reader; (4) Handheld device QR coder reader.
The system supports information tracing of products during production process and post-production. The handheld RFID/QR code reader with WIFI connection to the database can be used for information tracing anywhere, and information of the tracing product item is displayed on the GUI of the device interface.

The major achievements of the RFID traceability module are on the broadness of data, the customization of database for food manufacturing, and multiple traceability methods. Main features are:

(a) A comprehensive product information traceability module with RFID
The traceability module can perform comprehensive production information traceability with the UUID and RFID. With UUID online generated data by all modules in the line are integrated. Then, RFID integrates the pre-registered information such as raw material information and outgoing information by identifying each product unit with RFID and monitoring the associated input crate and output crate. Therefore, the online generated data and offline registered data are integrated.

(b) Custom-designed database structure for data tracking and tracing of automated food manufacturing
The PicknPack line is a typical automated digital manufacturing system, and data collection is automatically performed during the manufacturing process. The designeddatabase model integrates both the SQL server relational database model and JSON structure to achieve flexibility for data management. Therefore, it is flexible for the multiple food categories, production strategies, and tracing methods.

(c) Multiple traceability methods with RFID and visual techniques
The RFID traceability module provides several product information tracing methods to gain convenience and flexibility for users. Fixed RFID reader and video camera can be used to trace product information, and handheld RFID reader with WIFI connection can be used for information traceability more conveniently without constraint of location.

In summary, the cross-module communication between modules in the line and the application of RFID allows the monitoring of food manufacturing process and data collection. The application of RFID enables the data integration of online generated data and offline registered data, which also provides methods for product information tracing. The objectives of the Workpackage 3 have been achieved.

2.3.4 Use of resources
The use of resources was according to the plan of the last amendment (2015-09-01). There were no significant deviations to the plan.

2.4 WP4 Quality assessment and sensing

2.4.1 Project objectives for the period

The project objectives for the third period of WP4, which concern the **Q**uality **A**ssessment and **S**ensing (QAS) module, center around the integration of the module in the food packaging line as well as the testing and demonstration of the QAS functionality.

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

- D4.7: Upgrade of the X-ray imaging system to provide 3D features based on 2D scanners ready for integration (Month 42)
- D4.10: Report on the performance of the QAS module (Month 42)
- D4.11: X-ray imaging module ready (Month 30, *delayed*)
- M16: Algorithm for product clustering based on combined sensor signals validated on data acquired with the QAS module (Month 36, *delayed*)

2.4.2 Summary of work progress and achievements during the period

In the 3rd period of the project, the focus was laid on the further integration of the two submodules of the **Q**uality **A**ssessment and **S**ensing (QAS) module into the PicknPack line, as well as on the implementation and testing of the desired functionality, leading up to the demonstrations in Wageningen (NL) and Holbeach (UK).

Submodule A (which contains the hyperspectral, RGB, 3D and microwave sensors) was fully integrated into the PicknPack line both in terms of hardware (calibration, safety, data acquisition) as well as software (PicknPack communication protocol, data processing).

Construction of Submodule B, containing the X-ray unit, was completed by InnoS and the module was integrated in the food line. However, due to the late stage of the project in which InnoS could join the consortium as a project partner, full integration with the PicknPack communication protocol could not be realized. So, Submodule B was able to acquire and process data, but could not communicate with the line controller in the same way as Submodule A.

Based on the knowledge gained in the previous stages of the project, a database of food samples (tomato trusses and chicken breasts) was created on the QAS module after which data models were trained to inspect various quality measures of these products. For tomato trusses this concerned for each individual tomato, the assessment of ripeness, shape, weight, brix value, presence of skin damage, presence of internal damage and presence of foreign bodies. For chicken breasts, moisture content, shape, degree of cooking (rawness) and foreign body presence was inspected. Furthermore, as specified by Milestone 16, the quality information from the different sensors was clustered to assign individual products to a quality class. The capabilities of the QAS module as described above were demonstrated in May 2016 during the demonstration days in Wageningen.

Since it was decided by the PicknPack consortium to not integrate and re-assemble the full line for the second demonstration days in Holbeach in September 2016, a new and smaller version of the QAS module was built for the purpose of this demonstration. In this setup, the 3D and hyperspectral sensors were integrated to assess the quality of tomatoes regarding ripeness (color and SSC), weight and shape. Beside this, 'deep learning' was applied to check the products for skin damage (cuts, punctures, bruises). This version of the QAS module ran in cooperation with a simulated version of the line, demonstrating the flexibility of the PicknPack line concept.

2.4.3 Work progress and achievements during the period

As explained in the 2nd periodic report, the **Q**uality **A**ssessment and **S**ensing (QAS) module comprises of two physical submodules: The first submodule (A) was designed and built by KUL and contains a hyperspectral imaging unit (HSI, 600- 1000 nm), a 3D imaging unit, an RGB camera and a microwave line scanner. The second submodule (B) contains an X-ray sensing unit and was constructed by InnoS.

2.4.3.1 Integration of the QAS module in Wageningen

Continuing on the work described in the 2nd periodic report, the integration of the QAS module in the food line at WUR (NL) was completed. In Figure 11 Submodule A and B as mounted in the food packaging line assembled in the food hall in Wageningen. both submodules are shown as mounted in the packaging line. Since InnoS joined the project at a late stage, the delivery and installation of the X-ray submodule was postponed to January 2016. More details on the X-ray setup are described in deliverable reports D4.7 and D4.11.

Figure 11 Submodule A and B as mounted in the food packaging line assembled in the food hall in Wageningen.

In terms of hardware, the integration pertained mostly to implementing and testing the capability of the submodules to work in the stop and creep regime dictated by the line. The ***spatial resolution achieved for each of the sensors at line speed*** is displayed in Table 1.

Table 1 Achieved spatial resolution

	resolution [mm/pixel]	
Sensor	**In direction of motion**	**perpendicular to direction of motion**
HSI	0.4	0.4
RGB	0.25	0.25
3D	1	1
Microwave	2.1	21
X-ray	0.135	0.135

Regarding the software integration, significant effort was spent on ***implementing the flexible PicknPack communication protocol*** which was developed in WP2 based on the *zyre* protocol. This was successfully implemented and tested for submodule A and all of its sensors (see Figure 2). However, due to the late stage at which InnoS joined the project the communication protocol could not be fully implemented on the X-ray unit.

Figure 12 shows the topology of ***the fully integrated QAS module*** which was demonstrated successfully during the demonstration days in Wageningen in May 2016. Each of the sensors is triggered by encoders which record the exact motion of the line. This makes that the scanned area is kept constant independent of the motion speed at the time of acquisition. Incoming data is processed using product information received from the line and relayed to the module controller which interacts with both the sensors and the line controller. More information on the design, assembly and performance of the QAS module and its components can be found in deliverable reports D4.5, D4.6, D4.7 and D4.10.

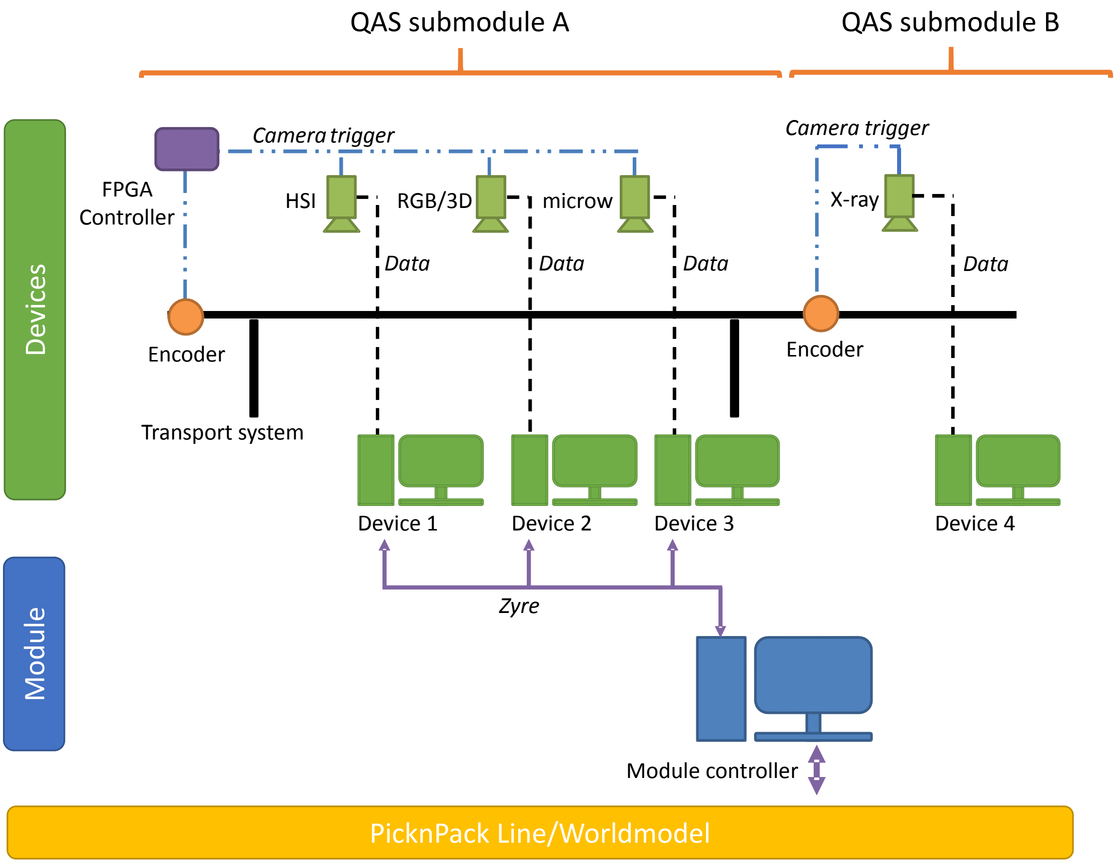


Figure 12 Schematic overview of the QAS module and its component as well as the interactions between the various actors/components.

The algorithms for data processing developed in the first periods of the project were implemented on the QAS module to perform on-line assessment of quality assessment of food products. As an example, Table 2. gives on overview of the most important results achieved for tomato trusses, which were the main product used during the demonstration days in Wageningen and Holbeach.

Table 2 Overview of the performance of the most important data models for tomato trusses.

Quality parameter	r^2	*RMSEC*	*Sensor*	*Unit*
Brix	0,51	0,25	HSI	SSC (°)
Color	0,97	3,01	HSI	Hue (°)
Ripeness	0,95	0,49	RGB	Color class (-)
Weight	0,53	3,9	3D	g

As specified in Milestone 16, the ***quality information from the different sensors was fused*** in the QAS module controller to assign individual products to quality classes which could then be used for printing custom labels and sorting. More information on these data processing algorithms, as well as the data models and processing techniques developed for other products and sensors can be found in deliverable report D4.10.

2.4.3.2 Integration of the QAS module in Holbeach

For the second demonstration event in Holbeach (UK), it was decided by the consortium to demonstrate the modules as stand-alone machines and not fully integrate the hardware of the line again. To be able to demonstrate the QAS related capabilities without integration with the thermoformer, it was decided to

build a ***smaller version of the QAS module*** which used a small conveyor to transport samples instead of relying on the sectional frame system loaded with a web of packages (Figure 13). In this smaller module, only the HSI and 3D sensors were used to the food products. The hyperspectral imaging setup was equipped with ***polarizing lenses to remove specular reflections*** (gloss) from the measured samples. As in the previous demo, the soluble solids content, ripeness and weight of the tomatoes in a truss were successfully assessed on-line. Again, the quality features were fused to assign the truss to user-specified quality classes. As a new feature, ***a deep learning algorithm*** was developed and implemented by WUR to inspect the tomatoes for surface damage based on the recorded HSI data.
To demonstrate the flexibility and (software) integration of the PicknPack line, the new QAS module ran successfully in concordance with a simulated version of the entire line.

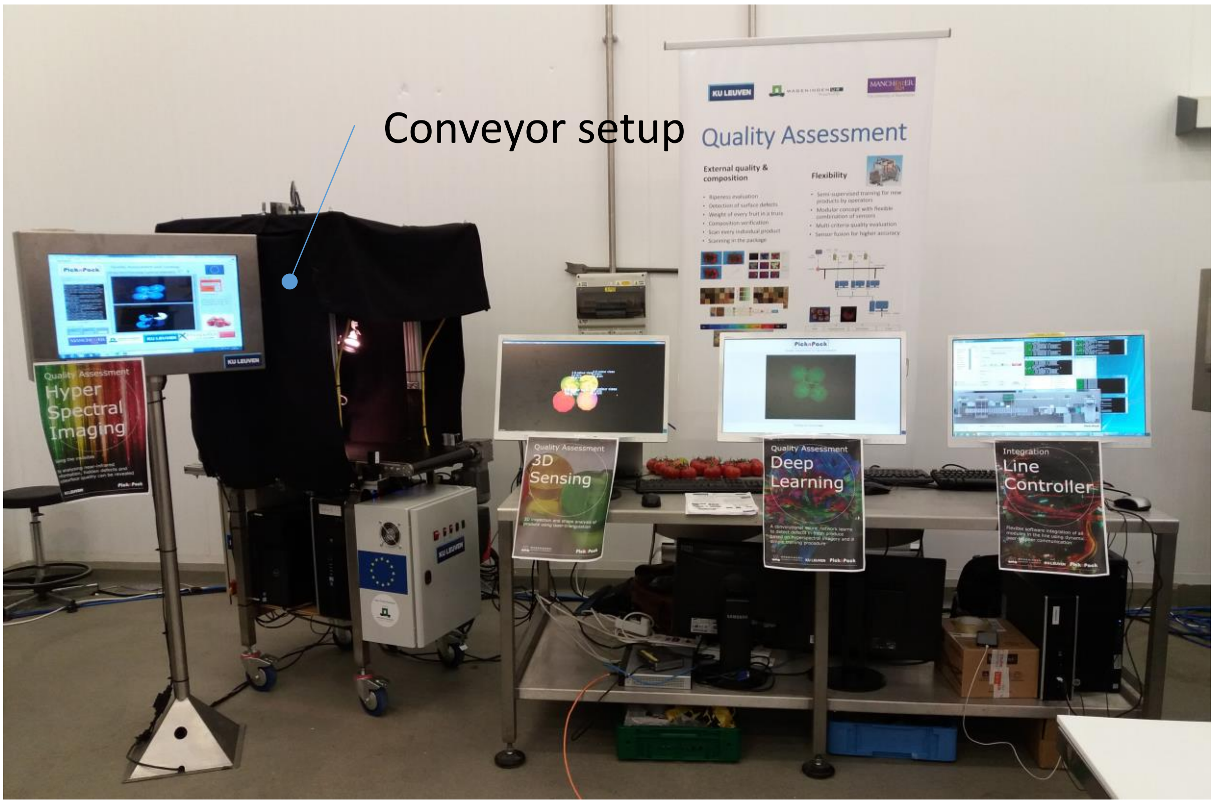


Figure 13 QAS setup, as demonstrated during the Holbeach demonstrations days. The conveyor setup contains the HSI and 3D sensors that are shielded from ambient illumination. The various screens surrounding the module display various aspects of the QAS module.

2.4.3.3 Overview of technological progress

Table 3 lists the most important (technological) results achieved in WP4 over the course of the project. For each result, the Technology Readiness Level (TRL) at the start and the end of the project is mentioned.

Table 3. Overview of technological results achieved in WP4 over the course of the project.

Results	TRL[1]		Partner(s) responsible	Relevant deliverables
	Initial	Final		
Contactless estimation of the weight of individual tomatoes in a truss	2	6	WUR	D4.9, D4.10
Automated ripeness assessment of individual tomatoes in a truss	2	6	KUL, WUR	D4.10
Detection of product anomalies based on spectral fingerprints of sound and defect tissues (via PCA models and via deep learning)	2	5	KUL, WUR	D4.8, D4.10
2.5D X-ray imaging to assess the internal 3D structure of products	1	5	InnoS, KUL	D4.6, D4.7, D4.10, D4.11
Automated inspection of ready meal (components) based on color/texture/distribution	2	4	WUR	D4.8, D4.10
Microwave line scanning to assess the distribution of water and the food composition inside a product	2	5	MU	D4.10
Sub-mm hyperspectral imaging at line speeds up to 25 cm/s	2	5	KUL	D4.4, D4.10
Intuitive semi-supervised algorithm for segmentation of hyperspectral image data	1	4	KUL	D4.8, D4.10
Illumination system with polarizing filters to eliminate specular reflections	1	6	KUL	
Clustering of quality features originating from multiple sensors to determine new quality features	2	6	KUL, WUR, MU	D4.10

[1]TRL, Technology Readiness Level:

TRL1: Basic principles observed and reported
TRL2: Technology concept formulated
TRL3: Experimental proof of concept
TRL4: Technology validated in the lab
TRL5: Technology validated in a relevant environment
TRL6: Technology demonstrated in a relevant environment

2.4.4 Use of resources

The use of resources was according to the plan of the last amendment (2015-09-01). There were no significant deviations to the plan.

2.5 WP5 Robotic product handling

2.5.1 Project objectives for the period

Looking at the general planning on the DOW, tasks for WP5 should have finished at September 30th, 2015. Whereas it was explained on the second period scientific report that, due to the complexity of the work, some of the tasks were still in progress. It can be here confirmed that **during this 3rd and final period, all the technical tasks have been finished** so as to fulfill general **objectives** proposed for WP5 (listed below). Those objectives were:

- 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

Technically, this handling module was formed by two robots, called cable-robot (Pickable) and delta-robot, the former at the end of the line and the latter at the beginning. For a better understanding, all the comments and explanations on this document will refer to those two submodules.

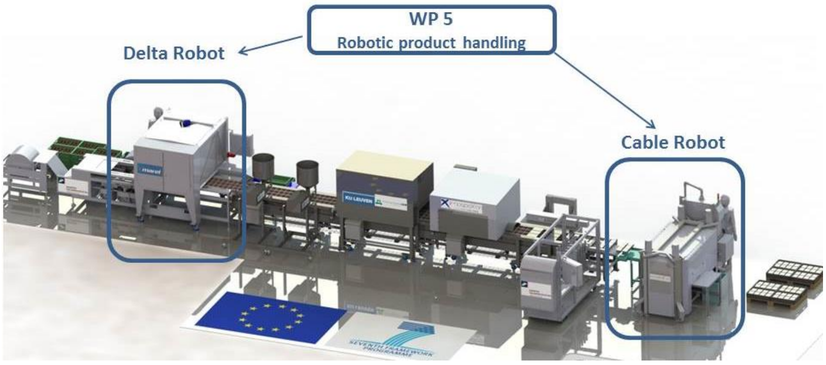


Figure 14 Graphical representation of WP5 in the Picknpack line

2.5.2 Summary of the work progress and achievement during the period

A summary of progress towards objectives and tasks is listed below:

- During the third period all the WP5 objectives have been achieved.
- There has been some delay from previous planning. WP5 should have finished at the end of previous period.
- Due to the difficulty of the developments there have been over costs for some of the tasks in comparison with the proposed budget.
- Objective 1. Development of a handling module: Instead of one handling module, two have been finally integrated during this period. Tecnalia has set up (patented PCT-EP2014-078932) an innovative robot (cable-robot) and Marel, DLO and Lacquey have set up a delta robot.
- Objective 1. Fulfilling the requirements of the sector: It was done in previous periods. Regarding safety both robots have been designed in agreement with the machinery directive. Regarding hygiene, Fraunhofer reviewed all the designs and has indicated guidelines so as to consider hygienic requirements in the developments.
- Objective 2. Development of end-effectors. Lacquey has setup the final version of the grippers so as to grasp the foodstuff products (grapes and vine tomato)
- Objective 3. Reprogramming method. For cable-robot Tecnalia has implemented two main functionalities regarding this issue. One machine vision system allocates packages on the conveyor belt so as to grasp them in a flexible way. Also a middleware system, as the rest of the modules, has been implemented for flexible communication among all the modules of the Picknpack line regarding the guidelines leaded by WP2. For the delta-robot DLO has also set up a machine vision system that allows switching between products by taking into account a description of the food products, the

gripper and the grasping process. Doing so makes it relatively easy to adapt the system to other varieties of the food products and to switch between grippers. The robot is also flexible to placing the products in different designs of the web of trays. The 3D camera system interfaces with the robot using internet protocols and Marel developed methods for the flexible interfacing of the complete robot system with the rest of the line.

2.5.3 Work progress and achievements during the period

As introduced before, current chapter will be divided in two main parts, one for every robotic submodule.

2.5.3.1 Progress and achievement for Cable-robot

As a summary of progress, it can be said that during the last 12 months of the project, all the challenges for Pickable (colloquial name for the cable-robot) were successfully achieved. On the previous period report, it was noticed that the task 'Development and testing of the robotic module on food products' was still on progress. Now it has been successfully finished, and following progress is remarked. Additional information can be found on deliverable 5.4 'D5.4– Report of robot performance in production line':

- The failures in the motion control hardware were solved. A multidisciplinary team (control engineers, electronic engineers, developers) from different departments joined a task force team including an extra external assistance of the electronics manufacturer (ETEL) from Switzerland and all the failures were solved. Some protection peripherals were added to the design of the electronics of Pickable to avoid any further damage.

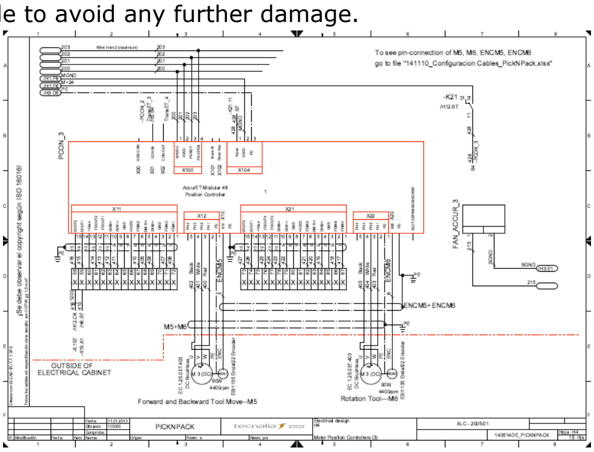


Figure 15 Update of the electronic design for solving HW failures

- The robot was finally assembled, tested and demonstrated together with the rest of the PicknPack line in Wageningen. The performance of the robot can be seen both in the video of the global line and in a particular video of Pickable. Apart from the manipulator, all its SW functions, communication with the line and Graphic user interface were tested.
    - Global video: https://www.youtube.com/watch?v=W-ZGoUbiCOI
    - Pickable video: https://www.youtube.com/watch?v=FXxco-LRgrg

Figure 16 Pickable in Wageningen and Tecnalia during tests and demonstration phases

The process of designing and manufacturing a complete novel robot has been extremely risky and some deviations from Annex I happened. This has produced a considerable impact on available resources and planning, which have been especially critical during the last period, in the way showed on following list:

- Failure in the motion Electronics system: Two power sources, one I/O card and one driver burnt. This specific electronics chosen to carry out a torque control of the robot, showed a weaker performance than desired for the project requirements. This situation produced a delay at the end of 2015 which was recovery at the beginning of 2016. There were extra costs for Tecnalia for replacing those parts and also customs duties because the supplier was in Switzerland
- Assistance of the supplier staff from Switzerland to Tecnalia. Due to work together with the team of Tecnalia and identify the origin of the trouble.
- Addition of a computer vision system not included on the DOW. The consortium encouraged Tecnalia to include a computer vision system in Pickable to improve the process of grasping the trays. Decision taken once the design of Pickable and part of its construction was finished. This produced an overcost (I/O card, camera, lens, lighting, PC, etc.) for Tecnalia not considered on the DOW.
- The overcosts for Tecnalia have been of about 7 PM in WP5, 9k€ in other direct costs, 16K€ in travels and 60K€ in consumables.

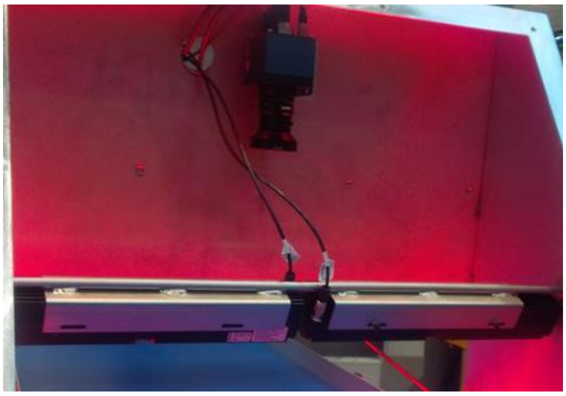


Figure 17 Additional machine vision system included in Pickable

Finally, the most significant results during this period are listed below.

- A complete innovative robot concept has been built and tested. It goes one step before the state of the art as certifies its patent (PCT/EP2014/078932) and no previous robots with all the characteristics of this one were previously developed.

- Regarding SW and communications:
    - Direct connection to the PnP line, without not changes needed, as long as the subnet accomplishes the Zyre based network requirements: UDP and broadcast allowed, and port 5760 opened. Flexible line configuration changes implemented by Cable Robot in realtime thanks to world data model reception, parse and process. Cable Robot data shipment to the Line in order to be shown in general line GUI.

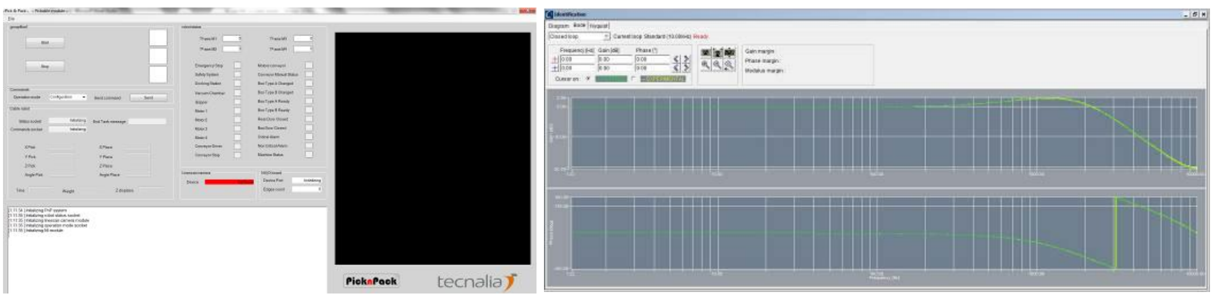


Figure 18 GUI for Pickable and performance of motor after and before tunning

- Regarding kinematics all the tune of the motors was achieved and the designed control model performed correctly.

2.5.3.2 Progress and achievement for delta-robot

In the third period the pick-and-place robot module was fully built up and integrated in the PicknPack line. The complete system consists of the following components in the order as they appear during processing:

- Reading of the RFID tags on the harvest crates for tracking and tracing
- Automatic transportation of crates with foodstuff into the robot cell
- Detection of the crate and of the products in the crates by the 3D+colour vision system
- Planning of grasping actions to get the products out of the crates and into the trays
- Weighing of the grasped product
- Transportation of empty crates out of the robot cell
- Flexible software integration and synchronization with the rest of the line by means of p2p internet protocols as developed in WP2
- Integration with the cleaning robot for automatic cleaning of the robot cell

In the following, a short description of the achievements of all three objectives is given, followed by a description of the performance in the line:

Development of a food product handling module that is flexible and fulfils the criteria of the food industry regarding hygiene, economy and safety
The hardware of the delta robot is largely based on a system that Marel sells to the industry and which is completely up to the standards of the food industry regarding hygiene, safety and economy. Added components meet the same standards. The grippers developed by Lacquey have been thoroughly examined on hygiene by Fraunhofer. Improvements have been made to full fill the necessary standards, which are high, as the grippers are in contact with the food. The vision system consists of off-the-shelve components and are housed in an enclosed vision box for hygienic reasons and for cleanability. All components meet stadards of safety and economy.

Development of end-effectors that allow handling of a large variety of (non-uniform, delicate) food products
In the first and second period, two end effectors have been developed by Lacquey, one for grasping vine tomato and grapes and one for grasping chicken filet. In this period, the fresh-produce gripper has been further developed with different fingertips which can easily be placed on and off the gripper to deal with variation in produce shape between different products and cultivars. Results of grasping are detailed below.

Development of a reprogramming method that allows fast change-overs to other products by non-specialized workers
Physically, quick change over is facilitated by a quick gripper-release system, allowing switches under 1 minute. Change over to other products software-wise can be done on the fly. To allow flexible switching to other products, the vision and control software uses parameters files which describe parameters of the products, the gripper and the grasping process. By putting the software in a (re-)configuration state, the required new information can be loaded and the system can be brought into running state again once the line is ready.

Performance in the line – Quantitative analysis
A quantitative and a qualitative analysis of the performance of the module in the line has been reported in deliverable D7.5. In this section, we give a conclusion of these analyses. For a more detailed description, we refer to D7.5.
Software communication: Internal communication between vision system and robot works reliably, as well as the communication of the module with the line. Flexibility with respect to the layout of the web of trays should be improved and a check if the right gripper is mounted should be included.
Grasping: The vine-tomato and the chicken filets are grasped and removed from the crates successfully when there is sufficient space around the products. The dragging action to move product to empty space when they are touching does not work well enough, as too many products are damaged in the process. The range of shapes, sizes and weights with which the grippers can work needs to be improved in order to

be able to deal with other cultivars. Grasping table grapes showed to be too difficult because of the deformability of the product.

Vision: The vision methods to determine grasping actions for vine tomatoes of different colours both non-touching and touching works well. Also for non-touching chicken filet and grapes, the methods are robust. For touching filets, the methods need further improvement to correctly segment all pieces. Entangles grapes are too difficult to ever be able to correctly detect with vision. Detection of the position of the crate is robust.

Speed: Total average time for filling a tray with vine-tomato, including transport is 4 seconds. For chicken filets, this is 3.5 seconds. This is not yet up to desired 30 picks per second. Most of the time is spend on the mechanical actions of grasping, transportation and releasing. The robot can move much faster. However, no experiments have been done to test what the effects on higher accelerations are on the product and the stability of the product in the gripper.

Shelf-life experiment

Fruits and vegetables are sensitive to all forms of handling. Touching or picking up a fruit or vegetable is already enough to trigger a number of biochemical reactions which will influence the product quality further in the chain. The effects of packaging fresh produce with a robot versus human handling have been tested in a shelf-life experiment.

A total of 80 bunches of vine tomato were used (cultivar: Roterno, grower: AC. Hartman). 40 bunches were placed in polypropylene trays by the robot and 40 by a human being. Bunches were randomly selected for robotic handling. The product was then stored at 18°C and 80% relative humidity. Different quality parameters were measured at the start (day 0) and after 3, 6, and 10 days of storage. At every measurement, 5 robot-handled and 5 human-handled products were tested. The products were tested on rot/decay, appearance stem/calyx, mould, damage, firmness, and weight loss.

The results, shown in Figure 19, and Figure 20, indicate that there is no significant difference in the development of firmness, quality of stem/calyx, rot/decay and weight loss between robot handling and human handling. Moulds were not present at all. Figure 21 shows that the robot handling does cause mild damages (dents) on the tomato skin. These dents do not influence the quality of the vine tomatoes. However, for appearance and customer satisfaction, this is an issue.

The finger tips are currently of hard plastic, causing the dents. By applying a softer material, such as silicon, the mild damages can be prevented.

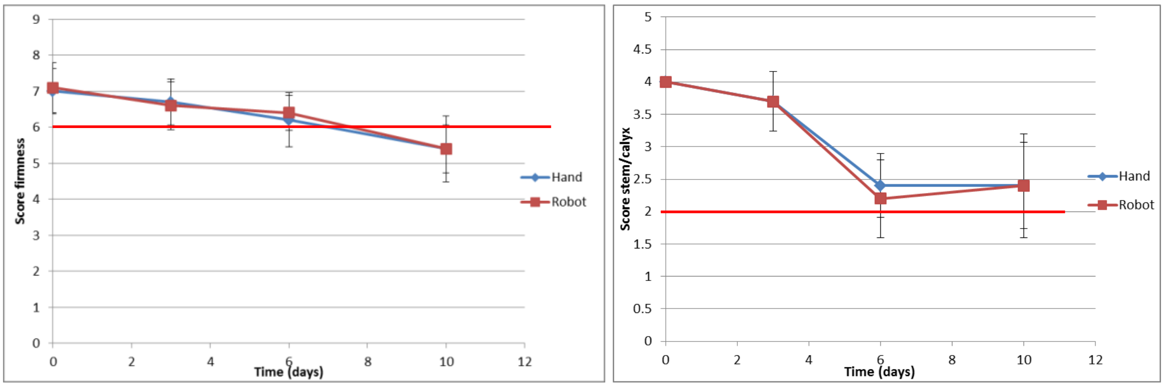
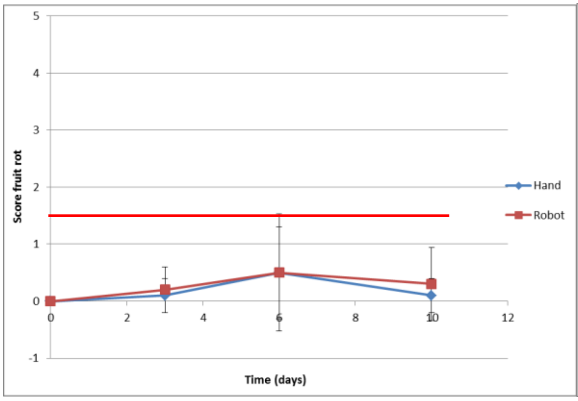


Figure 19: Left: Firmness on a level from 0 (very soft) to 9 (very firm). Right: stem/calyx appearance on a level of 0 (bad) to 5 (excellent). The red line indicates the acceptation limit.



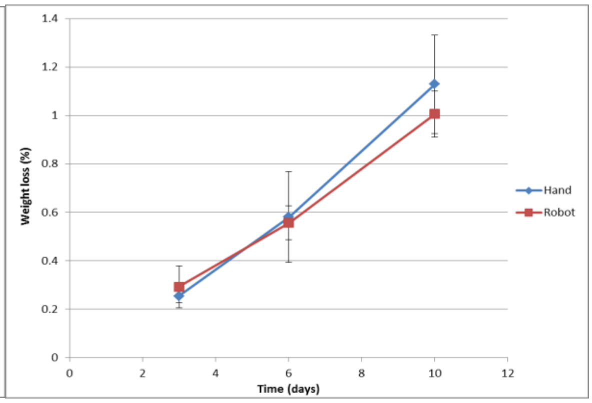


Figure 20: Left: Rot/decay on a level of 0 (no) to 5 (50% or more rotten/mould growth). Right: Weight loss in percentage

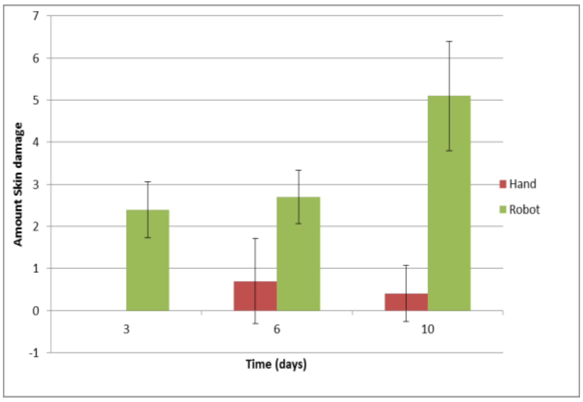


Figure 21: Left: Amount of mild skin damage on the tomatoes. Right: The fingers of the gripper cause mild skin damage.

2.5.4 Use of resources

The use of resources was according to the plan of the last amendment (2015-09-01). There were no significant deviations to the plan.

2.6 WP6 Adaptive packaging

2.6.1 Project objectives for the period

WP6 had following three deliverables in the second and third 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). But the packaging line was upgraded several times in the 3rd period.

2.6.2 Summary of the work progress and achievement during the period

The work of WP6 was almost ready in M36. Already in M36 the thermoformer and flexible mould system produced trays. The printer, the flexible heating system and integrity system did also work. The flexible sealing and cutting system was first done in the 3rd period. WP6 had serious problems purchasing 100% PP films as planned because these kind of packaging films was not produced more. WP6 had to replace the PP film with a PET-PE film. This made it impossible to build the PicknPack line together because the sealing and cutting system only can work with PP. The WP6 tasks was not completed with a full integration for this reason.

2.6.3 Work progress and achievements during the period

2.6.3.1 Digital Mould

Figure 22 ***Photo of the integrated adaptive packaging line with brick moulds***

PicknPack has developed several flexible and digital mould systems. A pin mould system with many small pins that together create a mould can change shape all the time and make each pack different. Moulds can be produced by rapid prototyping can create moulds very fast. PicknPack ended up using a brick mould system because this technology fit best to the food and packaging industry. The advantage with the brick mould system is that worker unskilled in computing can create and produce new moulds in seconds just as assembling LEGO. These moulds can automatic be digitalised and digitalised data can be used all over the flexible packaging line. Only 3 types of bricks are needed to each packaging height plus an extra for unused area. In case of four different heights all needed packaging sizes can be created using only 13 different kind of bricks. As in LEGO many special bricks can be added to the system in order to create logos, round or oval shaped packaging.

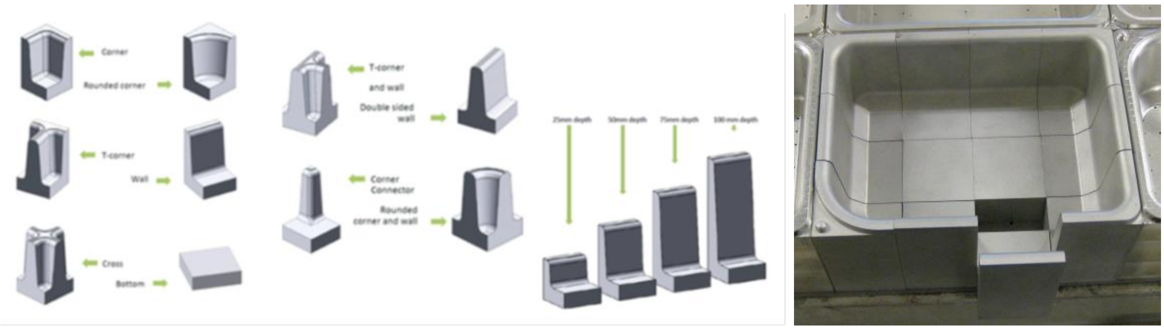


Figure 23 *Brick mould system*

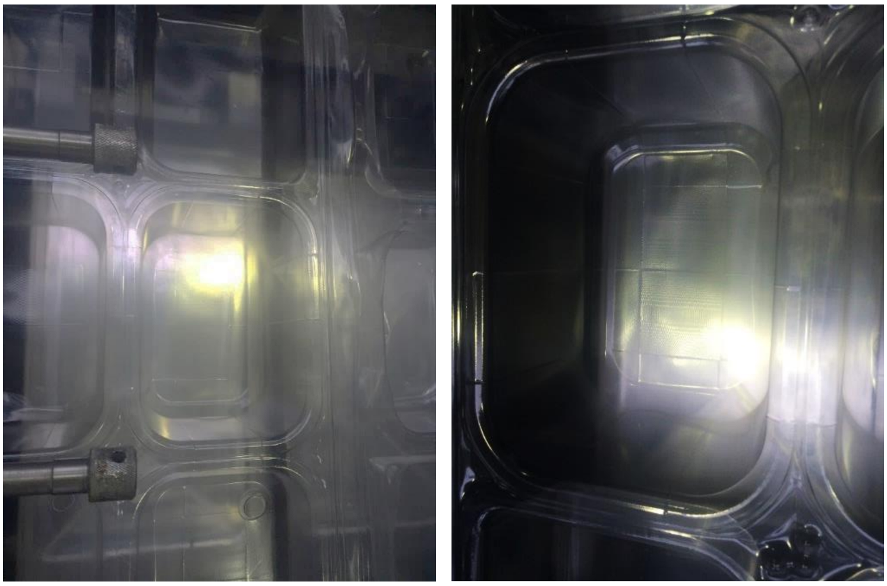


Figure 24 *Plastic trays made from the brick mould system*

The thermoformer was also equipped with an automatic exchange system. The moulds are placed on a placed on a plate with the same foot print as the forming chamber of the thermoformer. Several of these mould plates are stored in the automatic exchange system. After designing and producing the moulds on the plates these are slided into the thermoformer. An automated system moves the mould plates into form chamber in seconds. This movement shall best be performed as the film is moved from one position to another. This can make each packaging different to any needs.

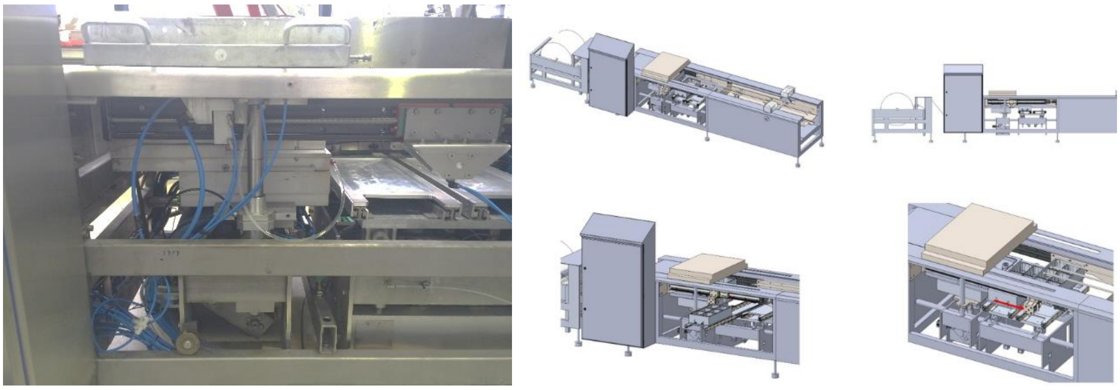


Figure 25 *The flexible mould shift system in Wageningen*

In the demonstrations both the brick mould and exchange systems documented. The other two moulding system was demonstrated off-line.

2.6.3.2 Flexible sealing and cutting

PicknPack has selected laser cutting and sealing in order to seal the top and bottom plastic films together to one packaging. The same lased was used to each individual packaging out from the long web with filled trays. This system work flexible as the laser beam is controlled by a mirror and a scanner to focus the beam over the packaging films. PicknPack was able to control the process. But PicknPack had problems to integrate the laser system to the total line. The problem was that type of laser need to be adapted to the type of polymer used in the packaging. PicknPack purchased early in the project a laser for PP plastic because this was a normal material when PicknPack started. Over the last few years a price drop in PET has out competed PP totally from the market. It was impossible to find PP to use for the demonstration.

Figure 26 ***Laser equipment together with printer and cross section.***

The advantage using laser is that the laser can seal and cut any shape created in the design process. The laser can also create small perforations in the packaging film to be used for eMAP in packaging of fruits and vegetables.

2.6.3.3 Flexible heating

PicknPack also developed a microwave active printing layer to be printed on the top film of the packaging. The print was done with current ink printed in different patterns on the top film. The current layer works as shielding in the microwave own. Printed in specific patterns the energy can be directed into the food components needed to be heated and also shield other components from the energy. In this way it is possible to control the heating process of ready meals with different food components. The technology can also remove all problems about hot and cold spots in microwave heating.

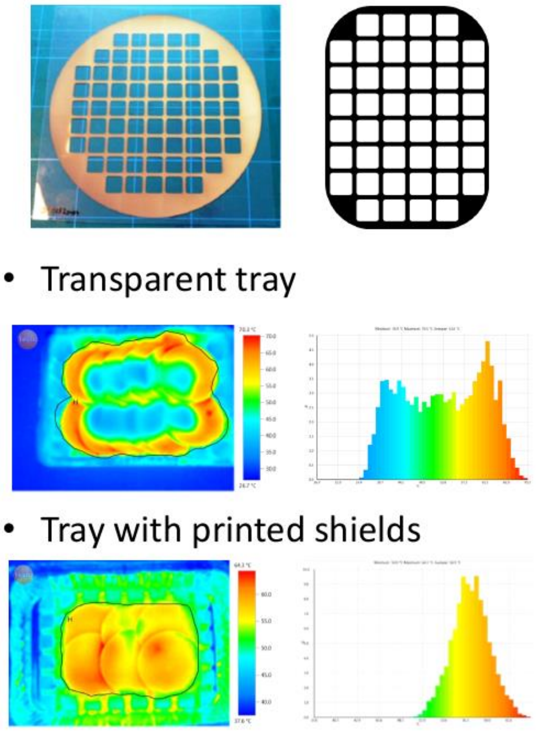


Figure 27 *Printed pattern can distribute heat correct.*

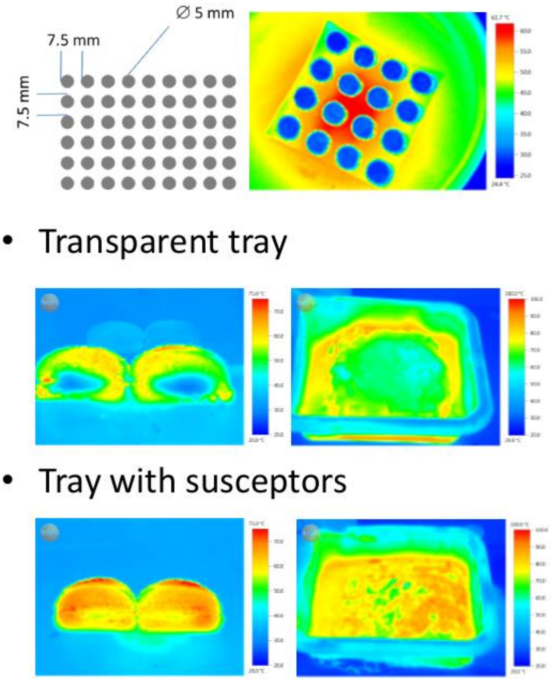


Figure 28 *Printed dots create a susceptor surface heating*

PicknPack also developed a technology to print susceptors using the same print. PicknPack made many small dots of the same shielding ink. The result was a susceptor absorbing the energy and heating up the packaging. This technology can only be used for packaging materials able to operate under high temperatures as CPET or paper.

2.6.3.4 Flexible decoration

Figure 29 *Printer build together with the laser welding and cutting*

PicknPack designed a flexible decoration system based on ink-jet technology. Ink was sprayed on the packaging in 360 dpi resolution. Each colour need a line of print heads. The flexible printer receives files from the central control system and print the package just before sealing the pack. The food and packaging industry has been very interested in this flexible printing technology because shifting decorations creates many shifts on the packaging lines. Also the delivery of printed films to the industry is a practical daily challenge as the lead time will be increased with 1-4 months. PicknPack demonstrated the flexible printing technology in two colours. The system has room for full five to six colours.

Figure 30 ***Prints with different text and decoration able to be printed flexible on the top film.***

2.6.3.5 Integrity checking

PicknPack has developed a flexible integrity system using near infrared imaging technology. An IR camera was mounted over the area for welding and cutting the packaging out of the web. The system can audit all packaging to secure full integrity of each pack. If a pack has problems the integrity system can send a message to the welding laser to upgrade the welding in specific areas.

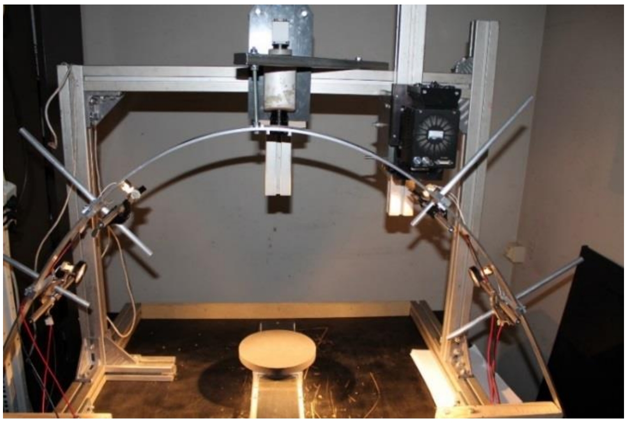


Figure 31 ***Hyperspectral set-up used for the measurements***

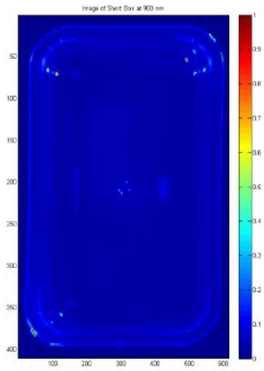


Figure 32 ***Image of an empty package at 900 nm.***

As the laser was not able to work other films than PP and not mounted on the PicknPack line it was not possible to integrate this system on the line too. For this reason Integrity checking was demonstrated separately.

2.6.3.6 Other functions

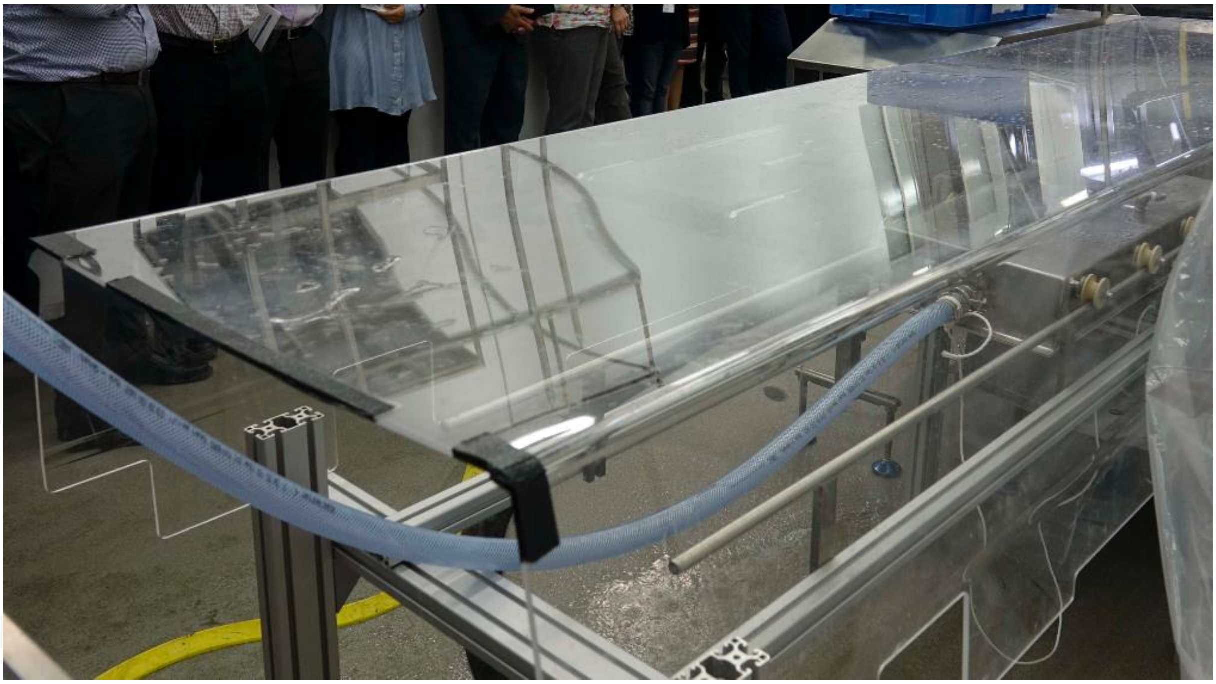


Figure 33 ***The cover for water spray protection for the hygienic robot (WP8) can have the extra functionality to create MAP or eMAP.***

The PicknPack system will be covered with shields in order to prevent spraying from the hygienic robot. The area of the laser and quality assessment module also need to be protected as the laser, X-ray and microwave all involves risks. If the whole system is covered it is possible to flush this covered volume with a packaging gas. This demand glove boxes on the sides in order to intervene failures. The system can create MAP (=Modified Atmosphere Packaging) and has the extra advantage that the products will be merged together in the special atmosphere which prevent “pockets” of oxygen inside the food. As the PicknPack line never was assembled a complete line this system was only illustrated.

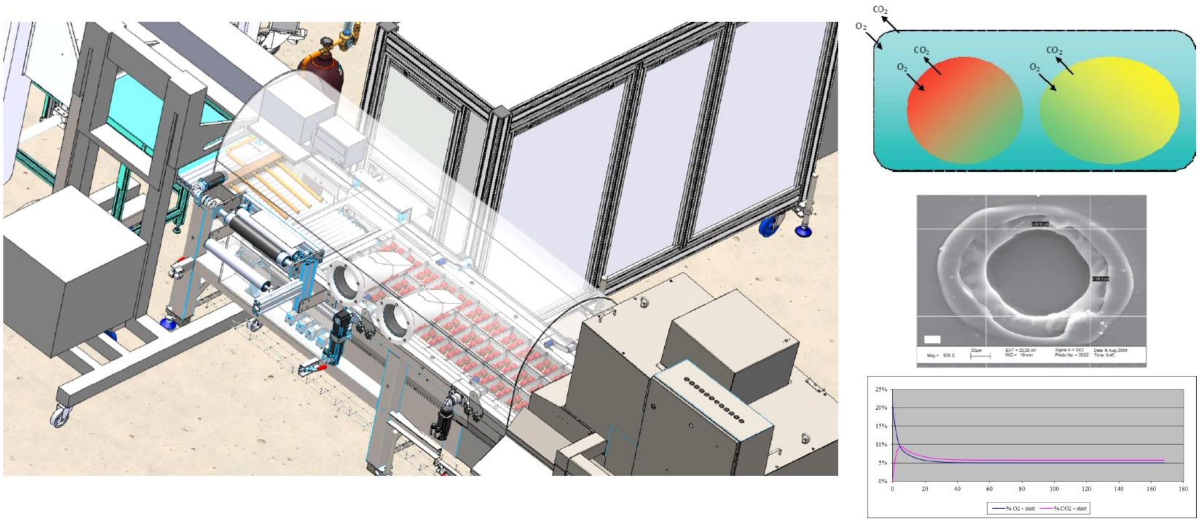


Figure 34 ***Illustration of a MAP and eMAP system build into the PicknPack line using the cover over the frames and laser system.***

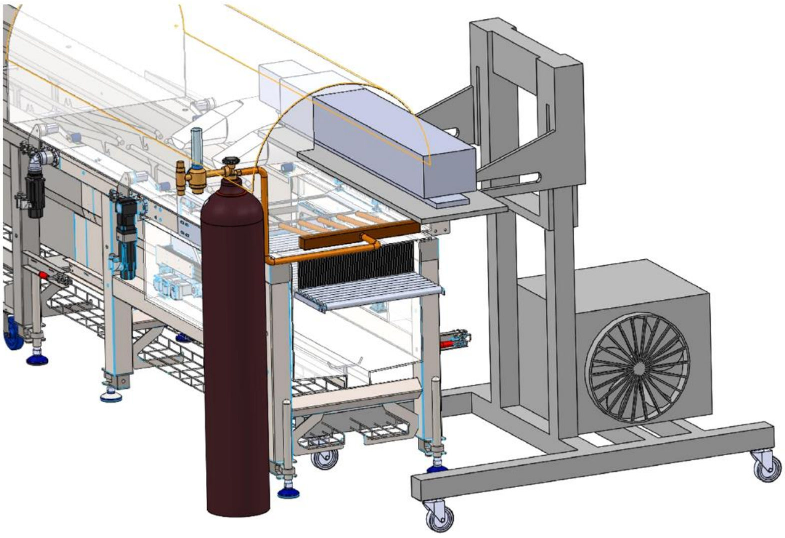


Figure 35 ***Gas mixture flushed from the laser unit in order to make MAP.***

2.6.4 Use of resources

The use of resources was according to the plan of the last amendment (2015-09-01). There were no significant deviations to the plan.

2.7 WP7 Fresh and processed food production line

2.7.1 Project objectives for the period

WP7 was devoted to develop, test and improve 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 and 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 main objective of the former (second) period was the assembly and integration of the modules in a complete line. As reported in the second periodical report, this was not fully realized as some modules were not shipped to the integration facility. Furthermore, although most modules were mechanically integrated, they were not yet functional as a complete line, mainly due to software integration delays. Therefore, the objective of the third period was i) Task 7.3 integrate the modules in the line further (in both software and hardware) and ii) Task 7.4 test and improve through production experiments. Furthermore, although not specifically described in the description of work, WP7 was also assigned to create the demonstrations using the line with vine tomato and chicken breasts.

2.7.2 Summary of the work progress and achievement during the period

In the third period, all partners delivered their modules to the integration facility. Each partner visited the facility often to do their part for the integration efforts, usaually for a week period at a time. A team of hard- and software engineers from Wageningen DLO supported their efforts, although often tasks were taken over to speed up the integration.

For Task 7.3 the final deadline was set at May 1st, 2016. At that point the line should be fully functional and working. However, this was not met for all functionalities, e.g. printer line controller software and automatic mould exnage of the thermoformer. At the deadline the functionality was frozen and all efforts were focussed to create demonstrations for the demo day. Still, the main functionality was able to be shown and physical integration was completed, except for the cable pick and place robot which was demonstrated separately. The line was fully operational during demonstration time.

For Task 7.4 each module was tasked to run individual experiments and tests. Improvements were continously suggested by WP7 and implemented by the partners during the third period. A taskforce for the software was formed in February 2016 to ensure all modules were connected through software.

2.7.3 Work progress and achievements during the period

After all modules are integrated, the total line performance was measured. The values were inherently the minimum of all modules' performances, because the sequential nature of the line; hence the bottleneck module will determine the values of the overall performance. The following indicators for the complete line were previously distinguished:

- Packages created per minute.
- Number of fresh and processed food types.

The number of fresh and processed food types the line could handle was **2**: tomato and chicken breasts. The second indicator depends on how many trays per cycle the thermoformer creates. For tomato, this was 3 trays per 11 seconds, or **16 packages per minute**.
For the chicken breasts this was 6 trays per 21 seconds, or **17 packages per minute**. The objective for the demonstrator was set at 30 packs per minute, which is considered state-of-the-art. The bottleneck for both lines was the pick and place robot for the food products.

Other modules were able to speed up to the set goal of 30 packages per minute. For each individual module, it's current performance is reported in D7.5 Report of prototype test under laboratory (and industrial) conditions, as well as suggestions for future improvements.

The cable pick and place robot at the end of the line was demonstrated seperately. This module was delivered too late in the project and could not be integrated. It functioned stand-alone and was not connected to the line controller. This is a deviation from what was promised, mainly due to the partner's struggle with hardware subfunctions in this period.

The printer module was not integrated with the line underneath that provided the packages. The topfoil was moved over the web of packages and rolled up thereafter, but did not connect to the packages with the planed motor system in the sectional frames. This was due to the limit in software engineering capability under supervision of DTI and could not be solved by other partners.

The laser was demonstrated seperately in another room that could be encapsulated with proper safety shielding, as it was a hard problem to ensure no laser emission would escape a local closure when integrated in the line. A solution would have been to enclose the whole line, but that was deemed impractical.

It was achieved in time to make the integrated line safe for demonstration purposes (Figure 36). Mainly, the integration of the sectional frames with the X-Ray module was of high priority, but was succesfully approved by radiation specialists after each mechanical update. Furthermore, the whole line was interconnected with emergency stop buttons.

The integrated line still produced some errors and malfunctions, both in hard- and software. For example, the cut plastic edges from the packages at the thermoformer sometimes did not roll up properly or the software skipped a set of packages after a hard reset. Also, the web of trays occasionally bulged upwards when the load was not distributed correctly through the line. However, these errors can be considered minor issues and are were acceptable for a demonstrator module.

The line was integrated with the automated cleaning system. However, not all modules supported this. The second half of the line (X-ray, Printer and Cable Picking Robot) was not automatically cleanable. The first part was succesfully implemented and tested on site several times without damage to the modules. This was tested after the first demonstration at Wageningen, due to the risk of possible breakdown involved. A plastic cover was implemented over the sectional frames to prevent water distribution to other places.

Figure 36 Demonstration setup after integration

Although mechanically integrating modules is one part, the other major part of the work is in software integration. WP7 supported this WP2 goal with additional efforts. Regarding the use of resources, WP7 was in its peak in this last period. 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 was therefore reallocated to DLO and DTI.

2.7.4 Use of resources

The use of resources was according to the plan of the last amendment (2015-09-01). There were no significant deviations to the plan.

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:

- Integration of the cleaning system into the PicknPack line and start-up
- Cleaning tests with the implemented cleaning system regarding cleaning efficiency
- Future Concept Design of the Cleaning System

2.8.2 Summary of the work progress and achievement during the period

During the last twelve months of the project the focus of WP 8 was on implementation of the Cleaning System into the PicknPack line and determining its performance parameters. Therefore the concept of the Mobile Cleaning Device which was developed in the first part of the project was put into operation after serval amendments and optimization steps. After this it was integrated into the line for demonstration and experimental purposes. The concept was validated so that in the end a functioning cleaning system was available which can drive automatically through the whole line in order to clean all modules consecutively with individual cleaning programs.

In addition, for the Delta Robot module a conventional CIP-system was integrated in order to compare its performance parameters with the ones of the novel Mobile Cleaning Device. To assess those performance parameters cleaning tests with regard to cleaning efficiency were performed exemplary on the Delta Robot. Therefore, parts of the robot were reproducibly coated with a fluorescent food model soil. Then those areas were cleaned with the different cleaning systems and different cleaning parameters. The cleaning progress was monitored with a camera system in combination with a UV lamp which made the fluorescent soil visible for the camera. In this way it was possible to quantify the cleaning rate of the cleaning procedures time-resolved and to compare their efficiency. The tests showed that the Mobile Cleaning Device is able to reduce water consumption and also to improve process safety with regard to hygiene e.g. by reducing spray shadow areas.

After completion of the cleaning test a kind of feasibility study was conducted in order to develop a concept of the Mobile Cleaning Device, how it could look like in the future and which additional features can make it still more adaptive and flexible. So this future concept has an even more product-like look and contains an optical camera sensor which can automatically detect soiled areas.

2.8.3 Work progress and achievements during the period

2.8.3.1 Line integration of the automated cleaning system

In the first part of the project the concept of the Mobile Cleaning Device was developed (**Error! Reference source not found.**). It is an automated and self-driving machine which is moving through the whole PicknPack line and at the same time cleaning all modules consecutively with individual cleaning progress. Therefore, it has different nozzle types on-board and is able to spray several cleaning agents such as foam and water. This Mobile Cleaning Device was now integrated into the PicknPack line. Therefore, it uses the bars which support the product trays during production as rails on which it can drive (Figure 38). For the supply of cleaning agent it is connected to an automated hose drum (Figure 39). The hose drum is also driven by an engine and its rotation is synchronized with the speed of the Mobile Cleaning Device. In addition, the hose drum is standing on a movable table with wheels and with a docking station for the Mobile Cleaning. Hereby, the whole system can be moved easily through the whole factory so that the Mobile Cleaning Device can be used on several machineries.

Furthermore, the Software to control the Mobile Cleaning Device was also integrated into the line control system. Hereby, it is able to communicate with all the other modules of the PicknPack line. So when the position sensor of the cleaning device recognizes that it enters a module e.g. the Delta Robot it can send a message to the robot to start moving with a special pattern in order to support the cleaning progress by reducing spray shadows and moving relevant parts like the gripper closer to the cleaning nozzles.

2.8.3.2 Cleaning Efficiency Tests

After the line integration of the Mobile Cleaning Device several cleaning tests were performed to assess its cleaning efficiency in comparison the conventional CIP-systems and to determine ideal operating parameters. Those tests were performed exemplary for the PicknPack Delta Robot and the tunnels of the Sectional Frames.

For the tests in the Delta Robot the whole inner rear cover of the robot was coated with a fluorescent food model soil. In addition, a UV lamp and a camera (both IP69) were placed inside the robot to make the soil visible and to monitor the whole cleaning process. By this the cleaning process can be quantified. After the soil had dried for 20 hours the robot was cleaned with the different systems and with different operating parameters:

- Mobile Cleaning Device vs. Conventional CIP-System
- Cleaning agent (Foam) + water vs. water only
- Operating pressure: 3 bars and 4.5 bars
- Speed of the Mobile Cleaning Device: 2 mm/s (water only), 5 mm/s (foam + water), 10 mm/s (foam + water) → speed values based on first lab scale tests with rotating spray heads

From the analysis of recorded images of the monitoring system the cleaning time was determined. This time was defined as the time which is needed to remove 95 % of the soil. Together with the flow rate generated by the two different cleaning systems in combination with the operating pressure also the water consumption was calculated.

The tests showed that in comparison to the conventional CIP-system with static nozzles the Mobile Cleaning Device needs more time to clean the robotic cell. This is due to the fact that the CIP-system consisted to two rotating spray heads mounted on the side covers of the robot while the cleaning device carries only one rotating spray head. But in return the Mobile Cleaning Device is able to reduce the water consumption by around 20 % (Figure 40). In addition, the tests showed that the Mobile Cleaning Device is able to eliminate spray shadow area due to its movement. Thereby, it is able to clean areas which cannot be reached by the static nozzles of the conventional CIP-system (**Error! Reference source not found.**). So not only water consumption is reduced but also food safety is improved significantly.

Furthermore, the tests showed that using foam and water as cleaning agents instead of water only can reduce water consumption by around 60% (

Figure 42).

2.8.3.3 Future Concept Design of the Mobile Cleaning Device:

The current version of the Mobile Cleaning Device is a prototype to show the feasibility and its advantages in comparison to conventional cleaning methods. The module will be developed further. Size will be reduced and the hygienic design will be improved to increase its suitability for the use in product contact areas. There will also be a version without wheels which is only carried by conveyors. To make the device also more adaptive, it is planned to add an optical sensor system for automated soil detection. Since most food products contain fluorescent ingredients, it is possible to make them visible for a camera with a UV light. Both components will be integrated into the Mobile Cleaning Device. With this sensor system it will be possible to improve adaptivity during the cleaning process. It will be possible to determine which areas are really soiled and require cleaning and which areas don't need to be cleaned. And it will also be possible to determine if all surfaces were successfully cleaned or if further cleaning is required.

Figure 43 and Figure 44 show the smaller conceptual design of the cleaning device with and without wheels and including the camera sensor to detect soil.

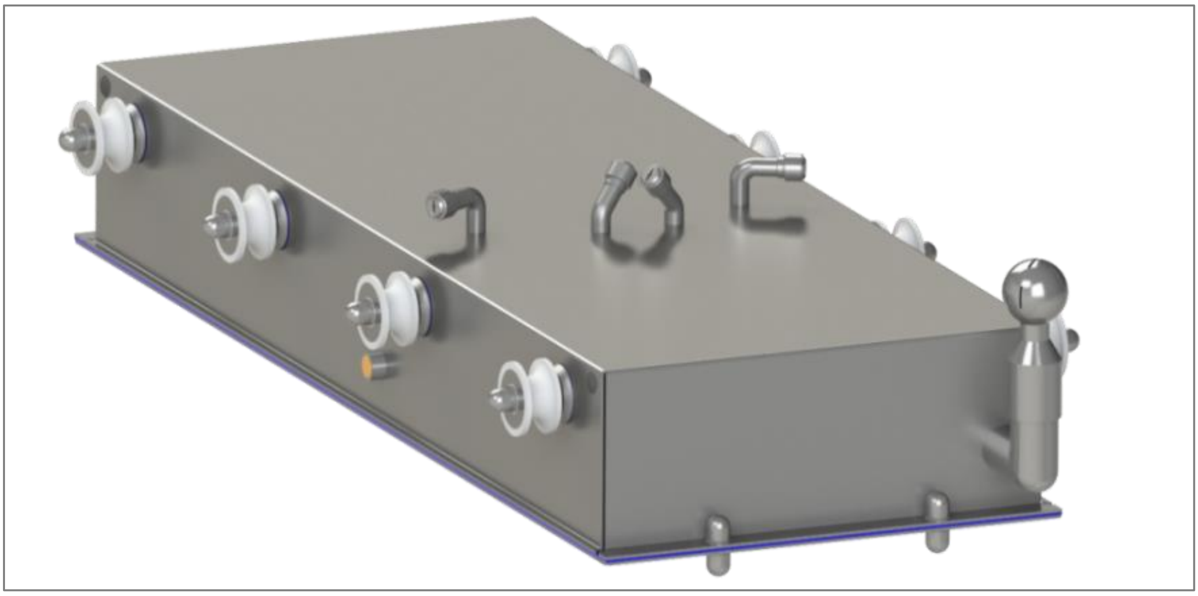


Figure 37: Prototype of the Mobile Cleaning Device.

Figure 38: Mobile Cleaning Device integrated into the PicknPack line

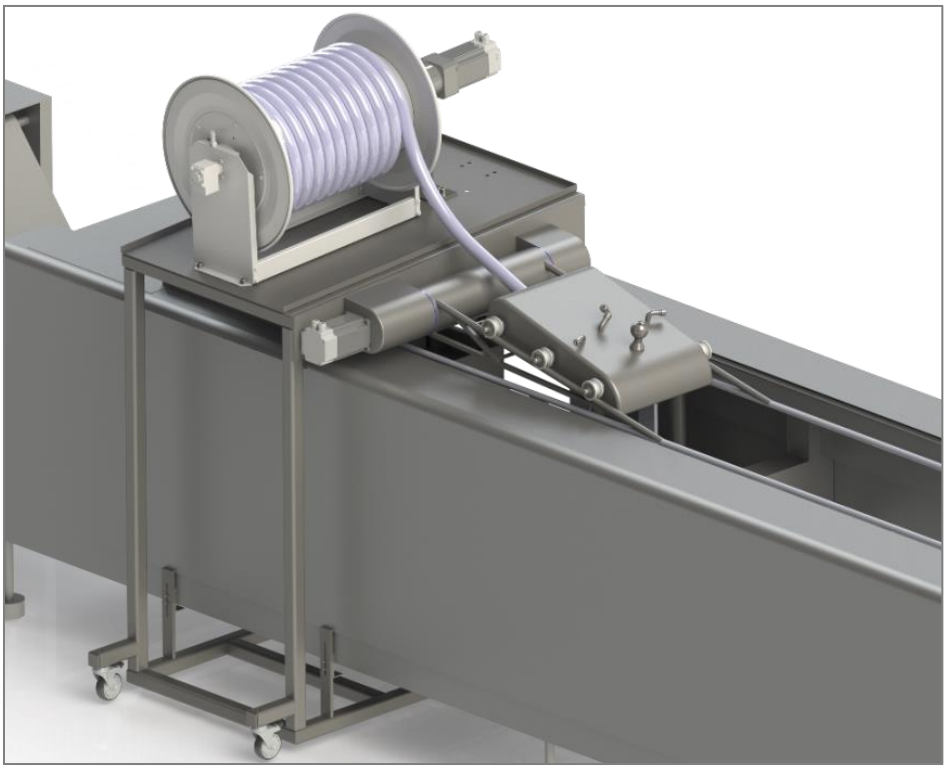


Figure 39: The Mobile Cleaning Device connected to the hose drum table, driving into the line.

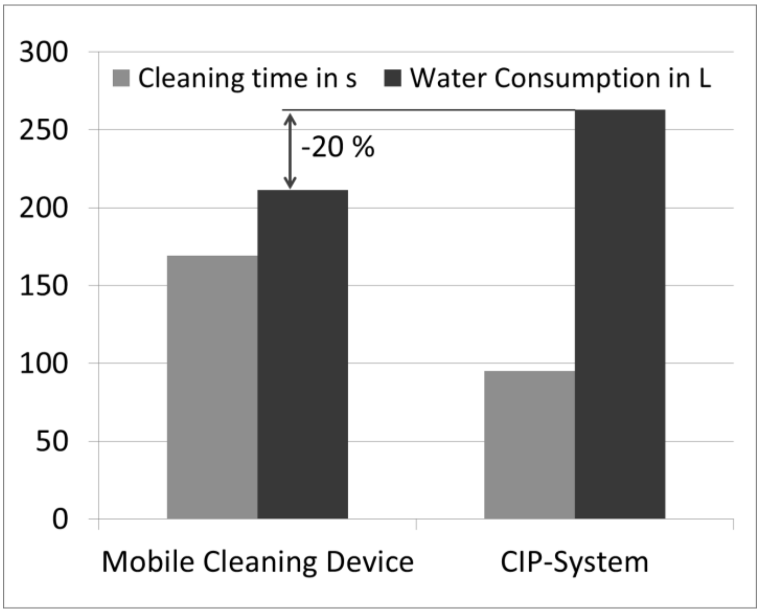


Figure 40 Comparison of Mobile Cleaning Device and conventional CIP-system regarding cleaning time and water consumption (water and foam @ 3 bars)

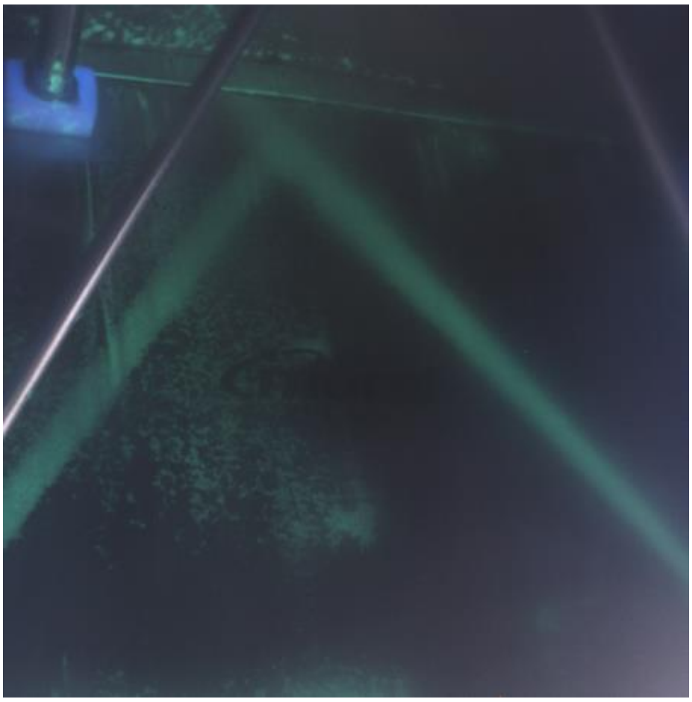


Figure 41: Spray Shadows resulting by cleaning with conventional CIP-System leading to increased cleaning time

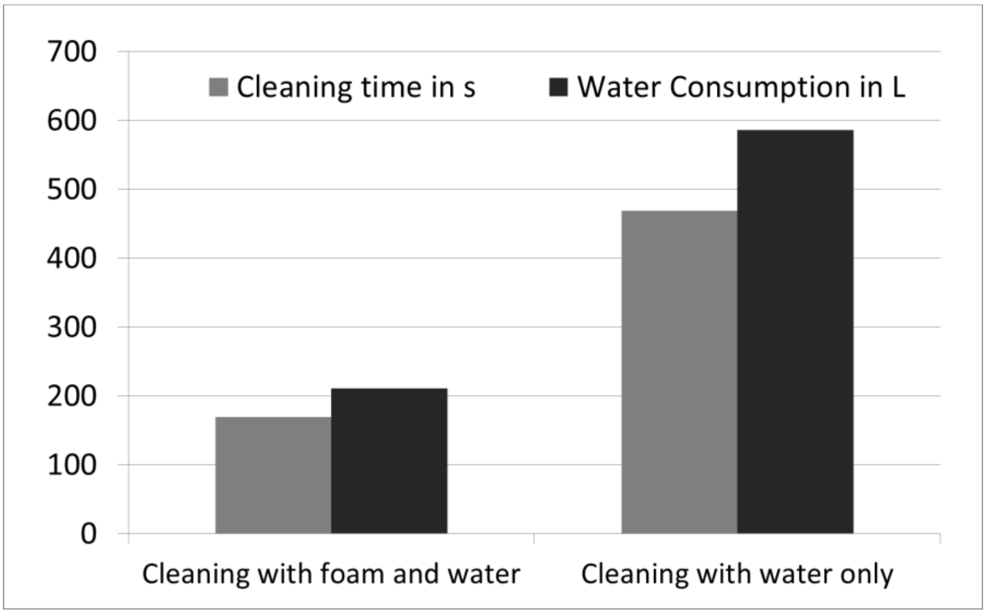


Figure 42: Comparison of Cleaning with and without foam (Mobile Cleaning Device @ 3 bars)

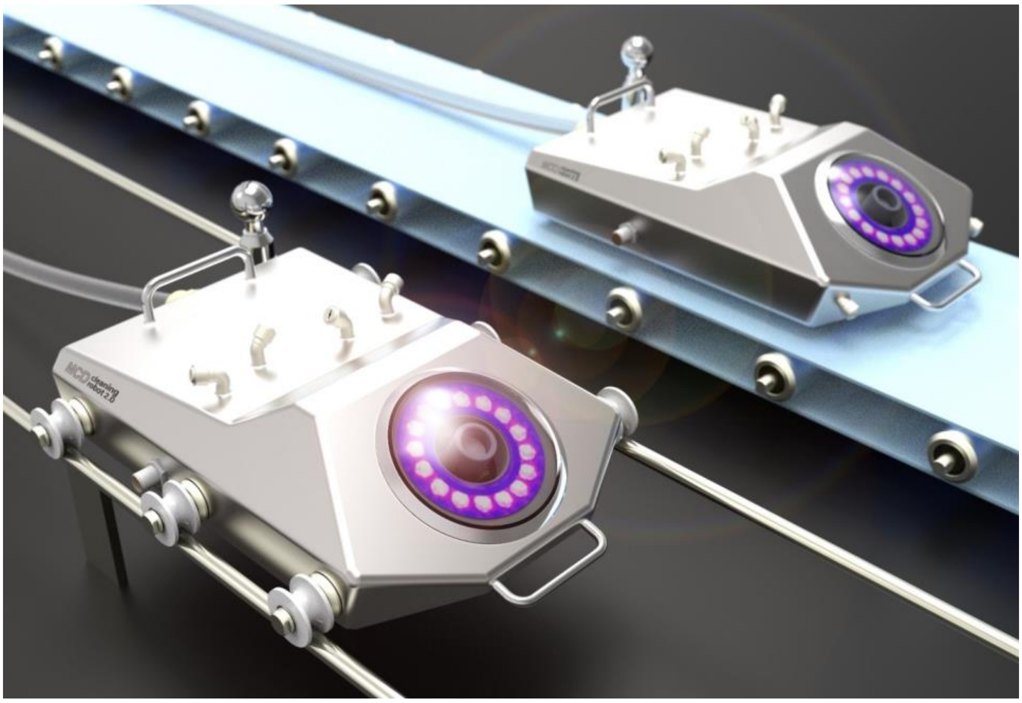


Figure 43:Design Concept Mobile Cleaning Device with optical cleaning sensor.

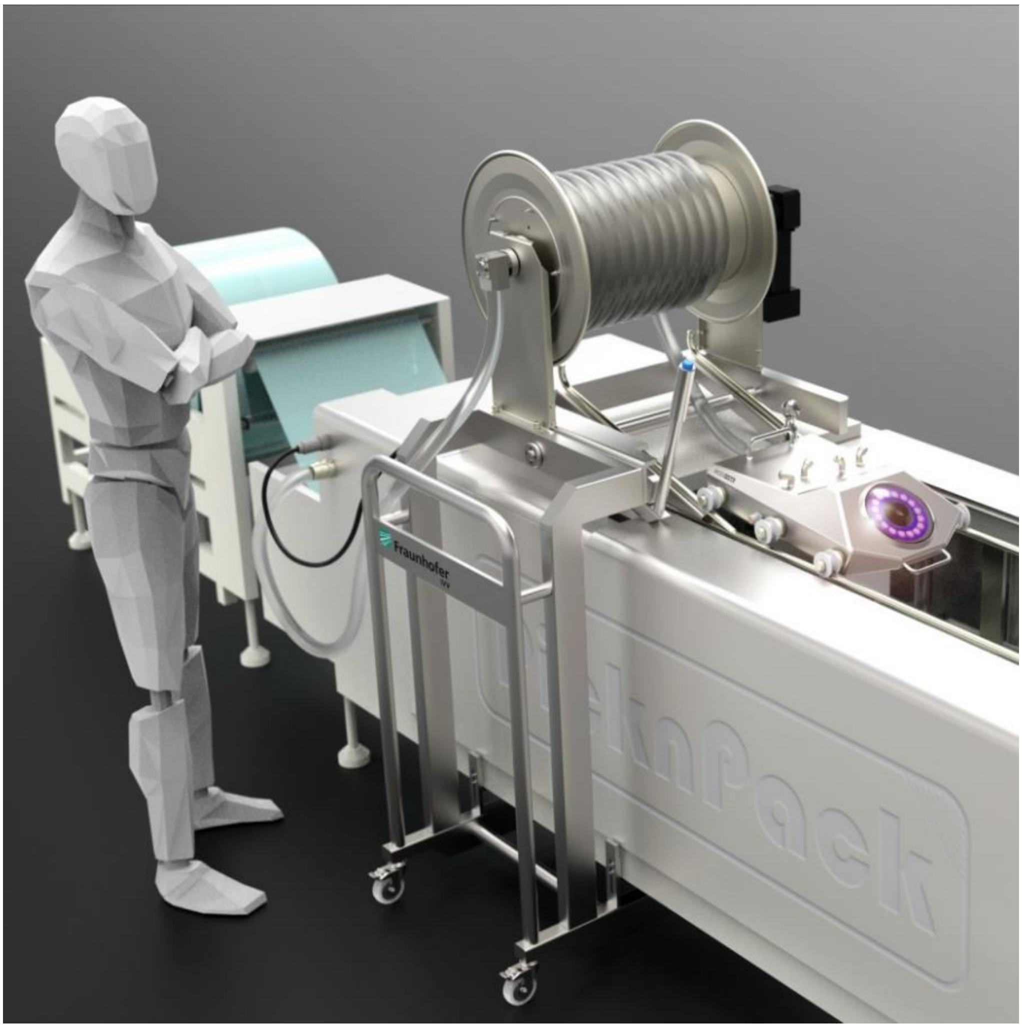


Figure 44: Design Concept Mobile Cleaning Device and hose drum table with docking station.

2.8.4 Use of resources

The use of resources was according to the plan of the last amendment (2015-09-01). There were no significant deviations 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:

- 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 4 as well as the Objective 4, as well as the final development of the LCA, LCC and social evaluation included in the objective. The full life cycle picture of the automated systems (Objective 1) has been also updated with the final design of the packaging line for food and ready meals.

2.9.2 Summary of the work progress and achievement during the period

1) Life cycle diagrams and LCA data collection for the PicknPack line have been successfully achieved. Additionally, LCA data collection and diagrams has been also completed in three additional benchmark packaging lines. To sum up, data from three additional thermoformed packaging manufacturers, was also collected in addition to the data already collected for two thermoforming lines and one foodstuff packer (coupled with these two packaging producers). Additionally, the life cycle data for a tomatoes line has been also made by visiting the facilities of DC Prominent in Zuid Holland (The Netherlands).
2) Real power measurements in three additional benchmark packaging lines and the PicknPack packaging line in Wageningen were possible by using three-phase electric power measurement devices purchased for such purpose.
3) Besides the power consumption measurements made for some of the components of the packaging line, all partners contributed effectively to fill in the table of data collection of the PicknPack line. This comprised the type of equipment used, the nominal power, the power factor and the expected use time. Moreover, materials, chemicals and water were also considered.
4) The packaging materials were effectively modelled in the LCA software SimaPro, including four formats made of PET (for fruit & vegetables) and three made of PP (for ready meals).
5) Extrapolations based on conventional thermoforming equipment were also made in order to estimate the weight of packaging material, plastic packaging scrap material and electricity consumption as function of the material and the size of the tray.
6) All these information was compiled, processed and modelled in SimaPro LCA software in order to obtain the Life Cycle Inventories (LCI's) for the calculation of the potential environmental impacts in the LCA with three different geographical scopes (UK, NL, ES).
7) The LCI's were also the basis for the calculation of the economic flows of the LCC. The individual costs of electricity, water, plastic packaging materials, labour, transport etc., were found and applied in order to calculate the estimated life cycle impact for the delivery of 1000 kg of packaged food to the market
8) Because of the difficulties found to carry out a packer acceptance study then it was decided to consider a different approach for the social evaluation by focusing on three main social hotspots: (1) human resources, (2) productivity of the employees (3) qualification of the employees. This assessment allows the identification the opportunities created with the new technology developed by PnP project.
9) Because of the qualitative behaviour of the social evaluation, the sustainability evaluation was made calculating the eco-efficiency of the PicknPack and conventional packaging equipment. This represents the ratio of economic cost (LCC) vs. the environmental impact (LCA).

2.9.3 Work progress and achievements during the period

As pointed out before, during the third and las reporting period (Oct 2015 to Sep 2016), work has been mainly focused on the finalization of the Task 9.1 (Life Cycle Definition) and Task 9.2 (LCA). Tasks 9.3 (LCC), 9.4 (Social Evaluation) and 9.5 (Sustainability Evaluation) have been developed based on the feedback from partners and the final design of the PicknPack line. More precisely, the following activities have been carried out during this 1st reporting period:

Task 9.1. Life Cycle Definition:

Subtask 9.1.1. Description of the life cycles of current manual operations and conventional equipment: In this subtask the data collection was completed by finalizing some the measurements already made and extending them, to three additional conventional thermoforming equipment in Valencia and Murcia. Because data was only available for ready meals, data collection was extended to a tomatoes Packaging Line of DC Prominent in The Netherlands. For the latter case only qualitative data was obtained.

Table 4 *Summary of thermoforming and conventional packing lines considered as benchmark for the life cycle studies in WP9*

Machine ID	Location	Activity	Packaging material	Packaging dimensions (mm)	Thickness (mm)
A	Alicante, Spain	Production of thermoformed packaging	PVC	280x95x20	0.194
B	Valencia, Spain	Production of thermoformed packaging	A-PET	150x100x20	0.200
C	Valencia, Spain	Production of thermoformed packaging	PP	180x250x80	0.760
D	Valencia, Spain	Production of thermoformed packaging	PP	200x300x65	0.825
E	Murcia, Spain	Production of thermoformed packaging	PET	255x153x38	0.490
N/A	Navarre, Spain	Packing of chicken-based foodstuff	A-PET	Only packing operations Quantitative data available	
N/A	DC Prominent, Zuid Holland, The Netherlands	Packing of tomatoes	Plastic and paper-based packaging	Only packing operations Only qualitative data available	

Subtask 9.1.2. Creation and continuous updated of a process life-cycle map of the PicknPack system: For the PicknPack packaging line, both power measurements with specific devices (Figure 1) and desktop power consumption analysis were carried out. For the power measurements, these were made through a visit of ITENE's staff to Wageningen (The Netherlands) in early March 2016. The thermoforming machine and conveyor belt were measurement under different operation conditions. The Marel robot with and without grippers was also tested in power measurements. Additionally, the Efergy® E2 power measurement devices were lend to Wageningen UR for additional collection of data of QAS module.

Figure 45 Efergy® E2 Classic three-phase units and amperometric clamps used for the experimental power measurements within the PicknPack line.

The desktop power consumption analysis was possible considering the final layout of the PicknPack line. Such analysis took into account the nominal power, the power factor and the operation time. With all this information it was possible to estimate a power consumption of 242.83 kWh for the whole line, while the water and cleaning agent consumption is of about 1000 L and 1 L, respectively.

Subtask 9.1.3. Data collection for LCA and LCC analyses: Additionally, it was calculated the amount of packaging material, scrap produced and power consumption to the different seven formats (3 in PP for ready meals, 4 in PET for fruit & vegetables) considered in PicknPack. The scrap produced of plastic packaging material was calculated with AutoCAD, while the amount of material by extrapolation based on the initial sheet volume prior the stretching stage, through the formula:

$$V = L \cdot W \cdot T$$

$$M = \rho \cdot V$$

V = volume; L = length; W = width; T = thickness; ρ = density; M = mass

The extrapolation strategy was also applied for the calculation of the power required for the thermoforming of the packaging material in accordance with the following equation:

$$Heat\ requirement = L \cdot W \cdot T \cdot \rho \cdot \left(cp \cdot \Delta T \cdot \Delta H_f\right)$$

cp = specific heat; ΔT = temperature difference between the polymer sheet and the thermoforming setting temperature; ΔH_f = heat of fusion of the material. Then, with the use of electricity, packaging material, water and cleaning agents, a life cycle inventory (LCI) was developed for the subsequent modelling in LCA (Task 9.2) and LCC studies (Task 9.3). Such data was further connected with the data collected for the modelling of food packaging systems which were based on literature data: tomatoes production (Cellura et al., 2012) and chicken breast with vegetables (Berlin and Sund, 2010).

Task 9.2. ILCD compliant Life Cycle Assessment:

Subtask 9.2.1. Life cycle inventory analysis, where the data will be analysed: 24 life cycle inventories were produced with the above mentioned data for all the 7 size formats considered and the 5 conventional thermoforming machines and the 2 PicknPack lines (fruit & vegetables and ready meals). An example of the life cycle inventories is provided in the Table 5 and Figure 46.

Table 5 Life cycle inventory for the LCI A-1 for the production of a functional unit, 1000 kg of packaged food ready to be sold in the market.

Input				Output			
	Flow	**Amount**	**Units**		**Flow**	**Amount**	**Units**
Tray	Packaging material extruded	89,4	kg	Tray	Packaging material	60,65	kg
Lid	Packaging material extruded	17,6	kg	Lid	Packaging material	11,97	kg
	Energy for the process	63.53	kWh	Tray	Packaging waste material	28,71	kg
	Food product	999,95	kg	Lid	Packaging waste material	5,6	kg

These inventories were modelled in SimaPro 8.3 LCA software for the calculation of the potential environmental impacts related.

Subtask 9.2.2. Life cycle impact assessment: for the impact assessment a full set of impact categories was considered (see table 3). It was also ensured that the LCA followed the ILCD provisions (see Deliverable 9.1 for further details).

Subtask 9.2.3. Interpretation of life cycle impact assessment results and sensitivity analyses: As above-mentioned, the LCA considered three different geographic locations in order to consider the effects of the different electricity mixes in the LCA results. **The following conclusions were obtained from the LCA:**

- ✓ Environmental profile for the fruit and vegetables line: **The units processed in the PicknPack fruit & vegetables line (P1) have almost a half of the impact in both CED and Global Warming in all the format sizes examined compared to their counterparts processed with conventional thermoforming/packing equipment (**Figure 47**).**
- ✓ Environmental profile for the ready meals line: the impact to CED and Global Warming is in a similar range than the packaging formats processed with the conventional machines D and E, although substantially lower than the units converted with the conventional machine C.
- ✓ Contribution of food: definitely, **the impacts of the product contained are the main contribution to the impacts, being even higher in the case of the ready meals systems.**
- ✓ Contribution of packaging: when the impacts of food are driven out, then the contribution of packaging in materials are the biggest contribution in both fruit & vegetables and ready meals systems.
- ✓ **Contribution of the packaging line equipment**: this is the third contribution to the environmental impact although this is higher for the fruit & vegetables line because of the higher depth of the tray. On the contrary, **the lower depth of the tray in ready meals contribute to decrease the impact of the packaging equipment.**
- ✓ Influence of the geographic location: **There are no significant differences between the three Countries (ES, NL and UK) about CED impact. However, the Spanish scenarios show the less impact for Global Warming, which are explained because of the higher share of renewable energy sources than UK and The Netherlands (more based on fossil resources)**
- ✓ Sensitivity to tray size: The results are sensible to the tray size and the amount of unconverted thermoforming areas. The less unconverted area, the less scrap and environmental impact.

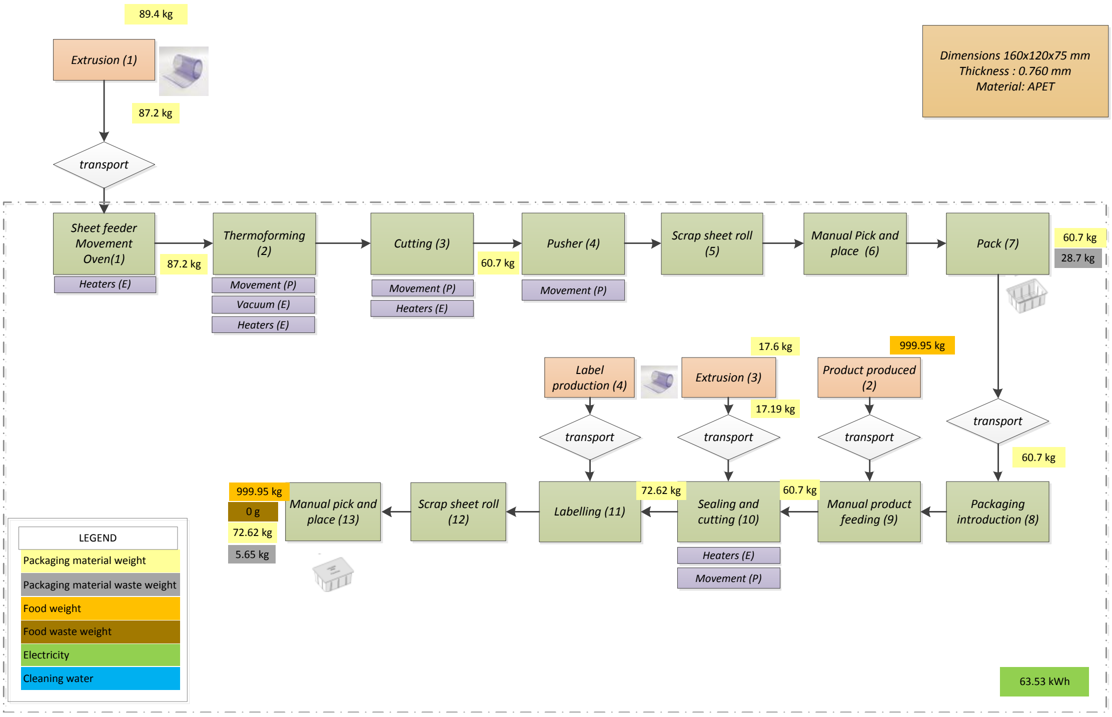


Figure 46 ***System boundaries for the LCI A-1.***

Table 6 Description of the environmental impact categories and impacts covered in this LCA.

Impact category	Abbreviation	Method	Units	Source
Climate change	CC	IPCC 2007	kg CO_2 eq	(IPCC, 2007)
Cumulative Energy Demand	CED	CED method	MJ	(Frischknecht et al., 2003)
Eutrophication (freshwater)	EU (freshwater)	ReCiPe* 1.05	kg P eq	(Struijs et al. 2009)
Eutrophication (marine)	EU (marine)		Kg N eq	
Acidification	AC	---	kg SO_2 eq	(Seppälä et al. 2006) (Posch et al. 2008)
Ozone Depletion Potential	ODP	CML 2002	kg CFC-11 eq	(Montzka and Fraser 1999)
Photochem. Ozone Creation Potential	POCP	ReCiPe* 1.05	kg NMVOC	(Van Zelm et al. 2008)
Abiotic Depletion	AD	CML 2002	kg Sb eq	(Guinée, 2002)
Water depletion	WD	Swiss Ecoscarcity	m^3 water eq	(Frischknecht et al., 2006)

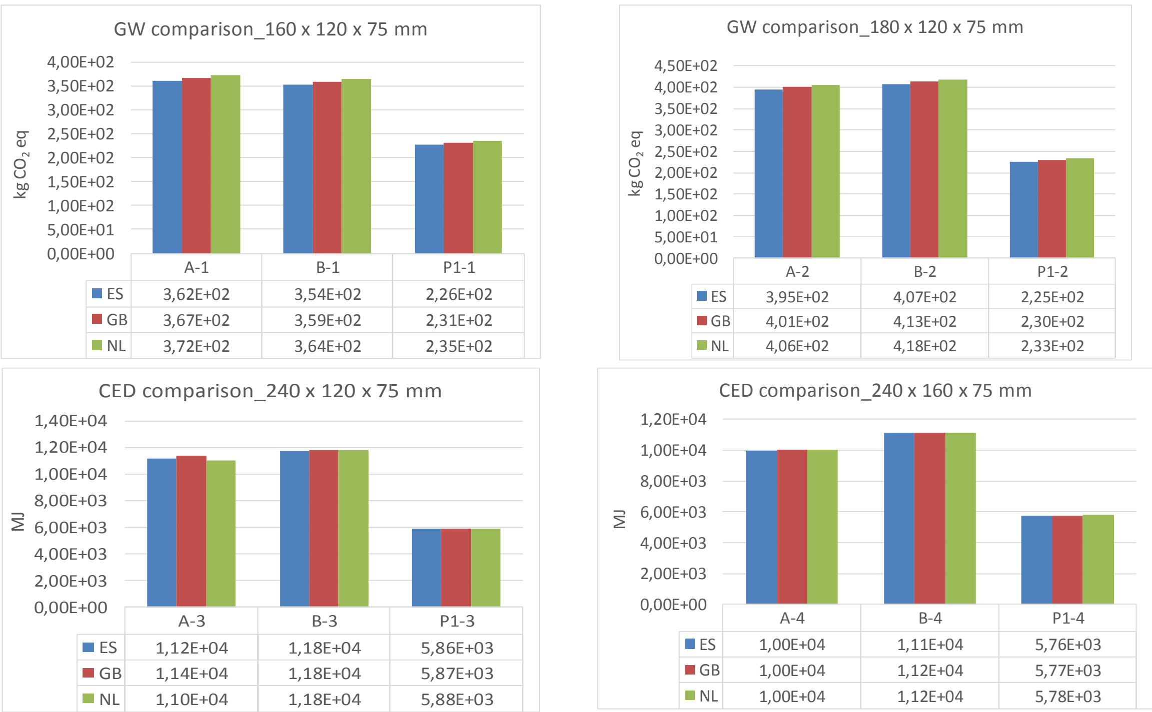


Figure 47 LCA results for the fruits and vegetable packaging line. P-systems refer to PicknPack line

Task 9.3. Life cycle analysis and sustainability:

Subtask 9.3.1. & 9.3.2. Life Cycle Costing analysis of packaging with conventional equipment and PicknPack line: Life cycle costing (LCC) was built on the basis of the Life Cycle Inventory developed in Task 9.1 and 9.2. The LCC included the following cost categories (Table 7 Cost categories considered in the LCC of package of food products.). As can be seen in Figure 48, the lower LCC costs are reached for the PicknPack formats. **The main conclusions from the LCC for the fruit & vegetables format are:**

- **The main contributions to the life cycle cost are the capital charges, the cost of raw materials (trays and the food product) and the labour costs, in this order.**
- **The relevance of the transport and electricity use within the total life cycle cost can be considered almost negligible.**
- **The best case is Spain and the biggest cost is in the Netherlands, mainly due to labour costs.**
- **Only in the largest tomato packaging format, the total life cycle cost is below 1000 € / 1000 kg of product packed.**

For the ready meals packing lines:

- **No big differences can be observed among different packaging formats and packaging lines.**
- **The cost of formats for ready meals is about 4.25 times that of the packages for tomatoes.**
- **The total life cycle cost is about 7000 € / 1000 kg of product packed.**

Table 7 Cost categories considered in the LCC of package of food products.

Cost category	Cost components	Data used			
		Avg EU	NL	UK	ES
Chemicals	Cleaning agent	X			
Raw material	Virgin PET/Virgin PP	X			
Water	Water abstraction + Water pollution tax for water discharges, per country		X	X	X
Energy	Electricity		X	X	X
Labour costs			X	X	X
Capital charges		X			
Delivery of empty trays to the packer (when required)		X			
Food product	Tomatoes		X	X	X
	Chicken breast with vegetables	X			

Figure 4 – LCC results for the P2-7 format

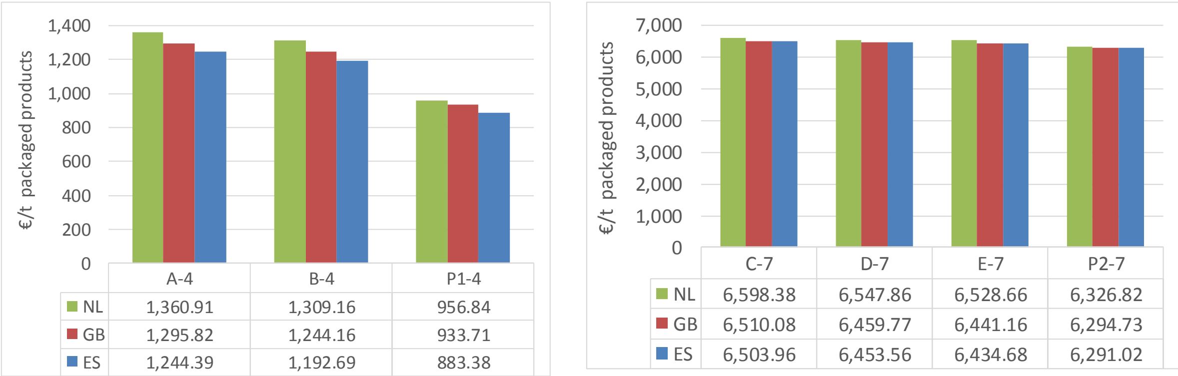


Figure 48 Sensitivity analysis of LCC results for the size format 4 (fruit & veget.) and 7 (ready meals)

Task 9.4. Social evaluation:

Even though it was planned to carry out a packer acceptance study, the delays on the final layout of the PicknPack line and the fact that a whole line was not functioning at the time of the demos, this will make for sure almost impossible to collect the necessary feedback for the calculation of the willingness-to-pay (WTP) by packers of the PicknPack machine. Moreover, most of the attendees to the demos were people with a very high technical profile which is not able to take decisions on the investment in packaging machinery. Therefore, it was agreed with the Project Coordinator to rearrange the social evaluation in order to estimate the potential social benefits that arise from the change from a conventional to a PicknPack line. This new approach was done in close cooperation with WP12. Therefore, three social hotspots were evaluated: (1) human resources, (2) productivity of the employees and (3) expectations on the of qualification of the employees. This assessment allows the identification the opportunities created with the new technology developed by PicknPack project**. The social evaluation showed that the introduction of the PnP line in the food industries will have positive effects, increasing the competitiveness**

of the European industry. PnP line reduces the labour cost because of the less number of working staff while increases the quality of jobs positions in comparison to the qualification required in conventional packaging lines. Additionally, the flexibility in processing reduces the dead times for changing of products and increases the labour productivity up to 75%.

Task 9.5. Sustainability evaluation

Because of the change in the approach of social evaluation (now only qualitative) it was no longer possible the sustainability assessment that considers the WTP from the social evaluation. Therefore, the sustainability evaluation was then focused to the eco-efficiency concept that seeks for the optimal solutions with less cost and less impact. The eco-efficiency results were presented in spider diagrams and dispersion diagrams as well. For the spider diagrams (Figure 49, all the impact categories), the less are the more eco-efficiency, while for the dispersion diagrams results were presented as scattered plots (Figure 50, only for GW and CED impacts).

The main conclusions that arise from this deliverable report on the eco-efficiency of the automated packaging systems in PnP vs. the conventional ones are:

- ✓ **For the fruit and vegetables formats, the most eco-efficient formats are the PicknPack ones in all the impact categories.**
- ✓ **For the ready meals packages, the most eco-efficient ones are those produced with machine D, which represents a state-of-the-art thermoforming/packing machine.**
- ✓ The eco-efficiency of the PicknPack line for ready meals is almost in all the cases in a similar range than the remaining conventional one machines.
- ✓ The relevance of the impact profile in accordance to the spider diagrams changes as function of the type of the product contained. CED, AD, Water Depletion and ODP are the most relevant ones for the fruit and vegetables formats, while for the ready meals packages, the highest contributions come from GW, ODP, POCP, AC, EU, CED.

In the view of these results, **the PnP solutions are eco-efficient for the tomatoes line and its related formats, while the PnP line for ready meals require of further effort to increase the eco-efficiency of the system**.

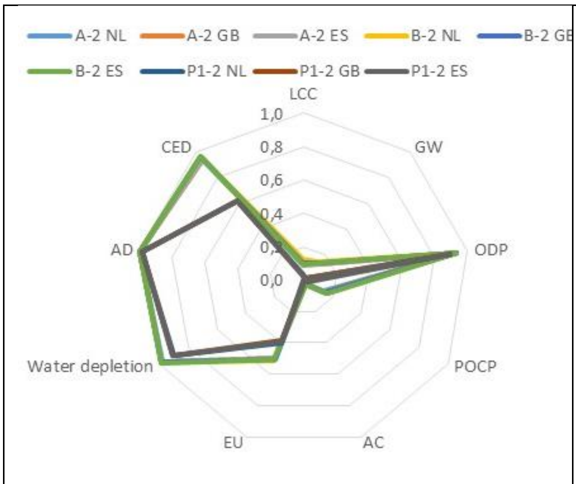


Figure 49 Spider diagram for the references 180x120x75 for fruit and vegetables.

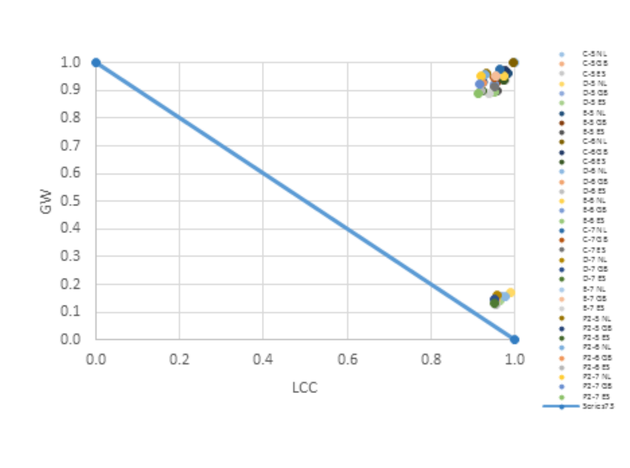


Figure 50 Eco-efficiency diagram for ready meal formats and GW.

2.9.4 Use of resources

The use of resources was according to the plan of the last amendment (2015-09-01). There were no significant deviations to the plan.

2.10 WP10 Dissemination

2.10.1 Project objectives for the period

1) To organise 2 project workshops/ Demonstrator events at different venues. (10.1)
2) To develop and upgrade the website with links to social media and ensure that all project videos and final public domain outputs are posted on the site. (10.2)
3) Maintain links with the IAB and ensure that they are fully informed about our activities and to facilitate feedback and comments. (10.3)
4) Develop our communication links with other websites and media such as relevant trade journals who could assist with dissemination. (10.4)
5) Plan two summer schools in association with our planned project workshop demonstrator events targeted at young workers and students. (10.5)
6) Encourage all partners to pursue patent applications on the technical outputs of their workpackages and record all such applications. (10.6)
7) Establish links with other projects and initiatives and organise co-sponsored events (10.7)

2.10.2 Summary of achievements

- Two workshops demonstrator events were organised. The first was held in Wageningen in May 2016 as a two day event with a registered attendance of about 100 mainly from industry. The second was held at Holbeach campus in September 2016 as a one day event with a registered attendance of about 40.
- The website has been continually updated with a significant increase in the number of pages and hits. All presentation from the last two workshops and final videos from the demonstrator have been posted.
- The final formal meeting of the IAB was held in Leuven in October 2015. Their advice on strategic issues relating to the layout of the demonstrator line proved to be invaluable
- Communication links were continually expanded within the UK and Europe to promote the dissemination of the PicknPack project.
- One training event was organised in association with the workshop demonstrator event at Holbeach in September 2015. It attracted 83 young workers and students from local colleges and technical colleges.
- Patent applications have been registered by Tecnalia on features of their innovative cable robot.
- We continued to exchange information and data on technical events with the coordinator of the EC project Smart-E and maintain links with a group of companies in Belgium who assisted in disseminating information on the Wageningen workshop.

2.10.3 Work progress and achievements during the period

2.10.3.1 Workshops

Fifth Workshop / Demonstrator 25th/ 26th May 2016

In accordance with a Board decision the final two workshops were to be combined with a full practical demonstration of the functionality of an integrated line that demonstrated the feasibility of all aspects of the PicknPack concept. No other technology was to be demonstrated at the event.

Because of the technical infrastructure required to support the extensive line integration process the demonstrator was assembled in Wageningen which thus determined the venue for the fifth workshop.

A two day event was planned to maximise attendance which each day was divided into identical afternoon and morning sessions. Each session having two parallel options one being attendance at a two hour technical session and the other being at a two hour guided tour of the working demonstrator and set of display booths.

Delegates were assigned by colour coded badges, and this arrangement allowed total flexibility to the attendees and feedback was excellent.

The technical presentations included:

- A project overview by Erik Pekkeriet
- An overview of the robotics and automation aspects by Richard van de Linde
- A description of the sensing module and the communication system by Wouter Saeys
- An overview of the system architecture and the GUI by Herman Bruyninckx
- The application of RFID technology for security and product traceability by Zhipeng Wu
- An overview of the novel automated purging and cleaning robot by Roman Murcek

Each day ended with a presentation by Idoia Olabarietta on the exploitation and expected routes to market of the technology. All presentations are published on the website.

The event was attended by about 100 people mainly from industry over the two days. It was clear that the event created a great interest in the outputs of the project and that the combination of a well organised workshop and demonstrator event was a success.

Sixth Workshop Demonstrator 13th / 14th September 2016

The organisation of the final workshop demonstrator event at a venue other than Wageningen posed significant logistic and technical problems for the Consortium. The compromise solution was to hold the event at the Holbeach Campus in the UK with a full complement of display booths but without the full demonstrator line. A professionally produced video film of the project would be available to compensate for any loss of impact. A great advantage of Holbeach if that I is ideally placed through its strong regional food industry connections to host a Summer School for young technical personnel.

Similar to the Wageningen event a two day demonstrator workshop was planned but with the second day focused on the School event. Because of the limited number of modules on display a simple structure was used to plan the event with a morning technical session being followed by a demonstration session which allowed delegates total choice as to where to focus their interests.

Both the technical presentations and presenters were similar to those given at the Wageningen event in May and listed above. A key difference was the inclusion of up to date video clips and the most recent technical results.

As before the event concluded with a presentation by Idoia Olabarietta on impact analysis and routes to exploitation again similar to her previous presentation but updated with fresh data. All these presentations will be posted on the website.

The event attracted some 40 registrants mostly from UK industry but representing international companies such as ABB, KUKA, Siemens, Festo, Bakkavor and Del Monte. Feedback was again excellent and invitations received to give presentations at future technical meetings. These invitations will of course be followed up.

During the event an opportunity was taken to convene a meeting of representatives from some of the leading academic and commercial UK groups focusing on food manufacturing and aspects of E-Agri to explore how best to exploit the emerging technology for the benefit of the food manufacturing sector.

2.10.3.2 The Website

Our approach was to develop a site that featured the ability to navigate easily, search with minimal clicks and improve usability. Since the launch in September 2015 we have seen a record number of visitors to the site in October 2015 the home page had 3837 hits, in April 2016 the site attracted 19117 visitors and in Sept 2016 figures have reached an impressive 55450 (27 Sept), we registered 2278 hits on the demonstration workshop. We have continuously worked to ensure information is timely and accurate and introduced visual enhancements to improve user experience.

Investing the time and energy in improving the design, look and feel of the site has attracted and increased audience numbers and clearly been successful.

Currently the website contains the details of every workshop and the Summer School together with all technical presentations, videos, lists of publications and reports and will act as a comprehensive archive of the progress and outputs of the project.

The PicknPack Mail Chimp tool used for disseminating newsletters has also helped drive engagement and increased traffic to the site. Campaigns have an above average open rate and a very low bounce rate indicating content is engaging thus retaining visitors. Top locations by open are UK, Netherlands and USA.

2.10.3.3 Social media

Twitter, Facebook and YouTube have been set up to disseminate the technical outputs of the project. The pages were continuously maintained. However despite repeated requests many partners are still not connected to social media so they cannot join the PicknPack channels.

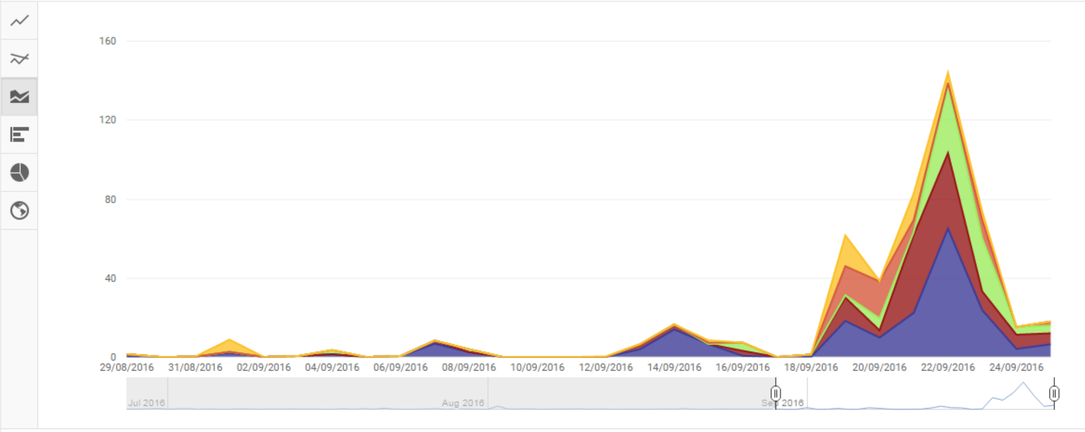
You tube channel analytics indicates that 83% visitors are male and remaining 17% female. Top watch locations are Netherlands, UK and Spain.

The metrics indicate views for the PicknPack line video:
Traffic sources (Figure 51):

Last 28 days (29 Aug 2016 – 25 Sep 2016)

WATCH TIME (MINUTES)	VIEWS
524	354

More metrics ▾ | Daily ▾ | Show totals | Show as % of totals



Traffic source	Watch time (minutes) ↓	Views	Average view duration	Average percentage viewed
External	189 (36%)	152 (43%)	1:14	49%
Suggested videos	127 (24%)	94 (27%)	1:21	53%
Direct or unknown	86 (16%)	42 (12%)	2:02	48%
Other YouTube features	53 (10%)	20 (5.6%)	2:37	67%
YouTube channels	47 (8.9%)	29 (8.2%)	1:36	45%

Figure 51 Watch time per video (last 28 days 29 Aug 2016 – 25 Sep 2016)

Video	Watch time (minutes) ↓	Views	Average view duration	Average percentage viewed
Flexible Robotic Systems for automated adapt...	278 (53%)	131 (37%)	2:07	49%
PicknPack laser sealing of food packaging	122 (23%)	41 (12%)	2:58	48%
Vine Tomato Grasping from Crate 2014 10 23	40 (7.5%)	42 (12%)	0:56	74%
PicknPack Flexible printing	21 (3.9%)	27 (7.6%)	0:45	49%
PicknPack Bin Picking Module	20 (3.7%)	25 (7.1%)	0:47	54%
PicknPack Flexible Thermoformer	14 (2.6%)	15 (4.2%)	0:54	67%
Design of an automated food assembly and p...	12 (2.2%)	37 (11%)	0:19	63%
Unidentified video	9 (1.7%)	4 (1.1%)	2:13	51%
Pickable. Cable robot by Tecnalia	5 (1.0%)	8 (2.3%)	0:38	43%
QAS ScanningTomatoes	3 (0.6%)	4 (1.1%)	0:45	83%
Delta Robot Cleaning with fixed nozzles	2 (0.5%)	20 (5.6%)	0:07	91%

Figure 52 Clicks per video

2.10.3.4 Industrial Advisory Board

At the Leuven meeting in October 2015 a technical issue was raised concerning an incompatibility between material used for thermoforming and that suitable for the sealing process. This was a fundamental matter that impacted on the layout of the demonstrator line which was being planned for exhibition in 2016. Members of the Advisory Committee played a key role in resolving this very difficult issue and their advice was taken as to how we should present the relevant set of functionalities in a logical and industrially acceptable way. This advice represented a major contribution to the PicknPack project and was at a crucial stage in the integration process.

2.10.3.5 Communications

- Strong links exist with the UK's Food Manufacturing Engineering Group who cosponsored the 6th PicknPack workshop and the Summer School and promoted events on its website.
- Links have been established with the IEEE UKI Sections Robotics and Autonomous Systems Chapter who cosponsored the 4th and 6th PicknPack workshop and who have invited a plenary address on the technical outputs at its annual meeting planned for March 2017.
- The IML Publishing Group which host the large annual Appetite for Engineering (A4E) trade meeting published details of the 5th and 6th workshops in their Process Engineering Journal, attended the 6th workshop in Holbeach and invited a formal presentation on the project at their next meeting in Birmingham this October (2016).
- The New Food journal has published a paper on Idoia's impact analysis in early 2016 and has given an open invitation to prepare a special issue on the project which will highlight the key technical outputs. This opportunity will be discussed with all work package leaders.
- The Coordinator of the E.C project Smart-E has invited a presentation on the PicknPack project at one of their technical meetings on 2017.
- Representatives from ABB, Festo, Kuka, Siemens, Omron, Nestle and Bakkavor attended the 6th workshop at Holbeach. In September 2015 Unilever requested details of the project and a presentation was given at their UK headquarters in February 2016 with attendance at Senior Engineer and Technical Director Level. Ongoing discussions have focused on aspects of instrumentation and data processing.
- Representatives of the UK's National Centre for Excellence in Food Engineering which hosts the Food and Drink Federations training programme attended the Holbeach summer school in September and participated in a meeting to discuss trends in food manufacturing and the requirements for advanced training facilities.
- Innovate UK's RAS KTN's Northern Robotics Network Group have requested the use the outputs of the PicknPack project, particularly the latest videos, to encourage the formation of a regional industrial cluster to promote the uptake of robotics and autonomous systems technology in the food manufacturing sector. It has been suggested that the PicknPack software architecture could be extended to encompass up stream processes in the supply chain and links are now being established with the UK's E8 Agri F00d Consortium to explore R/D possibilities.

2.10.3.6 Training events

The focus on the PicknPack May 2016 event in Wageningen was to present a fully working demonstration and to obtain maximum impact and future exploitation. It was decided by the Board not to combine a Summer School with this event and dilute already limited technical resources. This decision restricted the Summer School activity to the September 2016 event which was held at the University of Lincoln's Holbeach campus.

This campus was an excellent choice as the University's Centre for Food Manufacturing has very strong connections with major food manufacturing in the region and liaison with local university associated technical colleges. The Centre agreed to assist in organizing the student cohorts with a mixture of attendees from industry and technical colleges. The target figure was 100 attendees which was fixed by the room capacity and safety restrictions at the demonstration site. At the event we had 83 student registrants with an additional nine industrial and academic supervisors.

The event began with a detailed overview of the PicknPack project presented by Erik Pekkeriet and supported by an impressive video of the full working line. This was followed by a well-illustrated presentation of the role and advantages of automation in the food industry given by Mike Dudbridge who also outlined the possibilities of factory of the future concepts. The students were then directed in organized groups to the large machine display area which had sets of working modules of the PicknPack automated line and a set of booths each of which had poster displays and examples of relevant equipment associated with each workpackage in the programme. Some 32 PicknPack researchers were in attendance to interact directly with the students and to answer any technical questions posed.

An added demonstration feature was the operation of a large (1000kg payload) Robot cell moving bulk food material in an emulated food factory test site. Due to commercial sensitivity the cell was shrouded during the previous Industry Day but the commissioning company was persuaded to run the demonstrator for our "School" event. A 6m high platform was available so that groups of students could obtain an overview of the rapid movement and precision placement of large bulk food containers which provides an innovative material handling solution for industrial level food mixing and preparation.
The enthusiasm and interest of the students was obvious and the researchers became completely involved in the interaction process.
The event ended in a wrap up session chaired by Mike Dudbridge who encouraged comment and feedback from the students. It was clear that we had made an impact and inspired an interest in latest technology.
The feedback obtained from accompanying academy and industrial supervisory staff was also excellent and the event was judged to be a complete success.
Food manufacturing companies represented included Bakkavor, Nestle, Greenvale, Dalehead, ADDO Food Group and Foldhill Foods. As some of the attendees were under the age of 18, due to UK law no attendance lists can be published or photographs can be presented.
For audit purposes this information can be obtained in confidence from Professor Val Braybrooks, Dean of the National Centre for Food Manufacturing, University of Lincoln, Holbeach Campus, UK.

2.10.3.7 Patent applications

All patents were continually polled regarding possible patent applications relating to the fore ground IP generated by the project. This process was repeated at a personal level during the sixth workshop event in September. The only patent applications reported were those made by Tecnalia relating to their innovative pickable cable operated robot. Details of these can be obtained from Jose Perez Larrazabal at tecnalia and will be included in Deliverable D10.4.

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
- IML Group, A4E series of events
- Links with Northern Robotics Network
- Continued communication with Flanders FOOD, Sirris and Agoria

2.10.3.9 List of recent publications and video presentations

Magazines/ Journals/ Papers:

- IOT-based Techniques for Traceability online M2M-Interactive Itemised Data registration and Offline Information Traceability in a Digital Manufacturing System, IEEE Transaction on Industrial Informatics.
- Zhipeng Wu, Zhaozong Meng, John Gray. Submitted
- "Acceptance of innovative automatic equipment in the postharvest and food industry", New Food Magazine, Volume 19, Issue 2, 2016
- ACEPTACIÓN DE SISTEMAS AUTOMÁTICOS INNOVADORES EN LA INDUSTRIA DE PROCESADO DE ALIMENTOS Y POSTCOSECHA
- Journal: Automática e Instrumentación
- Development of a visco elastoplastic contact force model and its parameter determination for apples KU Leuven, 2016
- Realtime SWIR HSI apple bruise detection KU Leuven, 2016
- PicknPack in the Swedish newsletter NordEmballage 2016, pg 30
- "Beitrag für AFT-quarterly" Anuga Food Tec newsletter March 2016

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:

- Automated Adaptive Packaging of Fresh and Processed Food Products the PicknPack project. Appetite for Engineering Conference 19 Oct 2016, Birmingham, UK. John Gray
- Demonstration of Pickable Cable Robot
- (June, 2016)
- IET Flexible Automation in Food Manufacturing
- (September. 04. 2015)
- 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 in the background)

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 Channel film
Erik Pekkeriet, Zhipeng Wu and Mike Dudbridge video and presentations
(September 04, 2015)

Video:

- Full PicknPack line
- Video showing Bin Picking module
- Video showing Flexible Thermoformer module
- Video showing Flexible Printing
- Video of Flexible Cleaning Robot for food processing and packaging line
- Pickable cable robot Tecnalia
- Vine tomato grasping from crate
- Animated production line
- Delta robot cleaning with fixed nozzles
- QAS scanning tomatoes
- PicknPack laser sealing of Food

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

The use of resources was according to the plan of the last amendment (2015-09-01). There were no significant deviations to the plan.

2.11 WP11 Demonstration

2.11.1 Project objectives for the period

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, DLO, UM, Tecnalia, Marel, Fraunhofer, MS) was delivered in the 2nd period:

- 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

Task 11.2. Demonstration at two companies in different food packaging sectors (DTI, DLO, UM, Marel, MS, KUL, Spectro, Cam-Tech, Lacquey) was delivered both in 2nd and 3rd period:

- Transport PicknPack system to demonstration site
- Assemble the system and test operation
- Test under demonstration production circumstances
- Communicate with users during and after the demonstration

2.11.2 Summary of the work progress and achievement during the period

Already in the 2nd period an agreement was made between University of Lincoln and PicknPack to have several demonstrations. And in the 2nd period the first demonstration was performed in Denmark 23 February 2015 with 40 participants from Scandinavian companies.

In the 3rd period PicknPack made several other demonstrations:

Table 8 Demonstrations

	Place:	Date:	Participants	Period:
1	Denmark	23 February 2015	40	2
2	The Netherlands	26 May 2016	48	3
3	The Netherlands	27 May 2016	54	3
4	Spain	June 2016	90	3
5	England	13 September 2016	36	3
6	England	14 September 2016	81	3
	TOTAL		349	

2.11.3 Work progress and achievements during the period

2.11.3.1 3.1 Denmark 23 February 2015

Figure 53 ***Photos from presentations at the Danish Technological Institute***

11:30	Welcome and lunch
12:15	Project ideas (Søren Østergaard, DTI)
12:30	Implementation of flexible packaging lines (Helene Wagtberg, DTI)
13:00	Industrial needs for flexible packaging lines seen from the perspective of a food producing company (Bent Dahlgaard, Tulip Food Company)
13:30	Demonstration (Cam-Tech, Thorslunde)
14:30	Workshop: Brainstorm about design details
16:30	End of the day

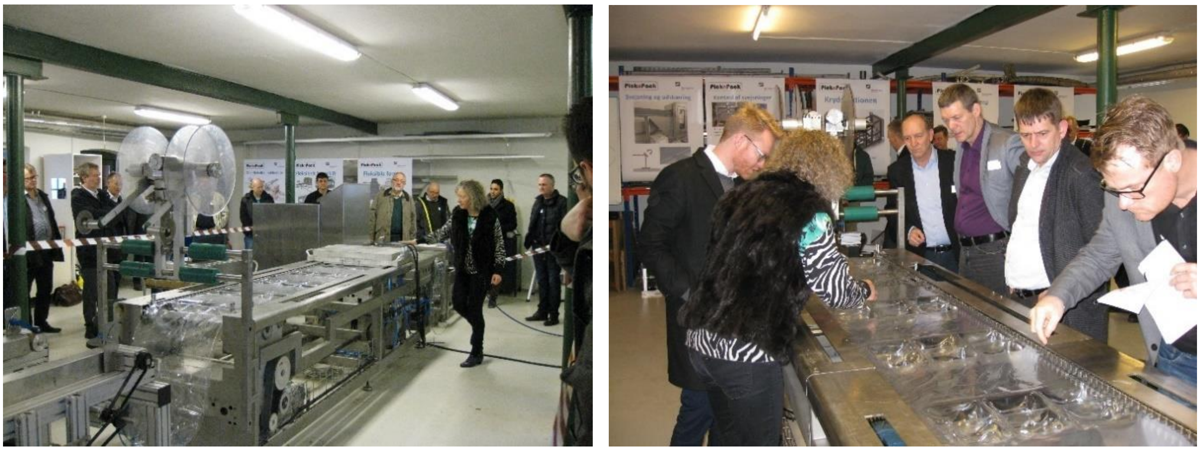


Figure 54 ***Photos from demonstrations of thermoformer at Cam-Tech***

This event in the 2nd period had 40 participants from the Scandinavian industry.

2.11.3.2 3.2 The Netherlands 26 and 27 May 2016

Figure 55 *Photos from registration in Holland*

The overall plan

Figure 56 *Photos from the welcome by the coordinator*

09:15 - 10:00 Registration
10:00 - 10:30 Welcome and overview of PicknPack Project (Erik Pekkeriet) in the big hall with reception
10:30 - 11:30 Session 1
11:30 - 12:30 Session 2
12:30 - 14:00 Lunch – Technotron next to booths
14:00 - 15:00 Session 3
15:00 - 16:00 Session 4
16:00 - 17:00 Closing session with soft drinks (Idoia)

Plan for 4 groups

Tour guides	Red group Fatima	Blue group Gert	Green group Fatima	Pink group Gert
10:30 - 11:30 Session 1	Presentation	Presentation	Booths	PnP Demo line
11:30 - 12:30 Session 2	Presentation	Presentation	PnP Demo line	Booths
14:00 - 15:00 Session 3	PnP Demo line	Booths	Presentation	Presentation
15:00 - 16:00 Session 4	Booths	PnP Demo line	Presentation	Presentation

Workshop presentations

Group red and blue are together in the morning.

Group green and pink are together in the afternoon.

Place: The conference room next to the reception.

- Flexible Automation for Food Packaging, from Bin to Pack in One Step (Richard van de Linde of Lacquey)
- Software Architecture for Data Processing and Control of Modular Reconfigurable Automated Systems (Herman Bruyninchx of KU Leuven)
- Non-destructive, in-line Assessment of Surface, Subsurface and Internal Quality of Food Products (Wouter Saeys of KU Leuven)
- RFID Enabled Traceability Systems in Food Manufacturing and Distribution (Zhipeng Wu of University of Manchester)
- PicknPack project Impact Analysis and routes to Exploitation (Idoia Olaberrieta of AZTI)
- SHORT EXTRA SHOW about Hygiene (Marc of Fraunhofer)

Plan for Demonstration

Place: Food Hall

Figure 57 *Photos from demonstrations in Food Hall*

			session 1	26-27 May		
1	10:30	10:35	max 25 guests enter the foodhall	26-27 May	Tour guide	
2	10:35	10:45	short introduction	26-27 May	Bart	explain what will be done; how is the demo organised; explain what is seen on the video.
3	10:45	11:04	explain what happens at the PnP line	26-27 May	Bart	
4	10:45	11:04	empty/roll-up web of trays at the @ of line;	26-27 May	Toon / Francesco	chickens are stored in crates; the empty web is rolled up
5	10:45	10:52	place crate with chicken on conveyor belt	26-27 May	Richard	
6	10:45	10:52	remove crate with chicken on conveyor belt	26-27 May	Freek	
7	10:45		demo leader signals LC - go	26-27 May	Ruud	
8	10:45		Line runs; 5 empty bacthes (trays of chicken)	26-27 May	Angelo / Gert Jan	Marel does not place any chicken
9			Line runs; 5 batches with chicken (30 chick)	26-27 May	Angelo / Gert Jan	Marel places chicken
10		10:52	Line runs; 45 empty batches	26-27 May	Angelo / Gert Jan	Marel does not place any chicken
11	10:52		demo leader signals LC - stop	26-27 May	Ruud	
12	10:52		LC sends hold to the line	26-27 May	Angelo / Gert Jan	
13	10:52	11:02	mold exchange to tomatoes	26-27 May	Kiril	maximum time needed for mould exchange is 10 minutes
14	11:02	11:04	place crate with tomatoes on conveyor belt	26-27 May	Richard	
15	11:02	11:04	remove crate with tomatoes on conveyor belt	26-27 May	Freek	
16	11:02		demo leader signals LC - go	26-27 May	Ruud	
17	11:02		Line runs; 8 empty batches (trays of tomatoes)	26-27 May	Angelo / Gert Jan	Marel does not place any tomatoes
18		11:04	line runs; 5 batches of tomatoes (15 vine tomatoes)	26-27 May		Marel places vine tomatoes
19	11:04		demo leader signals LC - stop	26-27 May	Ruud	
20	11:04		Line Control stops the PnP line	26-27 May	Angelo / Gert Jan	
21	11:04	11:15	guests walk along the line	26-27 May		in-depth discussions are at the booths not at the line
22	11:15		demo leader asks guests to go to Pickable demo	26-27 May	Ruud	
23	11:15	11:25	pickable demo + explanation	26-27 May	Gorka Duro	
24	11:25	11:30	guest leave foodhall	26-27 May	Tour guide	

Plan for Booths

Figure 58 *Photos from presentations in booths*

The group will walk from booth to booth under the tour guides control. Each booth leader has about five minutes to make a short presentation of their booth.

Lay-out of booths:

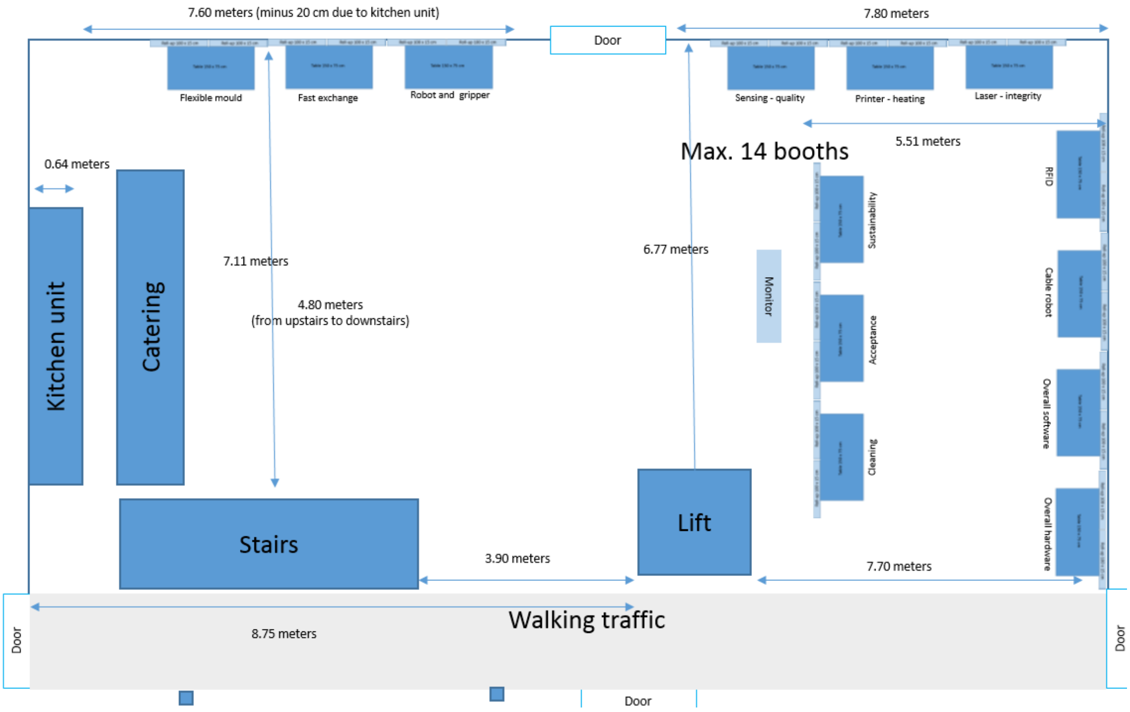


Figure 59 *Lay-out of booth presentations*

1. Flexible mould
2. Fast exchange
3. Robot and gripper
4. Sensing-quality
5. Printer-heating
6. Laser-integrity
7. RFID
8. Cable robot
9. Overall software
10. Overall hardware
11. Cleaning
12. Acceptance
13. Sustainability

Please note that the booths need a person in the session with a short introduction and under lunch etc. to service participants.
Monitor control in:

- Technotron
- Food Hall

Tours to Laser and Integrity Audit

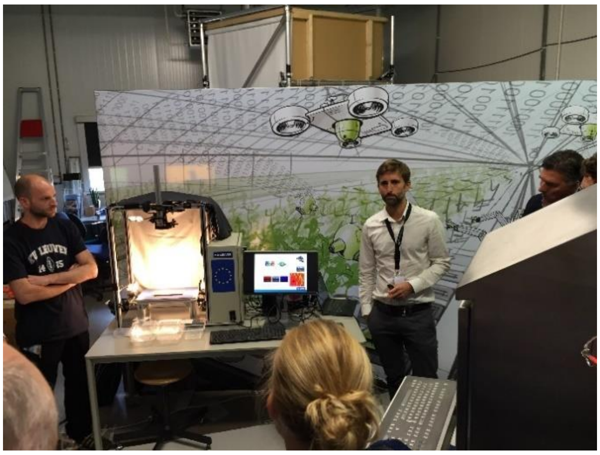



Figure 60 *Photos from the laser laboratory*

The tour guides had all four groups on a visit to a special laser laboratory in order study the laser and integrity audit equipment. Both made small special presentations of the functionality.

Participants in The Netherlands

These two demonstration days had in total 102 participants:

1. 26 May 2016: 48 participants
2. 27 may 2016: 54 participants

2.11.3.3 Spain June 2016

During June 2016 three demonstration events were carried out in one of the headquarters of Tecnalia, the one in Mikeletegi 7, San Sebastian. The demonstrations were:

- RoboTT-net OpenLab 09th June
- Visitors from USA 10th June
- Visitors from Austria 15th June

RoboTT-net OpenLab

The PickandPack project was introduced to about 60 experts in robotics. Pickable was demonstrated as follows:

- Scope of the project:

http://robott-net.eu/this-is-robott-net

- Video of the project:

https://www.youtube.com/watch?v=bNzTy7E5oLo

- Video of the event:

https://www.youtube.com/watch?v=mOX8KbhgjbQ&index=1&list=PLA0D61AEED6A4BEF3

Figure 61 *Photos from presentation of Pickable to the Robott-net attendants*

Visitors from USA

Students from four universities from the USA visited Tecnalia due to an initiative of ESPA agency of Navarra (Spain).

- Clemson University
- University of Alabama
- Auburn University
- University of Kentucky.

Figure 62 *Photos from presentation of Pickable to the North American visitors*

Visitors from Australia

In the scope of the relation with the Austrian Cooperative Research, companies from Australia visited Tecnalia:

- This cooperative lead a visit to Tecnalia.
- About 30 Australian companies participated in this visit

http://www.acr.ac.at/news/acr-war-auf-studienreise-im-baskenland.html

Figure 63 *Photos from presentation of Pickable to the Australian visitors*

2.11.3.4 England 13 September 2016

Figure 64 *Photos from demonstrations in England (Marel and hygienic robots on sectional frame)*

General description

It was decided in PicknPack to perform two different events in University of Lincoln, Holbeach as follows:

- 13 September 2016: Demonstration-workshop as a limited event
- 14 September 2016: Education event for students

Timeline

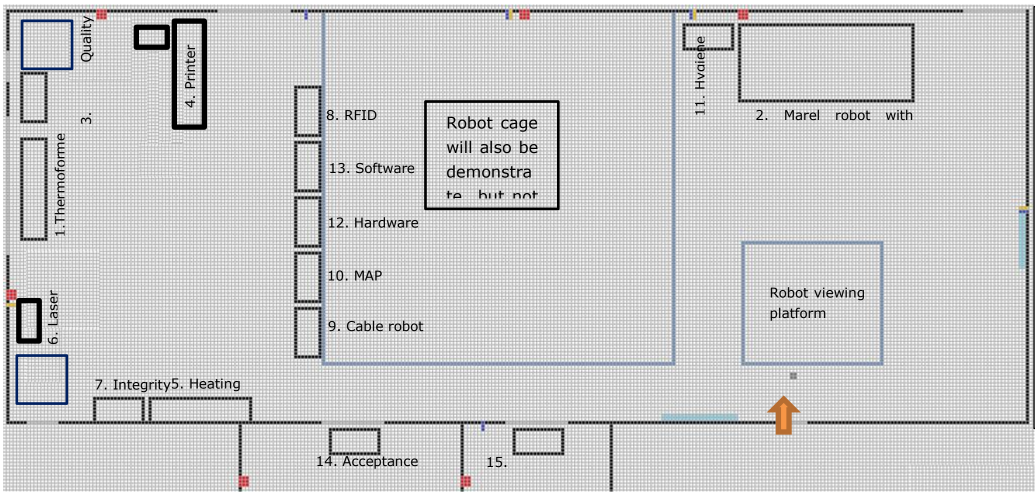
- Week 35-36 (29 August – 9 September): Arrival of demonstration equipment and demonstration booths to Holbeach.
- Week 36-37 (5 September-12 September): Installation of equipment and booths by the responsible partners. It was possible to install equipment in the weekend 10-11 September between 9 am. to 5pm.
- Monday 12 September: Audit of all functions.
- Tuesday 13 September 2016: Demonstration-workshop.
- Wednesday 14 September 2016: Education event for students from 9.45 – 12.30.
- Thursday 15 September 2016: University of Lincoln has a management event.
- 14-16 September packing of equipment to storage.
- 14-23 September shipment of equipment back to partners.

Equipment and cases are reported in Table 9.

Table 9 Equipment and cases demonstrated in Holbeach

Demonstrations and booths:	**Demo in Holbeach**
Mould and thermoformer	The demonstration used the special video produced in May-June and with the brick moulds placed on tables. The demonstration included samples of trays and produced packaging.
Robot and gripper	Marel robot was installed with grippers and sectional frames in order to demonstrate cleaning.
Quality module	Illustration using a simple camera setup with 2-3 sensors mounted over a translation stage to visualize the concept and sensing functionality.
Printer	Printer will be demonstrated with the cases from Wageningen.
Heating	Demonstration as in Wageningen with heating of UK ready meals in microwave owns.
Laser	Demonstration as in Wageningen.
Integrity audit	Demonstration as in Wageningen.
T&T - RFID	Demonstration as in Wageningen.
Cable robot	Only Roll-ups and commercial video was presented in a booth.
MAP	A booth presentation with roll-ups.
Hygiene	Hygiene will be demonstrated with real washing on a sectional frame and the Marel robot.
Overall hardware	Demonstrated with a sectional frame together with robot and hygiene.
Overall software	Presentation and demonstration on computers.
Acceptance	Roll-ups as in Wageningen
Sustainability	Roll-ups as in Wageningen

Lay-out in Holbeach



1. Mould and thermoformer
2. Robot and gripper (over a drain).
3. Quality module
4. Printer
5. Heating
6. Laser
7. Integrity audit
8. T&T - RFID
9. Cable robot
10. MAP
11. Hygiene (over a drain)
12. Overall hardware
13. Overall software

Figure 65 *Lay-out in Holbeach*

Programme 13 September 2016

Figure 66 *Presentations in conference room in Holbeach*

09:15 - 10:00 Registration
10:00 - 10:30 Welcome and overview of PicknPack Project (Erik Pekkeriet) in conference room
10:30 - 12:30 Presentations in conference room (approx. 24mins each)

- 10:30 – 10:50 Richard van de Linde Director Lacquey - to be confirmed - Automation of Food Packaging, from Bin to Pack in One Step
- 10:50 – 11:10 Professor Wouter Saeys KU Leuven - Non-destructive, in-line Assessment of Surface, Subsurface and Internal Quality of Food Products
- 11:10 – 11:30 Professor Herman Bruyninchx KU Leuven - Software Architecture for Data Processing and Control of Modular Reconfigurable Automated Systems
- 11:30 – 11:50 Professor Zhipeng Wu The University of Manchester - RFID Enabled Traceability Systems in Food Manufacturing and Distribution
- 11:50 – 12:10 Roman Murcek of Fraunhofer - Presentation of Roman Murcek Hygiene

12:30 - 13:30 Lunch
13:30 - 15:00 Demonstrations and booths incl. coffee served

- 13:30 – 14:50 Participants walk around the Hall
- 14:50 – 15:00 Special demonstration of Fraunhofer Hygiene Robot

15:00 – 15.20 Closing session: Impact Analysis and routes to Exploitation – delegate networking

Figure 67 *Photos from Holbeach*

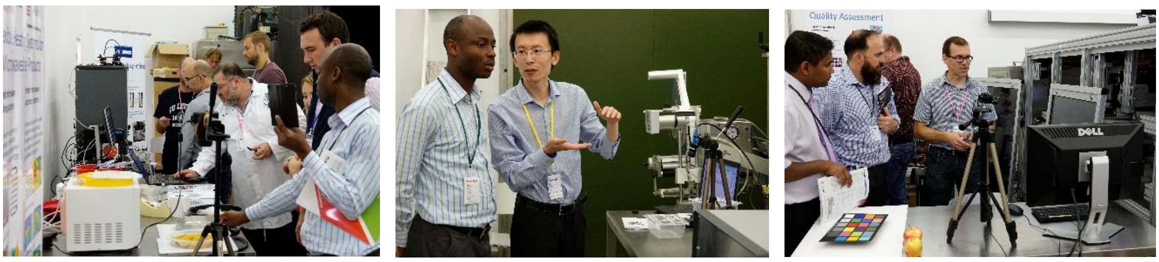


Figure 68 *More photos from Holbeach*

The event had 36 participants from the British food and packaging industry.

2.11.3.5 Student's day in England 14 September 2014

Program for student's day

<table>
<tr><th colspan="2">Time</th><th>Activity</th><th>Group</th><th>Comments</th></tr>
<tr><td colspan="2">Session 1 - NCFM</td><td rowspan="2">Schools arrive from 9.45 onwards (schools to bring list of students) (times allow for movement of student groups)</td><td rowspan="2">Suggested 8-12 per group</td><td rowspan="2">Split between groups A to J, target 50 young people am only (2 tables required in main reception for registrations (on 13th)).</td></tr>
<tr><td>From</td><td>To</td></tr>
<tr><td colspan="2">10.00 to 10.15</td><td>Welcome and overview of PicknPack Project
Wageningen UR, Erik Pekkeriet</td><td>All groups</td><td>Presentations to all students in conference room. Chairs to be set out conference style.</td></tr>
<tr><td colspan="2">10.15 to 10.30</td><td>Opportunities in Food Engineering
University of Manchester, Mike Dudbridge</td><td>All groups</td><td>Presentations to all students in conference room. Chairs to be set out conference style.</td></tr>
<tr><td colspan="2">10.30 to 10.40</td><td>Organisation of 6 groups of 8-12 students</td><td colspan="2">Move down to factory area (times allow for over run/movement of students)</td></tr>
<tr><td colspan="2">10.40 to 11.40</td><td>Guided tours between packaging machines etc.
<table>
<tr><th>Event</th><th>Time in min.</th><th>Group A</th><th>Group B</th><th>Group C</th></tr>
<tr><td>2. Marel robot and gripper</td><td>10</td><td></td><td></td><td></td></tr>
<tr><td>11 Hygeine robot</td><td>10</td><td></td><td></td><td></td></tr>
<tr><td>8 RFID T&T</td><td>5</td><td></td><td></td><td></td></tr>
<tr><td>4 Printer</td><td>5</td><td></td><td></td><td></td></tr>
<tr><td>3 Quality Sensing</td><td>10</td><td></td><td></td><td></td></tr>
<tr><td>1 Mould and thermoformer</td><td>10</td><td></td><td></td><td></td></tr>
<tr><td>6 Laser</td><td>5</td><td></td><td></td><td></td></tr>
<tr><td>5 Heating</td><td>5</td><td></td><td></td><td></td></tr>
</table></td><td colspan="2">
<table>
<tr><th>Event START</th><th>Time, min.</th><th>Group A</th><th>Group B</th><th>Group C</th></tr>
<tr><td>2. Marel robot and gripper</td><td>10</td><td>10.40</td><td>11.20</td><td>11.00</td></tr>
<tr><td>11 Hygeine robot</td><td>10</td><td>10.50</td><td>11.30</td><td>11.10</td></tr>
<tr><td>8 RFID T&T</td><td>5</td><td>11.00</td><td>10.40</td><td>11.20</td></tr>
<tr><td>4 Printer</td><td>5</td><td>11.05</td><td>10.45</td><td>11.25</td></tr>
<tr><td>3 Quality Sensing</td><td>10</td><td>11.10</td><td>10.50</td><td>11.30</td></tr>
<tr><td>1 Mould and thermoformer</td><td>10</td><td>11.20</td><td>11.00</td><td>10.40</td></tr>
<tr><td>6 Laser</td><td>5</td><td>11.30</td><td>11.10</td><td>10.50</td></tr>
<tr><td>5 Heating</td><td>5</td><td>11.35</td><td>11.15</td><td>10.55</td></tr>
</table></td></tr>
<tr><td colspan="2">11.40 to 11.50</td><td>Demonstration of hygiene robot with water spray</td><td colspan="2">All groups together</td></tr>
<tr><td colspan="2">11.50</td><td>Q+A with Mike Dudbridge</td><td>All groups</td><td>Groups move back into conference room</td></tr>
<tr><td colspan="2">12.30</td><td>Departure</td><td></td><td></td></tr>
<tr><td colspan="2"></td><td>Lunch for PicknPack team only</td><td></td><td></td></tr>
</table>

Lay-out and guided tour

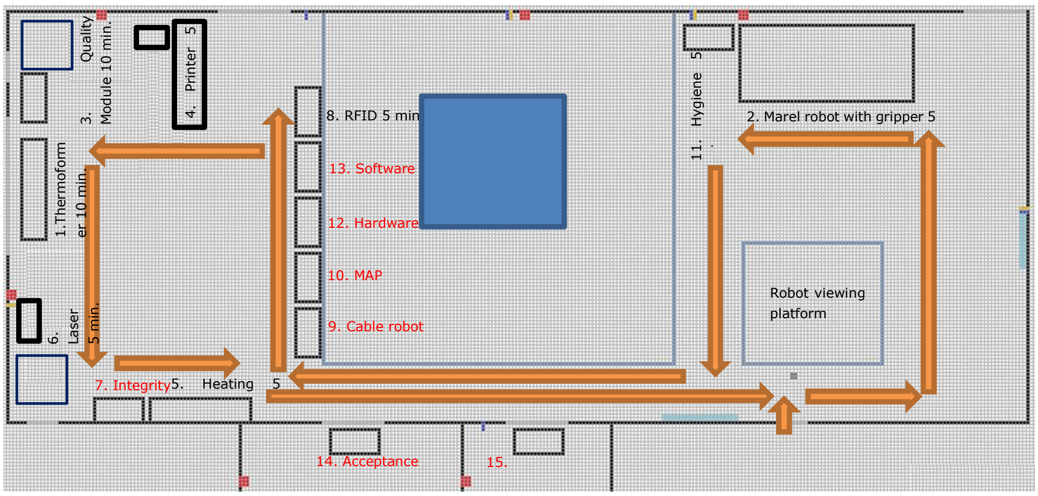


Figure 69 *Guided tours for students in Holbeach*

81 participants from local schools and trainees from local industry participated in the demonstration in Holbeach the 14 September 2016.

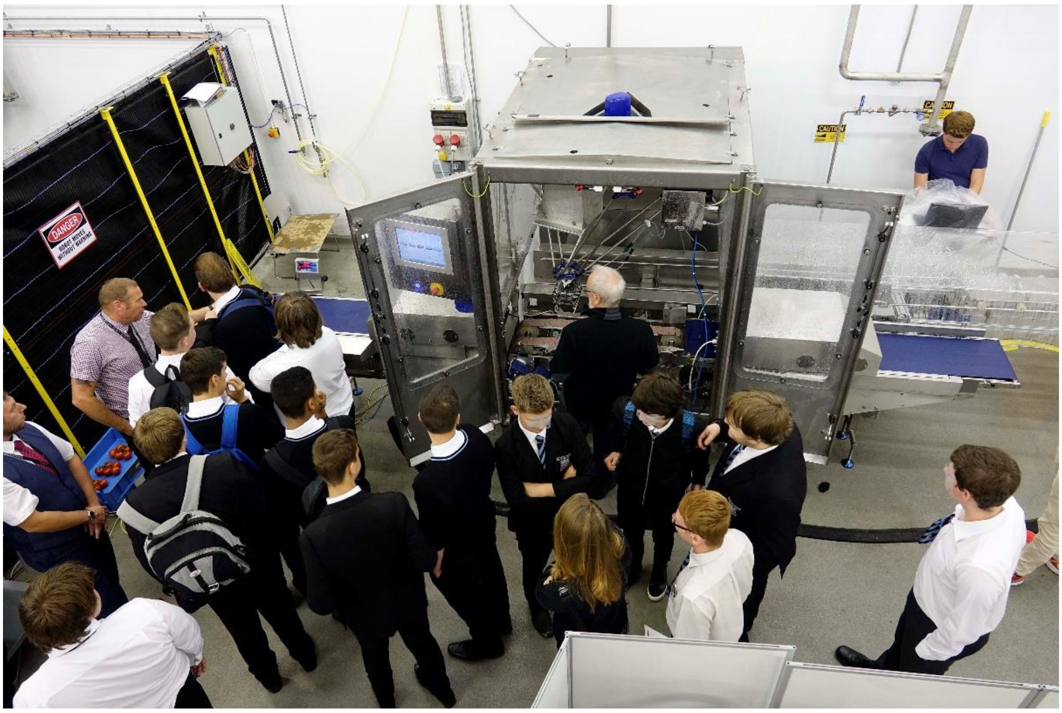


Figure 70 *Photo from Student's day in Holbeach*

2.11.4 Use of resources

The use of resources was according to the plan of the last amendment (2015-09-01). There were no significant deviations to the plan.

2.12 WP12 Acceptance, economics and exploitation

2.12.1 Project objectives for the period.

The objective of this third period was to complete and use the developed tools and the generated information during the project, to perform realistic exploitation plans of the results and to offer to the partners the most useful information, in order to develop forward the technological readiness level (TRL) of the results oriented to the market needs and requirements.

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

- To make the **global interpretation of the results** of the acceptance study, regarding investing intention and drivers and barriers towards implementation. The purpose of this study was to generate the most specific information about the requirements regarding automation to perform a consistent exercise in order 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 perform an assessment 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).
- To **describe the overview of the different results integrating the PnP line and their corresponding exploitation paths**. For each module/unit, problems, solution, description of the technology and benefits of it, TRL and expected IPR were defined moreover the nest steps to be performed by the partners in order to go further in the TRL of the developed technologies or results.

2.12.2 Summary of the work progress and achievement during the period

In the last period of the project a final update and analysis of the acceptance study performed in the former period was done. The study investigated the acceptability of innovative automatic systems by the FOOD and POSTHARVEST industry.
A close communication between partners was kept in order to define and discuss the characteristics, benefits and exploitation plans of the achieved results. The objective of this task was to describe the results of the Picknpack project and the potential ways of their exploitation via different approaches for future scenarios in order to reach a closer level of readiness towards the market. Collaboration with ProBio Consortium: B3O (Bio-Based Business Opportunity) project experts contacted Wp12 leader to offer the support in this task. 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.

2.12.3 Work progress and achievements during the period

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

Under the last period of the project a final update and analysis of the **acceptance study** performed in the former period was done. In summary, the study investigated the acceptability of innovative automatic systems by the FOOD and POSTHARVEST industry. The investment intention by companies of both sectors, and the factors that push them to declare a positive or negative intention were analyzed. The study also provided a context to these factors. Thus the knowledge of the particular and common characteristics of both sectors helped to orient the approaching strategies to design the adequate exploitation plan (in task 12.4), for automation suppliers to facilitate a greater implementation in the food industry of today.
Under this period a focused **analysis of the OPPORTUNITIES and THREATS** that arise in FOOD and POSTHARVEST sectors was concluded. This led to consider the aspects that already encourage companies to invest, i.e., the drivers of those answering YES to the question of investment intention. THREATS were

deduced from the importance attributed to potential barriers by companies with in advanced negative intention to invest in automation. That is, the acceptance study helped to get an **external view of the current situation** of the FOOD and POSTHARVEST sectors. The study helped the exploitation task by identifying the helpful (OPPORTUNITIES) and harmful (THREATS) factors that could affect the business in the current situation of the sector. The discussion and conclusions from this study helped to **define main recommendations for the technology suppliers** in order to orientate their business in function of the factors influencing the implementation decisions of the food companies. The results and conclusions of this work were useful to contextualize the exploitation plans described in in Deliverable 12.5 "Technology Exploitation plan".
As a result of the work done in this task the following outputs were generated:

- ***Deliverable 12.2: "Report on social, technological and economic barriers influencing the acceptance and implementation".***

The report described the objectives, methodology, discussion and conclusions of the study done in order to analyse the factors influencing the acceptance and implementation of automatic systems in fresh food processing plants in Europe.

AUTOMATION

Idoia Olabarrieta, Izaskun Pérez, Raquel Rodriguez, Jaime Zufía

Acceptance of innovative automatic equipment in the postharvest and food industry

PICKNPACK is a large collaborative project granted by the EU within the 7th Frame programme, with the aim of boosting the development and implementation of innovative automatic systems in food industry. In order to find strategic approaches for facilitating greater deployment of new flexible and autonomous robots, sensors and packaging modules in the food industry of today, an acceptance study was done within this sector. This article summarises the main conclusions achieved from that study for both food processing and postharvest sector.

Introduction

I. Olabarrieta, I. Pérez, R. Rodriguez, J. Zufía, "Acceptance of innovative automatic equipment in the postharvest and food industry" **New Food** Magazine, Issue 2, 2016 http://www.newfoodmagazine.com/magazine.

Industria alimentaria

Proyecto Picknpack

Procesado de alimentos y postcosecha: nivel de aceptación de sistemas automáticos

Picknpack es un proyecto de colaboración subvencionado por la UE dentro del 7º Programa Marco cuyo objetivo ha sido desarrollar sistemas automáticos innovadores flexibles para la industria alimentaria planteando el concepto de línea modular para su integración en planta. Con el fin de conocer enfoques estratégicos que faciliten la implantación de dichos sistemas automáticos, *Azti*, como socio de dicho proyecto, realizó un estudio a nivel europeo sobre las necesidades e intereses de las industrias alimentarias en cuestión de automatización y sobre su percepción a la hora de realizar una posible inversión en tecnología. En este artículo se muestran los resultados del citado estudio.

I. Olabarrieta, I. Pérez, R. Rodriguez, A. Melado, J. Zufía, "Procesado de alimentos y postcosecha: nivel de aceptación de sistemas automáticos", **Automática e Instrumentación**, nº 486, Septiembre 2016

Figure 71 Articles: The main conclusions and results of the work were summarized in two different articles

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

During this last period, the social impact of an automated line such a **PicknPack line** was concluded. This study was focused in the **impact of the automatic lines regarding workers and consumer** (food safety).
For assessing the impact of the Picknpack line in the workers welfare, the study was done in **terms of occupational Risk Prevention (ORP)** and focused in the ergonomic improvement of the labour work. The investment in automation does not mean by default a direct improvement in ergonomy and quality of workers. Badly designed automatic equipment can make the worker in charge of the equipment to suffer higher risk of accidents or sickness. This means that automatic tasks must be well designed to adjust workers activity to the processing work and time. In order to study the PnP line impact on worker conditions, the **line design of PicknPack was checked and evaluated** in order to **identify and reduce the ergonomic hazards** present in it and to minimize their effect on the workers' health. For that issue **a theoretical identification of the critical points** or critical tasks was studied and suggestions of improvement were described. As a reference, several studies were consulted in the field of worker

conditions and ergonomics. The used **methodology** was **based on international recognized ergonomic evaluation methods**, which was explained to the partners in the former period, in order to serve as a basis for future developments and technological improvements in process and thus, minimize the negative impacts from the ergonomic point of view. However, due to the functionality of the entire line of PnP was not reached, and thus, limited data were available for ergonomic assessment, this study was proposed as an orientation on ergonomic design to take into account to further developments. Moreover to complete the **study the impact** of these **robotic systems on consumers regarding food safety** was **discussed**.
For defining and identifying the factors affected by the Picknpack line regarding workers welfare the following actions were carried out: (a) *data collection*: in the former period data from partners was required about equipment design and tasks identifications and descriptions. This information was updated under this period; (b) *Tasks identification and description based on the final and theoretical design of the line*, in which there were identified three tasks where it was necessary to take into account the human work intervention; (c) *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.
In the study several ergonomic risks and suggestions for minimizing them were done. Although the study was semi theoretical, information, methodology and guidelines were proposed to be followed when integrating this process line in a real production plant, so the equipment manufacturers were encouraged to, as much as possible, to take into account such recommendations in order to make the equipment user friendly and safe for the workers.
Related to the influence of the PicknPack line on consumers, the impacts of the line on the final consumers of products were identified. The automation and the use of new technologies enable to have high process control and production flexibility. This allows meeting the expectations of consumers more accurately and efficiently than traditional forms of production. This impact was also confirmed with the acceptance study performed in the same work package in which several European companies were surveyed about needs and perceptions about automation in their business. From this study the impacts on social aspects and the impacts that were related to the **consumer's product acceptance** were confirmed.
The results, discussions and conclusions from the evaluation of societal impact were described in the following report:

- ***Deliverable 12.3. "Report on aspects and measures to minimise societal risks and impacts of robotics systems in food"***

This report described the objectives, methodology and results of the study done in order to evaluate the societal impact of robotics systems in the food packaging sector. Its objective was the evaluation of the positive and negative impact of the development of automated systems on worker conditions and consumers. On one hand, the impact of automated systems was evaluated on the safety and ergonomics of the workplace and of the whole food process line, focusing mainly on the ergonomic aspects of the manual labour done by the workers. On the other hand, the impact on consumers related to food safety, like a hygienic handling, reduction of cross contamination, etc., was discussed.
This deliverable included:

- *Introduction to the impacts of robotics systems with advantages and disadvantages of automation focusing in the societal impacts on worker conditions and consumers.*
- *PicknPack line workstations and tasks description. Workstations analysis in order to identify critical tasks and its estimation of the ergonomic risks.*
- *Specific measures of improvement in order to minimise ergonomic impacts.*
- *Impact on consumers.*

2.12.3.3 Task 12.4. Promoting exploitation of the project results and stimulating new applications.

Under this period a close communication between partners was kept in order to define and discuss the characteristics, benefits and exploitation plans of the achieved results. The objective of this task was to describe the results of the Picknpack project and the potential ways of their exploitation via different approaches for future scenarios in order to reach a closer **level of readiness towards the market.** Although the whole system was not entirely functional, the **different modules** that compose the PicknPack project reached a different state of development during the course of the project. There are eight different technology modules that have been developed, and most of them have reached a TRL between 4 and 7. Some of the modules were even quite close to market. After finishing the PicknPack project, the aim was each individual partner to keep on developing the technology, alone or in collaboration with partners, in order to reach a higher TRL closer to market.

In order to achieve the needed information, several communications and two workshops were done under the project, in order to explain to partners the main issues and to ask them oriented inputs. With the aim of not only them to describe the innovations, but to really **translate the impact in their business** by describing the **benefits of the innovations** in terms that are **understandable** to the potential clients. The challenge of this task was to make the partners conscious **of the importance of describing, to the potential clients, the added value** of their research in an understandable and clear way. For that aim, the information was asked in several formats (questionnaires, tables, message maps, elevator pitch, etc.) in order to get clear answer to the problem solved by the results, a clear description of the solution, the benefits and the reason why the achieved solution was better than one of competitors (unique selling point), among others.

For structuring this task different information, collected from the different partners, deliverables, results, reports etc. was used as input. In addition to the information obtained from the partners (developers), inputs from the WP9-Life Cycle Analysis and Sustainability, WP11- Demonstration and WP12- Acceptance, Economics and Exploitation, were used. D11.2-"Report on Two Demonstrations", gave us the confirmation of the interest of the industry to fill the gaps that still exist in packaging lines in both food processing and postharvest industry. Specifically, the two demonstrations that took place in Wageningen (Netherlands) and in Holbeach (United Kingdom) allowed not only to gather information about the requirements of the industry, but also the opportunity to make contacts and to build a strong network that will help in the promotion of further developments. D 12.2.-"Report on Social, Technologic and Economic Barriers Influencing the Acceptance and Implementation", allowed drawing up a SWOT analysis, with all the information gathered from the study made at EU level in both food and postharvest industries. D12.3.- "Simulation Model of Economic for Each Application" provided an estimation of the impact that the implementation of the equipment in the business would have in the potential target companies.

The outputs generated form the work performed in this task were the following ones:

- ***Deliverable 12.5. "Exploitation plans"***

The developed deliverable was addressed to strengthen the Picknpack approach and to promote the Picknpack outcomes for the promotion and future exploitation of the results towards direct access user services and to the commercialization or use of these services as well as of the technological products.

The report had as main goals the identification of exploitable outcomes of PnP project, and the elaboration of plans for their exploitation by partners involved in the project. *Exploitable outcomes include robotic modules, software artefacts, methodologies and skills developed and acquired during the project (know-how) that could be transferred to a third party as a product or service. The main objective is to give value to the results achieved by the project for their commercial exploitation. This deliverable was structured as follows:*

- *Introduction to the Picknpack project results, main objectives of the report are described as well as the corresponding activities that are needed to accomplish those objectives.*
- *SWOT Analysis of main strengths, weaknesses, risks and opportunities of the project.*
- *Define the Technology Readiness levels of the components of the PicknPack system.*
- *The feasibility study is illustrated in the next section, including the exploitation and replication roadmap for PICKNPACK global result. Economic exercise.*

- The value innovation analysis of **individual project results**.
- Each partners exploitation plans for the developed solutions during the project.
- Conclusions from the report.

- **2 Workshops of exploitation plans (Leuven, October 2015 and Valencia, May 2016)**

The workshops were done in order to explain the partners how to describe the benefits of the results and in order to describe the **story** and **convince** the industry that our modules have **potential innovation** that can be **of interest for them.** In those events, 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.
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** 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 discuss it during the project meetings, 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.

- **Overview presentation of the project results**

A visual ppt presentation overview of the system was presented in which it is possible to click on individual modules and elements to get additional information on these. This presentation was used in the demonstration days for displaying the results.

Figure 72. Snapshot of the initial interactive screen of the presentation of the overview of the project results

- **Oral Presentation of the project results (Wageningen May 2016, Holbeach October 2016)**

Under the two demonstration events held in Wageningen (NL) in May 2016 and in Holbeach (UK) in September 2016, a presentation "Impact and Routes to Exploitation" was done to the participants in order to show the main outputs of this Work package.

Figure 73. Title of the presentations done, by WP12, as Wrap-up speeches in the two Demonstration events.

- **Collaboration with ProBio Consortium**: **B3O (Bio-Based Business Opportunity)** project experts contacted Wp12 leader to offer the support in this task. 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 sent with the general results and with detailed information of the most developed module so far. An extensive questionnaire about exploitation of results was received and the two partners with the most advanced results were asked to fill it. The ProBio Consortium offered under the support actions an education seminar which was shared within the partners: "ProBIO Webinars for KBBE projects' result owners coached by ProBIO". The webinars gave insights on how to improve the exploitation aspects of a research project proposal to fully exploit all the opportunities brought by the corresponding project's results.

During this period two project meetings were held: In Leuven (September 2015), in Valencia (may 2016) where the current progress and results of the WP12 were explained and discussed with the rest of the partners, in May and September 2016 the demonstrations of the PicknPack projects were held in Wageningen and Holbeach respectively. WP12 actively participated in them in order to show the overview of the results and the potentiality of them for the market.

2.12.4 Use of resources

The use of resources was according to the plan of the last amendment (2015-09-01). There were no significant deviations to the plan.

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.

All deliverables are submitted. Project meetings were 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. Due to strategic changes within the Marel company the project moved from Marel Iceland to Marel UK and back to Iceland/Danmark again. Because of these changes, Marel could not fulfil all the integration tasks and tasks were handed over to other partners. Also Marks and Spencer could not fulfil all of its task. Although cooperation with Marks and Spencer was improved in the last period. Because Marel and M&S did not use their full budget. Task and budget allocations were proposed in the Project Board meeting and discussed with the Project Officer. Budget and task allocations were agreed in the third Amendment.
2. The Technalia cable-robot was delayed several times. When Tecnalia proposed a new delay, the coordinator took a flight within a week to San Sebastian to discuss the issue and agreed on a detailed action plan. Reports were made on a weekly basis with top management at Tecnalia in the loop. Actions were carried out according to the plan. The cable-robot was received in operational condition on time.
3. A few months before demonstration there were a lot of issues in software development to connect the modules to the novel and flexible line-controller. Demonstrating the working line was delayed several times. As a coordinator I took the initiative to organize a crisis meeting with all WP leaders and engineers involved. Main reason was the limited level of knowledge and skills of software engineers in this flexible way of programming of module owners. We started up a specific taskforce (with partners form WP2, WP4, WP6 and WP7) to solve the problems on a day by day schedule and a meeting once a day and a small daily report to the coordinator. After the problems were solved we had a working line.
4. To make the full line operational for demonstration it took a lot of effort. To have the full line operational in the second demo it would not add enough value to the project and the modules would not develop further to achieve a higher level of flexibility and gaining scientific results. For

this reason it was better to improve the modules between the first and second demo. And focus in the second demo not on the full line but on the flexibility capabilities of the different module. Line integration could still be performed on a specific combination of modules. The took the issue to the Project Officer (Stefan De Vos). He agreed to make the second demonstration different form the first one. Many improvement were added between the first and second demonstration.

5. After the line was integrated and started to become operational. The project team found out that demonstrating fast change-overs and a huge variety of products was difficult and risky to demonstrate in a research line with all the innovations. Due to safety issues people could not see everything and the number of people to attend the demonstration were limited. To demonstrate the full capability and flexibility of the line the team decided to make a professional video. With the EU project officer the coordinator agreed on a budget and save costings on the second demo. Although the budget was limited and partners needed to sponsor the video outside the project the result of the video has I high impact. Marks & Spencer took the project video to their suppliers as a great example of flexibility. The video is already boosting new developments with over a 2000 views on Youtube.

3.3 Project meetings

Three project meetings were organized during the second period:

1. October 27-29, 2015 Leuven (Belgium)
2. April 19-213, 2016 Valencia (Spain)
3. May 26 and 27, 2016 Wageningen Demonstration Days (Netherlands)
4. September 12-13, 2016 Holbeach Demonstration Days (UK)

During integration and demonstration 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. The project achieved all objectives of the project.

3.5 Impact of possible deviations

The project achieved all results before the end of the project. A few scientific publications are pending but are in process to be published.

3.6 Changes in the consortium, if any

There were No further changes in the project consortium in the third period. Marks and Spencer did not administrate their effort in the correct way. They decided not to declare any costs. The contribution to the project of Marks and Spenser in the third period improved compared to the second period. A summary of their effort and statement to the project results is reported in appendix 1. Of this report

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

No further changes in position of work package leaders or project board members occurred.

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14 October 2016

Mr Erik J Pekkeriet
Wageningen UR
Droevendaalsesteeg 1
6708 PB Wageningen
Netherlands

Dear Erik,

Can I start by saying thank you for inviting Marks & Spencer to be a part of the PicknPack project. I hope that we have helped contribute to the project by providing:-

- A retailers prospective on the future of food manufacturing and what innovation is required to meet the demands of our customers.
- Facilitating visits to UK food manufacturers and access to Marks & Spencer specification details.
- Providing a location for the 'exchange' meeting in the UK with the PicknPack research team.

I believe this support helped give direction to the Picknpack project and helped push the project in a direction that Marks & Spencer can support.

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(England and Wales)

We did attend the final demonstration meeting held at Holbeach to help evaluate the final outcomes of the project. We were pleased to see how the work streams had progressed their ideas to a stage where physical demonstrations were possible. This really brought to life the benefits of each work stream and demonstrated how they link together to give a totally integrated system.

Unfortunately, over the period that the project has been running we have not been able to participate as much as we initially hoped, this has been due to greater demands on our time here in the UK. This has sadly meant that we have not been able to support our co-workers on the project on occasions resulting in extra work for them. For this reason Marks & Spencer will not declare any costs for the work carried out and are happy that if the Marks & Spencer budget is re allocated to areas within the project.

Finally, and on reflection, I believe that in time this project and the elements within it will have an effect upon the way the food industry addresses its future innovation agenda. I have already had a number of conversation with my colleagues and Marks & Spencer suppliers and shown them the PicknPack video. They have been excited by the innovation opportunities it has highlighted and we are now thinking how we bring PicknPack to a wider audience here at Marks & Spencer and with its suppliers and I will be contacting you soon to discuss how we best do this.

I would like to thank and congratulate the PicknPack team for their work and you for the coordination and leadership of the project. I hope we see the results in the food industry soon.

Yours sincerely

MR S D LUSHEY

Specialist Food Technical Manager

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