EUROPEAN COMMISSION
Community Research

SEVENTH FRAMEWORK PROGRAMME

PICKNPACK

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

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Month 01 (October 1st 2012) – Month 18 (March 31st 2014)

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PicknPack

Table of Contents

1 Project objectives for the period 5
1.1 General objectives of the PicknPack project 5
1.2 General assumptions 7
1.2.1 Model products 7
2 Work progress and achievements during the period 7
2.1 WP1 Coordination 8
2.1.1 Use of resources 8
2.1.2 Deviations from DoW 8
2.2 WP2 Flexible systems integration 8
2.2.1 Project objectives for the period 8
2.2.2 Summary of the work progress and achievement during the period 8
2.2.3 Work progress and achievements during the period 9
2.2.4 Use of resources 12
2.2.5 Deviations from DoW 12
2.3 WP3 Information, communication and traceability 12
2.3.1 Project objectives for the period 12
2.3.2 Summary of the work progress and achievement during the period 13
2.3.3 Work progress and achievements during the period 13
2.3.4 Issues and actions 17
2.3.5 Use of resources 17
2.3.6 Deviations from DoW 17
2.4 WP4 Quality assessment and sensing 17
2.4.1 Project objectives for the period 17
2.4.2 Summary of the work progress and achievement during the period 18
2.4.3 Work progress and achievements during the period 18
2.4.4 Results 22
2.4.5 Use of resources 25
2.4.6 Deviations from DoW 26
2.5 WP5 Robotic Handling Module 26
2.5.1 Project objectives for the period 26
2.5.2 Summary of the work progress and achievement during the period 27
2.5.3 Work progress and achievements during the period 27
2.5.4 Use of resources 32
2.5.5 Deviations from DoW 32
2.6 WP6 Adaptive packaging 32

2.6.1 Project objectives for the period 32
2.6.2 Summary of the work progress and achievement during the period 33
2.6.3 Work progress and achievements during the period 33
2.6.4 Use of resources 46
2.6.5 Deviations from DoW 46
2.7 WP7 Fresh and processed food production line 48
2.7.1 Project objectives for the period 48
2.7.2 Summary of the work progress and achievement during the period 48
2.7.3 Work progress and achievements during the period 49
2.7.4 Use of resources 53
2.7.5 Deviations from DoW 54
2.8 WP8 Hygienic food handling 54
2.8.1 Project objectives for the period 54
2.8.2 Summary of the work progress and achievement during the period 54
2.8.3 Work progress and achievements during the period 55
2.8.4 Use of resources 60
2.8.5 Deviations from DoW 61
2.9 WP9 Life cycle analysis and sustainability 61
2.9.1 Project objectives for the period 61
2.9.2 Summary of the work progress and achievement during the period 61
2.9.3 Work progress and achievements during the period 62
2.9.4 Use of resources 69
2.9.5 Deviations from DoW 69
2.10 Dissemination 70
2.10.1 Project objectives for the period 70
2.10.2 Summary of progress 70
2.10.3 Work progress and achievements 71
2.10.4 Use of resources 74
2.10.5 Deviations from DoW 74
2.11 WP11 Demonstration 74
2.11.1 Project objectives for the period 74
2.11.2 Summary of the work progress and achievement during the period 75
2.11.3 Work progress and achievements during the period 75
2.11.4 Use of resources 76
2.11.5 Deviations from DoW 76
2.12 WP12 Acceptance, economics and exploitation 76
2.12.1 Project objectives for the period 76
2.12.2 Summary of the work progress and achievement during the period 77
2.12.3 Work progress and achievements during the period 77

2.12.4 Use of resources 82
2.12.5 Deviations from DoW 82
3 Project management during the period 83
3.1 Consortium management tasks and achievements 83
3.2 Problems which have occurred and how they were solved 84
3.3 Changes in the consortium, if any 85
3.3.1 Tecnalia France and Lacquey Packaging added as third parties. 85
3.3.2 Staring the termination of Spectroscan 85
3.3.3 Transfer of work from Marel HF to Marel UK Ltd 85
3.3.4 Changes of positions of Work Package leaders and Project Board members 85
3.4 List of project meetings, dates and venues 85
3.5 Project planning and status 86
3.6 Impact of possible deviations from the planned milestones and deliverables 87
3.7 Any changes to the legal status of any of the beneficiaries 87
3.8 Development of the Project website, if applicable 87

1 Project objectives for the period

1.1 General objectives of the PicknPack project

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

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

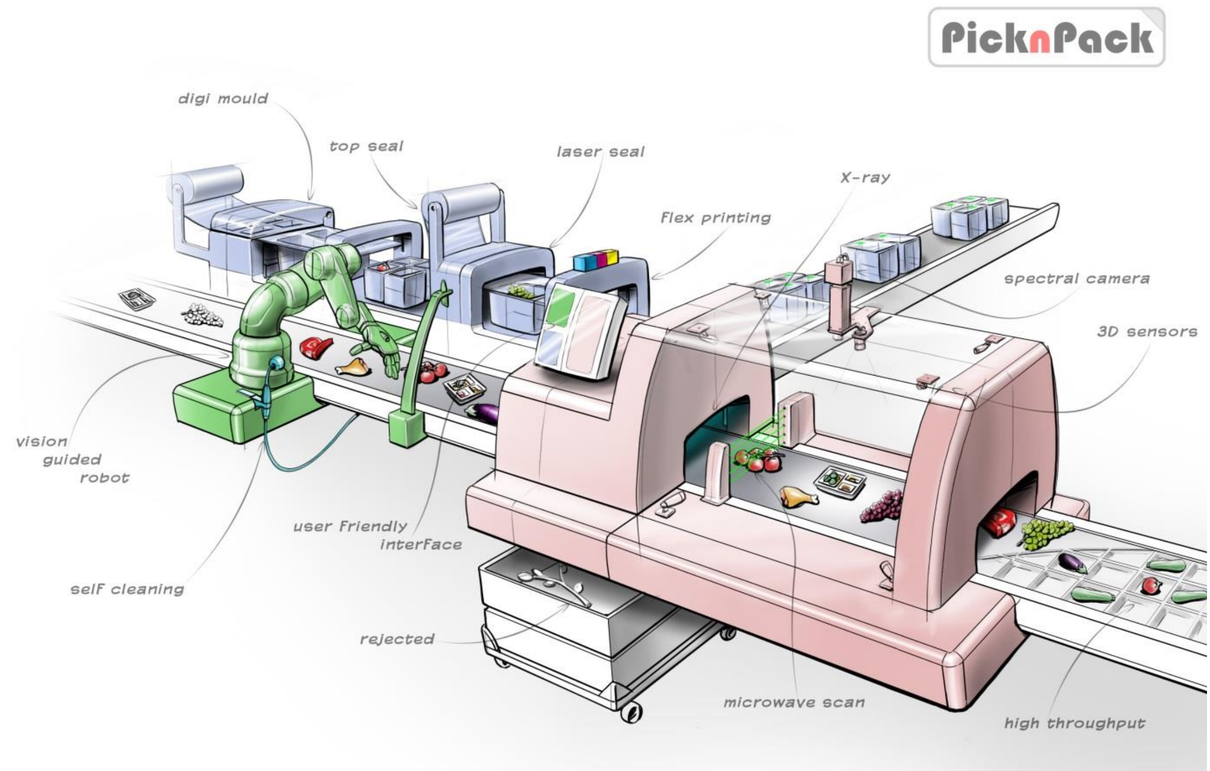


Figure 1 A basic three module adaptive production line

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

WP1 Coordination

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

WP2 Flexible Systems Integration

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

WP3 Information, communication and traceability

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

WP4 Quality assessment and sensing

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

WP5 Robotic Product Handling

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

WP6 Adaptive Packaging

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

WP7 Fresh and processed food production line

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

WP8 Hygienic food handling

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

WP9 Life cycle analysis and sustainability

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

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

WP10 Dissemination

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

WP11 Demonstration

- Not started in this first period

WP12 Acceptance, economics and exploitation

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

1.2 General assumptions

1.2.1 Model products

In the DoW (section 1.2.1) it was decided to focus on grapes, tomatoes for the fresh food line and ready meals for the processed food production line. Basis for these products are that they are normally packed by a human workforce, high flexible requirements, challenging to process automatically (quality, handling and packaging) and normally manual packed with a cycle time of approximately 30 packs per minute.
At the beginning of the project, the model food products are analyzed, further specified and fixated. Food factory visits with the team, workshops and discussions at Marks and Spencer and global analysis of the market demands in WP12 where the basis for the definition of the model food products.

For the fresh food application the model products are:

- Vine Tomatoes (types: regular & alternative)
- Grapes (color: white/green)

For the ready meal appliucatiuon the model products are:

- ready meals consist of three components: a meat component, a carbohydrate component and vegetables. This could for example be a combination of chicken breast, carrots and peas or beans, and mashed potato

Further specifications (dimensions, product range and packages and raw material bins) are given in D7.2. The project is not limited to these products, also other products should be tested on the system (not further specified yet). At the beginning of the project it was mentioned by M&S to incorporate fresh pizzas and the shepherd pie’s. Although we think that these products could be processed on the line it seems more logical to focus on the three component ready meal (fresh pizza market is still small with a specific packaging type and shepherd pie can already be processed fully automatically, so the challenges are limited). M&S supports the choice.

2 Work progress and achievements during the period

This report covers the first project period (from October 1st, 2012 until March 31th, 2014) of the activities in the different Work Packages.

2.1 WP1 Coordination

WP1 is part of the Management task and is explained and evaluated in chapter 6.

2.1.1 Use of resources

Cost type	PM	Costs
Personal	18.1	€ 192,970
Other		€ 23,739
Total		€ 216,709

(Indicated Costs and Person Months extracted from C-Forms, Excluding the input of MS and Spectro)

2.1.2 Deviations from DoW

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

2.2 WP2 Flexible systems integration

2.2.1 Project objectives for the period

. The single most important core objective of WP2 ("Flexible Systems Integration") for this first reporting period was to design an approach to support the whole project with a software infrastructure and methodology that was sufficiently credible, flexible **and** concrete to convince all partners. A necessary activity during the whole period was to identify the real requirements of all partners that are responsible for developing modules in the "PicknPack food processing line", and to adapt those to the (not seldom contradictory) requirements of that whole line. More concretely, these objectives were required in the following two sub-domains of the whole project: (I) sensing and motion control of the inspection and robot modules, and (ii) semantic annotation, capturing, storing and tracing of the many different types of data that are created in the line, and that must be available for traceability queries long after the food left the factory.

2.2.2 Summary of the work progress and achievement during the period

A systematic approach, and concrete semantic models ("ontologies") have been designed, to represent the most important data in such a way that (i) modules by different vendors can be connected together without loosing interpretability of the data produced by these modules, (ii) minimize the data and knowledge representation primitives while still allowing full capturing of all relevant information, and (iii) the control software of the different modules can be configured with product-specific knowledge, in an automatic way.

A methodology (the "System Composition Pattern") was achieved to make software architectures that can support all envisaged variations of the PicknPack food processing line, and that takes into account explicitly the pragmatic challenges of incorporating "legacy" systems, of various degrees of granularity. The methodology comes with (a first draft of the) constructive guidelines to help partners developed their modules towards optimal integratability into the larger PicknPack line architecture.

KUL and DLO have started a reference implementation of a concrete prototype sub-system (a robot module that grasps a tomato based on visual recognition and servoing) that conforms to the above-mentioned systematic approaches, in order to (I) prove the feasibility of the methodologies, and (ii) serve as concrete examples to help other partners develop their modules as variations of the reference implementation.

KUL and MU have co-developed the generic semantic interfaces between one PicknPack processing line and the overall tracing database. The protocol is a feasible trade-off between minimality and completeness of the meta data: all existing data, down to the smallest detail, can be found back via queries from the tracing database, but most often one query will have to be chained through several "big data" servers; the design is such that this chaining can be realised fully automatically.

2.2.3 Work progress and achievements during the period

The work reported below was performed without significant deviations from the expected work allocation in the DOW. All the envisaged objectives are still deemed to be achievable within the foreseen resource constraints.

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

Ontologies

During the first reporting period, the initial expectation was confirmed that the large *heterogeneity* of modules, functionalities, vendors, programming languages, communication infrastructure, etc., can only be tackled successfully at the system integration level, if all modules and functionalities get highly formalized "*semantic data models*". That is, the concrete numerical or symbolic values and properties of all software entities in the system must conform to a formal meta model that represents their meaning *and* all module providers must provide software interfaces that "understand" those formal meaning representation and can transform it to the concrete software representations used inside the module. Eventually the objective is to let the module control software become "smart enough" so that it can create the "glue code" needed to link the software components in two modules, as soon as these modules are connected physically by a communication infrastructure.
To help the module builders in this difficult task, WP2 provides a systematic approach to create concrete semantic models or "ontologies". The approach is conceptually simple: for each "domain" for which an ontology is required, the domain experts should identify the following four complementary pieces of formal knowledge representation: the *Primitives* that occur in the domain, the *Relationships* between these *Primitives* that represent the meaning of the domain, the Constraints on the properties of the Primitives and the Relationships, and the *Tolerances* that can be allowed on violating these constraints. Two complementary and concrete sets of ontologies are under development:

1. the tomato ontology: it represent the knowledge about tomatoes that sensing and robot modules need to have. For example, size, shape, color, grasping locations, etc.
2. the robot and sensing module ontology: it represents all hardware and core software functionalities of generic robot and sensing devices. For example, actuators, transmissions, joint, kinematic chains, etc. A snapshot of this ontology is shown in Figure 2.

DLO drives the first one, and KUL the second one; but the developments are taking place in highly interactive and intensive workshops. The major challenges to be finalised are: the selection of the "right" knowledge representations infrastructure (OWL, UML, dedicated Domain Specific Languages, XCOre, etc.)

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            targetNamespace="http://www.example.org/X-RDSL-KC_Chain_Top"
            xmlns:top="http://www.example.org/X-RDSL-KC_Chain_Top"
            xmlns:hh="http://www.example.org/X-RDSL-KC_HH"
            elementFormDefault="qualified"
            attributeFormDefault="unqualified">

    <xsd:import schemaLocation="../HierarchicalHypergraphs/X-RDSL-KC_HH.xsd"
                namespace="http://www.example.org/X-RDSL-KC_HH"/>

    <xsd:element name="X-RDSL-KC_Chain_Top">
        <xsd:complexType>
            <xsd:choice minOccurs="1" maxOccurs="unbounded">
                <xsd:element name="chain" type="hh:NodeType"/>
                <xsd:element name="link" type="hh:NodeType"/>
                <xsd:element name="port" type="hh:PortType"/>
                <xsd:element name="joint" type="top:JointType"/>
                <xsd:element name="connects" type="hh:ConnectsType"/>
                <xsd:element name="contains" type="hh:ContainsType"/>
            </xsd:choice>
            <xsd:attribute name="version" type="xsd:decimal" use="required"/>
        </xsd:complexType>
    </xsd:element>

    <!-- Complex types -->
    <xsd:complexType name="JointType">
        <xsd:complexContent>
            <xsd:extension base="hh:ConnectorType">
                <xsd:attribute name="type">
                    <xsd:simpleType>
                        <xsd:restriction base="xsd:string">
```

Figure 2 Software structure

System Composition Pattern

The project needs to develop software architecture(s) that can support all envisaged variations of the PicknPack food processing line and that take into account explicitly, the pragmatic challenges of incorporating "legacy" systems of various degrees of granularity. Some of the major drivers for the architecture are: some modules are full systems in themselves; some modules produce a lot of binary data (images of hyperspectral cameras, for example); all modules must produce tracing information to the tracing database of WP3 in a guaranteed "transaction modus"; data representations between modules must be transformed because of different legacy implementations; and some modules require hard real-time behaviour, such as the motor control in the robot modules.
All these requirements are very difficult to meet by one single architecture, so we set out to find a methodology to create architectures with context-specific trade-offs. The result is a "meta language" for system architectures with a high degree of "composability" and with many opportunities to introduce links with the "ontology servers".
The methodology is now being documented in detail and the delivered version will come with (a first draft of the) constructive guidelines to help partners developed their modules towards optimal integrate ability into the larger PicknPack line architecture.

Illustration: the System Composition Pattern

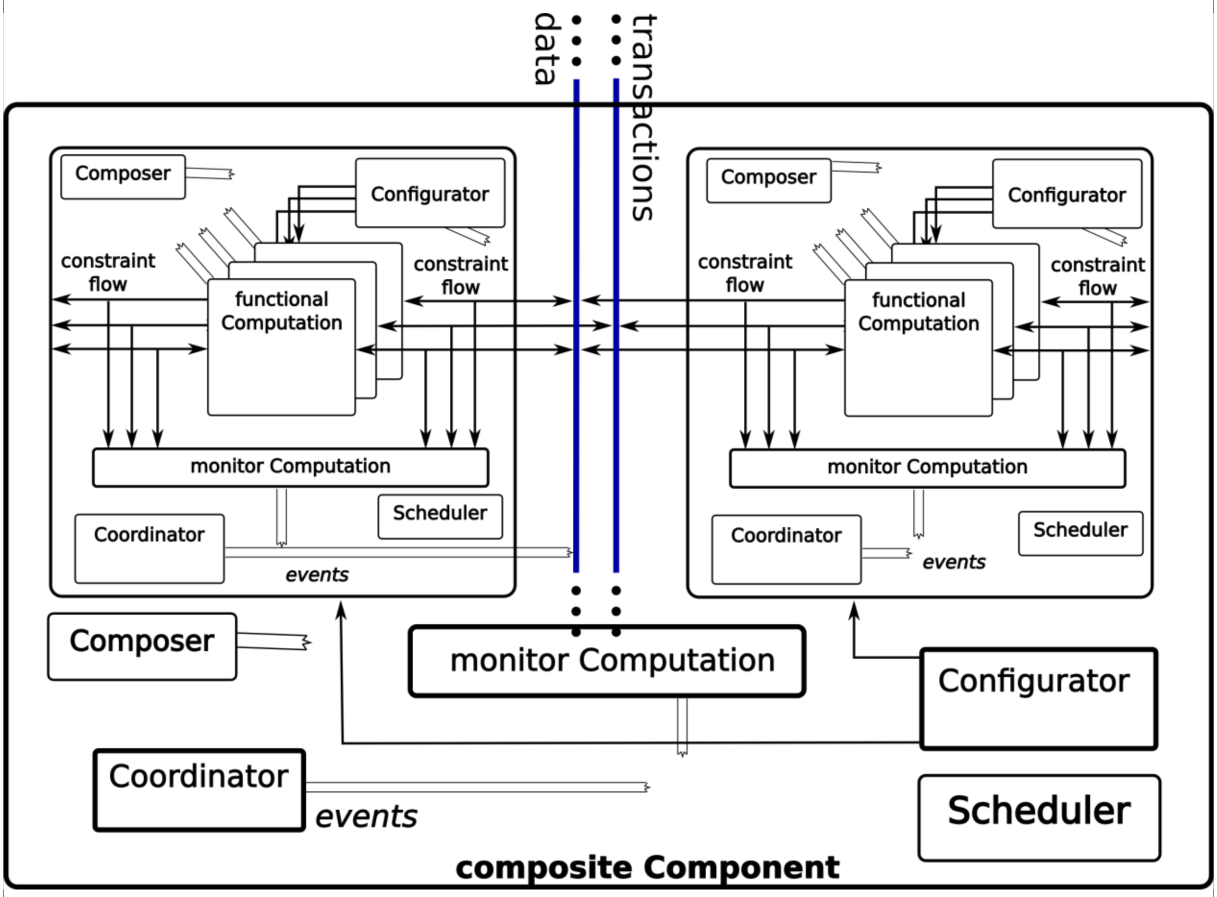


Figure 3 Software acrhitecture

Reference implementation with "Microblocks"

The meta modelling language of "microblocks", as well as the concrete infrastructure code are about to be released online, via http://www.microblx.org. That website will also host sub-system architectures and implementations for the many "bridge subsystems" that are necessary to embed the many "legacy" systems that have to be integrated into a PicknPack processing line. Figure 3 shows the "top level" architecture of the "world model" that will reflect the instantaneous (and past) situation of a line, with software 'agents" embedded into the world model for the purpose of cooperation between modules. The most important responsibilities of the world model will be (i) to give unique IDs to all pieces of food that enter the line (in agreement with the PicknPack UID standard to be co-developed with WP3), (ii) to pass on the software datastructures between the module controllers, and (iii) to incrementally add more and more information as provided by those modules. The line model will also be the natural place to host the "big data server" needed to store all detailed information of what happened on the line, and to answer to later "tracing queries" coming from the meta data tracing database of WP3.

Guidelines ready

In the project's timeline for system integration, a first complete model of a full line is envisaged to be ready in September 2014. At this occasion, WP2 will provide concrete suggestions about the sofware aspects of this integration (component design and possibilities, communication design and possibilities, data representation and tracing, etc.), and each of these concrete suggestions will come with a guideline document; that is, why are the designs the way they are, and how should/can the other WPs make best use of these guidelines.
The guideline documents are planned to evolve in synchronization with the evolution of the project-wide integration.

Universal Identifiers for traceability

The current work is to scan the (long) list of already existing standards for "unique identifiers" (such as GUID, USB, and several others) and to make a choice that fits best to the various needs in PicknPack.

2.2.4 Use of resources

Cost type	PM	Costs
Personal	28.4	€ 263,766
Other		€ 37,244
Total		€ 301,009

(Indicated Costs and Person Months extracted from C-Forms, Excluding the input of MS and Spectro)

2.2.5 Deviations from DoW

There are no major deviations from the Dow. Less man months were planned than in the middle of the project. Main effort will start after the first period when integration starts. It is in line with the overall budget of WP2.

2.3 WP3 Information, communication and traceability

2.3.1 Project objectives for the period

The objectives of WP3 for the period are:

1. To establish a database for upstream food component tracing and vendor managed inventory with respect to the software architecture in WP2
2. To establish RFID systems and other common product identifiers such as barcodes for upstream food component tracing and downstream product tracking and vendor managed inventory

The tasks corresponding with the objectives in the period are:

1. Task 3.1. Identification of Traceable Information
2. Task 3.2. Development of Database and Software for Intelligent Production
3. Task 3.3. RFID Systems Implementation

The focus for the first period was to establish a database for upstream food component tracing and vendor managed inventory with respect to the software architecture in WP 2 (the first objective of WP3) and the Tasks 3.1 and 3.2.

2.3.2 Summary of the work progress and achievement during the period

Task 3.1 and Task 3.2 have been completed. Task 3.3 is expected to be completed in the second period in Month 24.

During the first period, an extensive report on the "Analysis of the state of the art: Legal requirements and voluntary standards for traceability of fruit, vegetables and ready meals (D12.1), has been produced by AZTI. Regulations and commercial practices for the food chains have been investigated and the information flow between links in the food chains has been identified. Traceable information including the breadth, depth and precision of the traceable parameters has been outlined for the development of the traceability database.

A traceability database has now been established with the consideration of EU regulations and production line operations. Microsoft Windows based software with a user-friendly interface has been developed for the information management of traceability database. Interface with RFID and barcode hardware has also been incorporated into the software. The work on RFID system implementation has started and it is expected to be completed in Month 24. During the first period two milestones, i.e. M4: Database establishment and M5: Software development, have been achieved, and two deliverables have been made. Deliverable D3.2 focuses on traceability system database and software design, and Deliverable D3.1 outlines the operation of the software and database for the PickNPack project.

In summary, the tasks in WP3 scheduled for the first reporting period have been completed according to the work plan.

2.3.3 Work progress and achievements during the period

Summary of progress towards objectives and details for each task

So far the identification of traceable information (Task 3.1) has been carried out. An extensive report on the "Analysis of the state of the art: Legal requirements and voluntary standards for traceability of fruit, vegetables and ready meals", has been produced by AZTI (D12.1).. Regulations and commercial practices for the food chains have been investigated and information flow between links in the food chains has been identified. Traceable information including the breadth, depth and precision of the traceable parameters has been outlined for the development of the traceability database.

A traceability database (Task 3.2) has now been established with the consideration of EU regulations and production line operations. Microsoft Windows based software with a user-friendly interface has been developed for database information management. Interface with RFID and barcode hardware has also been incorporated in the software. The work on RFID system implementation has started and it is expected to be completed in Month 24. During the first reporting period two milestones, i.e. MS4: Database establishment and MS5: Software development, have been achieved, and two deliverables have been made. Deliverable D3.2 focuses on traceability system database and software design, and Deliverable D3.1 outlines the operation of the software and database for the PickNPack project. The work for the second objective (Task 3.3) extends over the first period in the work plan. It is expected that this will be completed in Month 24.

Highlight of key results

Flexibility level

The system is flexible in the way that new requirements could be defined as parameters in the database. The current traceability database has been designed so that new parameters can be defined by the end-user in accordance with the application or regulatory requirements.

The traceability software can be applicable to multiple production lines. The consideration of a single production line in the report is mainly for the demonstrator.

Legal requirements and voluntary standards

This work serves as a regulatory guide to the development of traceability system for the PickNPack project. Both legal requirements and voluntary standards have been identified.

The EU regulation, Regulation 178/2002, states that all food businesses must have in place a traceability system, and that the legal minimum is a system in which a food business records what ingredients/food products it receives and from who (including contact details) together with what product it dispatches to which customers (including their details) with the only exception of being direct supply to final consumers. This is called the one-up-one-down system. Traceability information must be transferred up/down the chain on the product or on accompanying documents. Further regulations for the fruit and vegetables are governed by Regulation 1182/2007 and Regulation 1221/2008. Furthermore, a typical fruit and vegetable chain and a ready meal process have been investigated for the sake of that this project deals with both fruits and ready meals. This study forms a base for defining traceable parameters in the traceability database for the PickNPack project.

Database establishment

The traceability database is the core of the traceability system. It registers and records all the information that may be traced for product query and production optimization. Figure 4 The data model shows the data flow taking place in the traceability system, and Figure 5 The traceability design shows the design of the traceability system specially considered for the registration and tracing of information in the PickNPack project.

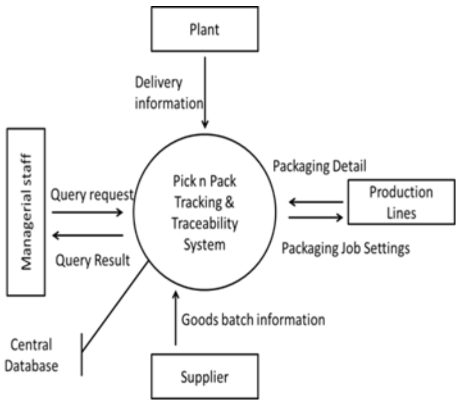


Figure 4 The data model

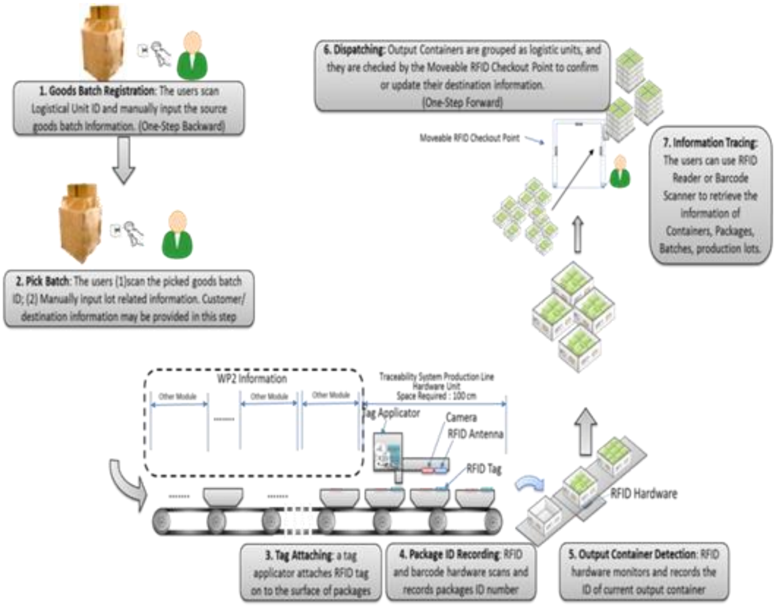


Figure 5 The traceability design

Taking into account of the information in the traceability system, a database with registered parameters required for information recording throughout the supply-packaging-delivery process has been established. The parameters in the database and their relations are shown in Figure 6 Database structure: parameters and relations. The database developed for this project is based on Microsoft SQL Server software package. This choice was made following a WP3 meeting in Marel, Iceland in May 2013. Microsoft SQL Server is well suited for the structured data, such as those in the traceability system of this project.

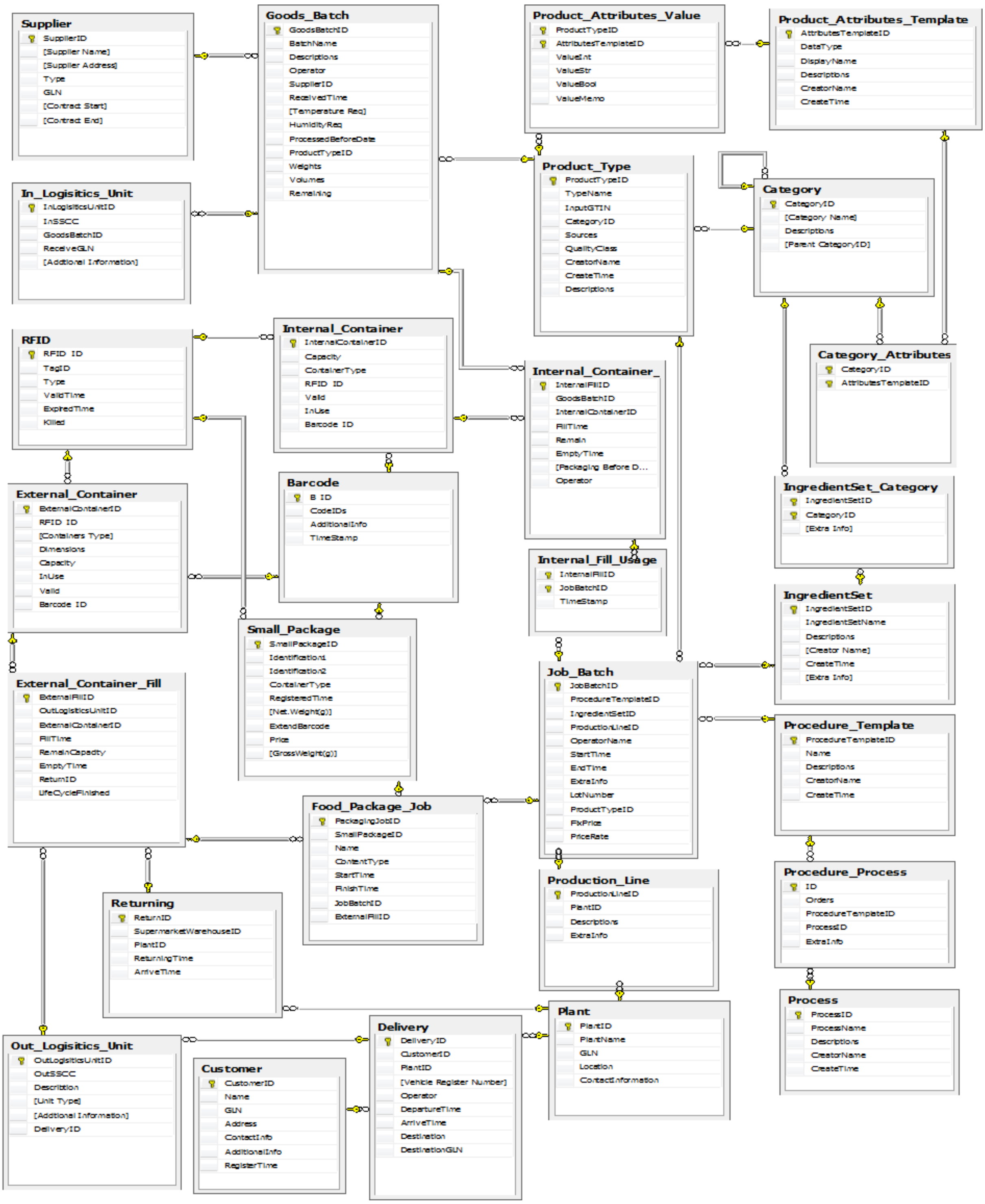


Figure 6 Database structure: parameters and relations

Software development

With the traceability system design shown in Figure 5 The traceability design and the database structure in Figure 6, the information handling in the software is shown in Figure 7. The software has been implemented using Microsoft C#. The user interface of the software is shown in Figure 8. The software takes a simple one-screen design. All functions could be called from the short-keys on the top of the user-interface screen. The functions are grouped into 9 categories, i.e. New Material, Subdivision, Packaging Setting, Logistical Units, Delivery, Management, Batch Setting, Scan & Query and RFID. These functions could be used to define the parameters of suppliers, goods batches, factory and production line information, job batches, input and output containers, product type and attributes, delivery and customer information, to get information from the RFID hardware and to scan and make queries.

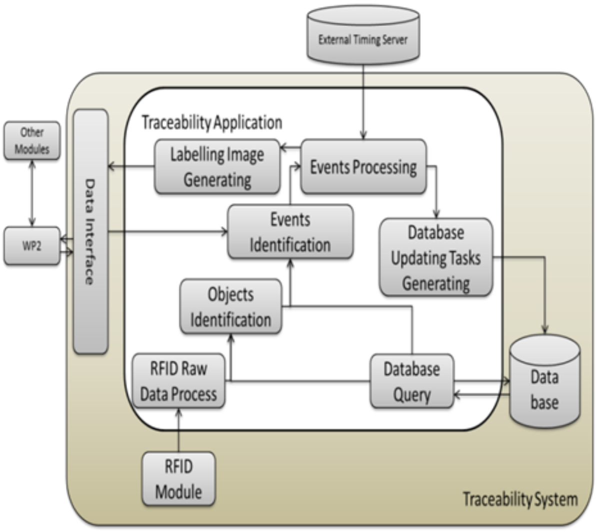


Figure 7 Information handling in the software design

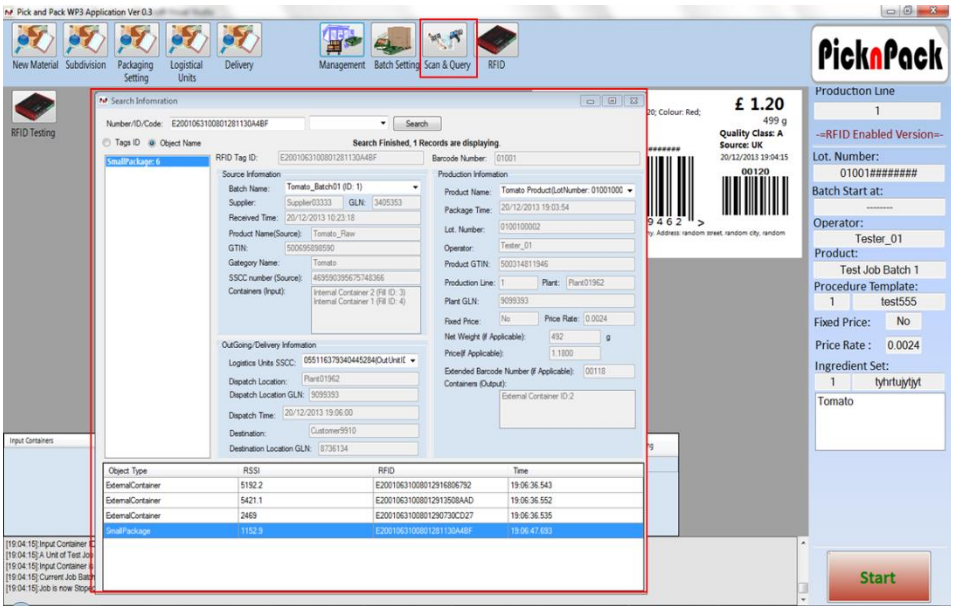


Figure 8 User interface of the traceability software

RFID system implementation

As a part of Task 3.3 RFID system implementation has been a major task after Month 12. Being able to obtain information from the RFID hardware is a key function in the traceability software in Figure 5. The RFID product from Alien Technology as shown in Figure 9 has been chosen for the project to realize the RFID tracing technology and capability. After 6 months of work, the RFID hardware has been integrated with the traceability software. RFID tag information could be read into the software for information processing. Further work is needed to fully implement the RFID functions in the traceability software.

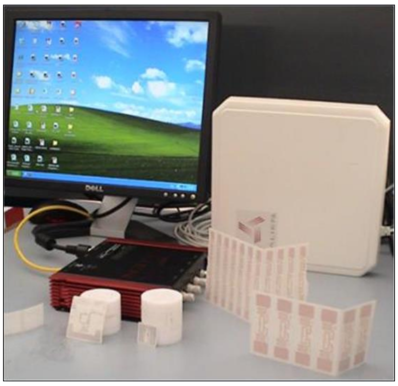


Figure 9 RFID system implementation

2.3.4 Issues and actions

In Task 3.1, two sub-tasks, i.e. "Assign ID numbers, codes and ranges" and "Highlight key parameters for process automation" can only be implemented fully when the PickNPack demonstrator is built.
As the software architecture in WP2 has not been clearly defined, the interface of the traceability software with WP2 and databases in other modules remains to be completed. Interaction with WP2 has taken place to resolve the issue.

2.3.5 Use of resources

Cost type	PM	Costs
Personal	17.9	€ 122,740
Other		€ 41,618
Total		€ 164,358

(Indicated Costs and Person Months extracted from C-Forms, Excluding the input of MS and Spectro)

2.3.6 Deviations from DoW

There are no major deviations from the Dow. Less man months are needed than in the middle of the project. Main effort will start after the first period when integration starts. It also took some time to acquire Phd students at the beginning of the project. It is expected that the work package will achieve its tasks according to the plan. It is in line with the overall budget of WP3. Also more other costs (materials) are planned in the second period.

2.4 WP4 Quality assessment and sensing

2.4.1 Project objectives for the period

The project objectives for the first period for WP 4 concerning the quality assessment and sensing were to

- Define generic product properties relevant for robotic handling and flexible packaging
- Design a module that assesses the shape, position and quality of individual food products

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

- D4.1: List of key product properties to be provided to the robotic handler (Month 6)
- D4.2: Report on the food quality ontology (Month 12)
- M8: 3D imaging unit ready to scan products (Month 6)

- M9: Hyperspectral imaging unit ready for scanning products on a transportation system (Month 6)
- M10: Microwave sensor system hardware ready to scan products on a transportation system (Month 9)
- M11: X-ray imaging ready to scan products on a transportation system (Month 9)
- M12: Algorithms for shape and volume measurement from RGB and 3D imaging ready for validation (Month 18)
- M13: Algorithms for hyperspectral detection of surface and subsurface quality ready for validation (Month 18)
- M14: Algorithms for product composition assessment by Microwave ready for validation (Month 18)
- M15: Algorithms for internal quality detection based on X-ray imaging ready for validation (Month 18)

2.4.2 Summary of the work progress and achievement during the period

Key product properties have been listed for vine tomatoes, table grapes, ready meals. Based on this information a document has been made with an ontology for each of these products. Also, the design of the complete sensing module, including the hygienic requirements, has been worked out. These drawings have been approved by the project board at the project meeting in Iceland. Apart from this general work for the entire module, the different sensing techniques have been developed and tested individually in preparation of their integration into the module which is planned for September 2014.
DLO has developed a system to measure colour and 3D-information by using an RGB camera and a 3D-laser triangulation sensor. They built a prototype of the sensing module where three different sensors are working together. Colour information has been registered on the 3D data, as a first step towards integration of the different sensor data. Also, an object segmentation algorithm has been elaborated and a way to estimate the weight of the vine tomatoes has been worked out.
A setup to test hyperspectral imaging above a transportation system has been built at KU Leuven. By using ray-tracing software the illumination for this setup has been optimised for illuminating flat and round geometries. With this improved illumination, experiments were already conducted on tomatoes to detect external defects and to distinguish the ripeness class of each tomato.
The laboratory X-ray imaging setup of KU Leuven was adapted and optimized to emulate scanning on a transportation system and the software was adapted to simulate scans in any geometry. CT scans of model systems (tomatoes/grapes) with and without defects have been conducted. Algorithms for image analysis (shape/size determination, defect identification) have been developed and are ready to be validated. Based on the laboratory scans and analysis, conditions for an online X-ray scanner were determined. This conceptual design of the X-ray module was developed by KU Leuven.
Unfortunately Spectroscan did not collaborate in these activities, did not start the development and testing of a prototype based on these results nor did they respond to multiple requests to do so.
For the microwave sensor, several sensing arrays of varying size have been built by UM. The microwave circuits have been designed to generate, transmit and receive microwaves, to control the flow of microwave signals and to detect them. Some laboratory tests have been carried out using microwave sensors for the sensing of ready meals and tomatoes. Besides, some algorithms have been developed to process the signals.

2.4.3 Work progress and achievements during the period

The two deliverables, described in Annex 1 (Description of work) have been finished and submitted in time. For the first deliverable (D4.1), a questionnaire was built and sent to each partner. This questionnaire asked which product properties were important for the tasks of each partner and what properties are important to describe good quality of the products.
The most important *quality parameters* which were identified, are:

- For fresh fruits: maturation stage, external defects, internal damages, colour, size and shape
- Ready meals: colour, topping, weight, size and composition of the meal

The most important *marking and packaging parameters* which were identified, are:

- For fresh fruits: life, weight, packaging and traceability
- Ready meals: traceability

For each product property, it was decided which sensing technology will be investigated to measure it.

The construction of the food quality ontology for the different products was reported in the second deliverable (D4.2). Mind maps were made of four different products to clarify the interdependence between different quality parameters. Each property has also been clearly defined and pictures of acceptable and unacceptable products are shown.

Design of the QAS-module

Next to the deliverables, the quality assessment (QAS) module has been designed (Figure 10). The sensing module consists of 2 different submodules. One submodule is the X-ray imaging unit. The other contains the RGB-camera, the hyperspectral camera, the microwave sensor and the 3D imaging. In the sensing area a Plexiglas tunnel has been designed which forms a barrier between the sensors and the products and makes the line easier to clean. This tunnel has been designed taking into account lighting and hygienic requirements. The most computationally intensive sensors were placed in the beginning of the line and, for reasons of hygienic design, the tunnel does not contain places where vapor can be trapped.

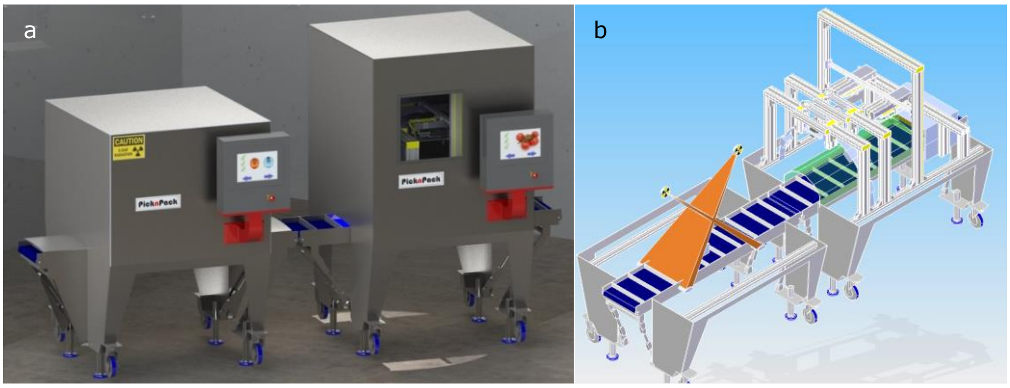


Figure 10. Drawings of the sensing module. a: The outside view of the quality assessment module, b: the sensing module without the casing. From left to right: X-ray-imaging, RGB-imaging, hyperspectral imaging, 3D-sensing, microwave sensor. A Plexiglas tunnel [green drawing in (b)] protects the products from contaminations and protects the sensors during cleaning in place (CIP).

To achieve milestones 8 to 11, the different sensors had to be ready for scanning products on a transportation system. This is elaborated in the next paragraphs for each sensing technology separately.

The colour and 3D sensors (DLO)

In **Figure 11** a prototype of a part of the sensing module is shown, as it was built in Wageningen by DLO. This module contains three different sensors: 1) two 3D laser-triangulation sensors to sense the 3D structure of the products, 2) a hyperspectral camera to sense the product in the near-infrared part of the electro-magnetic spectrum, and 3) a 3-CCD RGB line-scan camera to get visual colour information from the surface of the object. The lighting arc to illuminate the scene for the colour and hyperspectral cameras can also be clearly seen in the figure.

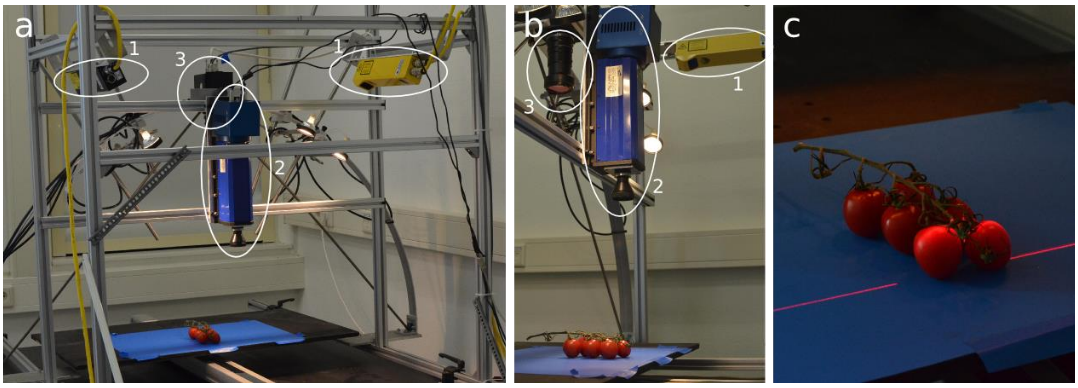


Figure 11: a&b: prototype version of the sensing module in Wageningen. The sensors shown are: two 3D laser-triangulation sensors (1), a near-infrared hyperspectral camera (2), and a RGB line scan camera (3). c: a bunch of tomatoes that is being scanned by the 3D laser-triangulation sensor

Colour camera

The 3-CCD colour line-scan camera is a camera that obtains high-quality colour information by recording the Red, Green and Blue light separately, instead of using a Bayer filter. For the PicknPack setup, with a width of the conveyor belt of 540mm, this camera has a resolution of approximately 3.7 pixels/mm. We deem a resolution of 1-2 pixel/mm to be sufficient for assessing the quality of the products.

The camera is currently synchronized with the other sensors in the module using a common trigger signal. In the final PicknPack setup, the sensors will be synchronously triggered based on the movement of the transportation system to ensure that we obtain a uniform resolution, irrespective of the speed.

To accurately measure angles and surfaces in the images, we need to compensate for lens deformations, sensor misalignments and perspective projections. This can be done by means of a calibration procedure which involves the imaging of a calibration pattern. This procedure is currently a manual procedure, but we will develop a semi-automated calibration procedure. Moreover, the calibration procedure only has to be carried out once if no changes to the lens or mounting of the camera with respect to the transportation system are made.

Acquisition software has been developed to get colour information for every object on the conveyor belt. The software can deal with multiple products placed side-by-side, as long as the products are separated and not touching.

3D laser-triangulation

We utilize two laser-triangulation sensors, viewing the products from 45 and -45 degrees off the vertical axis. This allows us to observe approximately 50% of the surface of the products (the top half).

The mounting setup developed in PicknPack allows to accurately align the two sensors, so that their laser lines are perfectly in parallel. The 3D point clouds that both sensors obtain are then aligned with a simple calibration procedure, consisting of two black dots on the conveyor belt so that the red laser light is completely absorbed by the dots and not by the rest of the conveyor belt. Using this, the orientation and offset of both sensors with respect to the belt and each other is determined.

Similar to the colour acquisition, we developed software to acquire the 3D profiles of the products. Only points above the conveyor belt are stored as part of the object. DLO is currently in the process of applying the same algorithm as in the colour acquisition, so that multiple products on the belt are separated in the 3D data and individually sent to other processes for further analyses.

Microwave sensor (UM)

In the case of the microwave sensor, two setups were built with 2 x 16 and 2 x 32 antenna arrays, respectively (Figure 12). For these antennas, the electronic circuits were also designed.

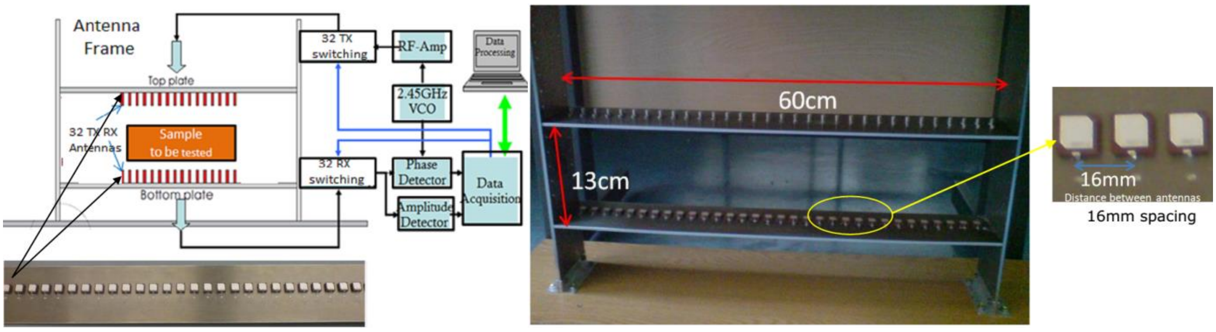


Figure 12: Left: schematic overview of the microwave sensor system; right: photo of the microwave sensor system with 2 x 32 antenna arrays.

Hyperspectral and X-ray imaging (KUL)

Hyperspectral imaging

To achieve good and robust results with hyperspectral imaging in industrial environments, the illumination of objects should be as homogeneous as possible. For this reason, a lot of different hygienically designed illumination setups have been simulated by using the ray-tracing software TracePro (Lambda Research, USA). The homogeneity and intensity of the illumination on a flat sample and on a ball-shaped sample are investigated. The optimal illumination setup resulting from this research was an arc-like setup which uses four halogen spots as light source. It was built (Figure 13.a) and tested (Figure 13.b) and it will be incorporated in the QAS-module.

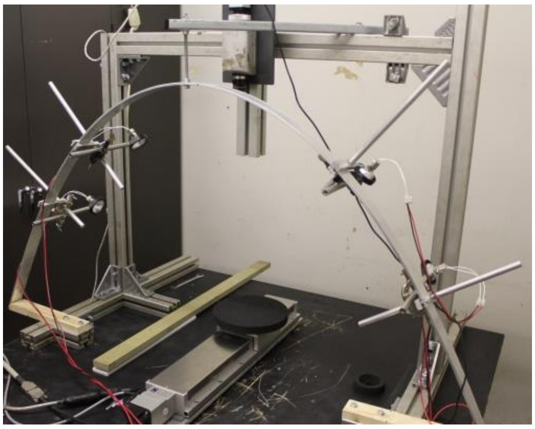
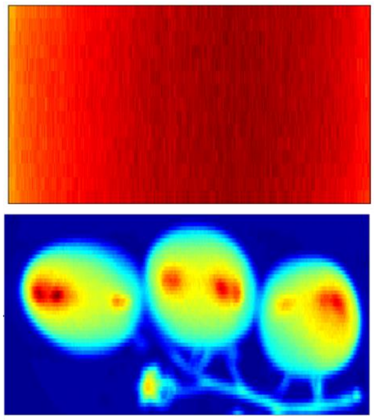
a  b 

Figure 13.: a: Hyperspectral setup, b: Illumination of a flat Teflon plate (top) and a truss of vine tomatoes (bottom) by the optimized setup.

X-ray imaging

In order to obtain a maximum of 3D information, the aim is to build a module with two source-detector pairs to produce projections from two orthogonal angles of the product. This can be achieved as specified in Figure 14 or with an alternative configuration.

Based on the scan procedure optimization we carried out, we can advise that the system will operate at roughly the following specifications:

- Operating at max. 60 to 80 kV at 0.5 mA
- 30 trays per minute
- Maximal object width 400 mm
- Image pixel resolution 0.1 mm

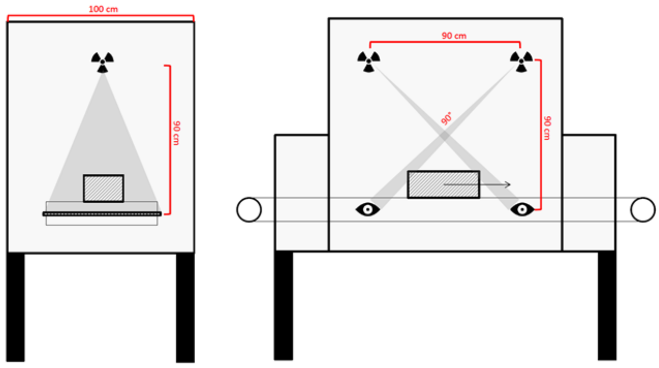


Figure 14: Conceptual presentation of an orthogonal X-ray scanner (dimensions not fixed), front and side view.

Because of the lack of any collaborative effort from Spectroscan, the design of the X-ray module could not progress beyond the conceptual phase yet. Spectroscan has been assigned the following tasks (ref. DoW): "Spectroscan will build the sensing module in WP4, that incorporates the integration of their X-ray technology plus other quality sensing technologies from partners in this WP." "They will cooperate in integrating this module in WP7 and they focus on the acceptance, the economics and the exploitation of the PicknPack results in WP12."
Thereto, Spectroscan should be active in WP4, tasks 4.2 and 4.4 to deliver the X-ray module such that partner KU Leuven can implement and test shape measurement and quality assessment of products. To this end, on month 9, Milestone 11 should have been successfully reached with partner KU Leuven: "X-ray imaging ready to scan products on a transportation system". Scans were performed by KU Leuven on an in-house stand-alone X-ray system to simulate such conditions and assess the feasibility which was successfully completed. However, no X-ray imaging system or design has so far been supplied by Spectroscan. Many attempts have been made by KU Leuven and the PicknPack coordinator to progress the work: a visit to the company by Dr. Pieter Verboven on March 19, 2013 and multiple follow-up e-mails and telephone calls since then did not result in any progress from the side of Spectroscan.

In conclusion, Spectroscan:

- has not reported progress since month 9,
- has not given response to multiple requests by e-mail and telephone by the WP Leader and project Coordinator,
- has not attended project and WP meetings since April 2013.

2.4.4 Results

Colour and 3D sensors (DLO)

Colour mapping on the 3D point cloud

To allow multi-modal quality analysis of the products, the information of the different sensors needs to be fused. For the colour and 3D information, we implemented a method to map the colour information on the 3D point cloud. To do so, we need to accurately determine the transformation between the coordinate system of the RGB camera and the 3D sensors. This is realized by a calibration procedure, which uses the same calibration pattern as the one applied for the individual sensors. Knowing the dimensions of the pattern and the intrinsic camera parameters, we can calculate the 3D position of each of the circles on the pattern in respect to the camera coordination frame. Similarly, we detect the circles in the 3D information (note that apart from 3D info, the sensor records the brightness value of each 3D point). Knowing the 3D position of the circles in both coordinate frames, we can estimate the affine transformation between the two coordinate systems. We then use this transformation matrix to calculate which pixel in the RGB image, belongs to which point in the 3D point cloud.

In figure 15 the result of the colour mapping on the 3D point cloud of a bunch of tomatoes is shown. The mapping is accurate though some errors still exist and are mainly due to occlusion. We are working on a method to identify occlusion and solve this issue.

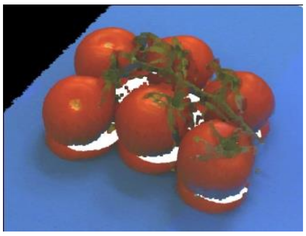


Figure 15 : The 3D and colour reconstruction of a bunch of tomatoes. Mind that some tomatoes are detached from the bunch. This is not a reconstruction error

Segmentation

After data acquisition, the quality analysis of the products starts. For the fresh fruits (tomato bunches and grape bunches), the berries and stalk should be segmented, as both have different quality aspects.
Segmentation of fruits and stem is currently based on colour and 2D shape information. This information is based on prior knowledge about the product, such as the typical colours and shape of the different elements. Based on the colour information, the pixels in the image are labelled as either tomato, stem, or unknown. The resulting image masks are then analysed based on shape. In figure 16 the result of this segmentation is shown for a bunch of tomatoes. On the left, the seven individual tomatoes are detected. On the right, the stalk and its orientation are detected.
The developed technique has already shown positive results for red tomatoes and blue grapes. Currently, we are improving the existing methods to deal with additional cases such as green tomatoes or white grapes.

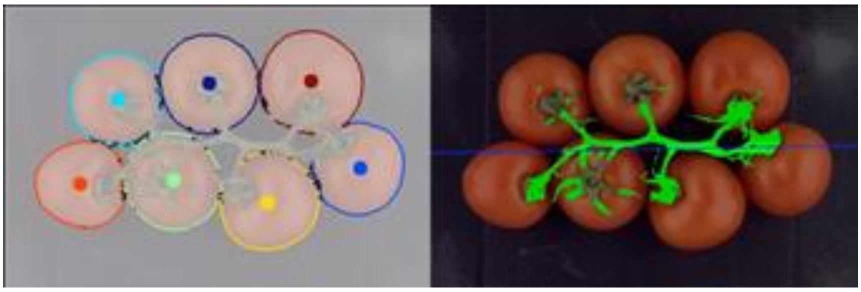


Figure 16: Results of segmentation of the bunch in the seven individual berries (left) and the stalk (right).

Weight estimations

We developed an algorithm to estimate the weight of the tomatoes based on their 2D shape in the colour image using regression models. For single tomatoes, the regression models were trained on a dataset with 17 tomatoes that were weighed by hand and validated on 67 tomatoes. 68% of the tomatoes were estimated with an error between -3.8g – 6.2g on an average weight of a tomato of 117.9g. The mean absolute error was 3.3g (2.8% error). For the complete bunches, the model was trained on 15 bunches with in total 84 tomatoes and tested on 47 bunches with 267 tomatoes. The weight of 68% of the bunch was estimated with an error between -15g – 21g on an average weight of the bunches of 666g. The mean absolute error was 25.2g (3.8g). Although the mean error is low, there are a few outliers with ±20% error for the tomatoes and ±18% for the bunches. These outliers are caused by erroneous ellipse fits on the contours of the tomatoes caused by limited visibility of the contour. The method to fit ellipses to the contour will be improved by adding constraints.

Hyperspectral and X-ray imaging (KUL)

Hyperspectral imaging

For the fulfillment of M13 we developed an algorithm to automatically determine the quality of the measured products. In a first case, this algorithm has been applied to vine tomatoes (Figure 18). First a model was built to automatically distinguish the tomatoes from background and stalk (Figure 19). Afterwards, the mean-spectrum of each tomato was taken to link this with different tomato specific quality parameters. This part has already been successfully tested by automatically determining the appropriate ripeness class of each tomato with a correct classification of 85,71%. Additionally, a defect detection was performed based on a pca-model of good tomatoes. When this pca-model was applied on each pixel of a new tomato bunch, the outliers were classified as defects (some examples are shown in Figure 19).

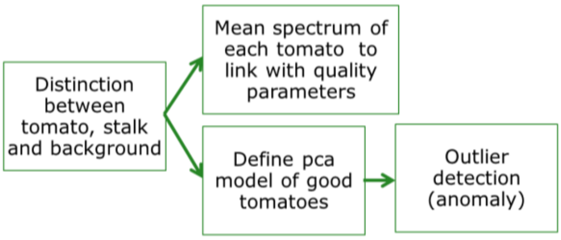


Figure 17: Schematic overview of the used algorithm

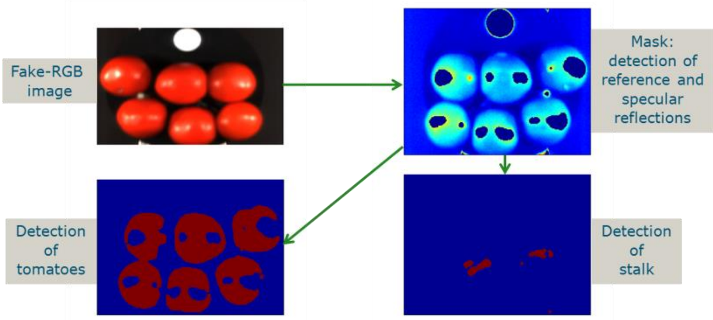
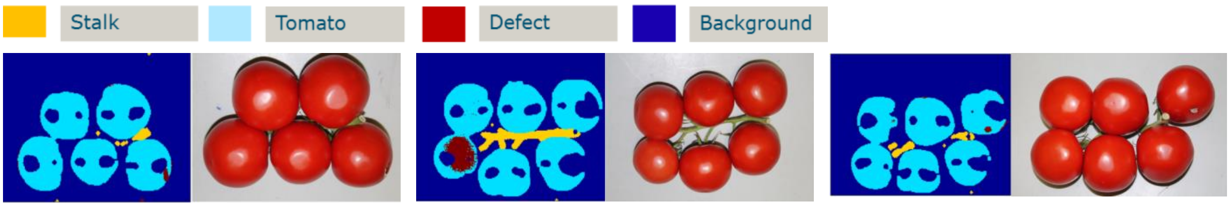


Figure 18: Segmentation of tomatoes

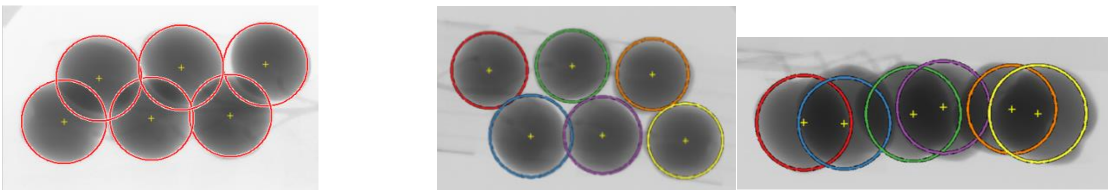


Mechanical damage: puncture injury | Discolouration | Mechanical damage: knife cut

Figure 19: Examples of defect detection on vine tomatoes

X-ray imaging

We seek first to detect individual tomatoes in the cluster directly from a radiograph and describe their contours and position (Figure 20).



(a) single radiograph *(b) two orthogonal radiographs*

Figure 20: Algorithm to detect individual tomatoes on the vine and describe their position and contour from X-ray radiographs (image property of KU Leuven). (Settings: 60kV, 0.5mA, 0.1 mm pixel size)

Typical skin defects may appear on the tomato due to damage during harvesting, transport and handling, cracking or insect damage. Based on a radiographic scan we aim to detect such defects that may occur on any part of the individual fruit (Figure 21).

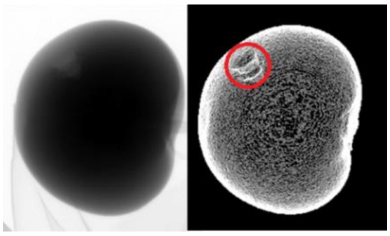


Figure 21: Algorithm to detect damage on X-ray radiographs of individual tomatoes (image property of KU Leuven)

Microwave sensor (UM)

Besides the development of the sensor technology, it was also tested on different products. It has been shown that different ingredients can be distinguished in the ready meals (Figure 22) and that the freshness of tomatoes influences the measured signals (Figure 23).

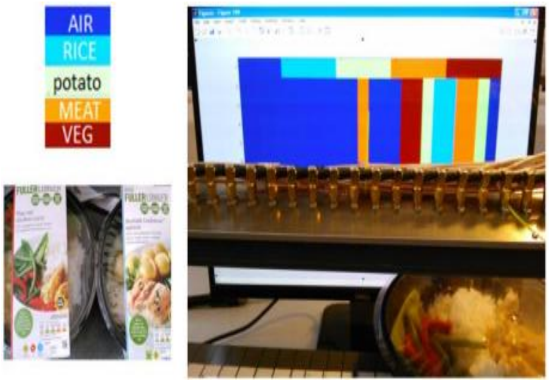


Figure 22: Laboratory test on ready meals, result shown on the computer

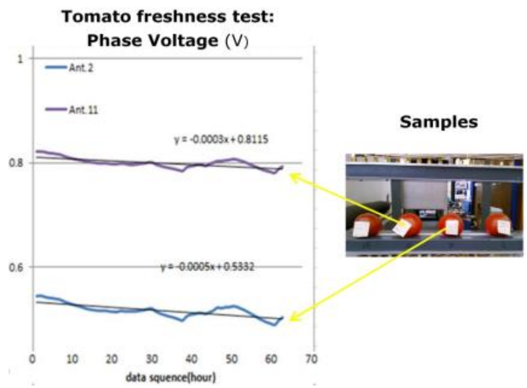


Figure 23: Laboratory freshness test on tomatoes and time varying voltage output over 70 hours

The milestones of UM in WP4 (M10 and M14) have generally been achieved. Some issues may be noted:

(a) The project had a delayed start. The research assistant was appointed 6 months after the official start date.

(b) The belt width of the production line had been determined and changed several times throughout the project to this date. This had a significant impact on the design of microwave sensing module.

(c) The microwave sensor system needs to be further optimized and tested in terms of both hardware and software, and it also has to be evaluated with more ready meal and fruit samples before integrating into the sensor module.

2.4.5 Use of resources

Cost type	PM	Costs
Personal	44.1	€ 233,310
Other		€ 97,947
Total		€ 331,257

(Indicated Costs and Person Months extracted from C-Forms, Excluding the input of MS and Spectro)

DLO
The work of WUR/DLO runs according the planning. Both the work done, and the used resources in terms of person-months is right on schedule. During the first 18 months, 15 man-months were used.

KUL
The work of KUL on the hyperspectral imaging runs according the planning, as well for the work done as for the used resources in terms of person-months. Regarding the part about the X-ray imaging, the problems are reported earlier in this report. For the whole WP, the used resources in terms of person-months is right on schedule. During the first 18 months only 15 man-months were used, because it took some time to hire the junior researcher.

UM
During the first 18 months of the project, UM used a total of 12 man-months of Senior Researcher and 0.5 man-months of Excellent Researcher regarding the microwave sensor subtask. However, the complexity of the circuitry involved was more than initially anticipated. Secondly, some circuit modules initially planned to be purchased have been self-designed and constructed. More man-months for both the Senior Researcher and Excellent Researcher were required to complete the task up to date. It is expected that more man-months are further needed to make the microwave sensors ready for integration into the sensor module, and to demonstrate its capability. Notwithstanding, the total cost for completing the tasks will stay within the budget allocated to UM for the work on the microwave sensor.

2.4.6 Deviations from DoW

There are no major deviations from the DoW accept the effort of the defaulting party Spectroscan . Effort of 44 PM is in line with the plan of total 133 PM. It is expected that the work package will achieve its tasks according to the plan when a new partner for Spectroscan is acquired. It is in line with the overall budget of WP4. Also more other costs (materials) are planned in the second period.

2.5 WP5 Robotic Handling Module

2.5.1 Project objectives for the period

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

The objectives for the first period of the project are:

- **Definition of the technical specifications for the robotic module:** Definition of requirements for the robotic module regarding range, speed, strength, cost, number of degrees of freedom, gripping specifications, hygiene, worker safety, environmental conditions, acceptance, etc as well as definition of types of information exchanged with other modules;
- **Development of a Pick and Place manipulator for food packaging sector and design of an innovative end-effector for picking variable delicate alimentary products (in progress):** Adaptation of an existing Pick and Place robot to perform the manipulations required to package food products and design of the end-effector that takes into account the products variability, fragility and the hygiene constraints;
- **Development of a flexible control for the robot (in progress):** Definition of the command scheme and strategies according to the aimed applications and the information exchanged with other modules (vision and packing);

- **Development of a vision system to control the robot to pick and place food components (in progress):** Development of 3D vision camera setup and interface for fast real-time control, development of learning algorithms to pick and place a common range of products and user friendly reprogramming solutions;
- **Development and testing of the robotic module** on food products (in progress): assembly, integration, calibration and test of the complete robotic module.

2.5.2 Summary of the work progress and achievement during the period

Technical specifications for the robotic module: The requirements and specifications of all submodules that compound the robotic module (manipulator, grippers, vision system, etc) have been defined, as well as the flow of information exchange inside and outside the module. This task has been successfully completed.

Pick and Place: Both a novel robot which fulfils the defined requirements is being developed, and one parallel robot developed by Marel is being improved. On the other hand, a novel gripper for fresh food able to adapt both as tomatoes and grapes and one gripper for breast chicken have been developed.

Flexible control: A flexible control for cable robot has been defined and is being developed. Both robot controllers will have digital input/outputs for the electrical control of the gripper, and different protocol communications to improve their flexibility and exchange information with the modules of the line. The robotic module is full flexible to handle any other products with lower payload than 3kg. Only modifications of the end effector must be taken into account

Vision system: Different 3D camera systems have been tested and analyzed. The best of them have been selected, as well as the required illumination. A first version of the software to detect the picking point and orientation for vine tomatoes has been developed and it is being continuously improved.

Testing of the robotic module: Some tests to check the proper behavior of the vision system, the grippers and the cable robot concept have been done.

For more information of all of these tasks, please consult the deliverables "5.1.-Report on system requirements" and "5.2.-Design report on robotic module" on the website www.picknpack.eu.
Critical decisions concerning design of the equipment are currently being taken since this is the period scheduled for detailed design. Despite the fact that these decisions can modify some previous outcomes, the initial planning is expected to be maintained.
During this period, Tecnalia-France and Lacquey Packaging have been added to the project as third parties. All the scientific changes in the DoW have been accepted and the financial changes in the ECAS (NEF) system have also been managed.

2.5.3 Work progress and achievements during the period

Definition of the technical specifications for the robotic module

To achieve this goal, all WP5 partners have done and sent to all project partners a questionnaire to fulfil the necessary information for the definition of robotic module specifications. This information, combined with exchanged emails and the conclusions of the issues discussed in the forum of the website have been used to define the robotic module specifications.
Below is a summary of the defined requirements:

Table 1 Summery of requirements for robotic module

ROBOT REQUIREMENTS	COMMENTS
Degrees of freedom	The degrees of freedom must allow grasp samples from a conveyor and place them in the packaging system.
Payload	The payload must be high enough to grasp all kind of samples (max 3Kg)
Speed	The speed of this module must reach 30 picks per minute
Accuracy	The handling system including the visual system should allow grasp samples in conveyor tracking mode.
Actuators	The actuators must be clean (according to food handling standards) and must me suitable for the dynamics needs of the manipulator
Robot mounted	Any configuration that could take samples from a conveyor
Envelope	To be defined according to the final layout
Other	The robot must fulfil other requirements regarding to defined communication protocols and hygienic issues
REQUIREMENTS	**VALUE**
Machine vision	3D perception is necessary to determine the 3D position and orientation of the grasp point. If higher-resolution 3D data is needed, the 3D sensing module developed in WP4 can be used.
GRIPPER REQUIREMENTS	**COMMENTS**
Degrees of freedom	The gripper has multiple DOF actuated by 1 actuator for opening and closing. It is possible to add one DOF for gripper orientation capabilities.
Mass	Total of gripper and product can't exceed 2 kg.
Payload	The gripper must be capable of handling payloads of up to 1 kg.
Moving speed	The gripper can be moved with 30 picks/min without product loss.
Opening and closing time	If product dimensions are known on forehand to have a variation of maximally 40 mm, the gripper closes and opens within 0.1 second.
Accuracy	The gripper can cope with 20 mm position accuracy. Placing accuracy therefore also has 20 mm accuracy.
Hygienic	The gripper must be foodgrade and cleanable with spray water.
Safety	The robotic module will fulfill following normative: EN-ISO 12100, UNEEN ISO 13849-1, UNE-EN 60204-1, EN-ISO-TR 14121-2, EN-ISO 13857, EN –ISO 10218-1
Environment	Electric Supply: 400V (3P+PE), I<32A Pneumatic supply: 6 Bar. Lighting: More than 500 lux. Mounting: On floor (flat and dry)
Gripper replacing	A gripper can be manually replaced within 1 minute.

Additionally, a schema with the flow of information exchanges inside and outside the module was done. The delay in the product specifications to be handled in the project has obstructed the proper execution of this task, but finally all the critical goals have been achieved.

Development of a Pick and Place manipulator for food packaging sector

The main extended robots used in the food industry are called parallel kinematics manipulators (PKM) or delta robots and are characterized by:

- Very high speed robot (Food industry requires large volumes).
- Inverted mounting (Foodstuffs are mainly transported on conveyors or belt systems).
- Low handling capacity (Individual foodstuffs are low weight parts).

However these robots are not easily reconfigurable in the workspace, have a big footprint and are expensive. For this reason, it was proposed to develop a novel cable robot that has the same dynamics, reduces costs, gains flexibility, makes work volume more efficient and has a reduced footprint. This change in the scope of this work package did not have a negative impact in the progress of the project.

Below is the final design of the novel cable robot that fulfils PicknPack requirements defined in the previous task. This design was sent to Fraunhofer to check the hygienic requirements. With their adjustments and advice, a complete food grade and washable design will be completed at April 2014.

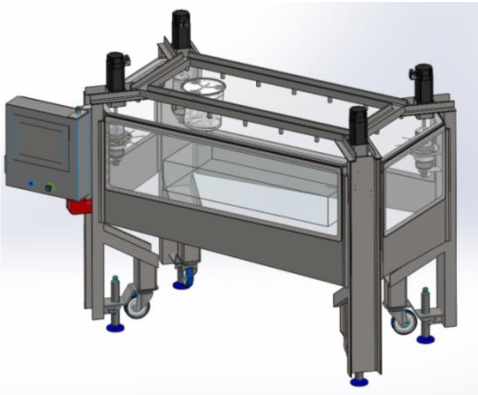


Figure 24: Cable robot detailed design

The project layout requires the use of two robots, so one parallel kinematics manipulator with improved characteristics designed by Marel will also be used in the final application. This robot has better performance for payloads of around the 1 to 2 kg, particularly in the rotary 4th axis capability, supports the industry standard IEC 61131 control system and has an improved hygienic design.

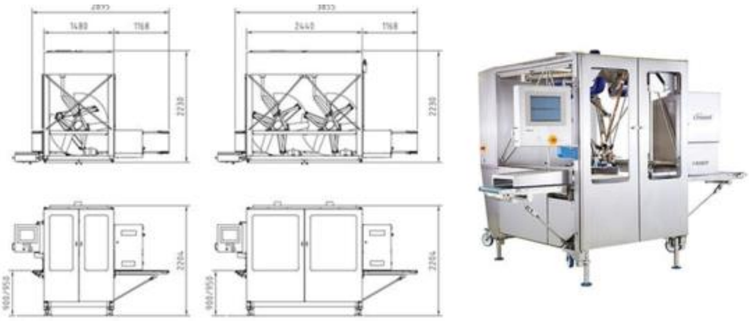


Figure 25: Improved delta robot detailed design

The layout of the line and the tasks assigned to each robot have been modified during the progress of the project, however the robots developed in this task are flexible enough to be adapted to these modifications.

Regarding end-effector, Lacquey has developed a gripper for picking chicken breasts and another gripper for fresh food which can be adapted with the use of a hook to pick vine tomatoes or grapes. The last gripper is composed by four fingers from each side of the product, which are all actuated with a single motor. On one of the two sides the fingers are completely flipped upwards above the bin edge level at the start of the gripping procedure. This will enable picking vine tomatoes from bins where space around the tomatoes is limited.

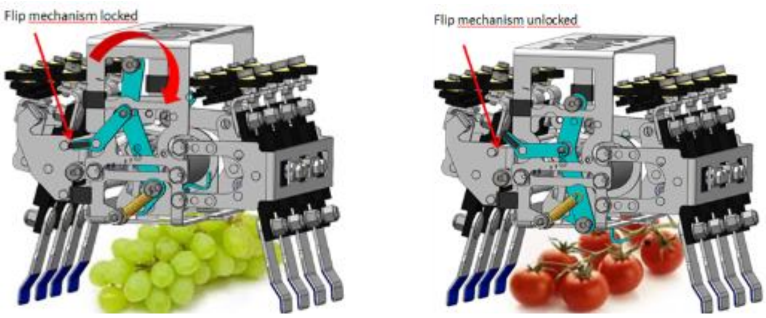


Figure 26: Gripper detailed design

Extra effort has been put into the hygienic design of the grippers. The initial designs were sent to Fraunhofer and the number of edges and crevices has been drastically reduced compared to the previous prototypes. Furthermore, almost all plastic bearings have been removed by using parts of the finger also as bearing material.

Development of a flexible control for the robot (in progress):

In parallel with the design of the novel cable robot, a flexible control has been defined and is being developed at this moment.

The model design of the cable robot will have a real time controller, closed loop control of the position of the platform and force feedback control to guarantee force balance. In order to develop a system closer to the industrial final users in food industry, one PLC will be used. Different control strategies will also be tested in order to fulfil the objectives of speed-acceleration while guarantying robustness of the controller.

Regarding Delta Robot, it has been ergonomically designed for efficiency and ease of operation. The system has straightforward and easy to use controls thanks to a universal graphical user interface developed by Marel. Remote access to customer's installations is possible, enabling rapid fault diagnosis and performance monitoring.

Both robot controllers will have digital input/outputs for the electrical control of the gripper, and different protocol communications (Modbus, Ethercat…) to improve their flexibility and exchange information with the vision system and the rest of modules of the complete line.

This task is being developed as expected and no delays have been detected.

Development of a vision system to control the robot to pick and place food components (in progress):

The task of the vision module is to find a suitable handling position and orientation (pose) for the parallel manipulator to pick the products from a crate and put it in the conveyor belt, and on the other hand, to find the suitable handling position and orientation for the cable robot to pick the products from the conveyor belt or crate and put it on the package.

For the cable robot it was decided to use the information of the vision system developed in the Quality assessment module to pick and place the products.

For the bin picking, an extended analysis of different 3D camera systems have been done (the Kinect structured light sensor, time-of-flight sensors, stereo-vision, and stereo-vision with structured light) and it was concluded that the stereo-camera setup is the most suitable for bin picking in the PicknPack project. After that, a program to detect the desired grasping points is being developed with this alternative.

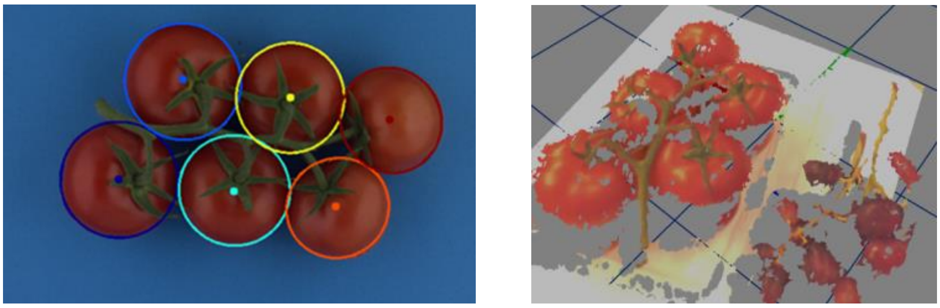


Figure 27: Vision system software

The products will be illuminated using diffuse lighting to reduce shadows and specular reflections. To control the lighting conditions in the robotic workcell as much as possible, the cell will be covered to prevent external light from entering.

As the final layout is still undefined, the location of the light sources is still somewhat unclear although this issue does not have big impact in the development of this task. For the Delta robot, several lamps and diffusers will be placed in a semi-sphere around the product location. For the cable robot it is possible to install the lamps and the diffusers at the side panels for the initial test. The final design will use transparent plexiglass, so the light source can also be installed above the glass to illuminate the products from above.

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

To check the proper behaviour of the vision system and the grippers, some trials have been performed. Both systems has been calibrated and integrated with a commercial robot and have been tested with tomatoes and chicken breasts. The vision system detects the picking point with sufficient accuracy and the grippers can successfully grasp the product for low speed. However the system needs to be improved for high speed.

Some feasibility trials have been also performed to check the proper operation of the cable robot concept. The results obtained have been successful and have validated the use of a vacuum +omni balls platform moved by cables for high speed applications.

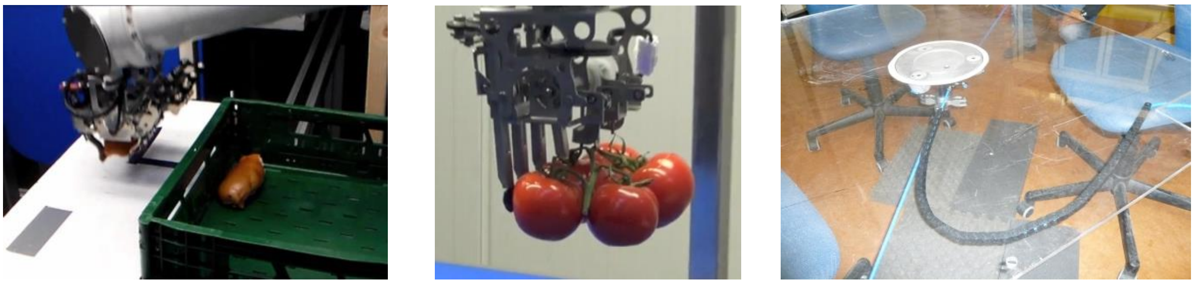


Figure 28: Testing of the grippers, vision system and cable robot concept

This task is being developed as expected and the results of this task have been very useful to improve the design of some elements of the robotic module.

Other comments:

During this period, the project coordinator worked on the request for amendment to add the third parties Tecnalia-France and Lacquey Packaging. He prepared all the scientific changes in the DoW and they were accepted by the project officer. The financial changes in the ECAS (NEF) system have also been managed. People from TECNALIA FRANCE are mainly involved in the design of the novel cable robot. At the present time, the technical work carried out by TECNALIA France is mainly related to work package 5 but they will be also involved in all the tasks in which Tecnalia will work. Lacquey has been reorganised. The technical employees of Lacquey BV are placed in the operating company Lacquey Packaging BV, founded in 2011 and a 90% daughter of Lacquey. Since the employees which were moved to Lacquey Packaging are active in the PicknPack project, this movement has consequences on the PicknPack project. It was suggested to enroll Lacquey Packaging as a third party of Lacquey in the consortium, and split the work and the according budget into two parts.

2.5.4 Use of resources

Cost type	PM	Costs
Personal	57.7	€ 429,953
Other		€ 64,661
Total		€ 494,614

(Indicated Costs and Person Months extracted from C-Forms, Excluding the input of MS and Spectro)

2.5.5 Deviations from DoW

As indicated in the report, there was a slight delay in the product specifications to be handled. The decision on product specification was carried out in other WPs. This delay did not have consequences on the general scheduling of WP5. Main material costs are scheduled in the second period.

2.6 WP6 Adaptive packaging

2.6.1 Project objectives for the period

The project objectives for the first period for WP6 concerning the adaptive packaging line were to:

- Define packaging performance levels
- Create ideas and test these ideas for digital mould system
- Create ideas and test these ideas for a flexible sealing and cutting system
- Create ideas and test these ideas for flexible heating system
- Create ideas and test these ideas for flexible decoration system

These objectives correspond with following deliverables and milestones:
Deliverables:

- D6.1 Report on the industrial requirements for packaging lines (M6)
- D6.2 Definition of packaging performance levels in PicknPack (M12)
- D6.3 Design and drawings of all sub-components in the flexible packaging system (M14)

Milestones:

- MS 19 Analyses, evaluation and definition of packaging performance completed (M12)

2.6.2 Summary of the work progress and achievement during the period

WP6 is proceeding as planned with a number of changes. All deadlines have been fulfilled up to now.
The overall line layout has been changed several times with a final conclusion in April 2014. The selected layout is both elegant and flexible.
WP6 has made reports on the industrial needs and the performance levels for PickNPack. WP6 over the last year has made a number of prototypes and tests of all subsystems of the packaging line.
Several flexible mould systems have been built and tested. WP6 has selected to use a brick mould system supported by a digital system to inform all other processes in PicknPack. Sealing and cutting is tested by different laser systems. The decoration system has also been tested with success. Integrity checking (seal quality) system has been tested and is based on hyper-spectral image analysis.
The only area were WP6 has problems is the flexible heating system for ready meals heated in microwave ovens. WP6 has found a new innovative system to print both reflectors and susceptors. This is already done on the top film, but WP6 has serious problems with the tray. The problem is that these two patterns must be printed before forming the web to trays because ink-jet-printers need a flat surface to print. During the forming process in the mould the web not only changes shape, the printed metal layer is also cracking into small flakes. The results totally change its performance. WP6 is working on alternative solutions, but does not know if these solutions will be ready for demonstration. Research is ongoing to find an elegant way to have a flexible heating system.

2.6.3 Work progress and achievements during the period

Task 6.1 Definition of performance levels

Two different reports are delivered:
D6.1) Report on the industrial requirements for packaging lines: [month 6]
The report with a full description of the industrial requirements for packaging lines was delivered 31 March 2013. The report included analyses of the needs in Denmark, the Netherlands and United Kingdom with a focus on packaging of ready meals, fruits and vegetables. Based on this information the report has an overview of different technologies to be used to create a flexible packaging line.
The report also defines a number of specifications for a flexible packaging line including:

- Dimension range of packaging
- Packaging types and materials
- Packaging decoration
- Packaging design and product development processes in food industry
- Production speeds
- Production batches and needs for flexibility
- Business evaluation
- Hygiene, safety and general demands (hygiene, workers safety, track and trace, migration etc.)
- Modified atmosphere packaging (MAP)
- Etc.

D6.2) Definition of packaging performance levels in PicknPack: [month 12]
A report with several descriptions of performance levels of the packaging line in PicknPack was delivered 30 September 2013. The performance levels are based on the analyses done in D6.1

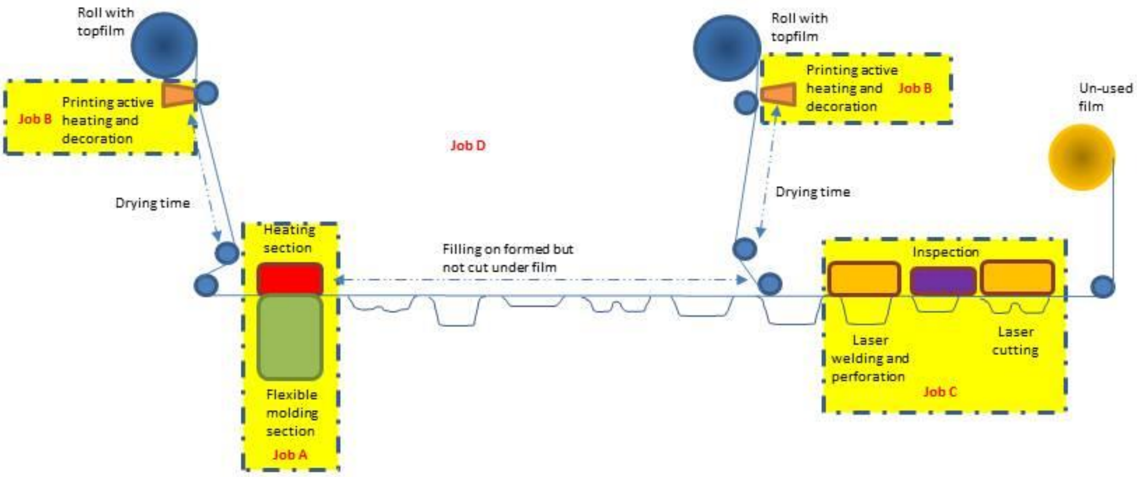


Figure 29 General lay-out with 4 jobs and tasks defined in D6.2

Each of these jobs has each own challenges. However, it was also obvious that these jobs can be solved in different groups.

A. Thermoforming system (Cam-Tech, DTI)

B. Printing of decoration and active heat system (DTI, Xaar)

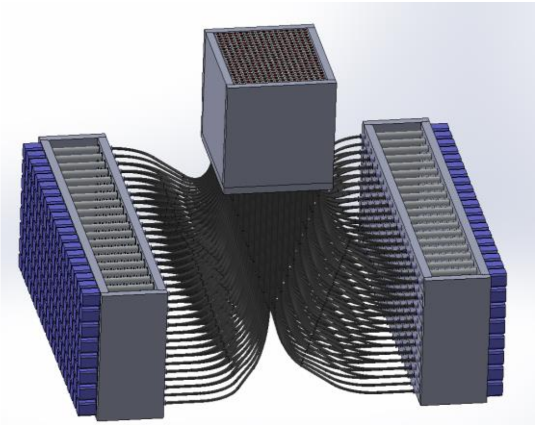
C. End-of-line-system (KUL, UM/University of Lincoln, DTI)

D. Integration of these units to PicknPack (All)

Task 6.2 Digital mould

WP6 has done research on several flexible mould systems:

Pin mould - In-line digital mould



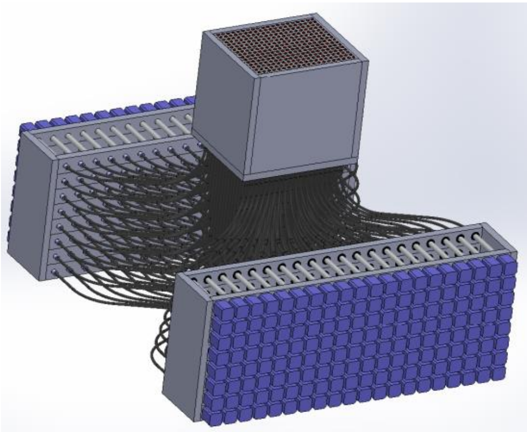


Figure 30 Digital mould with many pins operated with cables and servo motors

The mould has a number of pins able to move up and down. We produced three fixed prototypes with different resolutions and tested the performance in a packaging machine. We noted resolution and quality is a trade-off between price and quality.

In a mould of 150x200 mm, we need following:

Table 2 Pins for mould

Resolution in mm	**Number of pins**
10 mm	300
6 mm	833
5 mm	1,200
4 mm	1,875
3 mm	3,333
2 mm	7,500

As we realised such a system will be expensive, we are working on another idea.

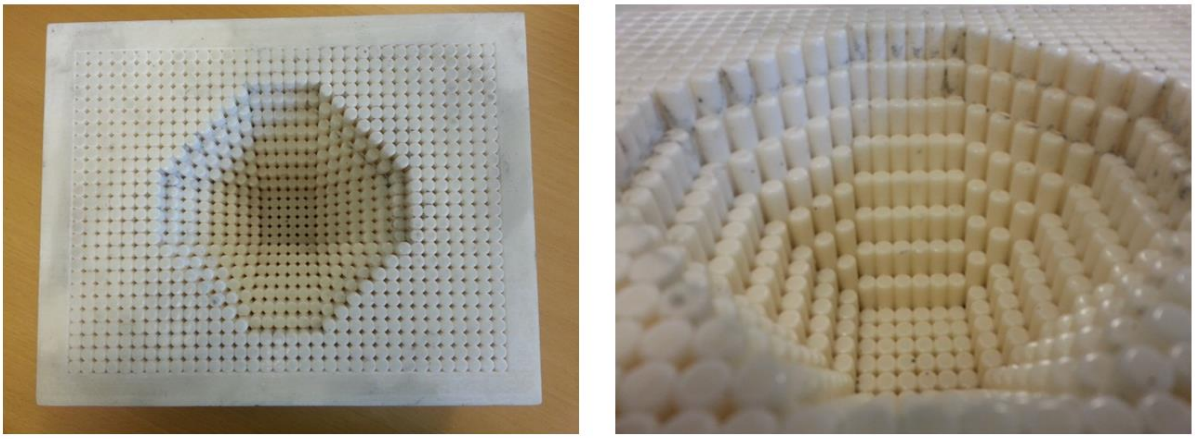


Figure 31 Mould with 5 mm pins

Figure 32 Tray produced in a mould with 5 mm pins

The quality of a tray made in a mould with 5 mm pins is not acceptable. In order to upgrade quality either the pins must be less and/or a flexible layer between the pins and the plastic shall result in a smooth surface.

Off-line digital mould

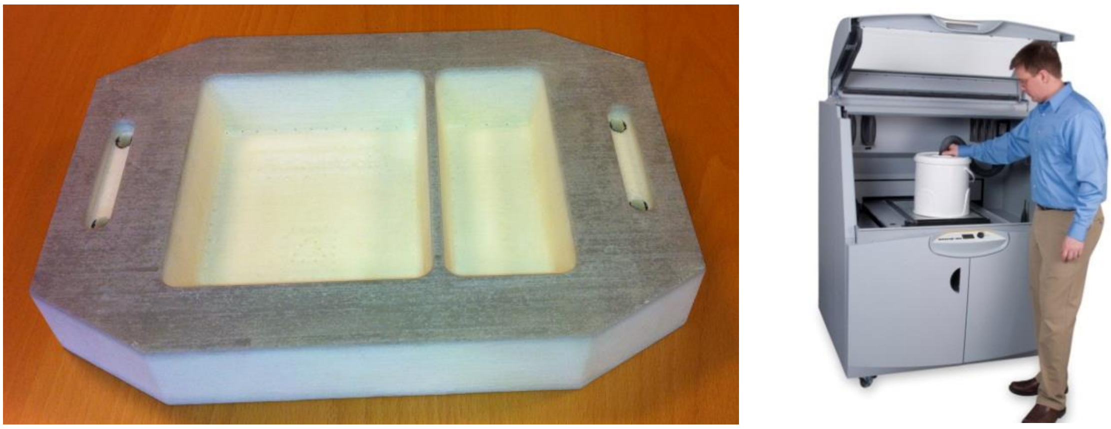


Figure 33 Digital produced plaster moulds produced off-line

Based on a standard 3-D printer for prototypes you can produce moulds which are able to produce about 1-3,000 trays and with a surface treatment, which is also more smooth.
The moulds will in the off-line system be produced off-line and shall be mounted on the thermo-forming-machine before the production. We need to develop an extreme fast changing system.
Moulds can be implemented in a standard thermo-vacuum-forming machine.

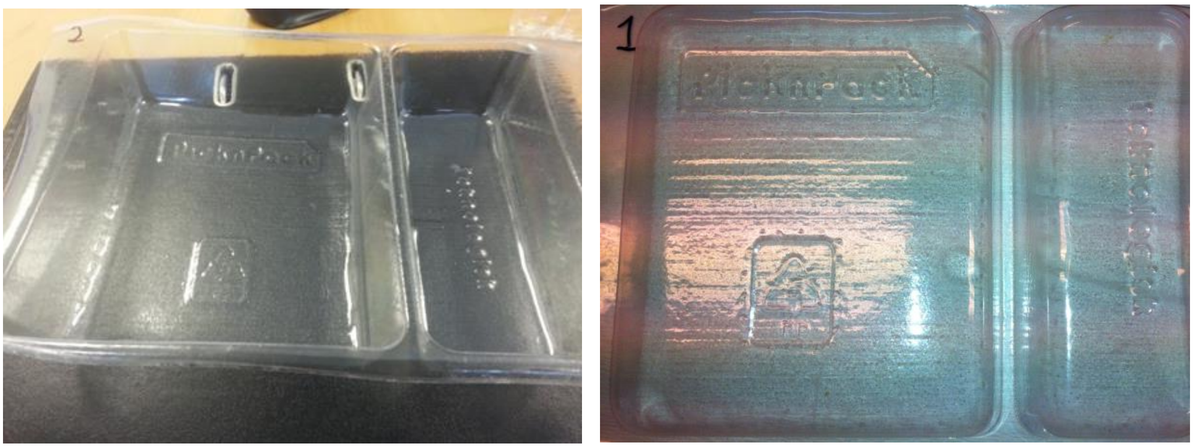


Figure 34 Tray made in a plaster mould from a 3-D printer

The plaster/concrete/ceramic/aluminium technology produces flexible moulds able to be used for more than 1,000 items in a very high quality.
Lead time for these technologies is 4-10 hours for 3-D plaster technology and 1-2 hours for CNC milling of concrete moulds. However, 3-D modelling is in a fast development these years and is expected to be more efficient, fast and inexpensive within a few years.

Brick mould system

Figure 35 Prototype of a brick mould

WP6 has already designed and produced a prototype of an innovative mould system. The system produces excellent trays as seen on the photo in figure 7. WP6 hope to create a fast system with only few minutes lead-time between design and production.
WP6 has selected to use the brick mould system in PicknPack as it stands out as the best system after many tests with many other prototypes. WP6 had some discussions about using the word digital mould for the brick mould system. It was decided to make this system digital as follows:

1. The design is done with bricks because this is the most natural way to work in the food industry
2. The design is scanned digital either using marking on the bricks or vision
3. The data from the mould is now digital and can be converted to inputs for all other processes in PicknPack.
4. As an extra option, WP6 is now evaluating if we are going to build a simple machine to build the mould out of digital data. Most likely WP6 will document such a solution but as this machine only has a little impact in demonstration, the machine is most likely not to be built.

After following interpretation of the word digital, we have decided that the brick mould system is a digital mould.
In order to demonstrate the digital nature of the Flexible Brick Mould solution, let us, first of all, refer to the basic definitions:
Digital *- relating to or using signals or information represented by discrete values (digits) of a physical quantity. (*Oxford American Dictionary*)*
Digitize *- Convert (pictures or sound) into a digital form that can be processed by a computer. (*Oxford American Dictionary*)*
The Table below presents physical quantities that characterized the colour image digitized into digital bitmap computer files. These quantities are put in a direct correspondence with the quantities of the Flexible Brick Mould digitized into set of bricks, exactly as a colour image is digitized into a set of pixels.

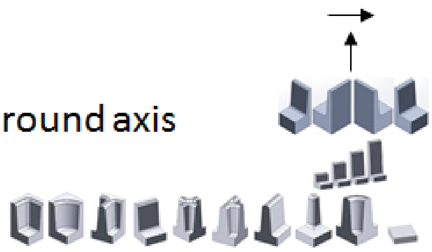
Color image (RGB)– digital bitmap file	Flexible Brick Mold – digital mold implementation
Pixels and their digitized parameters	Bricks and their digitized parameters
1. X position → 2. Y position ↑ 3. R (red color) 4. G (green color) 5. B (blue color)	1. X position 2. Y position 3. Orientation around axis 4. Brick height 5. Brick shape 

Figure 36 Digital nature of the flexible brick mould

Since the digital nature of a computer bitmap file is beyond any doubt, it is possible to conclude that the Flexible Brick Mould is digitised or simply is a digital object.

Conclusions
As WP6 evaluate the Flexible Brick Mould as a digital solution, WP6 has decided to focus the development on the Flexible Brick Mould system, as this system fulfil the requirements of the food industry best.
WP6 has given up working more with the off-line digital mould system, as these systems are not very innovative nor fulfil the requirements. However, WP6 is still evaluating if the pin mould solution is also

going to be demonstrated. If WP6 select to demonstrate the pin mould system this will be done either next to the demonstration site or partly in the in-line mould of the demonstration unit.

Task 6.3 Flexible sealing and cutting

The laser welder and cutter will be placed in the end of the packaging line after the trays are filled and after the top film is applied. The top and the under film are mechanical locked together at the same level under the laser. The laser will veld and cut by a controllable mirror system.

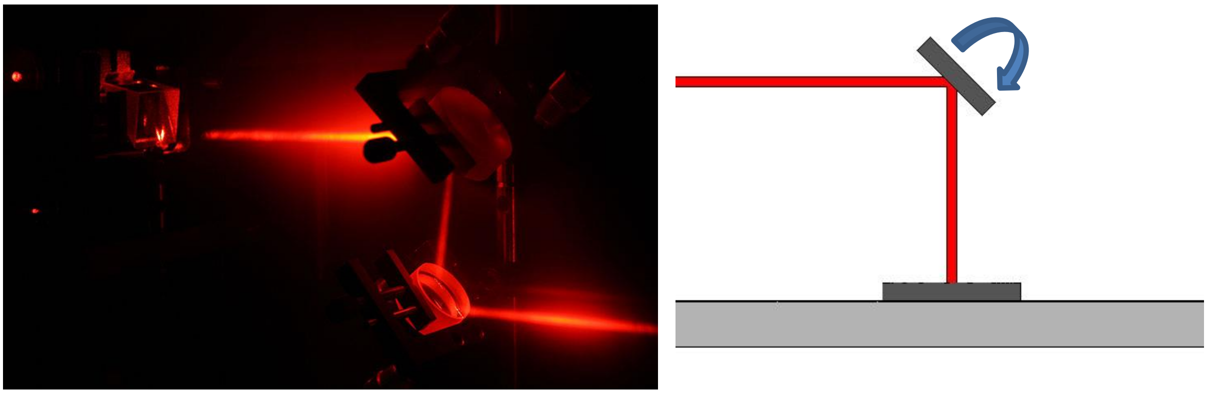


Figure 37 The laser with controllable mirror system

The laser must be able to follow this stop-go situation and process as follows:

1. Welding the two films together demand that the movement is stopped
2. Perforation of the packaging for MAP can be done both in stop and go
3. Cutting the trays out from the films can be done both in stop and in go after the top film is cut

The cutting system has a demand, that cutting points have to have a distance between top and bottom films. The mould for the tray sides need a little ditch/groove to create this distance.

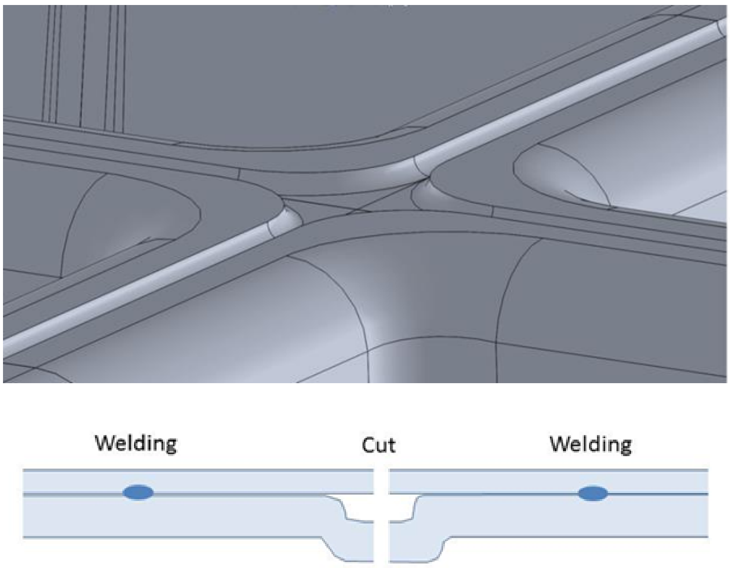


Figure 38 Ditches or grooves in brick moulds create a distance for cutting

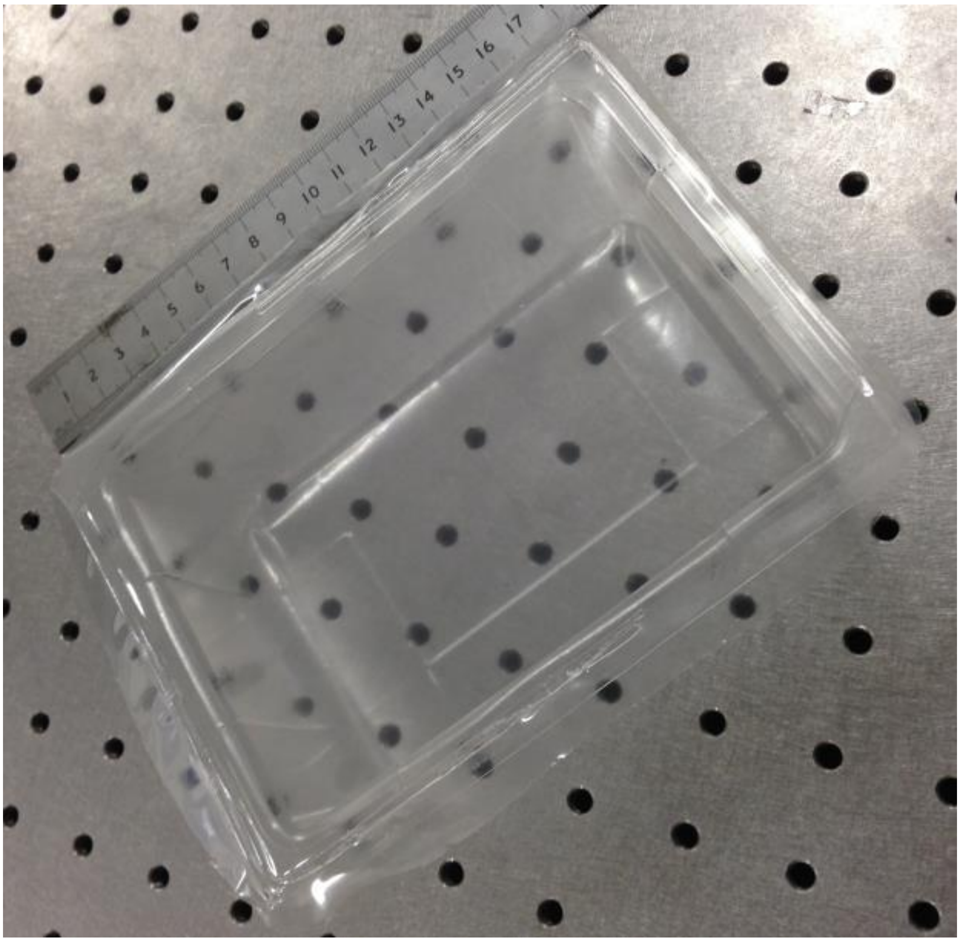


Figure 39 Tray made in the brick mould that is laser welded and cut

Trays made on the brick mould were tested on a prototype build by University of Lincoln with success. The experiences from these tests indicate a problem with having time for both sealing and cutting in the stop time. It is important that the under and over web is perfectly indexed under sealing which need a stop. If the over web is cut under sealing it will be possible to cut under the creeping movement.
The experiments also indicate that the sealing process will be the bottleneck to reduce the stop time.

Task 6.4 Flexible heating system

This text for flexible heating system is based on PicknPack report: *Laboratory study of inkjet printed electro-conductive elements of active packaging for microwaveable ready meals*.
Thin metallic reflectors and susceptors of microwave electromagnetic radiation (or simply microwaves) are inalienable elements of modern active packaging solutions for microwaveable foods. The effects of reflection and susception of microwaves in thin metal objects are controlled by their electrical conductivity (or resistance), thickness, and radiation frequency. Obviously, the mutual relations are as follows:

- The higher the frequency, the better the reflection and the worse the susception
- The thicker the sheet or the film of the metal, the better the reflection and the worse the susception
- The higher the conductivity, the better the reflection and the worse the susception

Thus, for a fixed frequency, the criteria of a thin metal layer transformation to the total reflector or the optimal susceptor (=optimal absorber of electromagnetic energy) can be expressed in terms of both *thickness* and the so-called *surface (sheet) electrical resistance*. This last is the resistance-to-thickness ratio for this layer that is measured in Ohms/square or Ω/□). These criteria are of course physically equivalent, but implemented differentially on manufacture and application of reflectors and susceptors for active microwave packaging:
Usage of the thickness criterion is based upon comparison of the layer thickness with the so-called *skin depth*. The skin depth is the depth below the surface of the conductor at which the eddy-current density caused by alternating electromagnetic field falls to 1/e (about 0.37) of its value at the surface. The skin depth depends on the resistance and frequency (the higher the resistance, the larger the skin depth; however, the higher the frequency, the smaller the skin depth). The skin depths of some bulk metals at 2.45 GHz is as follows:

- Silver (smallest of all materials) – 0.33 μm
- Aluminium – 0.86 μm
- Stainless steel (304) – 4.3 μm
- Titanium – 3.3 μm

Obviously, silver and aluminium are the best candidates for implementation of active packaging since they allow higher flexibility of the layer. Whereas cost-effectiveness dictates the usage of aluminium. Thus, in order to become a total reflector, the layer thickness must exceed 2.7 of the skin depth, or approximately triple skin depth. The layer of bulk aluminium must therefore be approximately 3-μm-thick to become a total reflector of 2.45 GHz microwaves, while the silver layer thickness needs to be just 1 μm. Obviously, the thickness of the susceptor must be much less than the skin depth. Experiments show that typical thickness of aluminium susceptor layer providing for 50 % absorption is of the order of 1 nm.

Laboratory studies

The only metallic inks that are currently available commercially and allow processing under conditions, which are compatible with polymer films on which the metal has to be printed, are silver inks. Thus, the deposited material is a porous silver film formed on the plastic film or tray after sintering of the inks. Its electrical conductivity is significantly different from the conductivity of the bulk silver and depends on many factors, which are difficult to control, for example, temperature and roughness of the sealing film. Therefore, the conductivity of the printed and sintered coating should be measured in order to control its capability to reflect 2.45-GHz microwaves.
The depositions made for proof-of-concept studies of the PicknPack concept for packaging of microwaveable ready meals were carried out using 200-μm-thick polyethylene-terephthalate (PET) substrate films, which were kept at the process temperature of 60^{o} C. In order to reach the necessary conductivity/thickness of the deposited silver layer, the printing was carried out in several passes of the printing head (actually, from 1 to 9 passes). The printing resolution varied from 120 to 360 dpi. The inks were sintered at 150^{o} C during approx. 30 min.

Figure 40 Inkjet printed silver coating on PET film installed in the experimental cell for the validation of its reflective power in a microwave oven

The coating that demonstrated ideal reflective behaviour in the 'microwave oven' tests was deposited for 9 passes with 360 dpi resolution. The water inside the cell covered with this sample remained cold after at least 10 min. of microwaving, and the electrical breakdown did not occur. For comparison, the water in the cell without coated film on the top reached the boiling temperature after 10 min.

The sample that already demonstrated somewhat absorptive (resistive) behaviour in the microwave oven (i.e. it is not a total reflector), was fabricated for 6 passes with the same resolution, on the same substrate, and using the same sintering procedure. Its sheet resistance was measured to be 0.200 ± 0.05 Ω/□ and the thickness of approximately 3.5 μm. This sample pictured after the 10 min 'microwave test' is shown in Figure 13. The rippling of the PET substrate dew to initial thermal sub-melting caused by the joule heating of the silver layer can be easily seen in this picture.

Figure 41 The sample with the silver coating printed for 6 passes with 360 dpi resolution.

Deposition of susceptors

Since the implementation of inkjet printed continuous metal microwave susceptor with the sheet resistance of 200-500 Ω/□ is not feasible, another solution was proposed and used. In contrast to the continuous metal coating susceptors, which are pre-heated by joule heat losses of radiofrequency eddy currents, the printed susceptors are heated by the radiofrequency displacement currents caused in a distributed capacitor. These distributed capacitors are formed by relatively small conductive metallic 'islands' printed on a dielectric substrate, e.g. on a polymer film or a paper sheet. These conductive islands may be either totally or partially reflective with regard to 2.45 GHz microwave radiation. One of the possible distributed capacitor patterns is shown in Figure 14.

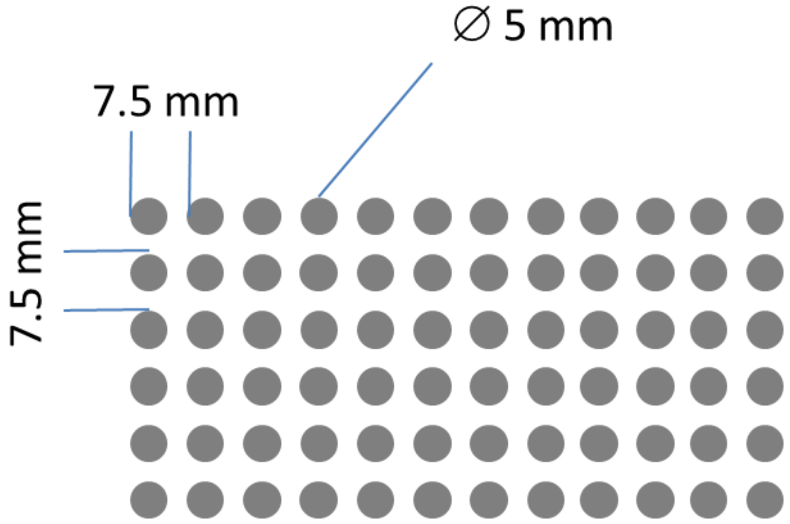


Figure 42 Pattern of totally reflective circular islands allowing heating up to 120-150°C.

However, the susceptor effect was also achieved in our experiments using the low-resolution one-pass inkjet printing of silver. In this case, the deposited silver dots and the PET substrate formed the distributed capacitor.

Experimental validation of susceptors

The susceptors have been validated in a very straightforward manner: After 1 min. of microwaving, the distribution of temperature resulted from absorption of microwave energy has been imaged by a thermovision camera Testo 875. This does not allow full characterization, but gives the possibility to make sure that the susceptor effect is observed. Anyhow, the development of the inkjet printed susceptor technology is not finished yet. We hope to find a better method for in-line characterization of the working temperature and efficiency of the susceptor.

The thermal images of the distributed susceptors right after 1 min. of microwaving are shown in figure 15.

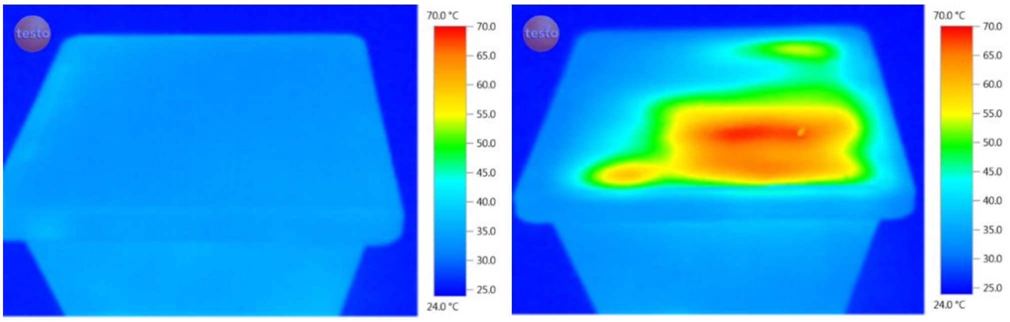


Figure 43 The thermal images of a plastic tray: left picture – the tray is open, right picture – the tray is covered by a PET film with a distributed inkjet printed silver susceptor deposited for one pass with the resolution of 120 dpi.

The susceptor shown in figure 16 is an actual sample of a pattern of totally reflective islands. It is based on the structure shown in Figure 6. So far, these patterns have only been made of aluminium and deposited on different substrates by means of CVD technique at the Tribological Center of DTI. However, there is absolutely nothing restricting inkjet printing implementation of the same pattern. DTI and XAAR plan to carry out some depositions and validation experiments with these susceptor structures in the near future.

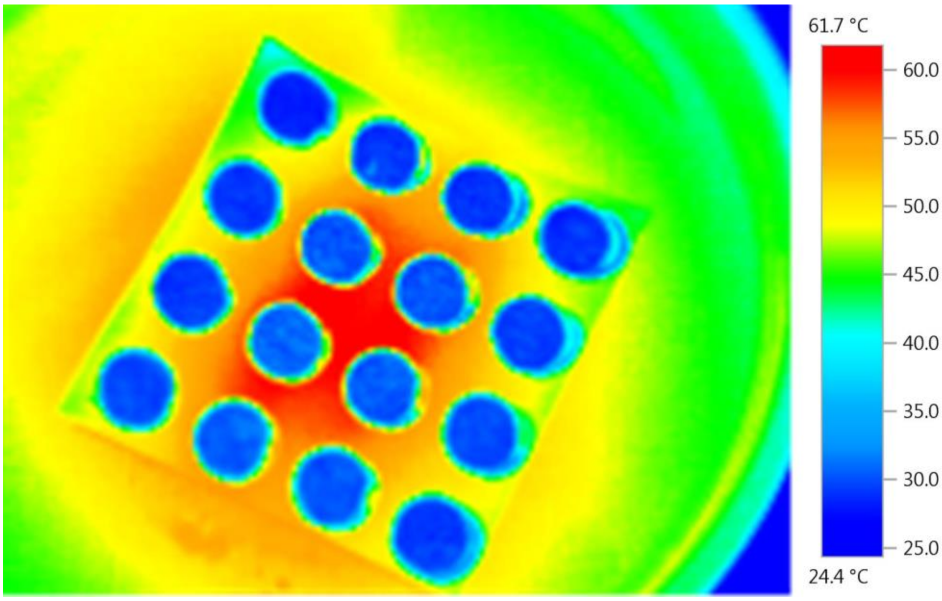


Figure 44 The thermal images of a printed susceptor formed by a paper substrate and a totally reflective islands of aluminium film. The metal pattern remains cold while the substrate is heated up by the radiofrequency electrical displacement currents caused by microwave electromagnetic field.

Conclusions

- The inkjet printed total microwave reflector was for the first time fabricated and validated in this study.
- The successful proof-of-concept experiments of inkjet printing of microwave susceptor has been carried out.
- The future work is to be done in order to develop inkjet printed flexible susceptors viable for application in PicknPack project for packaging of microwaveable ready meals.

As a conclusion for the flexible heating systems, WP6 has, together with the Project Board, decided to proceed with the research and make space on the line to apply these systems later in the process as WP6 do not believe to have an industrial system ready within the time frame of 2014. As a natural conclusion the Project Board and WP6 has decided to print with two different colours on the top web.
For these reasons, PicknPack do not expect to demonstrate the flexible heating systems in-line. PicknPack will demonstrate these technologies off-line as an integrated part of the demonstration event.

Task 6.5 Flexible decoration

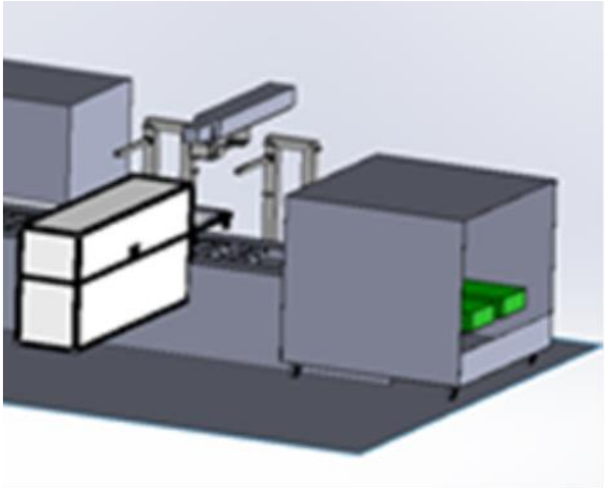


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Figure 45 Printer build together with the laser welding and cutting

WP6 has done several successful tests decorating plastic films in different colours.

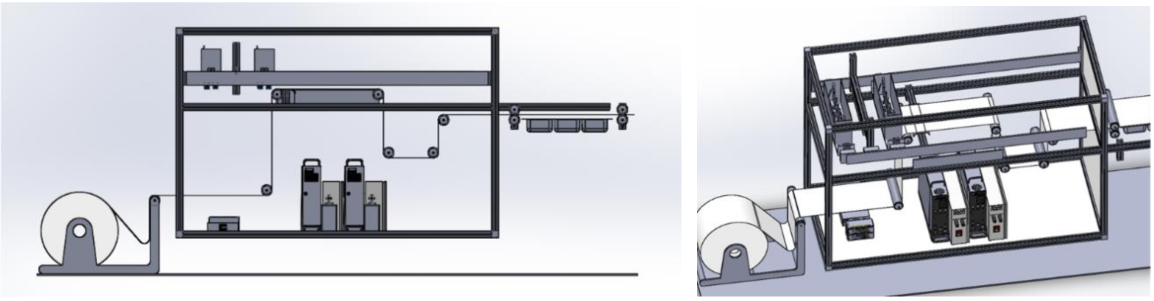


Figure 46 Two colour jet-ink printer

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

The printing system is designed in a way that individual information and decorations for batch sizes down to single units are printed onto the top-film, before it is sealed onto the tray. Work has also been performed to identify suitable low-migration UV-curable inks for this process, as it is a crucial part of the process that no ink components migrate into the food products. The inkjet print head selected for this process is the Xaar 1002 print head model, which allows to print in a grey-level-mode at 360 dpi, resulting in high apparent resolution and image quality. A unique feature of these print heads is the continuous ink recirculation past the back of the nozzles during jetting, which means that air bubbles or unwanted particles are carried away, resulting in highest printing reliability. These features make the Xaar 1002 the most suitable print head for this type of single-pass printing as employed in PicknPack, where it is important that the printed information like text and barcodes does not contain any defects that make it unreadable.

Beside this approach direct on the packaging line, DTI has decided also to experiment with another solution for a printer. DTI will try to rebuild an existing colour office printer with four colours to be able to print shaped and bended cardboard to be converted to sales boxes. DTI hope such a system can also be used for web printing of both plastic or paper based materials. Production speeds for such a design will be perfect for the ready meal industry, but in the low end for other business areas.

Task 6.6 Integrity checking

The integrity checking system is based on a hyper spectral imaging set-up. Two different detectors were used, being a VIS-NIR system (400-1000 nm) and a SWIR system (1000-2500 nm). Tests were performed on different package sizes in order to study image quality and potential issues with reflection. Illumination, which is provided using classical halogen sources, was optimized using ray tracing software so to minimize reflection issues, and to make illumination homogenous. Figures 19 and 20 show the set-up and a typical image of an empty package at a given wavelength (900 nm).

Measurements show that imaging is promising, but future tests on the final laser seal should now be performed to calculate accuracies. Seen the fact that laser seals will be small [smaller than the conductive seals we have used so far], resolution of the system might be a bottleneck, and will be investigated.

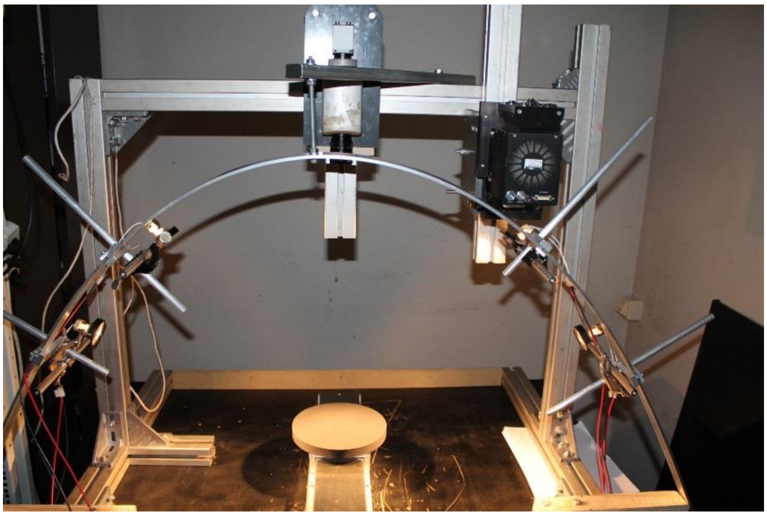


Figure 47 Hyper spectral set-up used for the measurements.

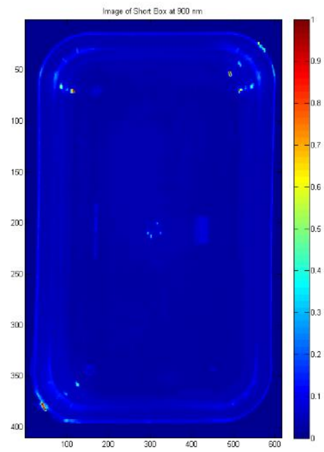
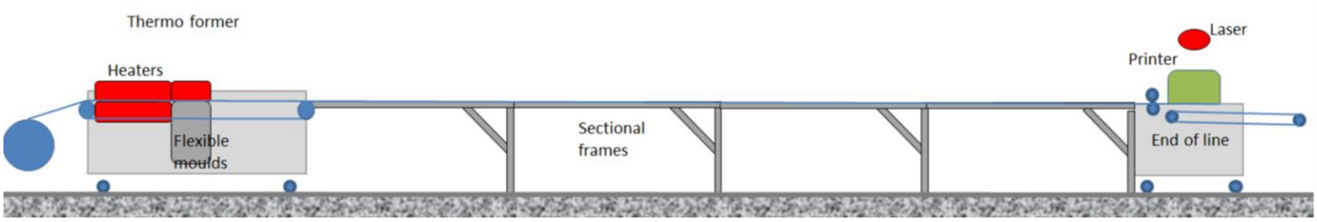


Figure 48 Image of an empty package at 900 nm.

Task 6.7 Integration of packaging modules



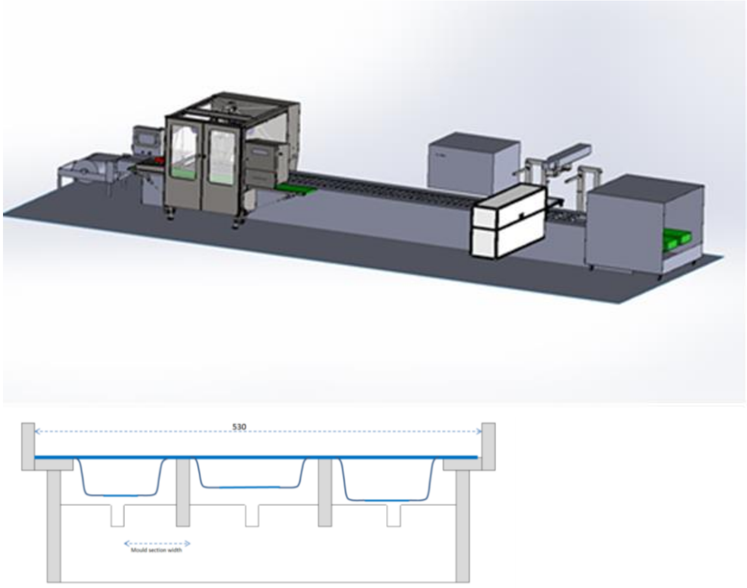


Figure 49 The flexible packaging line with thermo former, sectional frames and end-of-line

PicknPack has selected a line layout starting with a thermo former with a flexible mould system. The web with formed trays are moved together over a sectional frame for filling and scanning. An end-of-line unit contain a printer of the top film, laser and cutter, integrity checking and a robot for sorting up the packs on different boxes.
An important task has been to solve the challenge that thermo forming, and the application of a top film, and also welding and some cutting must be done in a stopped line. On the other side, scanning must be done in a constant speed. PicknPack has decided to use a production strategy of both stops and slow movements – called Stop-and-Creep.

2.6.4 Use of resources

Cost type	PM	Costs
Personal	49.8	€ 540,959
Other		€ 155,445
Total		€ 696,403

(Indicated Costs and Person Months extracted from C-Forms, Excluding the input of MS and Spectro)

2.6.5 Deviations from DoW

WP6 has up to now no deviations from DoW. See following evaluations based on DoW 1.2 progress beyond the state-of-the-art.

1.2.9. Digital mould
The most commonly used packaging platforms for food trays are either thermoplastic materials or moulded paper. Both packaging forms are shaped in moulds. These moulds are
Bottlenecks for flexible package production as the moulds are relatively expensive and demand a lead-time of several days to be produced and adjusted. Even once these moulds are produced, it takes some time to switch from one mould to another. The typical switch time plus adjustment to the next production batch is 1-8 hours. Flexible mould technology is the solution proposed in this project and will allow the production of batches of only 1-100 units per type of package. More specifically, digital mould technology will be used in the
PicknPack concept. The aim is to create a digital mould for either thermoforming polymers or moulded

paper. This digital mould can be changed from one design to another within seconds without any change of the packaging converting machine. Such a technology will be just as flexible as the robots, which manipulate the food components into a final product.

- WP6 hope that the brick mould system will be able to start production only 5-10 minutes after the beginning of the design process. If this is, the case WP6 deliver more than expected in lead-time.
- In addition, mould shifts shall be done in seconds, which is also better than expected.
- The system is perfect for bathes of 1-100 units.
- The brick mould system is a digital solution see chapter 2.6.3 under task 6.2 Brick mould system.
- The pin mould system is also digital will minimum be demonstrated off-line.

1.2.10. Flexible packaging system

Food products are often sealed into a specific controlled environment in order to maintain the best possible shelf life. Such a protective environment is the optimal combination of temperature, humidity, oxygen, carbon dioxide, nitrogen and other gasses. Typical food packaging lines either flush atmospheric air out of a packaging bag made of plastic films or flush the optimal air into the tray before sealing with a top film. Both these technologies suffer the problem that the product is exposed to atmospheric air and that that will also be locked into "pockets" in the food product. The advantage with the PicknPack system is that the entire operation can take place in a designed environment, which protects the food products being packed. Even the short time inside the PicknPack environment gives the advantage that the food components adjust to the modified atmosphere. This will as an extra benefit also increase the shelf life of the products. The sealing system shall be designed to take place as the last step before the product leaves the protected environment of PicknPack. The sealing system shall include both a sealing system and a cutting system to make the retail package ready for presentation and sale.

The text clearly define MAP created in a closed room with no humans looking directly on the packaging line. For the in-line demonstration activities, PicknPack has selected NOT to produce under these MAP conditions demanding all operations done in a sealed environment with access for humans.
PicknPack will create an off-line demonstration of these conditions in order to make it possible to demonstrate for humans.

1.2.11. Flexible packaging integrity system

As mentioned above, modified atmosphere packaging is often used in the food industry to guarantee the shelf life. It is evident that any flaws during the flexible sealing process that cause weak or defective seals should be detected before the package reaches the consumer. KUL has built a track record in developing seal integrity systems which can be seen not only from the patent that was granted on this topic, but also from the number of different world-class food companies now using the technology. However, the current systems face several drawbacks requiring research into novel technologies. Available systems are mainly based on camera vision systems, being only suited for transparent material, and on electronic sniffer systems that are only useable for specified tracer gases. A flexible solution should answer different needs, such as ease of adaptation to small batches and related geometry changes, as well as operating irrespective of the modified atmosphere used in the considered process. This will be the main focus in PicknPack where a system based on hyperspectral vision will be devised.

This is what PicknPack will demonstrate in-line.

1.2.12. Flexible heating system

Many food products are heated by consumers in the packaging. The heating processes can include baking, boiling/heating in water, and microwave heating among others. Baking in the oven and heating/boiling in hot water is the main method, which places demands on the packaging material properties. Preparation in microwave ovens is a method increasingly used for heating various ready meals. Traditionally microwave heating is a boiling process using a closed packaging made of a plastic film transparent to the microwaves. But also, other microwave heating technologies are available. Susceptor technology in the packaging material can absorb all the energy so that the packaging becomes very hot and can act as either an oven or, with oil between the susceptor and food product, can fry the food.

Susceptors can be created on the package, which are semi-transparent to microwaves. The food can also be shielded from the microwaves with a non-transparent material added to the packaging. These materials can be either different metals or carbons. The aim is the development of a method for the application of these semi-transparent or fully reflecting microwave materials onto packaging using advanced ink-jet printers. The purpose of this is to develop a fully flexible method for creating flexible heating systems in the package. Such a flexible heating system will allow the energy to be allocated in a completely flexible manner to different components of the food products. If PicknPack selects specific

food components, the flexible heating system shall be distributed over the packaging in order to obtain the optimal result for the ready meal.
With the innovative and promising results on both printed reflectors and susceptors PicknPack will be able to demonstrate these technologies off-line as an integrated part of the demonstration event. WP6 still need to perform some research in order to develop a commercial system for a cost fitting the food industry. PicknPack hope to find such more commercial methods within 1-2 years.

1.2.13. Flexible decoration *Nowadays, food is typically packed in a pre-printed plastic film or a pre-printed carton box.* *The printing process is done by the supplier of the packaging material. This results in a lead-time from ordering the decoration to the supply of the pre-printed packaging film, which ranges from a few weeks to half year. Another problem in the existing decoration system today is that the size of the production batches has to be at least several thousands. In order to overcome the need for smaller batches many food producers use a general design for basic packaging supplemented with a label in a poorer quality, but with a lead-time of only 1-5 days. If the packaging has a complex shape it is difficult to decorate these parts of the packaging. Food producers will in these situations typically only decorate the flat parts of the packaging. The aim of PicknPack is to provide the flexibility to produce batches of only 1-100 units before the next decoration change and to be able to decorate also complex shapes of food packaging. This would represent a huge step beyond the state of the art. The idea in PicknPack is to directly decorate the primary packaging material on each product with a custom design without delay down to a batch size of one unit. If this will be possible, even tailor made products will look professional and costs for additional labelling can be saved. In order to reach this goal PicknPack will develop a high-resolution package printer directly on the packaging line able to decorate packaging materials such as plastics and paper/carton.*
• The flexible decoration system will be demonstrated in-line in two colours on the top film. • We hope to demonstrate with equipment a four-colour printer off-line. • Printing of complex shapes of packaging will be demonstrated off-line. The printer used for in-line demonstration is able to decorate in a full digital way and batch sizes down to single units at the required process speed, but has limited performance in terms of colours and decorating the sides of the package. A printing system that would be capable of doing everything would be technically possible to build, but too complex and expensive for the scope of the project, especially as PicknPack does not have the budget for many print heads and an extra robot.

2.7 WP7 Fresh and processed food production line

2.7.1 Project objectives for the period

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

- Definition of the fresh and processed food production lines.
- Concept development and design evaluation.
- Fixate design and provide a go for development.

2.7.2 Summary of the work progress and achievement during the period

During the first period, WP7 has successfully defined the specifications and layouts of the PicknPack food production lines. The specifications and layouts were required so that each module in the line, developed by other work packages, knows what input it receives and what output it should generate.

WP7 also defined what shared components are used across modules, such as a trays transporting system and communication interfaces. Moreover, hardware elements that are not part of any work package but that are required to bring the modules together and complete the line, were defined by WP7. Examples of such parts are a sauce and vegetable dispensing unit.

Besides shared and additional hardware components, WP7 also fixated the food product input based on studies of current industrial common practice. The definition of the line layouts should be fixated before the Iceland meeting (M18) so that the development of the modules can start.

Coming to a fixated design was an iterative process. A number of processes steered the start of each new iteration.

First, a preliminary line sketch was drafted after the input of each partner. In this sketch, a product flow (fresh food & ready meals) from start to end was described through all modules, both functionally but also with respect to the location in the lines. A number of uncertainties in this early stage resulted in black box sketches of which the dimensions were roughly known, for example of the Sensing Unit.

Feedback of the Industrial Advisory Board on this layout triggered a new layout design. In the industry it is common practice to have a straight single line. Two new layouts, one for each application, were sketched. A quick changeover between lines would guarantee flexibility with the same modules.

During an additional project board meeting in January 2014 it was decided that all products would be placed directly inside the packages. This resulted in using less conveyor belts. Furthermore, the overall line strategy moved towards a convergence of the fresh food and ready meal application, which reduced the needed change over time dramatically.

In March 2014, WP6 purchased a thermoformer. By fixating this crucial element, a new option emerged for the global line strategy. Instead of packages moving on conveyor belts, the formed packages remain connected and are guided through all modules. This simplifies the overall task, as the location of each package is known. Furthermore, no changeover is required: one line can accommodate both fresh food and ready meal tasks.

2.7.3 Work progress and achievements during the period

The work progress for WP7 and achievements during the first 18 months of the project are reported in this section. For the here reported period the use of resources are in line with the Annex I of the project proposal. A slight delay in the fixation of other modules caused a slight delay in integration assembly preparations. However, we expect we can catch this up before the end of the year as the delays are not significant.

Three tasks were relevant for this period according to the Gant Chart:

- Task 7.1: Definition of fresh and processed food production lines. (Focused on the vine fruits (grapes and vine tomatoes) and ready meals). Subtasks included: System analysis and bottleneck assessment, Gathering input from experienced vine fruit and ready meals companies, Adjustment to systems integration and architecture, Analysis of available inputs generated from other work packages, Analysis system requirements on hygienic design (WP8) and sustainability (WP9) and Analysis economic viability.

- Task 7.2: Concept development and design evaluation. Subtasks included definition of required functions and working principles. Test trials of critical functions and working principles on vine fruits, conceptual design of entire system that satisfies the economical and functional requirements, quantitative simulation with mathematical models and design evaluation analyzing bottlenecks with expert assessment.

- Task 7.3: Assembly of fresh and processed food packaging line. Relevant subtasks for this period include the assembly and testing of individual modules and specific integration functions.

During the first period, major steps were taken in completing task 7.1 and 7.2. Although according to the Gantt chart these tasks should be finished, we experienced that slight amendments to the line specifications and concept development are the result of ongoing smaller iterations. However, the global definitions are fixated (MS23+MS24).

For task 7.1 the specifications of the productions lines was defined. This was achieved with several iterations. In Figure 50 the first iteration of the line layout is shown. This was made with partner input.

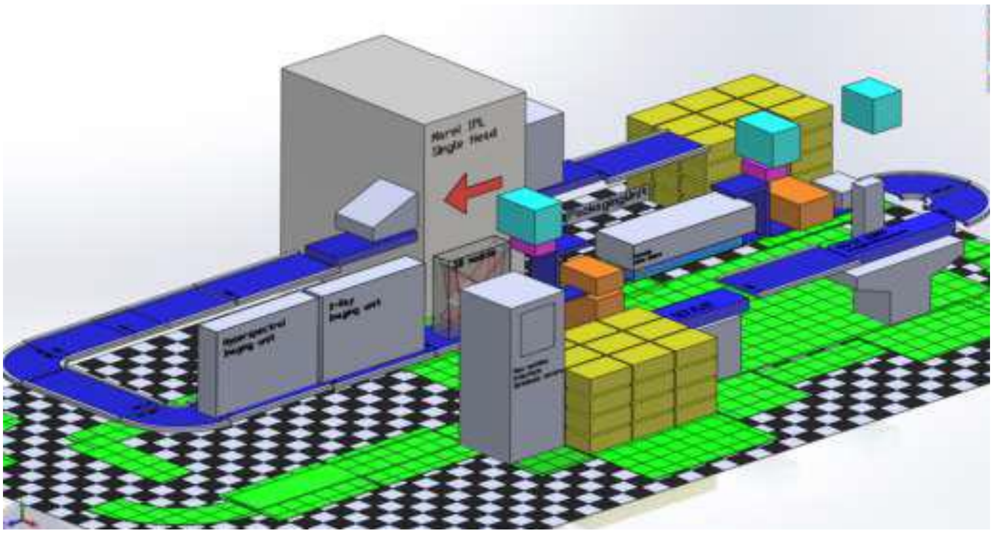


Figure 50: Preliminary sketch of the line layout

Feedback of the Industrial Advisory Board resulted into two separate new sketches, one for fresh food products and one for the ready meals. The feedback steered upon straight parallel lines. This development implied that a changeover is required between the two applications. See Figure 51 and Figure 52.

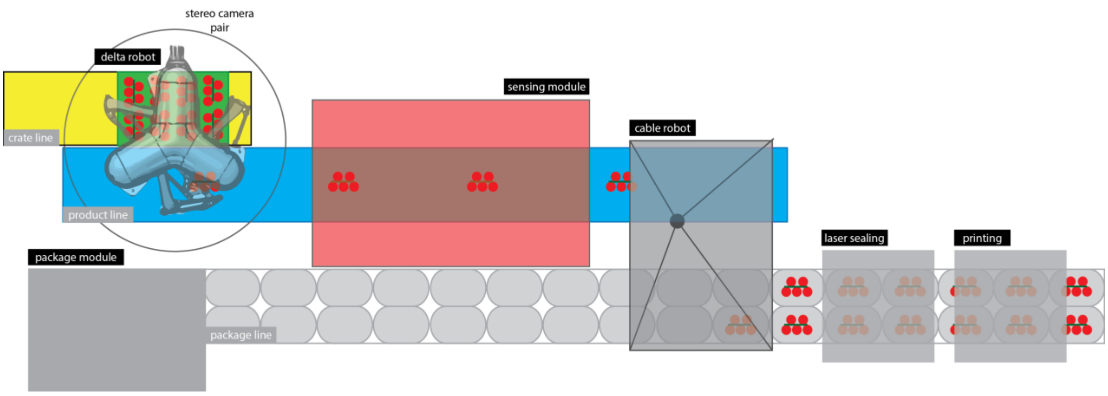


Figure 51: Second iteration sketch of fresh food product line.

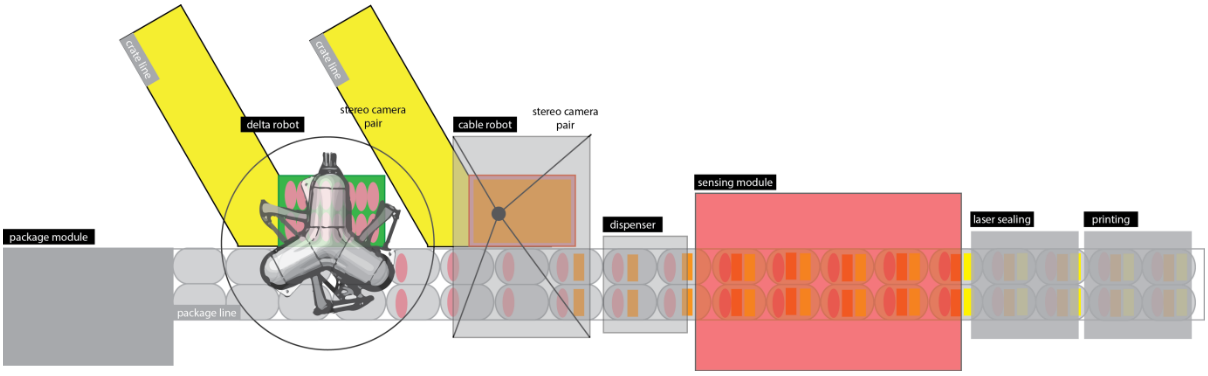


Figure 52: Second iteration sketch of ready meal line.

However, the changeover was not favoured because flexibility is not primarily introduced by topological arrangement, but by functionality. In January 2014 it was hence decided to do all tasks inside the packages, like placing, sensing and picking. A major change of the concept was the result as can be seen in Figure 53.

As part of task 7.3, we evaluated the consequences of the purchase of a central module of the line: a thermoformer by WP6. With this thermoformer now fixated, 3 global line strategies were plausible. To fixated the line design before M18 and to reach MS25 (conceptual design ready), a decision had to be made regarding which of the strategies above should pursued. After intensive project board discussions and an additional workshop organized by WP6, all favoured to pursue the 3rd strategy.

In this final fixated line design, see Figure 54, the thermoformer creates a set of packages in a stop-and-go manner. However, in contrast to the old strategy, the sets of packages are not cut and stay connected through all module until the end of the line (the so called 'web'). The sets of packages move in a custom made frame. These sections can be added up to any length. At the end of the line is the printing and sealing module. Thereafter the cable robot can pick and place the packages into crates from the belt.

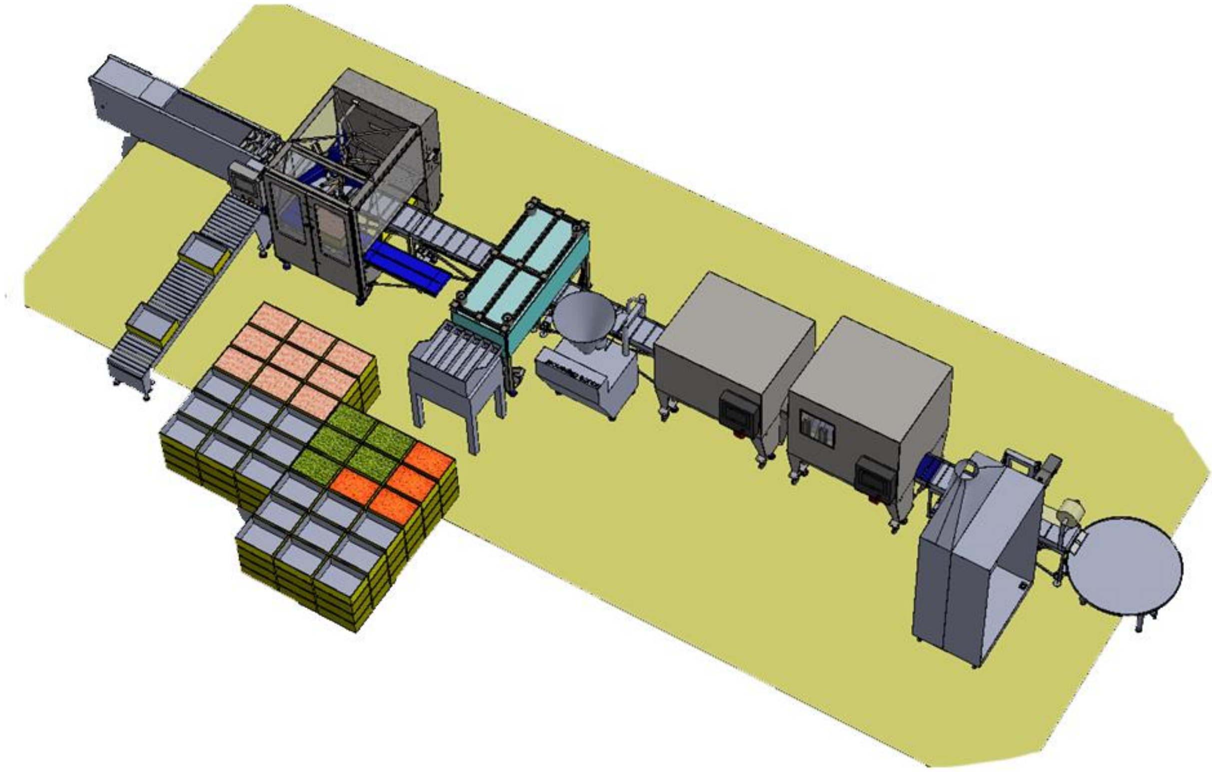


Figure 53: Updated line sketch. Fresh food and ready meal products are placed directly into a package on a conveyor belt.

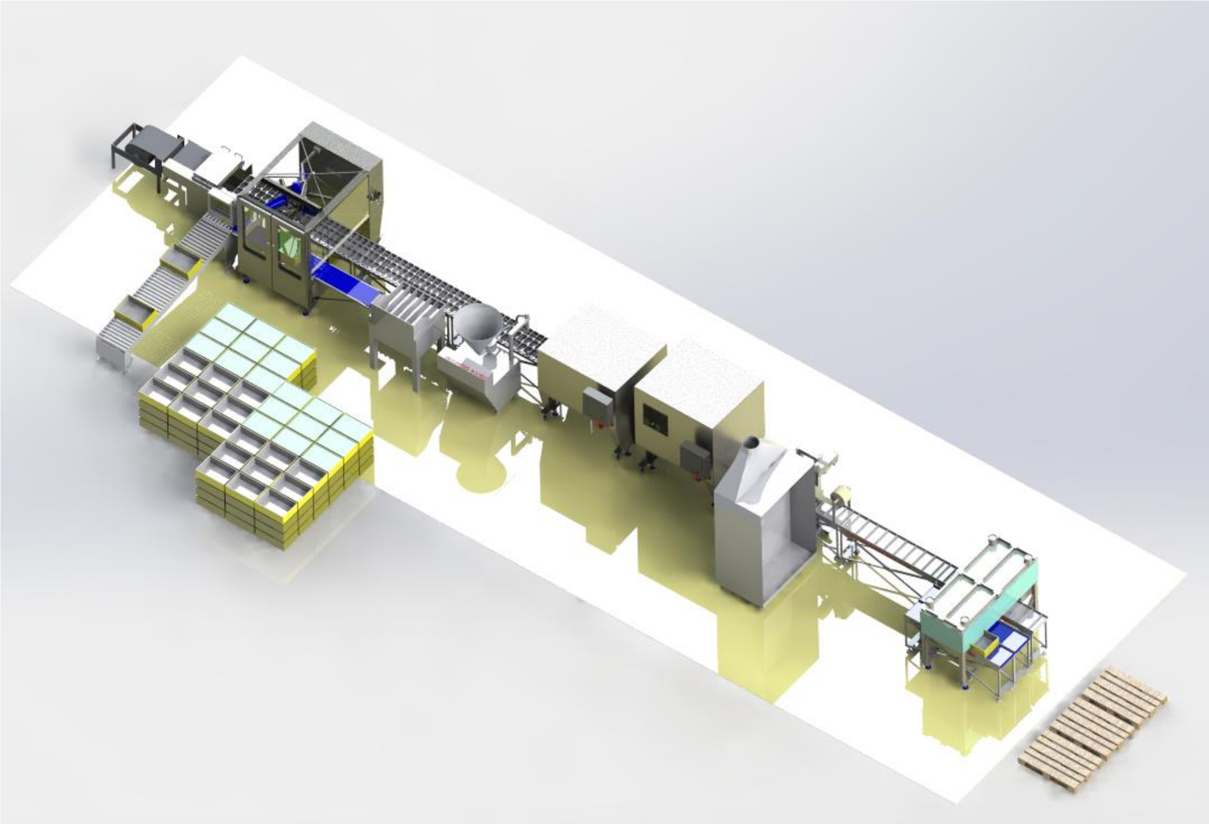


Figure 54: Final layout design fresh food & ready meal lines.

Part of task 7.2 was to define required functions and working principles. A part of such an overview can be seen in Figure 55. This diagram shows all the functions of the demonstrator ordered and linked together from input of products to output of products in shelf ready boxes. The function overview is created based on the information obtained from questionnaires and input from WP2 (systems integration), WP3 (track trace), WP4 (sensing systems), WP5 (handling system), WP6 (packaging) and WP8 (hygienic handling).

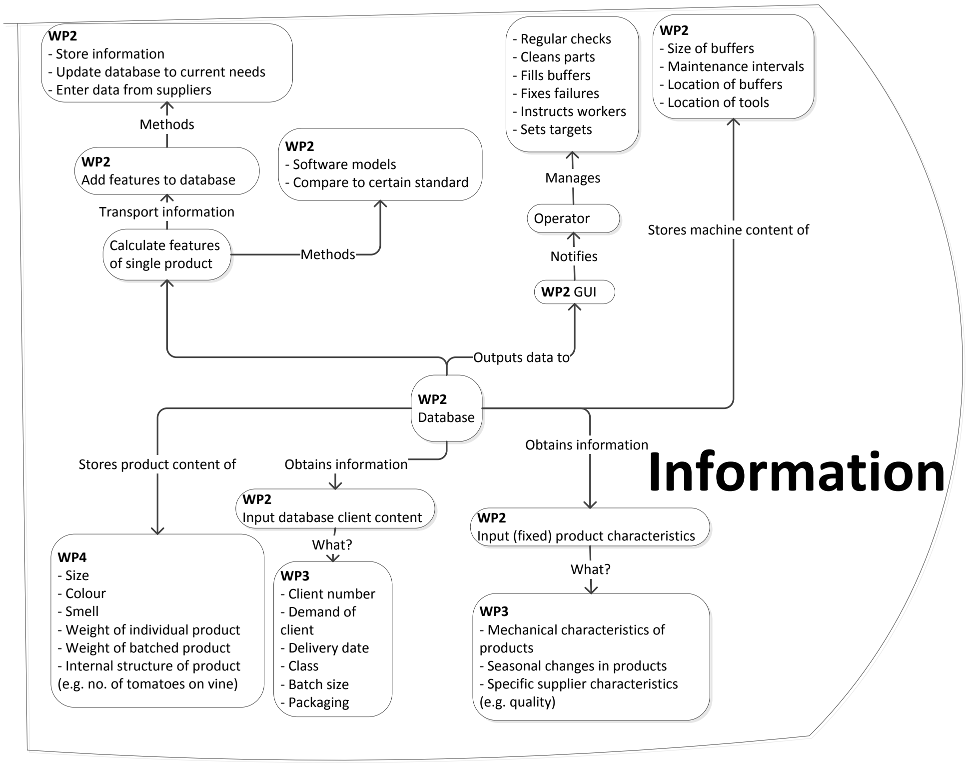


Figure 55: A subset of the function overview of the demonstrator applications.

Another subtask of 7.1, bottleneck assessment, was also performed on the basis of parameters supplied by other partners. A throughput model was created to estimate the number of created packages depending on these parameters. Conservative estimations indicated that the slowest application would be the ready meal line with 22 packs/minute. The aim at the beginning of the project was 30 packs/minute. However, the industrial advisory board noted that in ready meals this is usually at 15 packs/minute. Speeding up the line would be to increase speed of the slowest module. In this case the laser cutter. This can be easily realized by buying a more powerful laser, which will not be realized in the demonstrator.

Milestones

Two milestones were scheduled during the first 18 months of the project. Both were passed.

- MS23: Design specification and requirements ready. (M8) **[REACHED - Deliverable 7.1]**
- MS24: Conceptual design ready. (M18) **[REACHED - Figure 5]**

2.7.4 Use of resources

Cost type	PM	Costs
Personal	39.8	€ 309,295
Other		€ 12,287
Total		€ 321,582

(Indicated Costs and Person Months extracted from C-Forms, Excluding the input of MS and Spectro)

2.7.5 Deviations from DoW

There are no major deviations from the DoW. Main activities and investments are planned in the third year (second period) of the project. It is expected that the work package will achieve its tasks according to the plan. It is in line with the overall budget of WP7. Also more other costs (materials) are planned in the second period.

2.8 WP8 Hygienic food handling

2.8.1 Project objectives for the period

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

- Determination of system requirements,
- Development of hygienic processing line layout,
- Review of equipment design with respect to hygienic design issues including suggestions for revision and improvement and
- Development of an automatic cleaning system concept for the PicknPack line

2.8.2 Summary of the work progress and achievement during the period

System requirements relating to European food safety regulations, packaging technology, exposure of product, cleaning and traceability were defined based on discussion with equipment manufacturers, members from food industries as well as research institutes.
A workshop on hygienic design and hygienic processing topics was given in order to make all members of the project team aware of critical design issues, to be able to design food processing equipment that follows the relevant guidelines/regulations and that allows a high level of food security. The goal was to raise the awareness for the importance of good hygienic design already in the early phase of the project. The fundamentals of different subjects e.g. Legal requirements, Hazards in hygienic production, Hygienic design criteria, Materials of construction and Building/process layout were given in a concise manner underpinned by means of good/bad examples. Furthermore a hygienic design check list was prepared and shared with project team members.
Extensive work has been done regarding revision of the hygienic design of the:

- Cable robot (WP5), Delta robot (WP5),
- Grippers / end-effectors (WP5),
- Quality assessment and sensing module (WP4) and Adaptive packaging module (WP6).

The complete hygienically rework of the cable robot concept has been a major achievement of this period but hasn't been finished yet due to the complex design and the interaction of functional requirements and cleanability.
In an iterative process the hygienic design of the grippers/end-effectors has been improved. Due to the design concept of the gripper which involves e.g. many unhygienic metal-to-metal joints, open threads and void/niche areas that are hard to clean, the design process is still ongoing, but is within the schedule.
The design of the delta robot is more or less an industrial standard that has to be adapted to the innovative aspects of the cleaning concept of PicknPack. The relevant design aspects of frame work and the housing have been discussed with WP5 and a design concept was agreed.
Four basic strategies for the cleaning system of the complete PicknPack line and the individual modules have been developed and were proposed to the Industrial Advisory Board and relevant Work packages for discussion. In cooperation with WP4, WP5, WP6 and WP7 two concepts were chosen for further detailed preparation. The two concepts are cleaning in place system for the relevant modules and a novel

cleaning device that is moved through the line on the conveying system and cleans the necessary parts automatically.

2.8.3 Work progress and achievements during the period

Determination of system requirements

System requirements relating to European food safety regulations, packaging technology, exposure of product, cleaning and traceability were defined based on discussion with equipment manufacturers, members from food industries and research institutes. Based on the product properties, the intended supply chain and shelf life, the packaging technology was agreed to be "hygienic" and not "aseptic". A workshop on hygienic design and hygienic processing topics was given in order to make all members of the project team aware of critical design issues, to be able to design food processing equipment that follows the relevant guidelines / regulations and that allows a high level of food security. Furthermore a hygienic design check list was prepared and shared with project team members.

Definition of contamination: Introduction or occurrence of any biological or chemical agent foreign matter or other substance not intentionally added to product which may compromise product safety or suitability. In general the following types of contamination have to be considered in general: Foreign bodies, chemical, (micro)biological and allergenic contaminations.

Potential sources of foreign body contaminations are:

- raw materials or contaminated goods (e.g. dirty raw materials, stones, sand, leaves; packaging [film, containers, board, trimmings from packaging film])
- processing machines (e.g. equipment & replacement parts [washers, seals, screws, gaskets)
- environment (e.g. ceiling plaster, dust, fibres, broken glass, transport paletts…)
- personnel (e.g. ceiling plaster, dust, fibres, broken glass…)

Potential sources of chemical contaminations are:

- lubricants and additives
- cleaning and disinfection residues
- packaging material
- process fluids raw materials etc. due to incorrect process management
- microbial toxins (Staphylococcus aureus)

Potential sources of (Micro)biological contaminations are:

- pests (bugs, birds, insect, rodents, etc.)
- microorganisms (yeasts and moulds, algae; bacteria; viruses)
- parasites

Typical routes for water-borne contaminations are:

- condensate or wet films, stagnant water or liquid, drops (stagnant water or liquid, drops)
- non potable water,wet and dirty floors
- fresh water hoses (not frequently used)
- ancillary liquids in process machinery

Product residues may protect microorganisms from cleaning and disinfection. E.g. the thermal disinfection time increases up to 128 times if microorganisms are located underneath a soil layer of fat and protein.

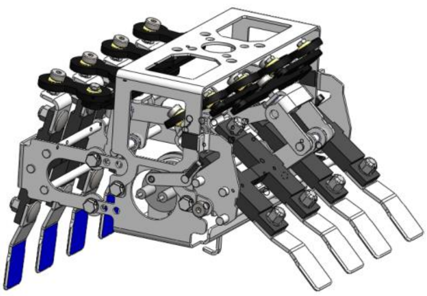
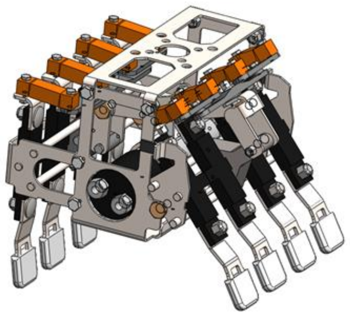
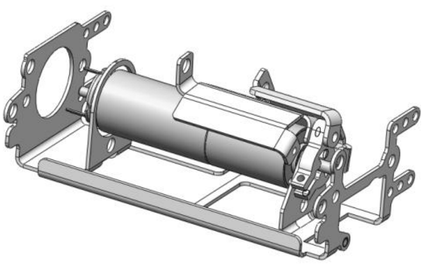
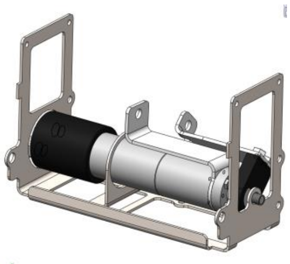
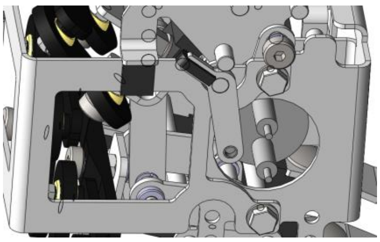
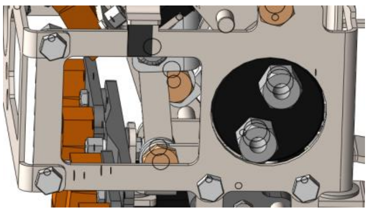
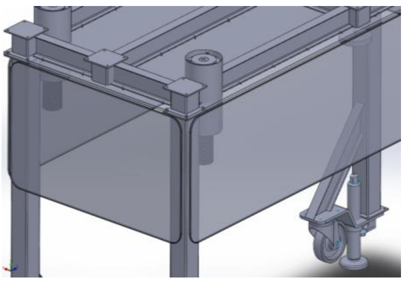
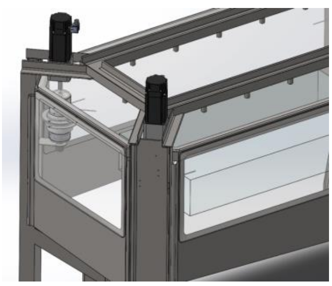
High pressure cleaning and draft in production areas are typical routes for air borne contaminations.

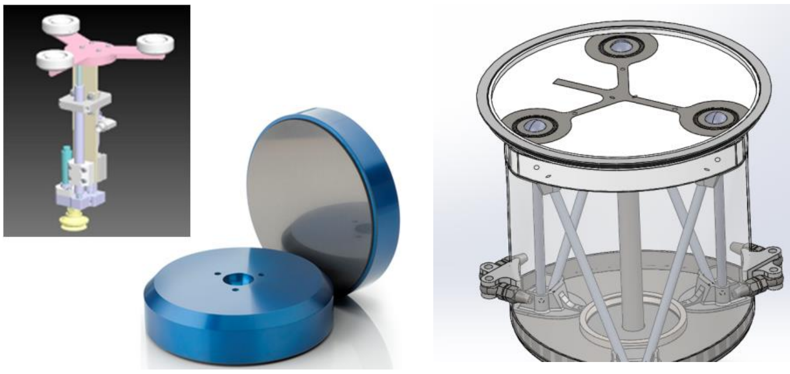
The human error and insufficient personnel hygiene is the contamination source No. 1!

Development of hygienic processing line layout

WP8 is in constant discussion with WP7 about the line layout. Based on the functional module design and line layout the requirements for the implementation of an automatic cleaning system were defined (see below). The issues relevant for a fast change over procedure are currently discussed with WP7 and WP5. In order to create a line layout that fulfils the demands of hygienic processing other requirements regarding process line installations e.g. electrical supply and process air have been defined.

Exemplary for the work progress and the achievements in the task "Review of equipment design with respect to hygienic design issues including suggestions for revision and improvement" a few significant amendments of the gripper (WP5) and the cable robot (WP5) are shown in Figure 56.

Old design	Improved design	Comment
		Current status of the gripper design with changes due to e.g. unacceptable metal-to-metal contacts, crevices, niche areas, materials of construction and poor cleanability.
		The motor assembly has dramatically changed. The motor-rod-bar itself is replaced by a clean plastic part with no gaps in it. The motor is sealed at both ends.
		The mounting of the frame plate to the top plate has changed. At the top there will be smaller flaps. There will be rubber seals between the bolts and the plates and between the plates.
		Cable robot: Closed frame design without gaps and crevices. Motor blocks outside the framework. Only rotating winches inside. No Spray shadows. Inclination for draining implemented.



Cable robot: Old Manipulator held on the top surface by air bearing made of porous material (not cleanable) leading to a risk of microbial growth.
New design: Manipulator held on the top surface by vacuum suction system and drainable ball bearings.

Figure 56: Exemplary design amendments due to hygienic design issues of the gripper and the cable robot

Cleaning system concept

A basic principle for the design of food processing lines including cleaning processes is "KEEP IT DRY". The presence of water may cause two major problems. Firstly, it may cause dilution of the chemicals used for decontamination. Secondly, when the machinery is standing idle (e.g. overnight or in the weekend) and water remains in the machinery, microorganisms are likely to multiply. The decontamination treatment might be insufficient for inactivation of the larger number of micro-organisms. Therefore, no water should remain anywhere uncontrolled in the machine at the end of the cleaning procedure. Hence, the equipment must drain well.
Cleaning liquids, applied as foam, gel or spray, are usually hot and cold water, detergents, acid /alkali solutions. To prevent excessive aerosol formation, high-pressure cleaning should be avoided.
Preferably, the design should allow In-place cleaning of the product-contact surface, without any dismantling. If this is not possible, each part of the machine must be accessible for cleaning manually, with or without dismantling. During automatic cleaning-in-place moving parts must be activated or be placed in a cleaning position.
The following four basic strategies have been developed:

- Cleaning in place (CIP) procedure with cleaning devices installed within modules, Figure 57
- Cleaning out of place (COP) where whole modules are wheeled out to washing machines in dedicated areas, Figure 58
- CIP with cleaning robots Figure 61
- CIP with a cleaning device on the conveying system carried through all modules, Figure 62

The CIP concept will be realised by installing various cleaning nozzles within each module. Fraunhofer has developed a software tool which can simulate spray shadows by using 3D-CAD files and data of spray areas of different cleaning nozzles. This will be done for each module to find good arrangements of nozzles for an efficient cleaning.

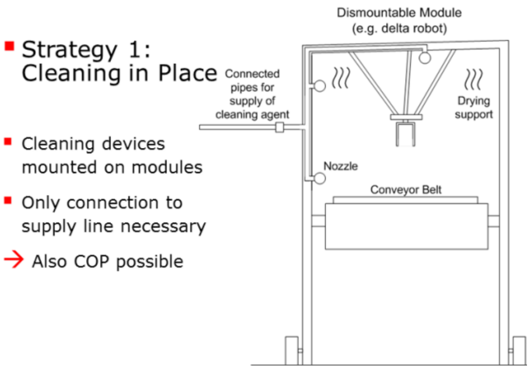


Figure 57: Schematic drawing of cleaning strategy 1

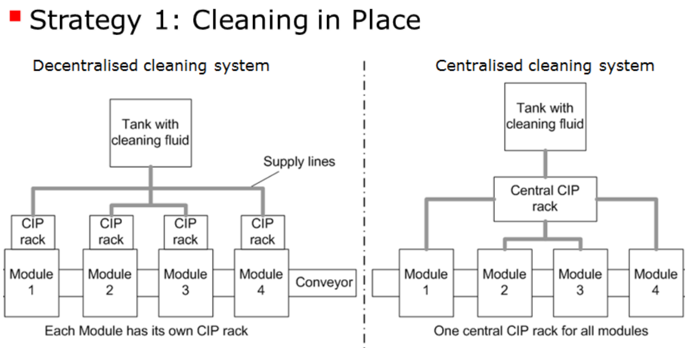


Figure 58: Schematic drawing of centralized and decentralized cleaning system

There are two options how to control the cleaning process. It could be either one central CIP rack which supplies all modules or each module could have its own CIP rack, which is optimised for the needs of the module. For the demonstrator the concept of a centralised CIP rack that is connected to all modules will be followed for the sag of cost reduction. It is agreed that the cleaning of outside surfaces of the modules is not in the direct focus of the project. An automated cleaning system will be installed only for inner surfaces which are important for food safety. To prevent food contaminations all modules and transfer areas where hygienic sensitive products are exposed to the environment have to be shielded in an appropriate way.

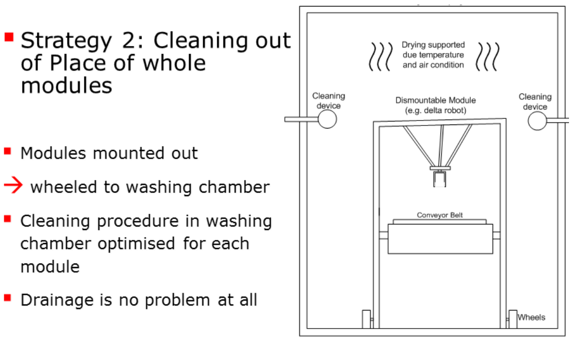


Figure 59: Schematic drawing of cleaning strategy 3

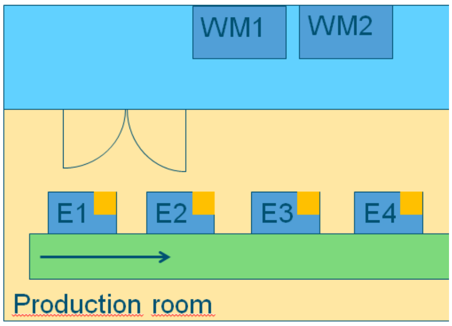
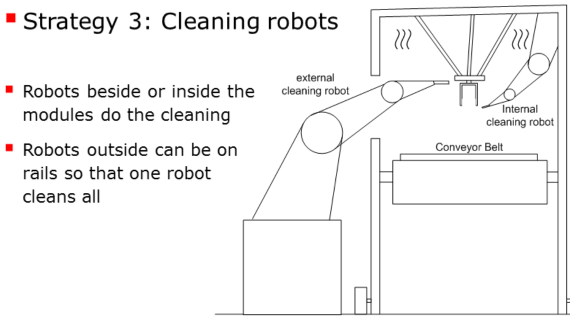


Figure 60: Possible building layout according to cleaning strategy 3 (WM-washing machine, E-Equipment)

For the conveyor concept there will be a cleaning device placed on the conveyor. It could consist of a base plate on which various nozzles can be installed. To activate different nozzles within the different modules for optimised cleaning either pressure valves could be used for controlling or there could be an independent control box on the plate which controls the valves. In which way controlling of the nozzles will be realised is not decided yet. The hose is also carried by the conveying system.



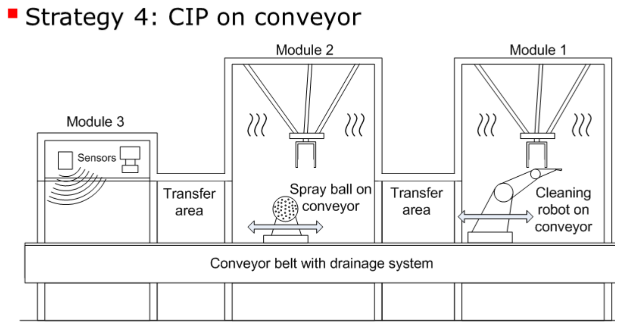


Figure 61: Schematic drawing of cleaning strategy 3

Figure 62: Schematic drawing of cleaning strategy 4

The first intention was to place the cleaning device on the conveyor belt and ensure the correct position with the belt segments. Since it was decided that there will be no conveyor belt but only sectional frames, it will be important that WP8 is involved in the design process of these frames and the conveying system for the trays, so that it can be ensured that the cleaning device can still be moved through the line.

Table 3 shows a comparison of the different cleaning strategies based on relevant criteria. In the cleaning workshop held in Düsseldorf, 2014-02-18 it was agreed to progress with strategy 1 and strategy 4.

Table 3: Comparison of cleaning strategy variants, preferred solutions are highlighted with red box

Criteria	Weigh-ting	V1: CIP Degree of fulfillment	V1: CIP Points	V2: COP* Degree of fulfillment	V2: COP* Points	V3: Robots Degree of fulfillment	V3: Robots Points	V4: Conveyor Degree of fulfillment	V4: Conveyor Points
Flexibility	3	3	9	4	12	5	15	4	12
Change-over-time	3	4	12	4	12	2	6	3	9
Automatisation effort	2	5	10	3	6	1	2	4	8
Constructive effort	1	3	3	4	4	4	4	4	4
Investment costs	2	5	10	1	2	2	4	5	10
Operating costs	2	4	8	5	10	4	8	4	8
Drainage and Drying	1	3	3	5	5	3	3	3	3
Operational safety	2	5	10	4	8	3	6	5	10
User friendliness	3	5	15	2	6	3	9	5	15
Degree of Innovation	2	2	4	3	6	4	8	5	10
	Sum		84 (80)		71 (65)		65 (57)		89 (79)

* Each module two times available

Rating: 1 … very poor fulfillment 5 … very good fulfillment

Weighting: 1 … not important 3 … very important

Implementation of the cleaning strategies

For the cable robot it was agreed to install both, the CIP concept and the conveyor concept (if necessary in combination with CIP on strategic points), so that there can be done efficiency tests with both concepts to compare them. The parts to clean are shown in Figure 63. For the CIP concept a main part of the cleaning is going to be realised by replacing the gripper with a nozzle holder for flat fan nozzles or rotating spray heads so that the robot can clean most of the covers, the ceiling plate and maybe also most of itself (Figure 64). An alternative would be to solidly install several nozzles on the module covers or framework.

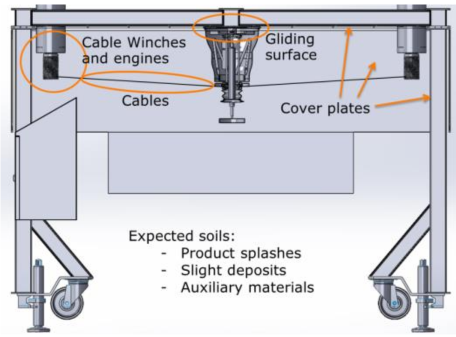


Figure 63: Parts to clean within the cable robot module

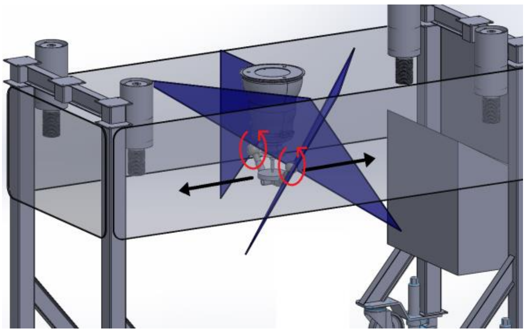


Figure 64: Cable robot with nozzle holder and spray areas of the flat fan nozzles

The parts of the delta robot that have to be cleaned are shown in Figure 65. CIP concept of the delta robot can be realised with two rotating spray heads (Figure 66). The spray shadow analysis of the 3D-CAD-data of the delta robot will show if two nozzles are enough. For the conveyor concept Fraunhofer has to test whether one rotating spray head is able to reach all parts directly or indirectly. But there is also the possibility to use more or other nozzles if tests reveal this necessity. For both concepts there is an option of installing additional stationary full cone nozzles in the upper areas to reach horizontal surfaces from there which would be difficultly accessible from the conveyor or the bottom. The robot should move while cleaning in a defined way to make all parts better accessible and the tool holder should move around the cleaning devices in a near distance to get fully cleaned.

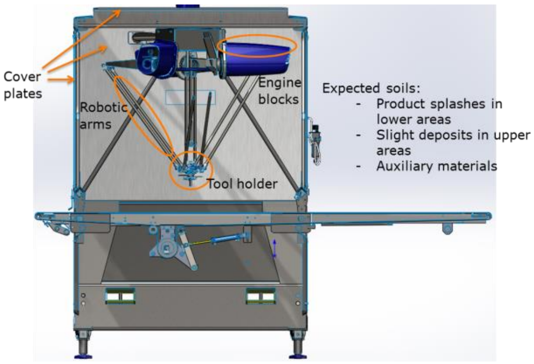


Figure 65: Parts to clean within the delta robot module

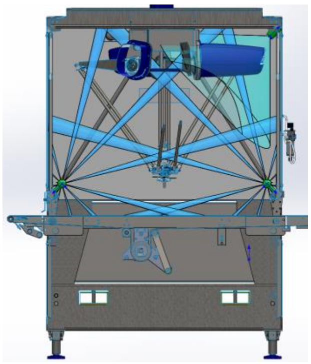


Figure 66: Delta robot with spray ball and full cone nozzle

The tunnel of the quality assessment module (QAS) which shields the sensors, suits perfectly for conveyor concept. Cleaning will be done either by flat fan nozzles or a rotating spray head. Which particular type of nozzle, which flow rate etc. is needed has to be determined by means of spray shadow analysis. Therefore the relevant 3D-design models (CAD) of the modules and the transport system are necessary. The CIP concept will not be implemented for the QAS module (Figure 67).

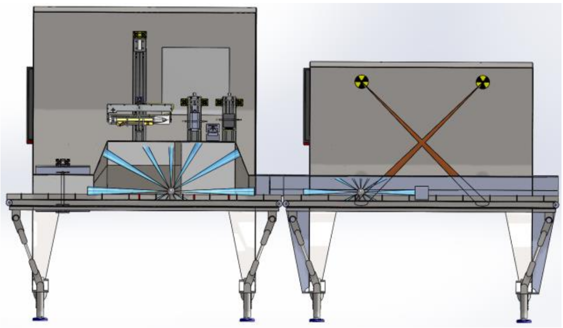


Figure 67: Quality assessment modules with schematic cleaning device placed on conveyor belt

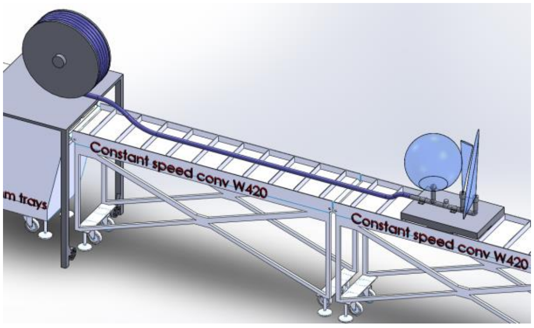


Figure 68: Schematic drawing of concept flexible cleaning device on conveyor belt

The grippers need to be cleaned more often than the whole modules. There are two possibilities for intermediate (short) and final / full cleaning:

- Cleaning in an internal cleaning station or
- Gripper change (dismounting) and cleaning in an external cleaning station.

Which concept will be implemented depends on i) the design of the robot modules and the available space in the modules for a cleaning station and ii) the changeover concept for the whole line. These issues are being discussed with WP7 and WP5.

2.8.4 Use of resources

Cost type	PM	Costs
Personal	16.8	€ 131,596
Other		€ 13,349
Total		€ 144,945

(Indicated Costs and Person Months extracted from C-Forms, Excluding the input of MS and Spectro)

2.8.5 Deviations from DoW

The work and all travelling expanses were necessary and in accordance with the planned resources.
There are no significant deviations between the actual status of the work package and the planned schedule.
In order to be able to manufacture the cleaning system partly Fraunhofer plans to convert its budget for "durable equipment" of 26.000 € into "consumables".

2.9 WP9 Life cycle analysis and sustainability

2.9.1 Project objectives for the period

WP9 has the following set of objectives in the project:

- Objective 1: Creation of full life cycle picture of the automated systems developed in the project.
- Objective 2: To assess the effects of automation of packaging of fresh and processed food products from a sustainability point of view.
- 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.
- 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.

The main objective during this first reporting period has been Objective 1 focused on the life cycle definition of the current manual packaging systems as automated systems developed in the framework of PicknPack project. This work includes some preparatory activities, which begun in month 1 related to the definition of the life cycle of the products to be packaged.

2.9.2 Summary of the work progress and achievement during the period

As above mentioned, during this first reporting period, the main effort has been focused on the life cycle definition (Task 9.1) of the systems including the three main components of the life cycle of the packaging line:

- The packaging line equipment itself which includes all the modules of singulation, sensing module, assembly, packaging, information and cleaning section.
- The products to be packed, which include the following ones:
    - Vine tomatoes (fresh products line).
    - Table grapes (fresh products line).
    - Pizza (ready meals line), although finally substituted by chicken breast with vegetables.
- The packaging systems to be used (thermoformed containers) based on PP and crystalline PET

For the time being, the life cycle definition has been made for both vine tomatoes and table grapes and modelled with SimaPro LCA software. Furthermore, a model for pizza has also been developed although changed to chicken breast with vegetables by Oct 2013. The life cycle models for chicken breast are currently under development in SimaPro 7.3 LCA software. Moreover, first LCA results for vine tomatoes, table grapes and pizza have been obtained.

Questionnaires for data collection have also been developed as well. However, in case of the packaging line data, data collection has been stopped until a final decision on the packaging line layout will be adopted in the next General Assembly (Iceland, April 2014). Moreover, life cycle models for the thermoformed PP and crystalline PET containers will start as soon as the final dimensions of the containers will be set by the consortium in the Iceland's General Assembly. This represent a small delay on the development of part of the work in Tasks 9.2 (LCA) and 9.3 (LCC) (official start date March 2014) until a final decision on the final layout for the line will be made.

Furthermore, the data collection for the manual packaging operations has started which will be used as for benchmarking of the sustainability advantages of the PicknPack automated packaging line concept.

2.9.3 Work progress and achievements during the period

As pointed out before, during the first reporting period (Oct 2012 to Mar 2014), work has been mainly focused on Task 9.1 (Life Cycle Definition). To be also pointed out that Task 9.2 (LCA), Task 9.3 (LCC) and Task 9.4 (Social Evaluation) have also been started by March 2014, although no significant achievements have been made due to the decisions on the final packaging line layout expected by April 2014. More precisely, the following activities have been carried out during this 1st reporting period:

- Task 9.1. Life Cycle Definition:
  - Definition of the products to be packaged (both fresh products and ready meals) in order to be included in the life cycle calculations. This work has started as preparatory activities since the beginning of the project in October 2012. The relevance for such work is justified by the fact that the sustainability advantages of the automated systems vs. current manual operations can only be demonstrated if the products to be packaged are considered. Therefore, it is possible to measure the amount of food waste produced in both systems and compare the advantages and disadvantages in sustainability terms. The products to be considered were wine tomatoes, table grapes and pizza. Figure 69 summarizes the approach followed for the life cycle definition of the fresh products considered: vine tomatoes and table grapes.

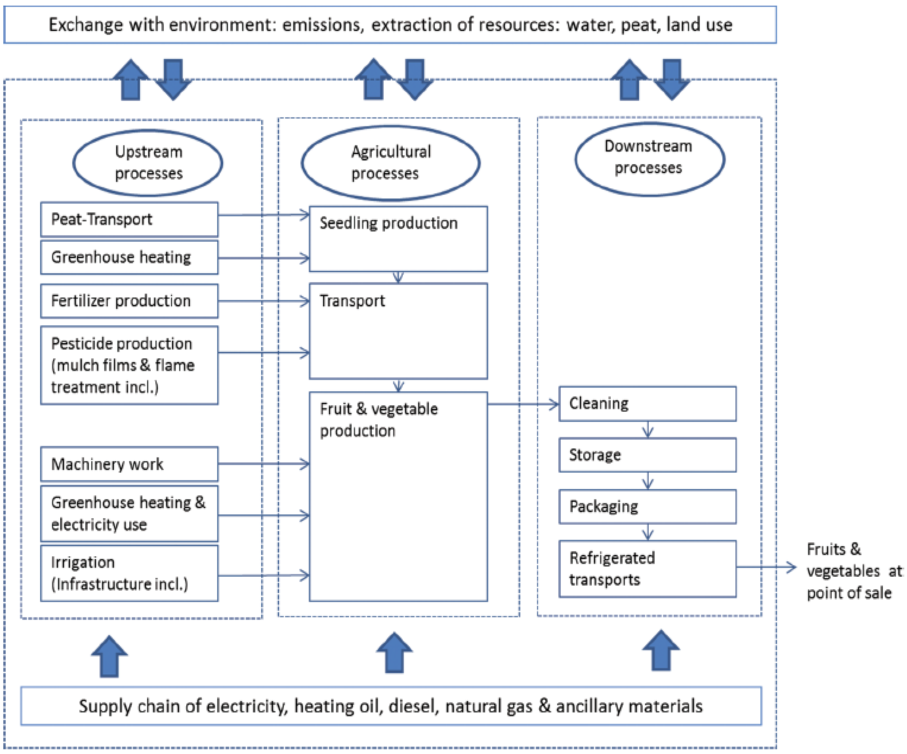
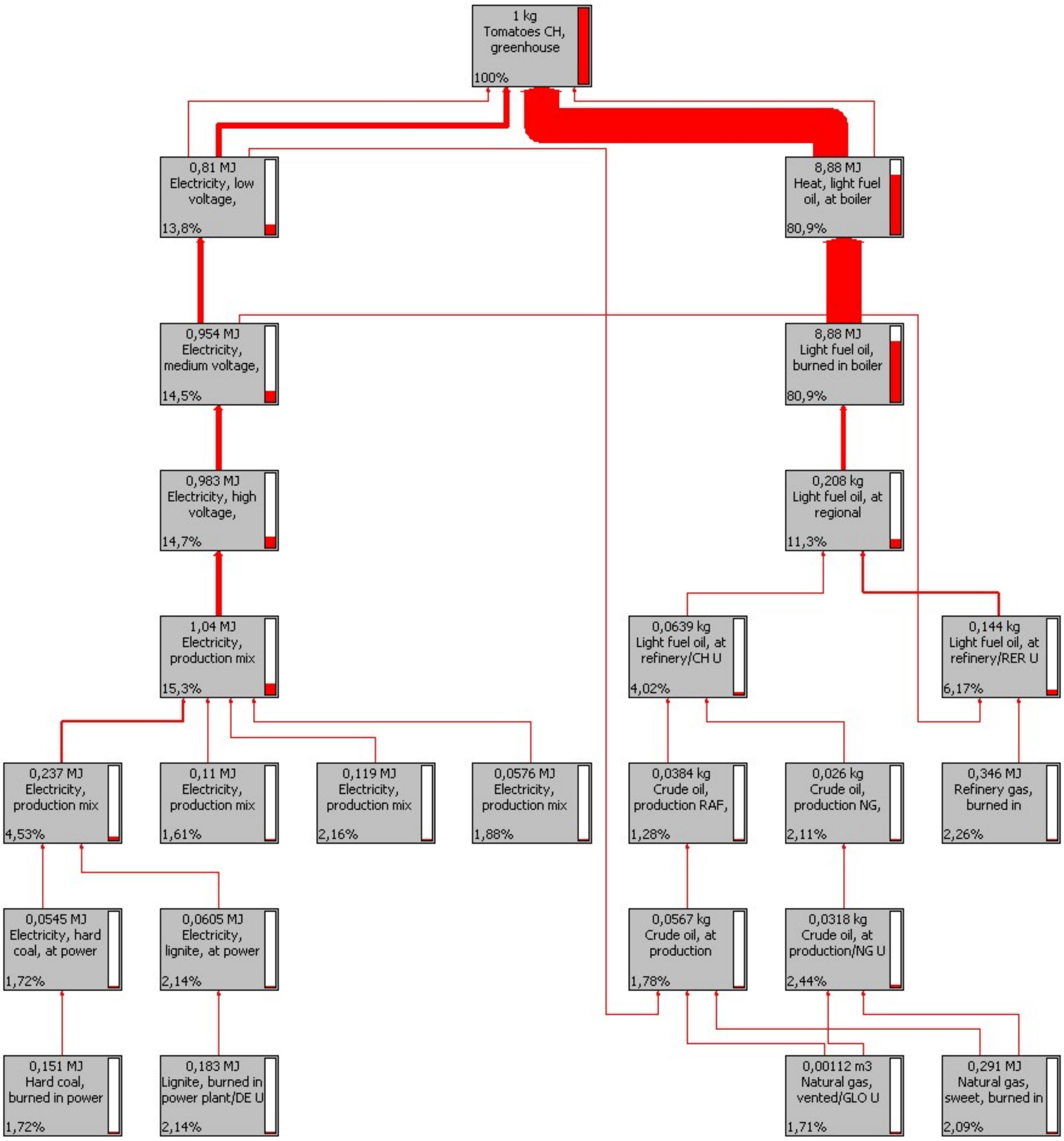


Figure 69. ***Life cycle system boundaries considered for both vine tomatoes and table grapes***

  - Modelling of the products to be packaged: two types of fresh food products were successfully modelled with the LCA software SimaPro: wine tomatoes, table grapes. Data for modelling was collected from Stoessel et al (2012)[1] which developed an exhaustive work for the life cycle inventory modelling of 34 fruits and vegetables of a large Swiss retailer. These results can be adopted to PicknPack as they represent the current tomato and grape production systems in Europe. Figure 70 shows the models developed by ITENE in SimaPro 7.3 for both products.

[1] Stoessel F, Juraske R, Pfister S, and Hellweg S. Life Cycle Inventory and Carbon and Water FoodPrint of Fruits and Vegetables: Application to a Swiss Retailer. Environ Sci Technol. Mar 20, 2012; 46(6): 3253–3262. Published online Feb 6, 2012. doi: 10.1021/es2030577

a)



1 kg Tomatoes CH, greenhouse 100%
0,81 MJ Electricity, low voltage, 13,8%
8,88 MJ Heat, light fuel oil, at boiler 80,9%
0,954 MJ Electricity, medium voltage, 14,5%
8,88 MJ Light fuel oil, burned in boiler 80,9%
0,983 MJ Electricity, high voltage, 14,7%
0,208 kg Light fuel oil, at regional 11,3%
1,04 MJ Electricity, production mix 15,3%
0,0639 kg Light fuel oil, at refinery/CH U 4,02%
0,144 kg Light fuel oil, at refinery/RER U 6,17%
0,237 MJ Electricity, production mix 4,53%
0,11 MJ Electricity, production mix 1,61%
0,119 MJ Electricity, production mix 2,16%
0,0576 MJ Electricity, production mix 1,88%
0,0384 kg Crude oil, production RAF, 1,28%
0,026 kg Crude oil, production NG, 2,11%
0,346 MJ Refinery gas, burned in 2,26%
0,0545 MJ Electricity, hard coal, at power 1,72%
0,0605 MJ Electricity, lignite, at power 2,14%
0,0567 kg Crude oil, at production 1,78%
0,0318 kg Crude oil, at production/NG U 2,44%
0,151 MJ Hard coal, burned in power 1,72%
0,183 MJ Lignite, burned in power plant/DE U 2,14%
0,00112 m3 Natural gas, vented/GLO U 1,71%
0,291 MJ Natural gas, sweet, burned in 2,09%

b)

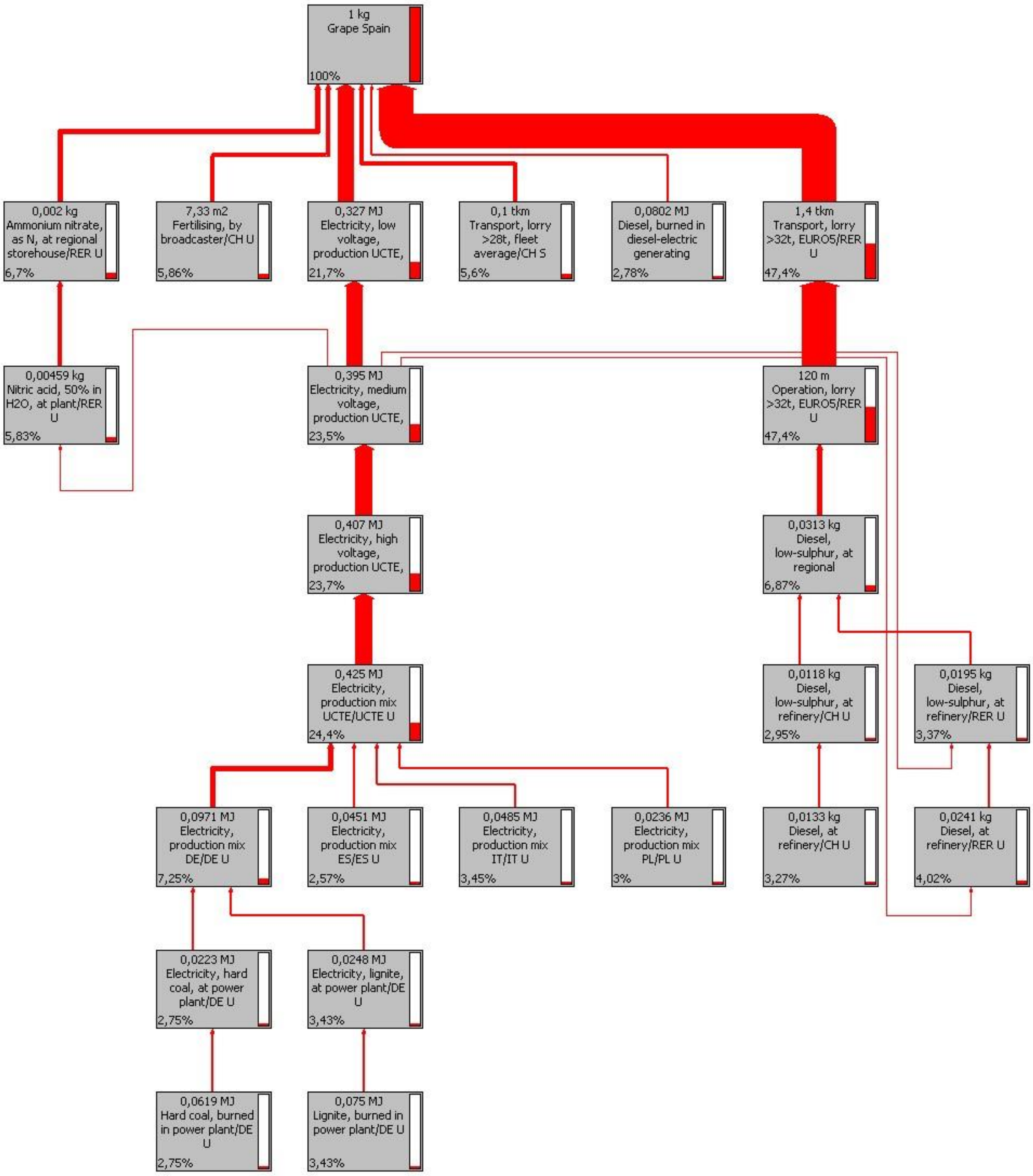


Figure 70*. System models in Sima Pro LCA software for: (a) vine tomatoes and (b) table grapes. Cut-off rule 2.2%*

- Furthermore, the ingredients for chilled pizza including tomato sauce, cheese and bread were also successfully modelled, as well the pizza itself. However, the work on pizza modelling was stopped in Oct 2013 (Figure 71) after the decision to focus on other type of ready meals as a result of the limitations of these kind of products in the automated line and flexible heating for microwave. Consequently, work on LCA modelling of processed has been moved to chicken breast with vegetables, which is currently under modelling with SimaPro 7.3 software.

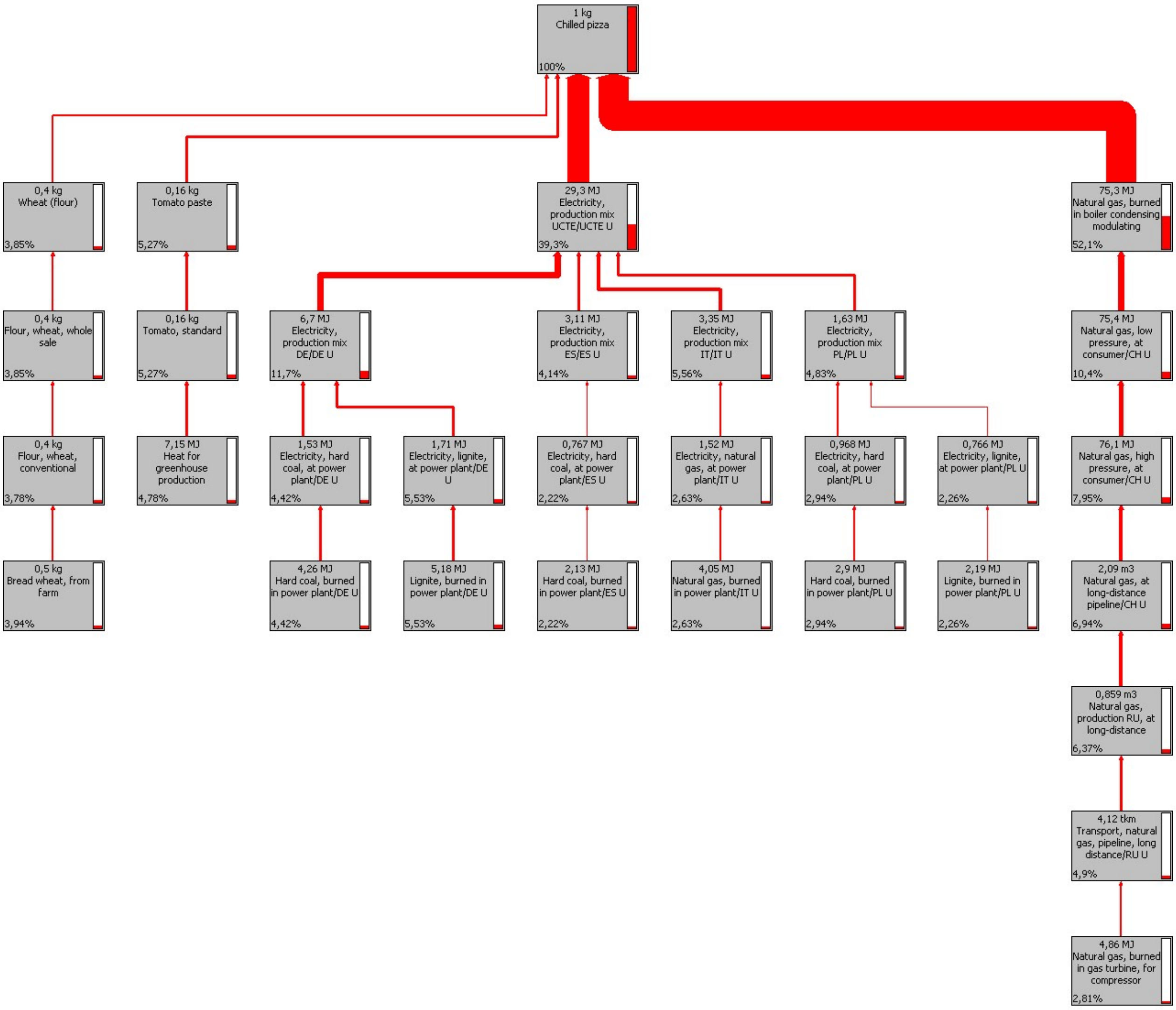


Figure 71 *Life cycle system boundaries for chilled pizza (stopped in Oct 2013 after the decision to focus on chicken breast with vegetables for processed meals). Cut-off rule 2.2%*

- Additionally, data collection of the packaging systems defined in WP6 has been also started. The aim of this work is to assess also the variations in terms of environmental impact as a result of the automated operations of discarded packaged units. This work is based on the findings from WP6 and more precisely on D6.1, 6.2 and 6.3. Based on the latest decisions made in WP6, thermoformed containers based on PP and crystalline PET will be modelled. The final sizes of the package formats will be modelled as soon as a final decision on the packing line strategy will be made in April 2014.

- Task 9.2. ILCD compliant LCA:
  - Work in this area has been started through the development of a set of life cycle data collection questionnaires, which have been presented during GA meeting in Copenhagen (Denmark) in October 2013. Table 4*. Data collection form for fresh food products (based on the original line layout based on conveyors). Currently under update.* shows the data collection questionnaires prepared for the fresh products packaging line. These forms were prepared based in the original conveyor-based strategy for the packaging line. Such original layout is comprised by the following components: (a) singulation, (b) sensing module, (c) assembly, (d) packaging, (e) information and (f) cleaning section.

Table 4. *Data collection form for fresh food products (based on the original line layout based on conveyors). Currently under update.*

(a)

PARTNER:	MAREL (DELTA ROBOT)
PACKING:	FRESH FOOD
PROCESS:	SINGULATION

Cesar Aliaga: This data will be taken by ITENE from European database

INPUTS								
Type	Description	Quantity	Unit (e.g. kg, kW, l)	Cost per unit (€)	Supplier	Transport mode	Distance (km)	Comments
Power consumption	Power rating		kWh	-	N/A	N/A	N/A	
	Hours		h					
Maintenance products	e.g. lubricating oil							
Cleaning products	e.g. water		l					
	e.g. detergents		kg					

OUTPUTS						
Type	Description	Quantity	Unit	Cost for waste management (€)	Subsequent use (e.g. recycling, feedstock, landill, incineration,waste water treatment)	Comments
Waste	Food loss		kg			
	Waste water		l			

(b)

PARTNER:	UNIVERSITY LEUVEN (Fresh food)/Spectroscan
PACKING:	FRESH FOOD
PROCESS:	SENSING

Cesar Aliaga: This data will be taken by ITENE from European database

INPUTS								
Type	Description	Quantity	Unit (e.g. kg, kW, l)	Cost per unit (€)	Supplier	Transport mode	Distance (km)	Comments
Power consumption	Power rating		kWh	-	N/A	N/A	N/A	
	Hours		h					

OUTPUTS						
Type	Description	Quantity	Unit	Cost per unit (€)	Subsequent use (e.g. recycling, feedstock, landill, incineration,waste water treatment)	Comments
Waste	Food loss		kg			

(c)

PARTNER:	TECNALIA (CABLE ROBOT)/DLO
PACKING:	FRESH FOOD
PROCESS:	ASSEMBLY

Cesar Aliaga: This data will be taken by ITENE from European database

INPUTS								
Type	Description	Quantity	Unit (e.g. kg, kW, l)	Cost per unit (€)	Supplier	Transport mode	Distance (km)	Comments
Power consumption	Power rating		kWh	-	N/A	N/A	N/A	
	Hours		h					
Maintenance products	e.g. lubricating oil							
Cleaning products	e.g. water		l					
	e.g. detergents		kg					

OUTPUTS						
Type	Description	Quantity	Unit	Cost per unit (€)	Subsequent use (e.g. recycling, feedstock, landill, incineration,waste water treatment)	Comments
Waste	Food loss		kg			
	Waste water		l			

PARTNER:	DTI (packaging materials)/CAM-TECH (packaging moulds)
PACKING:	FRESH FOOD
PROCESS:	PACKAGING MANUFACTURING (THERMOFORMING)

Cesar Aliaga:
This data will be taken by ITENE from European database

Cesar Aliaga:
Is there any maintenance product used?(CAM-TECH)

INPUTS								
Type	**Description**	**Quantity**	**Unit (e.g. kg)**	**Cost per unit (€)**	**Supplier**	**Transport mode**	**Distance (km)**	**Comments**
Energy Consumption	**Power rating**		kWh	-	N/A	N/A	N/A	
	Hours		h					
Packaging raw materials	e.g. PET							
Mould maintenance products								

OUTPUTS						
Type	**Description**	**Quantity**	**Unit**	**Cost per unit (€)**	**Subsequent use (e.g. recycling, feedstock, landill, incineration,waste water treatment)**	**Comments**
Waste	e.g. PET		kg			

(d)

PARTNER:	Xaar (printing systems)/DTI (packaging materials)
PACKING:	FRESH PRODUCT
PROCESS:	PACKAGING MANUFACTURING (PRINTING)

Cesar Aliaga:
This data will be taken by ITENE from European database

INPUTS								
Type	**Description**	**Quantity**	**Unit (e.g. kg)**	**Cost per unit (€)**	**Supplier**	**Transport mode**	**Distance (km)**	**Comments**
Energy Consumption	**Power rating**		kWh	-	N/A	N/A	N/A	
	Hours		h					
Packaging raw materials	e.g. inks							
Auxiliary materials	solvents							

OUTPUTS						
Type	**Description**	**Quantity**	**Unit**	**Cost per unit (€)**	**Subsequent use (e.g. recycling, feedstock, landill, incineration,waste water treatment)**	**Comments**
Waste	e.g. used cartridges		kg			
	eg. Solvents (acetone)		kg			

PARTNER:	UM (sealing)/DTI (packaging materials)/DLO
PACKING:	FRESH PRODUCT
PROCESS:	PACKAGING MANUFACTURING (SEALING)

Cesar Aliaga:
This data will be taken by ITENE from European database

INPUTS								
Type	**Description**	**Quantity**	**Unit (e.g. kg)**	**Cost per unit (€)**	**Supplier**	**Transport mode**	**Distance (km)**	**Comments**
Energy Consumption	**Power rating**		kWh	-	N/A	N/A	N/A	
	Hours		h					
Packaging raw materials	e.g. PET							

OUTPUTS						
Type	**Description**	**Quantity**	**Unit**	**Cost per unit (€)**	**Subsequent use (e.g. recycling, feedstock, landill, incineration,waste water treatment)**	**Comments**
Waste	e.g. PET		kg			

PARTNER:	UNIVERSITY LEUVEN
PACKING:	FRESH PRODUCT
PROCESS:	FOOD LOSS

(e)

OUTPUTS						
Type	**Description**	**Quantity**	**Unit**	**Cost per unit (€)**	**Subsequent use (e.g. recycling, feedstock, landill, incineration,waste**	**Comments**
Singulation						
Sensing						
Assembly						
Packaging						
Information						
Cleaning						

(f)

PARTNER:	FRAUNHOFER
PACKING:	FRESH PRODUCT
PROCESS:	CLEANING

INPUTS					
	Description	Cleaning product	Quantity	Unit (e.g. kg)	Cost per unit
Singulation					
Sensing					
Assembly					
Packing					
Information					
TOTAL					

OUTPUTS					
Type	Description	Waste water	Quantity	Unit (e.g. kg)	Cost per unit
Singulation					
Sensing					
Assembly					
Packing					
Information					
TOTAL					

- Additionally, a second set of data collection questionnaires was prepared also for the ready meals line, which essentially remains in the same format with some minor changes in the packaging section (d).
- Due to the changes in the layouts of the Picknpack packaging line, such questionnaires are currently under modification for a proper data collection procedure. Indeed, it was decided to stop data collection until the final layout for the packing lines is finally ready in April 2014.
- Furthermore first LCA results were obtained for the products to be packaged with the PicknPack line. Figure 4, 5 and 6, summarizes first results for the LCA obtained for vine tomatoes, table grapes and pizza.

- Task 9.3. Life Cycle Costing (LCC):
  - Activities in Life Cycle Costing have started through the preparation of the economic data collection forms (see Table 1 for further details).
  - Furthermore exchange channels with WP12 have been established as the data to be collected is similar in most cases. The economic questionnaires were discussed with AZTI-Tecnalia in Copenhagen General Assembly, as well as in the beginning of 2014 through exchange of several e-mails.

- Task 9.4. Social Evaluation
  - This task has not been started yet. It is expected to begin with this task as soon as the new packaging line layout is available.

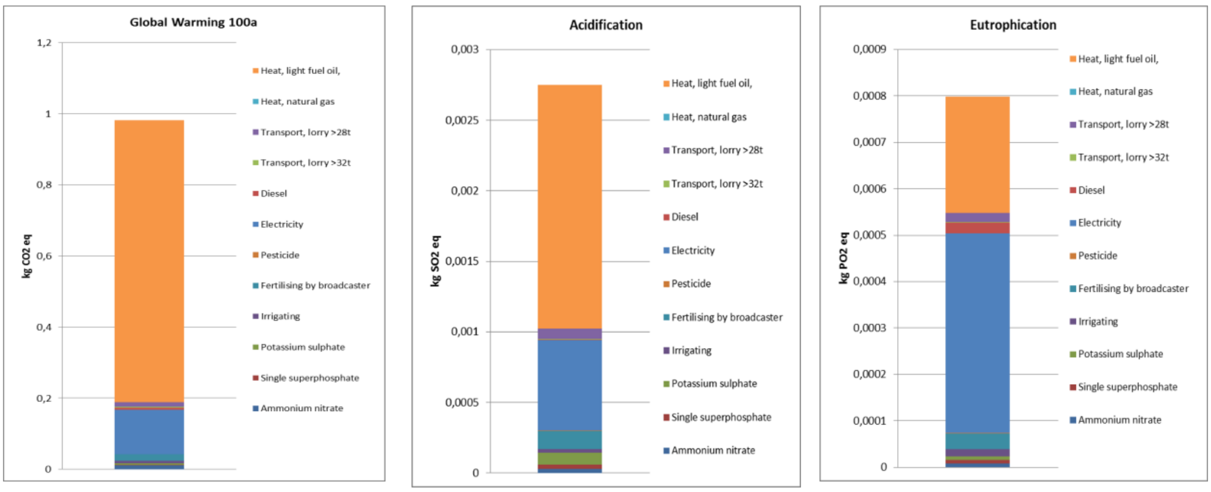


Figure 4. First LCA results for vine tomatoes

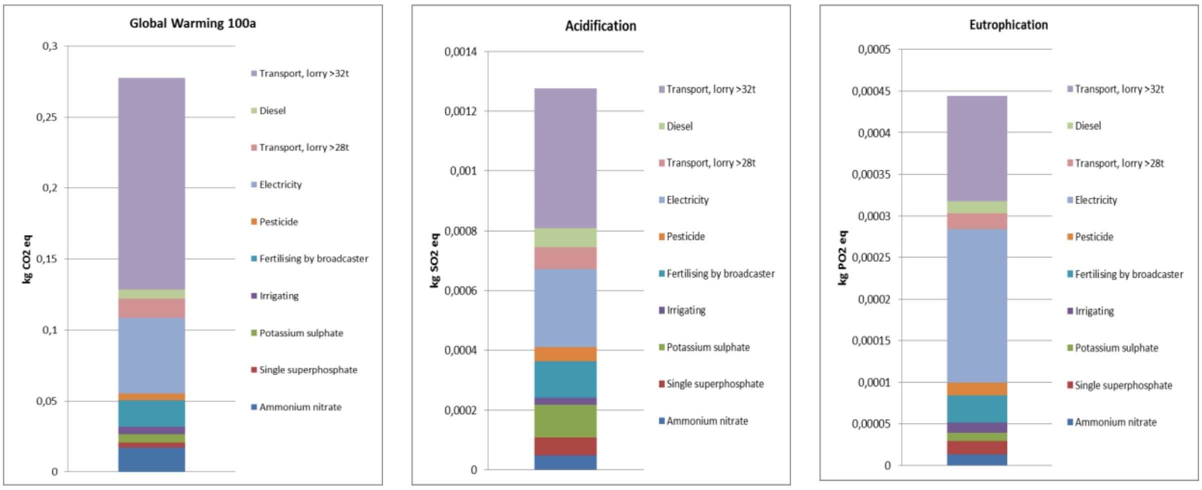


Figure 5. First LCA results for table grapes

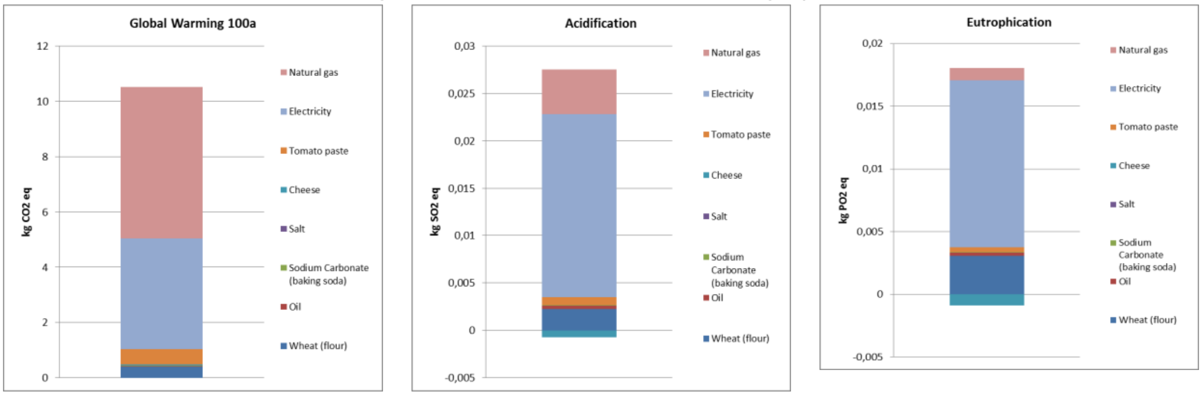


Figure 6. First LCA results for pizza (stopped and changed by chicken breast with vegetables)

- Task 9.5. Sustainability assessment
  - Activities in this task will start as of September 2014.

2.9.4 Use of resources

Cost type	PM	Costs
Personal	22	€ 65,888
Other		€ 5,818
Total		€ 71,706

(Indicated Costs and Person Months extracted from C-Forms, Excluding the input of MS and Spectro)

2.9.5 Deviations from DoW

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

2.10 Dissemination

2.10.1 Project objectives for the period

The key objectives for the period were (a) to establish an Industrial Advisory Board of distinguished and experiences industrial personnel who would have a European perspective and who could comment on and guide the technical programme of the project, (b) to establish a website which would disseminate the results of the technical work to a wide audience in an open and freely available format and (c) to plan and implement a series of workshops mainly targeted at the European food manufacturing sector which would disseminate the results of our work, raise awareness of the opportunities for the deployment of advanced techniques in automated food assembly and packaging and engage a large number of companies as associate members of our project and in communication with it through our website.

2.10.2 Summary of progress

An Industrial Advisory Board has been formed consisting of

- Josu Ugarte Barrena
- Christopher Buxton
- Peter Golz
- Kaarin Goodburn
- Angel Del Pino Gracia
- John Gray
- Neil Khandke
- Erik Pekkeriet
- Henk de Vlaaam
- Arie Zonneveld

All have agreed to participate in an advisory capacity and all have signed appropriate non-disclosure agreements. A number of them participated in the first meeting of the Industrial Advisory Board in Taastrup, Denmark (Oct 2013).

Public domain website

A public domain website has been established which contains detailed information on the technical aims of the project, details of our planned programme of technical workshops and details of all public technical presentation on project results at both PicknPack workshops and similar cosponsored events. A public domain newsletter has been published outlining the activities of the consortium and others are planned at six months intervals.
Extensions are now planned to generate an interactive forum section to encourage online technical debate and feedback.

Technical workshops

The first technical workshop was organised in Wageningen in October 2013, the next one is planned to be held at the University of Lincoln on June 25, 2014 with the third planned to be held in Madrid on October 2014.

2.10.3 Work progress and achievements

The task of creating the Industrial Advisory Board has been completed and interaction with it has been proved fruitful so far and excellent feedback was achieved at our first annual project meeting in Copenhagen in October 2014.

The public domain website has been established and fully supported by administration staff at the University of Manchester. Excellent liaison has been established with the coordinators website in Wageningen and we believe that we have achieved a high level of professionalism in our presentation. The website can be viewed at www.picknpack.eu/. As indicated we are exploring the generation of interactive facilities for the site. We are also exploring the possibility of permanent cross links with other large relevant sites for mutual support and dissemination.

First Workshop "Food Factory of the Future", Wageningen, October 31, 2013

The first project workshop with a theme was "Food Factory of the Future" was organised in Wageningen on October 31 2013 with an international set of technical speakers. The consortium first technical workshop attracted some 30 delegates from manufacturers, automation equipment suppliers and academia.
While the majority of the attendees were from Holland we had registrants from the U.K. Germany, Spain and Belgium. The programme of the event is published on the website but produced here for convenience.

The central theme of the workshop was the current state of the art in food manufacturing procedures which provided a background for Erik to give a comprehensive overview of the novel concepts within the PicknPack programme. Alan Spreckley described the application of robotic handling of chilled and other food products with his presentation being supported by a series of excellent videos. Joyce Shroot outlined her international experience in the processing of fresh fruit and vegetable products and indicated emerging trends in the sector. Mike Dudbridge focussed on the future marketplace, what the product mix might be and how this will influence the shape of future manufacturing sector and the manufacturing procedures adapted. Zhipeng Wu outlined the application of low power, non hazardous, non contact sensors for food quality monitoring and product traceability both key factors in the PicknPack programme. The final technical presentation was made by Richard van de Linde who like Zhipeng Wu, focused on a topic which is very specific to food manufacturing in this case the design of grippers for processing natural food products. A range of novel grippers was presented and the presentation was supported by a series of most impressive applications to real production lines.

The formal presentations were followed by discussion forum where feedback was requested from the participants. This was a lively and highly interactive event chaired by a panel of speakers. Topics raised included the need for hygienic system design, the effects of aggressive cleaning regimes, the need for standardisation in automation equipment, the requirement for simple graphic inputs, self diagnostics and self adjusting machinery to minimise down time, and the use of flexible modular automation equipment. It was also suggested that the workshop in future should be more work and less shop. i.e. the delegates should be asked to work harder and be more interactive. This is a good idea and will be a feature of our next event.

Figure 72 Speakers "Food factory of the future" after discussion forum. From left to right: Richard van der Linde (Lacquey), Zhipeng Wu (University of Manchester), Joyce Groot (Hessing Supervers), Erik Pekkeriet (Coordinator PicknPack), Martin van der Have (ABB), Mike Dudbridge (Lincoln University)

Table 5 Profile of Delegates

Representatives from the following sectors	
Food manufacturing:	Poultry processing Chilled food manufacturing Fruit and vegetable processing
Engineering industry:	Electronics system and instrumentation motors and drives Industrial robotics Factory automation Packaging machinery Software engineering Packaging automation Mechanics and biosensors Engineering design software Project management consultancy
Other:	University Fraunhofer

Next Workshops

The next workshop with a theme "Flexible Automation for Food Processing and Packaging" will be held at the University of Lincoln on the 25th June 2014 and will be supported by a technical exhibition of state of the art equipment supplied by Marel, Festo, Omron and Lacquey. Publicity will be enhanced by announcements on other websites such as PPMA, F.D.F, CFD and the distribution network of key companies such as Marel, Festo, ABB etc. (For details see website).

Planning is well underway to hold the third workshop in Madrid during October 2014 on theme of Automation in the Processing of Fresh Fruits and Vegetables. Our aim is to link it directly with the large national conference International Trade Fair for Fruit and Vegetables organised by Ifema and negotiation are now being undertaken with the organisers. Full support and local liaison is being provided by our Spanish Partners AZTI-Tecnalia, Itene as well as Lacquey, and Omron (Barcelona), A.B.B (Barcelona) have also offered support.

It is possible that the forth workshop could be held either in Leuven or Eindhoven next year (2015). Discussions on this have been initiated with our partners in Leuven.

In discussions with the University of Lincoln we are exploring the possibility of organising a Summer school next year at the splendidly equipped facility on the Holbeach Campus. Industrial support will be sought as well as sponsorship from key professional engineering institutions.

In addition to the PickNPack workshops we have organised presentations of the PicknPack concepts at the following technical events:

- FMEG workshop on "Food Processing for the Future" sponsored by the U.K's Defra and held at Festo UK headquarter in Northampton
- FMEG workshop on "Food Security and Traceability" sponsored by Defra and held at University of Manchester.

Details of these events are also included on the website.

Conclusion

It is considered that all key initial aims of the work package has been achieved and the dissemination work program is on schedule and has a well-defined road map for the coming years.

Publications

Because of sensitive I.P.R. issues the consortium is understandably cautious about premature publication of results. However we have arranged with the editor of New Food to publish two articles

- PicknPack general concept Erik Pekkeriet
- Survey of Automation Take Up within the European Community Idoia Olabarrieta (AZTI)

We have also requested the consortium to present a paper at the forth coming EFFoST 7th Food Factory of the Future conference, Sweden November 2014.

Selection of publications:

2012

- M&S backs EU PicknPack project for promoting robot use in food factories (projectleider voor Wageningen UR Glastuinbouw is Erik Pekkeriet)
  Halliwell, J. ; Pekkeriet, E.J. (2012)
  William Reed Business Media, , 2012-11-17
- "Meer operationele flexibiliteit in de voedingsindustrie"
  Pekkeriet, E.J. (2012)
  Wageningen : Wageningen UR Greenhouse Horticulture, ICT marktplaats Foodvalley, 2012-11-29
- PicknPack: International collaboration for development of packaging robot
  Pekkeriet, E.J. (2012)
  Freshplaza, , 2012-09-20
- International Collaboration for Development of PicknPack Robot (Erik Pekkeriet is projectleider voor Wageningen UR Glastuinbouw)
  Pekkeriet, E.J. (2012)
  New York, NY, USA : Thomas Publishing Company, , 2012-12-13

- Europees onderzoek gestart voor gerobotiseerd en flexibel verpakken van voeding
  Pekkeriet, E.J. ; Kampers, F.W.H. (2012)
  Wageningen : Wageningen UR Glastuinbouw, , 2012-11-19
- PicknPack: Internationale samenwerking bij ontwikkeling inpakrobot
  Pekkeriet, E.J. (2012)
  Wageningen UR Glastuinbouw, , 2012-09-19

2013

- Current developments and future perspectives; the PicknPack project
  Pekkeriet, E.J. (2013)
  Porto Antico, Genova, ITALIA : Wageningen UR Greenhouse Horticulture, RoboBusiness Europe, 2013-04-11
- PicknPack
  Pekkeriet, E.J. (2013)
  Bleiswijk : Wageningen UR Glastuinbouw, Themadag: Automatiseren in de Agro & Food, 2013-03-06
- De grote ambities van PicknPack - Slimme verwerkingslijnen die alles aankunnen (interview met Erik Pekkeriet)
  Janssen, A. ; Pekkeriet, E.J. (2013)
  Voedingsmiddelentechnologie 2013 (10). - p. 18 - 19.
- Meer flexibiliteit in verpakkingen
  Pekkeriet, E.J. (2013)
  Kennis Online 10 (jan/febr). - p. 9.

2.10.4 Use of resources

Cost type	PM	Costs
Personal	29.7	€ 119,443
Other		€ 18,299
Total		€ 137,742

(Indicated Costs and Person Months extracted from C-Forms, Excluding the input of MS and Spectro)

2.10.5 Deviations from DoW

All tasks have been completed by the resources provided to Manchester University and from the beginning we have carefully planned our activities to achieve a full set of contracted deliverables at the end of the four year period.

2.11 WP11 Demonstration

2.11.1 Project objectives for the period

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

Aim:

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

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

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

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

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

2.11.2 Summary of the work progress and achievement during the period

The work is just started. We work just now on a plan to demonstrate:

- Packaging of fruits and vegetables in the Netherlands (either in a private company or in WUR)
- Ready meal producer in UK (either in a private company or in University of Lincoln, Holbeach) or at AZTI Tecnalia Spain

Food companies are typical negative to have visits from competitors and PickNPack need to demonstrate the innovative system to all the industry we have a challenge. Just now we evaluate we get the best results to perform the demonstrations in a neutral environment under industrial conditions. These neutral environments will likely be WUR, Wageningen, University of Lincoln, Holbeach and AZTI Tecnalia Bilbao Spain. All three sites are near to the relevant companies and the companies can provide the demonstration with food products and workers.

2.11.3 Work progress and achievements during the period

The work is just started. For this reason we have only been dealing with the first jobs in task 11.1:

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

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

We work just now on a plan to demonstrate:

- Packaging of fruits and vegetables in the Netherlands (either in a private company or in WUR)
- Ready meal producer in UK (either in a private company or in University of Lincoln, Holbeach)

As food companies are typical negative to have visits from competitors and PicknPack needs to demonstrate the innovative system to a wide representation of the industry we have a challenge. Just now we evaluate we get the best results to perform the demonstrations in a neutral environment under industrial conditions. These neutral environments will likely be WUR, Wageningen and University of Lincoln, Holbeach. Both sites are near to the relevant companies and the companies can provide the demonstration with food products and workers.

WP11 Demonstration realizes that the DOW defines "*The demonstration will be conducted in food companies or companies related to the food industry.*" Both WUR and University of Lincoln have demonstration centres with the scope to demonstrate new technologies to the food industry and related industries. WP11 hope that these two demonstration centres will be accepted as "*companies related to the food industry*". WP11 will work with this strategy and need final written agreements in M36 (1 October 2015).

2.11.4 Use of resources

Cost type	PM	Costs
Personal	1.2	€ 11,395
Other		€ 778
Total		€ 12,173

(Indicated Costs and Person Months extracted from C-Forms, Excluding the input of MS and Spectro)

2.11.5 Deviations from DoW

The activity is not started yet. Only small orientations and discussions are made. This is according the DoW. There are no deviations expected

2.12 WP12 Acceptance, economics and exploitation

2.12.1 Project objectives for the period

The objective of the PicknPack project is to develop three types of automatic modules that can cope with the classification and packaging of the typical variability of food products (fresh fruit & vegetable and ready meals) and the requirements of the food sector regarding hygiene, economics and adaptability. These modules will work together: a sensing module, a vision controlled robotic handling module and an adaptive packaging module. The objective for the first period was to establish the technical requirements for each module and the basic common interface of the modules. Thus, during this first period the main design of the whole line was fixed together with the main parameters influencing the performance of the modules. Based on this information a first design and tests were done.

The food industry generally is traditionally oriented and reluctant to implement high tech systems. They assume that high tech systems require special personnel to maintain them and to change over to another product, are expensive, inflexible and should only be used in large batch processing jobs. The PicknPack project aims to resolve these issues, but it is recognized that the food industry might hesitate to adopt this system. For this reason within this project a special work package (WP12) was defined to research the factors that influence acceptance, including economics and exploitability of robotic systems in the food packaging sector. Moreover, as a part of the tasks to be done, the impact of these developments regarding risk assessment at workplaces, jobs or food quality and safety will be evaluated.

Specifically for this first period, the work within this WP12 has focused on the following two tasks/objectives:

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

The **objective** is to understand the real needs of the industry and to understand the factors influencing the acceptance and implementation of automatic systems in fresh food processing plants in Europe.

- *To analysis of the parameters/factors influencing the acceptability and implementation of an automatic packaging system in the food industry.*

Task 12.2-Economics.

The *objective* of the second task is to sort and organize all the information on the economic aspects (market analysis, industry perceptions, cost structure, simulations, investment amortizations, etc.) in order to estimate the economic viability of the PicknPack system investment for a model food industry.

- *Analysis of factors impacting the economic viability*
- *To develop a tool to analysis of the economic viability.*

2.12.2 Summary of the work progress and achievement during the period

In the first task about acceptance, the definition of objectives and methodology to study and analyze the acceptance factors of automatic systems in food industry was done. As a part of the work, a generic characterization of the fruit and vegetable sector in Europe was performed, together with the current situation of the horticultural sector regarding automation. Moreover, a literature research was completed about findings of previous studies/models with respect factors conditioning societal acceptance, or resistance to new technologies. For gathering information from food industries two different surveys were developed. The surveys were uploaded in the PicknPack website in four different languages. From the preliminary results a first report was done with the main concepts and first conclusions, which will serve as guideline for potential proactive intervention and which will be the base for the future SWOT analysis. During this period the overall methodology is finalized and the survey questionnaires are already available to the public at the official PicknPack website. The survey's preliminary results and analysis helped to define main recommendations in order to orientate the design of the PicknPack models.

In the second task about economics, the analysis of factors impacting the economic viability of automated food packaging systems was done. Moreover, a bibliographic research was done in order to have an orientated vision and costs and values of the business. Based in the collected data from the surveys and from a market and bibliographic research, an estimation of different cost of the fresh fruit and vegetables (F&V) industry was done. Then based in the gathered information, a tool to simulate economic viability was developed in Microsoft Excel™. This tool will allow defining different base scenarios reflecting the current target industries. The simulation tool makes it possible to display results in a simple and comprehensible way through figures, graphs and tables. Simulation on a current target industry situation shows an estimated graph of its cost structures. Based on this results a return of investment table is calculated showing the different key financial concepts that will allow to know if a determined PnP investment will be viable in that current scenario or not. Finally with the performance data of the developed prototypes, it will be able of displaying a new scenario which will tell the final benefits for the company after implementing these new PnP modules.

2.12.3 Work progress and achievements during the period

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

- *Analysis of the social, technical and economic factors influencing the acceptability and implementation of a specific automatic packaging system*.

Work progress and achievements within this task:

- A generic characterization of the fruit and vegetable sector in Europe.
- The current situation of the horticultural sector regarding automation.
- A literature research about findings of previous studies with respect to factors and conditions which stimulate societal acceptance or resistance to new technologies.
- Approach of the study. Description of the methodology.
- Survey development.
- Preliminary analysis of the results

The methodology for the acceptance study was based on the knowledge about the food industry and a literature review. However, in order to make the approach suitable to our study, modifications were done after feedback from the rest of the partners and after initial inputs from the contacted food companies. The final methodology and survey questionnaires were adapted to our objectives in order to get the most useful and complete answers to the research questions. The first questionnaire was generated in order to get characterization data from the companies (production, size, automation, etc.). The second one was developed in order to get perception inputs, about barriers and drivers, from the industry towards implementation of new automated systems. For the preliminary report answers from Netherlands and Spain were analysed. The answers were collected and treated statistically for getting preliminary conclusions.

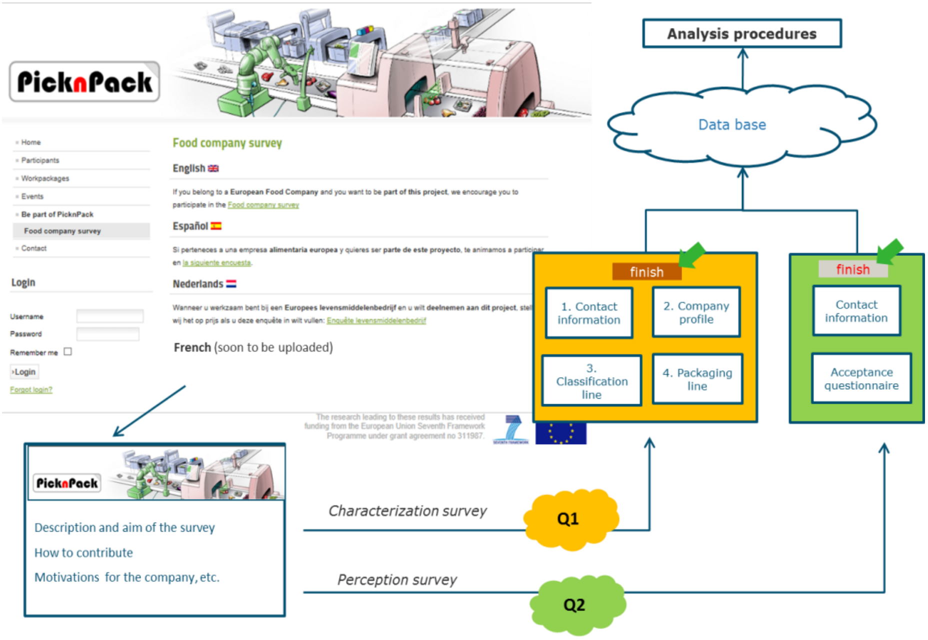


Figure 73. ***Overview of the research methodology (surveys uploaded in www.picknpack.eu)***

The higher automation level was found to be in traceability-labeling operations, product feeding/loading, product placement and sorting. The lower level of automation appeared in the grading line (of quality attributes) and packaging. These results seem to be coherent with the literature found about the current situation of the sector. The incorporation of robots to the processing line is no high. The higher amount of robots seems to be in the packaging and traceability/labelling process followed by palletizing and feeding line. Grading operation was the less automated one and hence, where the fewer amounts of robots are incorporated in the food companies. Regarding all the technologies contained in the survey, we observed that most the companies use electrical weighting scales followed by mechanical separators. With less presence, we can observe that the 3D vision, robots and air nozzles. Force/pressure sensors, NIR, X-ray and laser are not being deeply used in the food industry.

Industries rated from 1(unimportant) to 5 (most important) the most **interesting quality parameters for measuring** in their products. Most of the higher rated quality factors were the ones related to the external appearance. Thus, the most important resulted to be **colour** and **external defects** (both with an average score of (4.9) followed by the **foreign/undesirable matters** (4.6) and **firmness** (4.5). Some industries mentioned specifically the problems to measure these defects in the surface or to identify external anomalies due to bad handling, extreme temperatures or diseases.

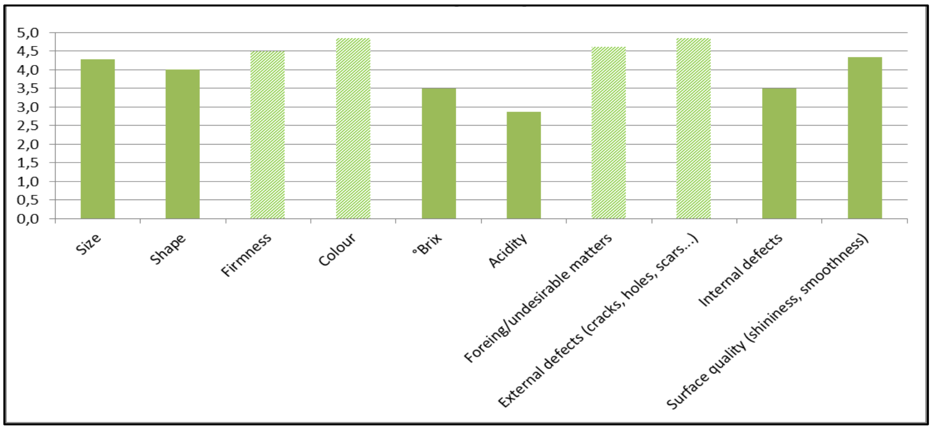


Figure 74 ***Assessment (average score) of the measuring interest of the different quality attributes (5 highest score)***

The proposed inner qualities were evaluated with less interest. This can be due to the lower occurrence in their products or simply due to a lack of knowledge about the different parameters could influence the organoleptic characteristic of the products. In fact, some of the answers reflect this lack of know-how about how to measure these internal attributes.

Regarding perception aspects, the most important drivers remarked for automatic systems implementation were, "the decrease in labour cost", "Increase the profit margin", "Homogeneous quality of product (standardization)", "Increase the production volume" and "Differentiation from the competitors".

As main barriers," Investment cost", "Limited resources for SMEs", "Production volume no big enough to invest in automation", and the "Resistance to change of workers and employees" were highlighted.

As explained in former chapters, the purpose was to correlate these perceptions with the profile and the characteristic of the companies in order to find a model or a trend. In this case, it was not done because the lack of time to gather sufficient amount of answers. This part, however, will be completed for the final report.

The amount of answers received in this phase of the study was low but they helped to test the methodology and to make the final modifications. The answers received in this first report, together with the literature review, helped to create an initial picture of the type of answers and information that this study intends to accomplish. The overall methodology is finalized and the survey questionnaires are already available to the public at the official PicknPack website.

Deviations:

The Gantt chart in which the timing of the tasks is shown (1.3.2. *p 25* in DOW) only displays the progress of the task 12.1 for the first 10 months of the project. In the reality this task is still in progress.

During this time the methodology was completed and the first conclusions and outputs from the surveys had already been discussed with partners. The task has first focused on The Netherlands and Spain, but due to the low responses from the contacted companies by the month 10 it was not possible to make any reliable conclusions and statement. Thus, several adjustments and dissemination strategies were developed during the first period to get a more realistic picture of the current state and perceptions. In the last part a translation to French was also done in order to cover this important fresh fruit and vegetable producing country. Due to the difficulties in contacting and involving industries the task has been extended. However the main factors and parameters affecting acceptance issued have already been identified and discussed.

It should be pointed out that the Gantt chart in the DoW is not completely correct with respect to WP12. The first deliverable, D12.1.-Report on social, technological and economic barriers influencing the acceptance and implementation, has been already submitted, on time (month 10), with all the methodology and preliminary results. The second deliverable D12.2, which is an update of the first one, with the final results and SWOT analysis is supposed to be submitted in month 48, but no work is planned in the Gantt chart for this purpose/task. So the fact is that the deviation shows to be a natural progress of the work in this task, in order to be able of updating this second deliverable. The result analysis and statistical treatment of the surveys will be performed during the second year of the project.

Task 12.2. Economics.

- *Analysis of factors impacting the economic viability of automated food packaging systems*
- *Development of tools to simulate economic viability*

The approach of the actions covered by this task was divided in three steps:

1. **Analysis of factors impacting the economic viability of automated food packaging systems and market analysis**: Surveys about acceptability of automatic systems performed within the same work package allowed to describe the main factors affecting the economic viability of the automatic system implementation in the food industry. Moreover, a market analysis was done in order to have an vision and values and cost structure of the business. Based in the collected data from the surveys and from a market and bibliographic research (Spanish government, EU reports, internet, interviews and others), an extrapolation of different cost of the fresh fruit and vegetables (F&V) food industry was done. This exercise allowed the configuration of the different cost of a model industry.

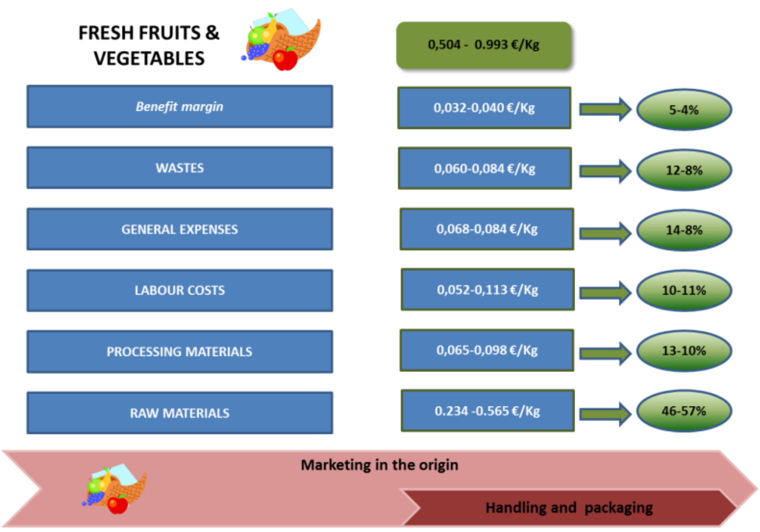


Figure 75. *Structure cost estimation of an average fresh fruits & vegetable industry*

2. **Development of tools to simulate economic viability**: with the information obtained in the above task, a simulation tool was developed in a spreadsheet program (MS Excel ™). The developed model allowes the quantification of different costs and services of a specific F&V food industry (raw material, human resources, packaging material, energy, etc.). As a result, with these inputs a tool to estimate the investment space return of the PicknPack systems was designed in order to check the viability of the developed concept.

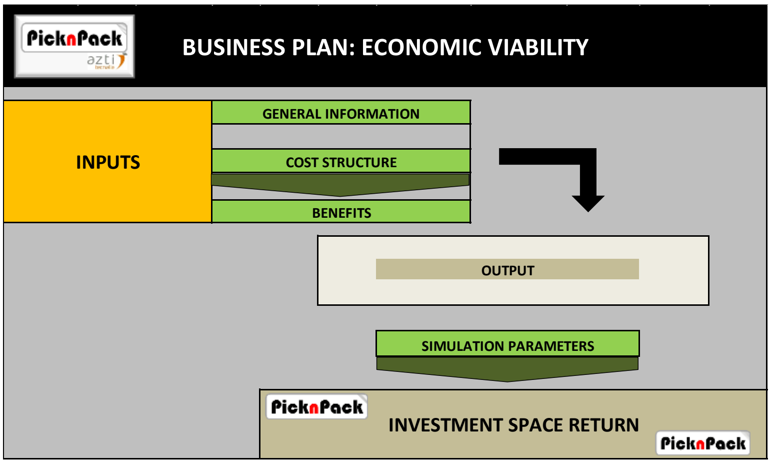


Figure 76. *Main screen of the simulation tool*

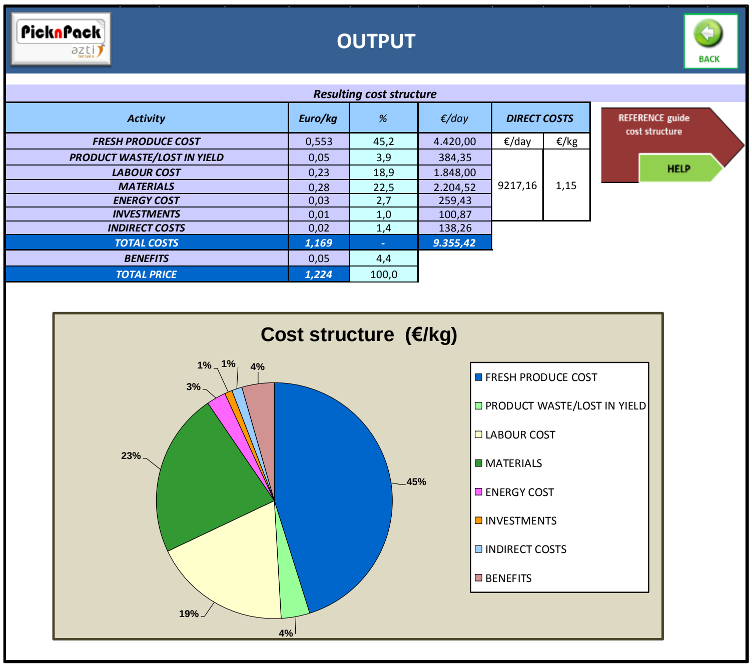


Figure 77. *Diagram of the output of the model (estimated cost structure of the target food industry)*

3. **Application of simulation tools to calibrate the design of the PicknPack modules**: At this time of the project life, prototypes are still under development, so no specific costs ranges are defined or available. For this reason, an example of a scenario was tested to have an estimation of the ranges for different hypotheses. Running the model on a scenario-testing basis, an evaluation of the impact of certain measures or decisions, or certain industries' strategies will be checked.

   In conclusion, during this period a first simulation tool has been developed in Microsoft Excel™. This tool will allow to define different base scenarios reflecting the current cost structure of the target industries. The simulation tool makes it possible to display results in a simple and comprehensible way for all PnP partners, through figures, graphs and tables. Simulations on the current situation show the estimated cost structures, based on these results a return investment table is shown calculating the key financial concepts that will allow to know if a determined PnP investment will be viable in that current scenario or not. Finally with the performance data of the developed prototypes it will be possible to display a new scenario which will demonstrate the final benefits for the company after implementing the PicknPack system. These key concepts from the simulation tool will be decisive for constructing the final exploitation plans of the developed prototypes.

The work within this task has been done as scheduled, so the deliverable D12.4 a simulation model of economic viability for each application was submitted on time (month 18). However, the approach is not completed yet. Further developments will take place, with two major orientations: (1) adjusting different concepts and other situations (2) validating the tool with real scenario (industries) This tool will be adjusted and validated in order to focus in the last part of the project on the final exploitation plans of the PicknPack system (year 4, see Gantt chart in DOW, page 25).

2.12.4 Use of resources

Cost type	PM	Costs
Personal	15.2	€ 126,778
Other		€ 11,967
Total		€ 138,744

(Indicated Costs and Person Months extracted from C-Forms, Excluding the input of MS and Spectro)

2.12.5 Deviations from DoW

There are no major deviations from the DoW. Main activities and investments are planned in the last period of the project. It is expected that the work package will achieve its tasks according to the plan. It is in line with the overall budget of WP12.

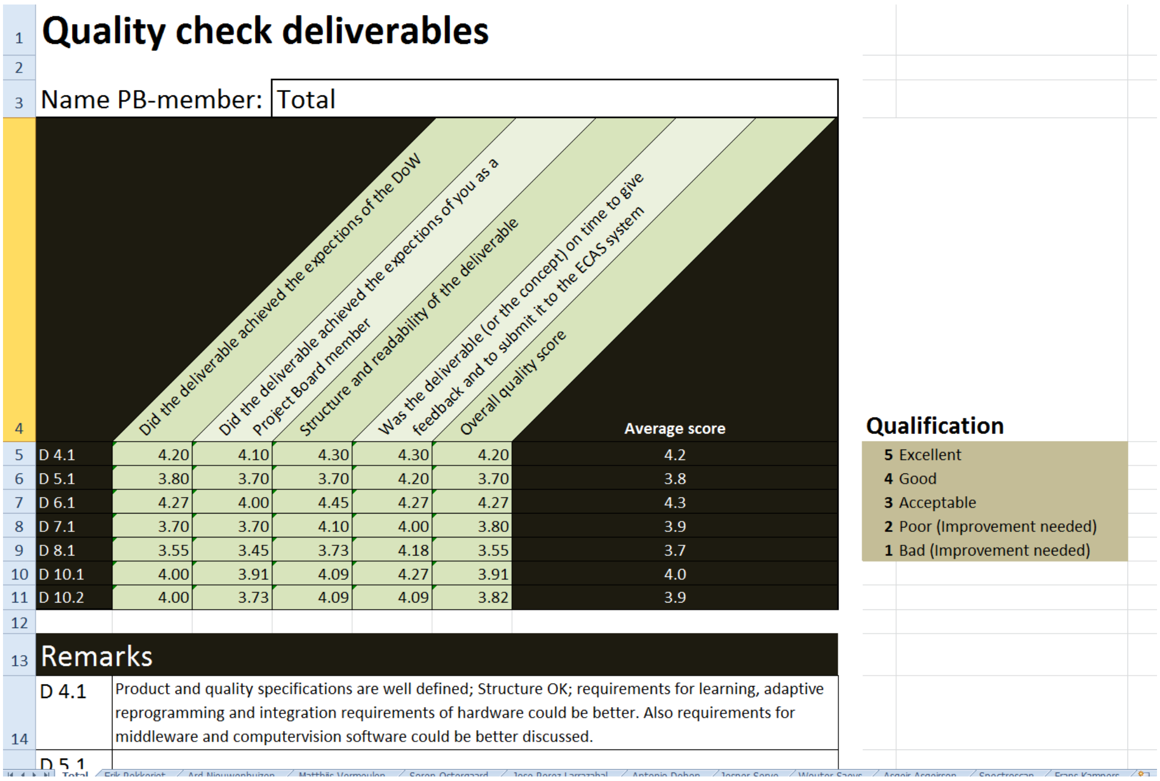
3 Project management during the period

3.1 Consortium management tasks and achievements

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

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

The coordinator is on schedule with the submission of all deliverables and other tasks. Project meetings are scheduled every 6 months according to the plan. The coordinator has set up 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. Figure 78 shows an example of a quality check result of several deliverables. A round Robin schedule is provided to devide the quality check to different Project Board members.



Quality check deliverables

Name PB-member: Total

	Did the deliverable achieved the expectations of the DoW	Did the deliverable achieved the expectations of you as a Project Board member	Structure and readability of the deliverable	Was the deliverable (or the concept) on time to give feedback and to submit it to the ECAS system	Overall quality score	Average score
D 4.1	4.20	4.10	4.30	4.30	4.20	4.2
D 5.1	3.80	3.70	3.70	4.20	3.70	3.8
D 6.1	4.27	4.00	4.45	4.27	4.27	4.3
D 7.1	3.70	3.70	4.10	4.00	3.80	3.9
D 8.1	3.55	3.45	3.73	4.18	3.55	3.7
D 10.1	4.00	3.91	4.09	4.27	3.91	4.0
D 10.2	4.00	3.73	4.09	4.09	3.82	3.9

Qualification

5	Excellent
4	Good
3	Acceptable
2	Poor (Improvement needed)
1	Bad (Improvement needed)

Remarks

D 4.1	Product and quality specifications are well defined; Structure OK; requirements for learning, adaptive reprogramming and integration requirements of hardware could be better. Also requirements for middleware and computervision software could be better discussed.
D 5.1	

Figure 78. Example of Quality Check

The coordinator has set up an emailing facility to facilitate communication between the project members (members@picknpack.eu) and will maintain the list of the Project Board and Steering Committee. This is available to the other project members.

A procedure according to the Consortium Agreement is agreed on how to publish foreground results. A special email format is made so that everyone directly sees that acceptance is requested to publish foreground.

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

Official documents were transferred to all partners.

3.2 Problems which have occurred and how they were solved

During the first period of the project, three important problems occurred where the coordinator took action to resolve them.

1. After the Kick off meeting (November 2012) it was not exactlyclear what the product range should be to demonstrate the flexibility of food production. With the WP-leaders involved (especially WP7 and WP12 leaders) and Marks and Spencer a number of visits where planned in the Netherlands (three tomato packaging facilities in Rotterdam area and a ready meal facility at Warmenhuizen) and the UK (Spalding and Carlisle) to visit ready meal and vine shaped tomato packaging facilities. Marel organized a visit to a state of the art facility with several robots in Germany. From the final evaluation at Marks and Spencer's the product range was determined.

2. The project has a very tight time schedule. To demonstrate flexibility, the new modules should be ready after two years, so that we have extra time to develop, demonstrate and extend the capabilities of the PicknPack line. In the planning after one year the designs should be ready as agreed in the DoW. At the third project meeting in Copenhagen/Taastrup (October 2013) we noticed that substantial technical progress had been made, but that the designs where not fixed yet. After this meeting a short term action plan was therefore started to catch up. This short term action plan included:

    - Request to come up with plans per work package in December 2013 on how to come to a final design for every module and functions
    - An extra project board meeting at Schiphol Amsterdam on January 31, 2014 to make final decisions on the designs
    - Clarify financial issues and time/task schedules before the next project meeting in Iceland.
    - Fix detailed designs and start building of the modules directly after the Iceland meeting

    This aim was achieved in most of the relevant WP's except WP6. WP2, 3, 4, 5, 7 and 8 are fixed now and have started with realization of the modules. WP6 is still a little behind due to many new functionalities that need to be integrated. The coordinator is involved in this process as are other WP leaders. It is still possible to have all modules ready after the second year according to the plan.

3. After the Bilbao meeting Spectroscan (April 2013) defaulted its tasks in the project. The involved project employee changed his position to another company and the director did not respond to any of the emails. After several phone calls, the director promised to show up on work package specific meetings, but never did. At the end of 2013 it became clear that Spectroscan would not take up his part in the project. The coordinator with urgent emails tried to activate them but without success. On the extra project meeting on January 2013 the Project Board agreed to start the exclusion of Spectroscan. By email also the Steering Committee agreed to take further steps of the exclusion of Spectroscan. The coordinator conferred with the project officer to inform her about the actual situation and asked advice. The coordinator sent out 2 official registered letters to Spectroscan to ask for clarification. But until now no response was provided by Spectroscan. With the project officer we will proceed to exlude Spectroscan from the PicknPack project in the second period. We do not expect input from Spectroscan. Recently their website was taken offline. Spectroscan received a first

payment of € 180k but since no results have been presented it is not clear how much of the budget was used..

The coordinator interacted in several other issues, such as the installation of the Industrial Advisory Board and the expenses of the IAB to visit the project meetings. Organizing workshops, visits to Marks and Spencer to extract market demands on food processing and share it with orther WP's, etc.

3.3 Changes in the consortium, if any

3.3.1 Tecnalia France and Lacquey Packaging added as third parties.

Tecnalia Research and Innovation Spain transferred work to Tecnalia France, which is a 100% subsidiary of Tecnalia R&I. Because of the different legal entity Tecnalia R&I requested to add Tecnalia France as a third party.

Lacquey also changed its structure. The workforce and R&D activities are transferred to Lacquey Packaging which is 90% owned by Lacquey. Lacquey requested to ad Lacquey Packaging as a third party.

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

3.3.2 Staring the termination of Spectroscan

The termination of Spectroscan started in the first period. This process is explained in chapter 3.2. The aim is to realize the termination and presenting a solution for the tasks early in the second period.

3.3.3 Transfer of work from Marel HF to Marel UK Ltd

Marel Hf headquarters transferred tasks to Marel UK at the end of the first period. Marel UK is a different legal entity, but 100% owned by Marel Hf. In the second period it is planned to start the procedure to add Marel UK as a third party of Marel Hf.

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

WP7 Work Package Leader Ard Nieuwenhuizen left Wageningen UR. He is replaced by Ruud Barth who was already involved in WP7.
WP5 Work Package Leader Cedric Baradat is replaced by Jose Pere Larrazabal. Cedric is still strongly involved in WP5.
Project Board member Asgeir Asgeirson left Marel. He is replaced by Richard Seager form Marel. Richard was also already involved in the project.
Project Board member Martijn Wisse was replaced by Mathijs Vermeulen.
Project Board member Patrice Guery left Spectroscan. Given the situation with Spectroscan his replacement is unclear.

3.4 List of project meetings, dates and venues

In the first period three major project meetings where organized:

- Kick off meeting November 12-14, 2012 Hotel De Paasberg, Ede-Wageningen The Netherlands

- Second Project Meeting April 24-26, 2013 AZTI-Tecnalia, Bilbao Spain
- Third Project Meeting Oktober 20-23, DTI, Copenhagen/Taastrup, Denmark

Between 30 and 45 people attended every meeting. An extra Project Board meeting was held at Schiphol, Amsterdam The Netherlands on January 31, 2014.

Below a list with smaller meetings:

2012 December 19	Determining Productrange at M&S London UK
2013 January 18	WP4 meeting in Leuven, Belgium
2013 February 14	Visit vine tomatoes p[ackaging facilities, Rotterdam area, The Netherlands
2013 April 16	WP2 meeting Leuven
2013 May 30	WP3 meeting Iceland
2013 June 20-21	Visiting M&S ready meal production facilities at Spalding, Carlisle and London
2013 June 24	WP2 meeting Wageningen
2013 July 2	WP2 meeting Leuven
2013 July 3	WP5 and 7 meeting Leuven
2013 September 17	WP2 meeting Montpellier
2013 October 31	Workshop food factory of the future Wageningen
2013 December 18	WP4 meeting Leuven

Also other work package specific meetings were organized. Project members used Skype group meetings several times. It was clear that project members needed to exchange many issues to come to an integrated line design.

Scheduled project meetings in the future are:

2014 October 28-30	Project Meeting Frauenhofer Dresden, Germany
2015 April 21-23	Project Meeting Universtity of Manchester, UK
2015 October 27-29	Project Meeting Katholic Univeristy of Leuven, Belgium
2016 April 19-21	Project Meeting Itene, Valencia, Spain

3.5 Project planning and status

Over all it can be concluded that the project is running according to the plan. At the end of 2013 the conceptual designs could not be fixed. However, with an extra effort from October 2013 until April 2014 the project seems to be on schedule again as indicated in this periodical report. Deviations that needs to be reported are:

- Due to defaulting participation of Spectroscan (Chapter 3.2) the X-ray quality assessment is behind schedule. This is also explained in Chapter 6.2.3.
- WP6 made tests with printed reflectors after thermoforming. The result does not look promising as the metal breaks up in small pieces either spoiling the functionality or creating un-controlled susceptors. At the moment WP6 can only create reflectors on the over film. WP6 has been working with alternatives for the heating systems. WP6 has been working with in moulded metal layers and metal labels. As a conclusion for the flexible heating systems WP6 together with the Project Board has decided to proceed with the research and make space on the line to apply these systems later in the process as WP6 do not believe to have an industrial system ready within the time frame of 2014.

Milestones MS4, MS5, MS8, MS9, MS10, MS11, MS12, MS13, MS14, MS15, MS17, MS18, MS19, MS23, MS24, MS28, MS29, MS34, MS35, MS39 are achieved according to the plan.

3.6 Impact of possible deviations from the planned milestones and deliverables

The defaulting party Spectroscan delayed the design and realization of the X-ray quality assessment sub module. WP4 managed to proceed with the research by using other X-ray machines. WP4 is preparing a plan on how to proceed. The design of the hardware of the X-ray module is not critical. This can be done by others. But part of the budget (180k) is already transferred to Spectroscan, without deliveries and could therefore be limiting and unclear. Part of the budget for Spectroscan has not been transferred yet (195k). WP4 will make a plan how this can be used to fulfil the core of the task and will estimate the consequences of the limitations of the budget. Presenting the new plan is scheduled at early of the second period.

WP6 is a little behind with testing and fixing the final detailed design due to complex integration of several new sub modules, but at the moment it is still to be expected that modules can be delivered on time. Coordinator and other Work Package leaders will support WP6 and give priority to WP6 requests.

There are no deviations in realizing deliverables and milestones.

3.7 Any changes to the legal status of any of the beneficiaries

There are no changes of the legal status of beneficiaries reported.

3.8 Development of the Project website, if applicable

The PicknPack website (www.picknpack.eu) hosts a public and a private section. The public section holds a description of the project and the partners and is used for dissemination activities. More information about the public section is given in chapter 2.10 of this report.
The private section is accessible only for members of the PicknPack consortium. It is used for communication among the partners and for archiving of important documents, deliverables, presentations and minutes. The private section is frequently used by the members, mainly for uploading and downloading these documents. Most of the internal communication is done by email using the PicknPack email distribution list.
A website with a file share facility is available to all project members to exchange information. The coordinator with help from colleagues tries to keep it up to date.