D2.11 TECHNICAL IMPROVEMENTS REPORT - M51

WP 2 – TRIAL MANAGEMENT

March 31st, 2021

Task 2.4 – Technical Improvements

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PROJECT SUMMARY

The internet of things (IoT) has a revolutionary potential. A smart web of sensors, actuators, cameras, robots, drones and other connected devices allows for an unprecedented level of control and automated decision-making. The project Internet of Food & Farm 2020 (IoF2020) explores the potential of IoT-technologies for the European food and farming industry.

The goal is ambitious: to make precision farming a reality and to take a vital step towards a more sustainable food value chain. With the help of IoT technologies higher yields and better-quality produce are within reach. Pesticide and fertilizer use will drop and overall efficiency is optimized. IoT technologies also enable better traceability of food, leading to increased food safety.

Thirty-three use-cases organised around five trials (arable, dairy, fruits, meat and vegetables) develop, test and demonstrate IoT technologies in an operational farm environment all over Europe, between January 2017 and March 2021.

IoF2020 uses a lean multi-actor approach focusing on user acceptability, stakeholder engagement and the development of sustainable business models. IoF2020 aims to increase the economic viability and market share of developed technologies, while bringing end-users' and farmers' adoption of these technological solutions to the next stage. The aim of IoF2020 is to build a lasting innovation ecosystem that fosters the uptake of IoT technologies. Therefore, key stakeholders along the food value chain are involved in IoF2020, together with technology service providers, software companies and academic research institutions.

Led by the Wageningen University and Research (WUR), the 100+ members consortium includes partners from agriculture and ICT sectors, and uses open source technology provided by other initiatives (e.g. FIWARE). IoF2020 is part of Horizon2020 Industrial Leadership and is supported by the European Commission with a budget of €30 million.

EXECUTIVE SUMMARY

The project Internet of Food & Farm 2020 (IoF2020) explores the potential of Internet of Things (IoT) technologies for the European food and farming industry. The core of the project is 33 use cases (UCs) that were organised in five trials (Arable, Dairy, Fruits, Vegetables and Meat) that develop, test and demonstrate IoT technologies in operational farm and processing environments all over Europe. The development is built around a lean multi-actor approach, that includes continuous testing and improving of the products and services that the UCs develop, along a Minimum Viable Product (MVP) approach. A first version of the product is released (MVP 1) and tested by end-users as soon as possible. Based on the results of testing and the end-user feedback, a second release is then prepared (MVP 2) and the cycle repeats itself until the final MVP.

This deliverable, D2.11 “Technical Improvements Report” is made at the end of the IoF2020 project in M51. It resulted from task T2.4 “Technical Improvements” from WP2 (Trial Management) and it’s the second iteration of the Technical Improvements Report (D2.6, M30). This deliverable discusses the technical challenges all 33 UCs of the IoF2020 project (19 initial use cases and 14 open call use cases) encountered during the lifetime of the project and provides an overview of the respective solutions the use cases developed. To obtain the best possible uniformity in the collection of information, a template was designed by WP2 that was included in the final progress report of every UC. This unified way of collecting data facilitated the process of compiling this deliverable. Every UC had to provide information about the technical development cycle or iteration cycle of the developed (sub)products or services, as well as to complete a table regarding the lessons learned from a technical point of view.

In this deliverable the technical development cycles are broadly discussed for every trial and in the confidential version of the deliverable, the inputs of every use case are included. In total, the 33 UCs delivered 58 technical development tables (between one and five per UC), with 3.16 IoT solution-related iteration cycles per table on average (minimum zero and maximum seven per (sub)product / service). The vast majority of UCs held to an MVP cycle and have significantly improved their products, prototypes and services throughout the lifetime of the project. In each iteration of a product, clear attention points and positive points were identified. The positive points were usually improvements made based on the attention points of the previous iteration. Testing and user feedback was crucial in the identification of the attention points. Therefore, UCs were most successful when they were able to adapt, prioritize issues and be (allowed to be) flexible in their approach.

As far as the timing of the iterations goes, also here variation and flexible adaptation of the UCs to their own needs and schedule can be seen. Some UCs had a more or less continuous improvement process in the lifetime of the UC, while others applied a yearly or longer improvement cycle. This all depends on the type of product and its complexity, installation cost or usage (for example during a yearly growing season). On average, an iteration cycle as reported by all UCs was 10 months long. For the initial UCs (duration of 4 years) the average iteration cycle was 11.73 months and for the open call UCs (duration

of 2 years) this was 5.56 months. The MVP cycle in itself was a very good mechanism to set timelines and match expectations for the UCs to adopt a lean multi-actor approach. This allowed to challenge UCs to keep on releasing and testing new versions, whilst increasing the number of deployment sites, but still allowed to take into account their specific situation.

Besides the technical improvement cycle, this deliverable also discusses the lessons learned by the UCs from a technological point of view. Just like in the previous deliverable (D2.6), categories were made of the different lessons learned. The results were analysed in two different ways: (1) the number of use cases that reported a specific category of the lessons learned and (2) the number of times a certain category was reported overall. The same seven categories were reported by most use cases and in total. Those seven categories are the lessons learned regarding dashboard user interface, network communication, additional features, sensor placement, data processing, interoperability and hardware design/placement. Those seven categories are related to the types of technical challenges that occurred during the lifetimes of the UCs and occurrence per trial is further analysed and discussed in this deliverable.

The 33 UCs of the IoF2020 project were very diverse teams, each with their own goals and a specific domain that they worked in. They developed and improved a multitude of IoT based solutions, resulting in diverse products and services for the agri-food sector during the project The way they have handled it shows on the one hand their diversity, but on the other hand also their common technical challenges and lessons learned. Real-life testing, end user feedback and also a flexible and adaptive approach were crucial to the success of the UCs.

LIST OF ABBREVIATIONS

CE-Marking	Conformité Européene (= European Conformity)
DSS	Decision Support System
EPS	EuroPool System
EU	European Union
FMIS	Farm Management Information Systems
FTIR	Fourier-Transform Infrared spectroscopy
GUI	Graphical User Interface
IoF2020	Internet of Food and Farm 2020
IoT	Internet of Things
ISO	International Standards Organization
KPI	Key Performance Indicator
MVP	Minimum Viable Product
PR	Progress Report
RDQ	Remote Dairy Quality
ROI	Return On Investment
RTI	Returnable Transport Item
TRL	Technology Readiness Level
UAT	User Acceptance Testing
UC	Use Case
WP	Work Package
WUR	Wageningen University and Research

TABLE OF CONTENTS

1. INTRODUCTION

The project Internet of Food & Farm 2020 (IoF2020) explores the potential of Internet of Things (IoT) technologies for the European food and farming industry. The core of the project is 33 use cases (UCs) that were organised in five trials (Arable, Dairy, Fruits, Vegetables and Meat) that develop, test and demonstrate IoT technologies in operational farm and processing environments all over Europe.

This deliverable D2.11 "Technical Improvements Report" is a result of task T2.4 "Technical Improvements" from work package 2 (WP2 Trial management) of the IoF2020 project, that deals with the management of the trials and use cases. It is the second iteration of the Technical Improvements Reports (D2.6, M30) and presents an overview of the respective solutions of the 33 use cases in the project. D2.11 is made at the end of the project, M51, and is also connected to D2.10 "Annual Implementation and Performance Monitoring Report" (M51) and its previous versions in which the statuses of the UCs implementations are discussed every year of the project.

IoF2020 is a large-scale pilot project under the H2020 innovation action programme. This means that the focus of the project is at demonstrating technologies in a relevant environment to bring them towards prototypes and even complete products for market entry (from TRL levels 5-6 to 8-9). In order to collect a sufficient amount of feedback and to rule-out possible coincidences in the research, large-scale testing was set-up as much as possible. In this project, large-scale testing means that a large amount of IoT devices, solutions, sensors, applications etc. are being tested, preferably at the same time and on different installation sites such as farms or processing plants. This method made it faster -often also easier- to spot technical problems or problems concerning the user-application. It also made the research more reliable, because the amount of tested solutions/devices was larger.

The process of the technical improvements during IoF2020 was user-driven. Meaning that the feedback of end-users to the technology providers was essential to further develop the products and solutions. So, whilst walking along their development path, the UCs never let the input from the stakeholders out of sight. This was an absolute necessity since adjustments and improvements to the solutions were based on their experiences. Every UC started with a minimum viable product (MVP) that they improved over time by testing it in real-life situations with real end-users. This testing then led to the development of a new and improved MVP (compared to the initial deployment), resulting in a second release (MVP 2). In turn, this second MVP was then re-tested, evaluated, improved and new MVPs followed, until the final MVP was reached. This report about technical improvements will broadly discuss the development path that all UCs have followed for their various solutions from the very beginning of the project until the end of IoF2020. The technical development cycles and the intermediate iterations to get to the final product will be closely examined and discussed in this report.

For the 19 initial use cases (UCs), a technical improvements report has already been provided covering the period M1 – M30 (D2.6 Technical Improvements Report – M30). For the 14 open-call UCs, this is the first technical improvements report in which they will be discussed. The previous Technical Improvements Report presented technical challenges and lessons' learned of the initial UCs halfway their lifetime. The current report covers the whole lifetime of the project of all 33 UCs.

Some UCs had to adapt the design of their IoT based solutions or the scope over time due to changed needs from the stakeholders or due to a better business plan in another scope. On top of that, COVID-19 has in many cases caused difficulties and backlog in real-life testing and further development. However, it is thanks to the hard work and persistence of all our partners that the realization (as discussed further in this deliverable) became possible.

This document will also briefly mention the status of the realized IoT based solutions. We are proud to announce that some of the products, services and applications developed by the UCs are already used for commercial purposes. Some products have already been sold, while others will continue to develop their products after IoF2020 in order to realize even better IoT applications in agriculture. More information can be found in D2.10 and several deliverables of WP4 as well.

The next chapter following this introduction is dedicated to the description of the methodology and the template that was used to collect the needed information from the UCs. The last two chapters of the deliverable include the overall analyses of the results and the conclusions. Together with the extensive analysis of the UCs progress in D2.10 (and its previous versions), this deliverable presents the full overview of the developments of the UCs during the lifetime of the project. The annex of this deliverable includes all the reports provided by the 33 UCs, grouped according to the five trials (Arable, Dairy, Fruit, Vegetable, and Meat). Due to the confidentiality of the data provided by the UCs, the 33 reports (around 180 pages) are included only in the more extended confidential version of deliverable D2.11. If the reader is interested in obtaining more information about a specific UC, it is suggested to contact the coordinator of the UC of interest. The contact details of the UC coordinators can be found on the project website www.iof2020.eu. Further information about IoT related components deployed, key performance indicators and deployment context is also available in the IoF2020 part of the IoT catalogue (www.iot-catalogue.com).

2. METHODOLOGY & TEMPLATE

2.1. METHODOLOGY TO COLLECT THE INFORMATION FROM UCS

Work Package 2 collected a yearly progress report for respectively D2.4, 2.8, 2.9 and 2.10 at M12, M24, M36 and M48 throughout the years of the project. This report included the progress of the tasks as mentioned in the UC work plans (D2.2 and the contracts of the open call UCs). This yearly progress report has served since the start also as a basis to include all needed documentation of the use cases and supports information collection for the other WPs. It has thus been populated also with sections on technical, business, dissemination and ethical questions for the UCs.

At the time of the previous Technical Improvements Report (D2.6, M30), the open call UCs had just started (6 months on-going) and the initial UCs had been overloaded with information requests already (preparation yearly event in Prague, M24 progress report, WP feedback towards UCs, etc.) and its timing did not coincide with a yearly progress report. So for D2.6 the information was gathered through various channels: previous progress reports, events, trial telco's, WP feedback. This was time-consuming and required a lot of post-processing to achieve consistency between use cases. Over the years, it was clear that a consistent reporting facilitates further processing of the data. To ease the preparation of this report, and since it coincides with the final progress report, a section on this subject has been included in the final progress report template that each of the 33 use cases (both the initial use cases and the open call UCs) had to fill in and submit by the end of their use case duration (and at the latest at the end of the year 2020, at M48).

The UC coordinators received this template between 1 and 2 months before the due date, and were alerted on this action beforehand so they could plan in this activity. Filling in the template was the responsibility of the UC coordinator, but was generally also performed together with the other UC partners. After submission to the WP2 responsible (BIOS for trial 1, 3, 4 and EV ILVO for trial 2, 5) the progress report was thoroughly checked by this WP2 (co-)lead and requests for additional information or revisions were sent back to the UC coordinator where needed. This process was repeated until the information was clear and consistent. Then, this D2.11 was populated with the input from the UCs and further analysis was done on the results.

Table 1 shows the overview of the 33 use cases grouped in the five trials. Initial use cases typically had a running time for the 4years of the project (2017-2020), although some were shorter and lasted only 3 years, while open call UCs started in 2019 and ended in 2020 (running time of 2 years or a couple of months less).

Table 1: Overview of the 33 use cases in IoF2020.

UC Number	UC Name	Type of UC
Trial 1: Arable		
1.1	Within-Field Management Zoning	Initial UC
1.2	Precision Crop Management	Initial UC
1.3	Soya Protein Management	Initial UC
1.4	Farm Machine Interoperability	Initial UC
1.5	Potato Data Processing Exchange	Open Call UC
1.6	Data-Driven Potato Production	Open Call UC
1.7	Traceability For Food and Feed Logistics	Open Call UC
1.8	Solar-Powered Field Sensors	Open Call UC
1.9	Within-Field Management Zoning Baltics	Open Call UC
Trial 2: Dairy		
2.1	Grazing Cow Monitor	Initial UC
2.2	Happy Cow	Initial UC
2.3	Herdsman+	Initial UC
2.4	Remote Milk Quality	Initial UC
2.5	Early Lameness Detection Through Machine Learning	Open Call UC
2.6	Precision Mineral Supplementation	Open Call UC
2.7	Multi-Sensor Cow Monitoring	Open Call UC
Trial 3: Fruit		
3.1	Fresh Table Grapes Chain	Initial UC
3.2	Big Wine Optimization	Initial UC
3.3	Automated Olive Chain	Initial UC
3.4	Intelligent Fruit Logistics	Initial UC
3.5	Smart Orchard Spray Application	Open Call UC
3.6	Beverage Integrity Tracking	Open Call UC
Trial 4: Vegetables		

4.1	City Farming Leafy Vegetables	Initial UC
4.2	Chain-Integrated Greenhouse Production	Initial UC
4.3	Added Value Weeding Data	Initial UC
4.4	Enhanced Quality Certification System	Initial UC
4.5	Digital Ecosystem Utilisation	Open Call UC
Trial 5: Meat		
5.1	Pig Farm Management	Initial UC
5.2	Poultry Chain Management	Initial UC
5.3	Meat Transparency and Traceability	Initial UC
5.4	Decision-Making Optimization in Beef Supply Chain	Open Call UC
5.5	Feed Supply Chain Management	Open Call UC
5.6	Interoperable Pig Health Tracking	Open Call UC

2.2. TEMPLATE TO COLLECT THE INFORMATION FROM UCS

Work package 2 (EV ILVO and BIOS) designed the template to collect the information for D2.11 and incorporated it in the final progress report template. This template about the technical improvements (included as section 11 in the final progress report template, for the other sections see D2.10) can be found in figure 1. Once completed, section 11.1 “Technical development cycle” contains information about the product the use case started from, the iterations done and the final product. Positive points and attention points are also highlighted. Each iteration cycle (can be an MVP cycle) had to be included in the table, as well as an indication of the time when the different iterations occurred. At the end of the table, there is a section about the final product. This section indicates the status of the UC product at the end of the IoF2020 project, including some broader topics regarding the market readiness, the feedback from the users, etc. This process regarding the technical development cycles had to be repeated and completed for every product / service or part of it that the use case had worked on during the lifetime of the IoF2020 project. Besides the gathered information about the technical development cycle, another important section, 11.2 “Technical improvements: lessons learned” was added. The use cases had to select a category and give a brief description about what they’ve learned about this topic. This resulted in having consistent pre-determined categories to collect the lessons learned.

This template was chosen as it reflects (a) the whole lifecycle of the use case from start to finish, (b) follows the structure of the lean multi-actor approach, i.e. the MVP cycles and the collected feedback from users and improvement points, (c) shows also visually the product by using images and (d) gives a clear overview of the status of the end-product(s) and the lessons learned. D2.10 on the other hand shows a very extensive and complete picture of the UCs in terms of achievements, tasks fulfilment, actors and deployment sites, deployed components, dissemination and demonstration, business model information, plans beyond IoF2020, serendipities, etc. So more information about these other aspects of the UC can be found there.

11. TECHNICAL IMPROVEMENTS

In this section, we aim to document the various technical improvements and iteration cycles you've went through with your product/service during IOF2020, based on user feedback or test experience. It can be that for your UC this equals the MVP cycle of your product, but don't feel limited by that.

11.1. TECHNICAL DEVELOPMENT CYCLE (M1-M48)

We will start from the status of the product/service at the start of your use case, and go through an iteration cycle towards the final product at the end of IOF2020. Also, within one MVP cycle, multiple iterations can have taken place on (parts of) your product, so you can take this flexibility to fill in the tables based on what fits best for your use case. For example, you can choose to follow an MVP cycle, or to make different tracks for hardware/software for example or different parts of the product (sensor placement, data exchange, GUI, etc.)

Indicate the product/service (part)* in the first table and give a general overview of its status in the beginning. In the following tables you should provide a chronological overview of the different steps your product/service (part) has gone through to come in the final table to the end product as it is now at the end of IoF2020.

Product/service (part) development: <Name the product/service (part)>

Iteration cycle:

Start Product: <Describe in a few sentences your service/product (part) at the start. What did you have at the start of IoF2020.>	Mx*
Positive points	**Attention points**
<Describe the positive points, use bullet points>	<Describe the attention points, use bullet points>
<Add image>	
Iteration 1: <Describe in a few sentences your updated service/product (part)>	Mx*
<Describe how the iteration takes into account the attention points raised concerning your start product, use bullet points>	
Positive points	**Attention points**
<Describe the positive points, use bullet points>	<Describe the attention points, use bullet points>
Iteration 2: <Describe in a few sentences your updated service/product (part)>	Mx*
<Describe how the iteration takes into account the attention points raised concerning your start product, use bullet points>	
Positive points	**Attention points**
<Describe the positive points, use bullet points>	<Describe the attention points, use bullet points>
Iteration X: <Describe in a few sentences your updated service/product (part)>**	Mx*
<Describe how the iteration takes into account the attention points raised concerning your last iteration, use bullet points>	
Positive points	**Attention points**
<Describe the positive points, use bullet points>	<Describe the attention points, use bullet points>

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Final Product: <Description>	Mx*
Technical improvements cfr. previous iteration	<Describe how this final iteration takes into account the attention points raised, use bullet points>
Deployment period	<MM-YY until MM-YY>
Deployment sites	<Site name, refer to the site in section…of PR>
Positive points	<Describe the positive points, use bullet points>
Attention points	<If applicable, describe the remaining attention points, use bullet points>
UAT feedback	<Describe the general user experience feedback when applicable>
Market readiness	<Describe if the product is on the market, ready to go to market or what is still needed to reach the market>
User manual	<Describe if a user manual is available, in which languages it is available, and where it can be found>
<Add image>	

*Mx: <Value between M1-M48> *In order to provide a chronological overview, please indicate/estimate when this product/service (part) was first operational.)*

**Copy part of this table for each of the iterations your product/service went through prior to reaching the final product/service (part).

Product/service (part) development: <Name the product/service (part)>

Iteration cycle:

*** Copy this table for each of your products/Services (Part).

11.2. TECHNICAL IMPROVEMENTS – LESSONS' LEARNT

Lessons Learnt	
Select a category	
Select a category	
Select a topic ory	
Select a category	

Efficient power management
Sensor Placement
Additional alerts
Additional features
Network communication
Data loss
Data processing
Interoperability
Calamities (f.e. Covid-19, dry weather, etc.)
Dashboard user interface
Sensor accuracy/calibration
Hardware design/placement
Quality of data
Prediction algorithms
standardization
data file formating
Other

53 / 72

Figure 1: Template for the information collection from the UCs for this deliverable.

3. ANALYSIS OF THE RESULTS

3.1. DESCRIPTION OF THE DIFFERENT TRIALS

Each UC supplied a table of the technical development cycle of their (sub)product(s) / service(s) from the start of the project until the end, according to the template of Figure 1. The purpose of this table was to collect and document the various technical improvements and iteration cycles they went through with their (sub)product(s) /service(s) in a chronological way and get a general overview from the start of the UC until the end. IoF2020 proposed a lean multi-actor approach with Minimum Viable Products (see Figure 2), so asking this information gives the opportunity to check if this approach was followed and was successful. In addition, highlights can be extracted from crucial points in the development such as attention points or positive points that were identified and that steered the development in one way or another. For each final product, some more details are listed like the market readiness and a user manual. The developments are also highlighted and shown visually by populating the table with images of the products, sensors, dashboards, etc.

Figure 2: Minimum Viable Product cycle and increase in involved users as was planned in IoF2020

UCs were given flexibility to fill in the tables according to what fitted their development path and use case the best. First of all, as several UCs were developing multiple products, the table needed to be filled in for each product separately. But also there flexibility was offered, as to what split-up they found the most logical. Some UCs have split up their offered service into different subproducts / services that together form the marketed total solution. This can be a more logical division because the subproducts are developed separately by different companies for example. Besides that, within one MVP cycle, different technical iterations can have taken place on different parts of the product. For example, they could choose to follow an MVP cycle for the whole product, or to make different tracks for hardware versus software for example or different parts of the product (sensor placement, data exchange, GUI, etc.). This means that the number of iteration tables can differ from the number of products. This technical development table can thus be filled in flexibly and focusses on the technical iteration cycles, whereas another table in the final progress report asked information about the Business Status and specifically also MVP cycle information for each marketable product of the UC. Although somewhat complementary to the information presented in the Technical Improvements section and this deliverable, analysis of this business info and more information about the MVPs and their specific numbers (amount and market-readiness) is beyond the scope of this deliverable and can be found in WP4 analysis of the UCs.

By taking a deeper look into the occurrence of the provided technical development tables (of solutions, products or sub-products), it can be concluded that there are 58 tables reported in total over all UCs. These are split amongst the initial and open call UCs equally, taking into account the relative number of UCs in each of these two categories. On average, UCs split up (or describe) their technical developments in 1.7 iteration tables. The number of iteration tables provided by a UC is not necessarily the same as the amount of IoT solutions or products the UC developed, see previous paragraph for more information. The minimum amount of iteration tables provided by a UC is 1 and the maximum is 5. The average number of provided iteration tables, is 1.84 tables for the initial UCs; whereas for the open call UCs the average is 1.64. So this does not differ substantially between initial and open call UCs.

Another aspect that can be studied from these technical development tables are the number of iteration cycles per reported table. To calculate the amount of iteration cycles, the final product is counted as one iteration cycle as well. It has happened in rare cases that a UC did not provide an overview in the tables, but in textual form (n[1] = 1; UC 1.1). In that case, the total amount of iteration cycles was taken as one. The same applies to UCs that did not display iterations, but that switched directly from the start product to the end product (n = 6; UC 3.4, UC 4.4 and UC 5.2 both in two iteration tables, and UC 5.6) When only the final product was provided in the technical development table this also applies (just like the other cases) only for one iteration cycle (n = 1; UC 3.1). An exception to this is when a UC explicitly reports that the start - and final product are the same (n = 2; both in UC 5.4). In that case, the amount of iteration cycles is counted as zero. So overall, 7 out of 33 UCs deviated slightly from the MVP cycle, 26 of them followed the MVP cycle more clearly. In terms of total amount of iteration tables, respectively 10 out of 58 iteration tables deviated from the classical MVP cycle.

In average, over all UCs, the number of iteration cycles within one technical developments table is 3.16. The maximum number of iterations for one product was 7. If we only look at the initial UCs, we can see that the average number of iteration cycles is 3.37; whereas the average number of iteration cycles within the open call UCs is 2.83. This differs slightly, which we can explain since the open call UCs had a shorter running time compared with the initial UCs. Therefore, they had less time to develop their

[1] n = the number of iteration tables.

products and to run multiple iteration cycles. However, knowing that relatively seen the open call UCs had about half the lifetime of the initial UCs, the difference is not as large as expected. To determine the average duration of a single iteration cycle, the duration of the iterations (from where this info was available) was listed. Across all UCs one iteration cycle takes about 10 months on average. For the initial UCs, the average iteration cycle lasted 11.73 months, while the average duration of one iteration cycle from the open call UCs is 5.56 months. These findings are in line with the theoretical approach to ask the initial UCs for four iterations in four years' time (12 months per iteration cycle) and to ask the open call UCs for four iterations in two years' time (6 months per iteration cycle). As previously explained, these are not necessarily the MVP-cycles of the developed IoT products, but it will be closely interrelated. It must be said that the numbers and durations of iteration cycles of the UCs are very diverse, so the conclusions listed in this paragraph are based on averages.

Overall, the technical development tables indicated that the vast majority of UCs held to an MVP cycle and have significantly improved their products, prototypes and services throughout the lifetime of the project. In each iteration of a product, clear attention points and positive points were identified. The positive points were usually improvements made based on the attention points of the previous release. Identification of attention points was done through various methods, but mainly the testing and user feedback was crucial in that. These attention points could be known upfront because of the architecture or the current status of its development. But during the lifetime of the IoF2020 project and through the frequent interaction with the UCs we know that issues often come unexpected or in unexpected ways. This because they only come up in real-life testing, or with larger amounts of farms or data. Sometimes the end users have a different view on what the product should do or look like compared to the UC team, so adaptations were needed. Other times, there were just faulty components or bugs. Sometimes it could take some time for faults or attention points to pop up, or to identify the root-cause of the issue. Likewise finding a solution was sometimes time-consuming. How long that takes exactly is very dependent on the issue itself, but also on its type, its priority and also on the type of product it is (software is more easily adapted than hardware in many cases for example). Therefore, for no single UC the roadmap as it was set at the start of their activities always remained the same. Adaptations needed to be done, issues needed to be prioritized and tackled one-by-one (or even put on a list for future improvements) and flexibility was the key to that.

As far as the timing of the MVPs goes, we also see a variation and flexible adaptation of the UCs to their own needs and schedule. Some UCs clearly stated or mentioned that filling in the iteration table was difficult for them, as they had a more or less continuous improvement process in the lifetime of the UC. This means they are continuously improving and adding new features, or solving issues and releasing this to the famers or users in a very fast way. This is for example possible for software or dashboards were adaptations can be made quite quickly and can be released remotely to the clients. Other UCs on the other hand needed sometimes more than a year to release a new MVP. This can be the case for very complex products with multiple components interacting, where the risk of instability is high if not properly tested, or for expensive or large numbers of installed devices that need to be replaced when a new version is released, where the risk of financial losses is high if the new release contains bugs for example. In those cases it might be better to have a longer development time and do more tests in controlled environments before making the decision to replace all active units at the test sites. There are also UCs that follow the proposed cycle of one yearly MVP very nicely. This is mostly also applicable to UCs that follow a certain seasonal demand. For example, a certain growing season of a plant or also a grazing season for livestock. In those cases, the UCs took the approach of doing installations at the start of the growing/grazing season, collected data and results, and then did improvements in the months in-between before deploying a new version for the new growing/grazing season. In essence, although the UCs adapted their own styles of implementation, we do believe that the theoretical guideline of one MVP every year (or every 6 months for open call UCs) was valid as it was a very good mechanism to set timelines, match expectations and push the UCs to adopt a lean multi-actor approach. Also the average duration of the iteration cycles of the UCs confirm this. This allowed to clearly monitor a deadline to have first installations in the first year of the project, and to challenge UCs to keep on releasing and testing new versions, whilst increasing their deployment sites.

The Technical Improvements reports of each UC can be found in Annex 1 of the confidential version of the deliverable. More information regarding the deployment sites, the countries the UCs were active in and other interesting aspects can be found in D2.10, while market ready products can be found in WP4 deliverables. Below, and for the public version, a summary of the iteration tables for each trial can be found.

It's beyond the scope of this deliverable to describe the aim of every UC. To better understand the description of the technical iterations, it might be useful to read more general information about the UCs on the IoF2020 website: www.iof2020.eu. Further information about the deployed IoT related components, KPIs and the deployment context can also be found in the IoF2020 part of the IoT catalogue: www.iot-catalogue.com.

3.1.1. TRIAL 1: ARABLE

The arable trial consists of nine use cases (four initial UCs and five Open Call UCs).

UC1.1 – Within-Field Management Zoning developed a product called: Soil map based variable rate application of pesticides and fertilizers with sprayer and spreader machines for potato farming. The product was built based on already existing components of the UC, which were connected via tailored software. In year one (2017) UC1.1 developed the Contractor app that allowed the farmer to order a soil map. In that year, a task map for soil herbicide based on an available decision support webservice could be made. This dose prescription task map was converted into a machine ready task map in the terminal of the Kverneland sprayers and spreaders. In year one (2017) UC1.1 still had some problems to get the task map being applied on the potato planter. In year 2 (2018) UC1.1 developed the webservice for making the dose precision task map. And the machine company partners developed the terminal software for easier use of the task maps on the machines. In 2019 UC1.1 had the flow from ordering a soil map to making a prescription map and optimal timing to application of the machine ready task map up in place. The farmers on the two demonstration farms were able to apply it themselves. In 2019 and 2020 UC1.1 kept on working on better sharing of data and prescription maps via API's. Some further development and testing is required in 2021. Points of attention are smooth connectivity between the webservice with the decision support for variable planting density and the smart planters. Each planter company has developed a different route for connectivity. In 2021, the specific test will be carried out to assess if these three routes will lead to successful variable rate planting. The partners in UC 1.1 remained owners of the components they connected. ZLTO/Vd Borne is delivering soil maps via a startup Soil Masters. Wageningen is making available to the market the decision support modules via Akkerweb and via an API. The machine companies are marketing smarter machines (better machine steering software and better connections with external sources). The business model of the variable rate planting density tool is still to be decided.

UC1.2 - Precision Crop Management developed two products: Monitoring and crop management dashboard. This use case provides following set of services: i) Data visualization of what happens in farmer's field, with possibility to consult the full growing season; ii) Advices on nitrogen management (amount and timing); Advices on water management (amount and timing) with the use of both IoT devices and satellite images. The final product combines crop observations available along the season and advices for water and nitrogen management. The solution was improved, so an adaptation of the model correction using less frequent measures has been developed. The overall service is similar in terms of advices, even if the accuracy can be slightly degraded. Along the years, the IoT component became optional, associated with enhanced services (visual control, phenology monitoring, disease alerts, etc.).

UC1.3 - Soya Protein Management developed one product: Soya Protein Manager. It addresses the current lack of technological innovation in the cultivation and processing of protein plants. Through smart farming technologies, such as decision support systems and better sensor data to optimise machine task operations, this use case aimed to reintroduce and increase soybean cultivation in the EU (European Union). The first demo version was ready one and a half year after the start of the project and it had just the core functions: i) access to weather stations in the field in real-time; ii) documentation of weather data and download as .csv; iii) manual assisted irrigation alert. In the next MVP, the dashboard was improved, and the feature to manually integration of soil, yield and quality maps was added. The third iteration after 26 months was more market oriented, with improved dashboard, the beta version of fully automated irrigation feature was added with semi-automated transfer of soil, yield and protein maps to cloud. The feedback from end-users if very positive, so the further developments are foreseen in terms of mobile version and interoperability.

UC1.4 - Farm Machine Interoperability integrates different machine communication standards in arable farming to unlock the potential of efficient machine-to-machine communication and data sharing between machines and management information systems. The starting position of this UC was that there are still gaps in standardisation, so they wanted to better define communication standards for agricultural data sharing. The first step in this horizontal UC was to investigate which standards are needed (including research on standards which are already being used in agricultural industry as well identifying standards needed by other IoF2020 UCs). The next iteration included interaction with the agricultural politics and lobbyist ecosystem (such as Standards Development Organisations). This included bi-weekly ADAPT Technical Committee meetings and monthly PT09 FMIS (Farm Management Information Systems) meetings. Towards the end of the project this UC focused more on acceleration of the adoption of Standards and Knowledge Transfer. Therefore, the final result of this UC is the newly financed H2020 project ATLAS.

UC1.5 - Potato Data Processing Exchange opens data flows between stakeholders in the supply chain as an important step towards smart digital farming. UC1.5 developed product AVR Connect caliber yield measurement. Their starting position included just the basic yield measurement system. The main attention point was price and cost-benefit relation of data gathered and its cost. The first significant milestone was lab setup caliber yield measurement. The second included setup on harvester to collect images which provided different perspective on laboratory work. The final product achieved in M42 was a fully integrated system on harvester. The information and caliber measurements are gathered throughout the entire season through sensors mounted onto machinery, in addition to soil mapping performed by drones or satellites.

UC1.6 - Data-Driven Potato Production is an innovative, market-ready smart farming solution that supports irrigation, pest management and fertilisation. At the start of IoF2020 the underlying data-collection mechanisms (IoT stations, data-loggers, telecom modules, data repositories) were available along with integrated (e.g. pest management) scientific models. All these are part of the Gaiasense smart-farming solution. However, there were no stations deployed at UC1.6 pilot fields and there was no end-user application (e.g. IoT4Potato service). In addition, no data interoperability mechanisms were available. The first MVP included the following: i) Deployment of IoT devices to new regions –outside Greece - and integration with Gaiasense smart farming infrastructure; ii) Web-services for data collection of environmental measurements, cultivation practices, field observations; iii) Provision of measurements and risk levels/advice for the targeted regions and cultivations through interoperable data models (NGSIv2 or NGSI-LD) and API calls (Orion Context Broker); iv) Rendering of measurements and risk levels/advice for the targeted regions and cultivations through user-friendly means (e.g. web-based GUI, email). In May 2020, the second MVP was developed and consisted of: i) Scientific models of pest management that with incorporated knowledge gained through the observation of the first cultivation period; ii) Improved data processing approaches and better rendering of information. The respective pages of the IoT4Potato application have been redesigned according to the requirements indicated by the farmers utilized the services during the previous cultivation period. The final version of the IoT4Potato service (November 2020) incorporates all the user-required functionalities but it also incorporates data from external IoT-hardware (namely Future Intelligence meteo-stations deployed for the needs of IoF2020 - UC4.5).

UC1.7 - Traceability For Food and Feed Logistics deploys an innovative approach that secures and authenticates the transport of bulk-goods in the agri-food chain, both for feed and food with zero risk of contamination. From the first field trials, it became clear that the flow sensor implementation poses some clear design threats on the complete integration process. To be more specific: i) flow sensor placement requires drilling holes into existing pipes and systems; ii) after removing a reader with flow sensor, the pipe aperture (hole) must be closed, requiring extra attention of the user plus an extra design step; iii) silo pipes have different, non-standardized diameters, making it challenging to design a universal aperture fitting. At M40 of the project, the IoTrailer solution became a standalone solution, from silo tag to server. In order for existing software houses to plug into the smart server, several API adaptations must be made. At the end of the project, this UC developed market ready silo reader with docking station and smart silo server.

UC1.8 – Solar-Powered Field Sensors relies on solar-powered plug and play sensors to provide farmers with instant access to data on their soil properties and crop health. These sensors measure parameters such as temperature, humidity, PH value or nutrients and subsequently store the information in online databases accessible through smartphones. At the beginning of the project, UC1.8 had a fully functional sensor device with simple IoT architecture that could measure the physical and chemical properties of the soil. However, further developments were needed in order to fit to users' request. After certain COVID-19 related issues, this UC established fully modular, scalable, plug and play wireless sensor, ready to be installed at end-users' fields.

UC1.9 – Within-Field Management Zoning Baltics demonstrates both in potato as well as wheat farms how data from different types of sensors - measuring parameters such as soil moisture and organic matter or climate conditions – combined with spectral data analysis can be used for precise decision-making and optimised crop management. The data gathered enables farmers to predict yields, define specific management zones, and accurately calculate the required fertilisers, herbicides and other agrochemical products. The UC started with the prototype of a solution for remote wheat nutrient composition assessment based on spectral data analysis and IoT technology. During the years, several development iterations occurred: i) Reconfiguration of the pre-existing analytical framework and development of a potato field nutritional state assessment solution prototype; ii) Calibration and validation of the wheat and potato field nutritional state assessment solution prototypes; iii) Deployment and demonstration of the wheat and potato field nutritional state assessment solutions.

3.1.2. TRIAL 2: DAIRY

The dairy trial consists of seven use cases (four initial UCs and three open call UCs).

UC 2.1 - Grazing Cow Monitor used a tracking device for containers as a start product and they further developed it into a neck-mounted collar that can gather information about the position of the cows (in the barn or outside on the pasture). The goal was to make it easier for farmers to proof that the milk they sell is milk from pasture (from grazing cows). This product is market-ready, but was discontinued after two iteration cycles due to the low ROI (Return on Investment) for farmers if it can only serve this one purpose. During the project, the UC shifted to track free-gazing beef cattle, which proved a better and viable business case, and they developed a second solution, named Remote monitoring of natural grazing cow – outdoor location tracking. They started from their previously developed product (grazing cow monitor) and after about 1.5 year and two iteration cycles, their final product was ready. Thanks to this solution, the farmers can find their cows in large outdoor areas and get warnings if a certain cow hasn't moved for a while (and therefore could be in need of assistance). This product is market ready and brings many benefits for the farmers, as well as a very positive ROI.

UC 2.2 – Happy Cow worked on a technology to detect oestrus (heat) and health issues in cows as well as calving events. Their product is called IDA For Farmers. They started from a system that could be deployed on a small herd to help the farmers to inseminate their cows, with some basic health alerts. The product was further developed during IoF2020 in about four iteration cycles. These included the incorporation of live feedback of the farmers on the alerts, which in turn made the algorithms and predictions much more accurate. In addition, links with FMIS were made and a more accurate model on calving detection was added. On the technical level, the developments led to a faster pipeline and 50% longer battery lifetime. Now the device provides better health and oestrus insights for any farmer, including those with larger herds and the possibility to share data, insights and KPIs (Key Performance Indicators) with the farmers' partners. This product is ready for market and clients are willing to pay for it.

UC 2.3 – Herdsman+ developed a solution that differs from other UCs in the sense that no commercially robust product resulted from the UC. This UC instead focused on the integration of various stand-alone farming systems (for example neck-mounted collars and milking robots) into one single data integration platform. This enables the farmers to check their data on a single platform, instead of checking it on different places for each FMIS individually. Several conditions of the cows can be identified thanks to the integration of those different FMIS like mastitis and heat stress. They worked on this solution for 42 months in which they have done three iteration cycles. Their solution Herdsman+ is not market-ready yet, since it is at proof-of-concept stage.

UC 2.4 – Remote Milk Quality didn't start with an actual product, but with an idea. During the four-years lifespan of the project they did about four iteration cycles to come to their final product, named the RDQ-tool (Remote Dairy Quality). This RDQ-tool allows dairy companies to do a correct pre-treatment of liquid raw-milk samples. Their product is already on the market in The Netherlands. UC 2.4 only provided information on the iteration cycles of this main product. During the second iteration, they made it possible to create a direct link with the internal Laboratory Information Management System to scan reference samples by barcode and thus solve manual identification. In the following iteration cycles, their main focus was on the presentation of the gathered information to make it easier for the end-user to understand the results and to make it possible to export the data. Besides that, they also worked on two other products, each with their own MVP-cycle. Their second product is called Sample pre-treatment device, but this was discontinued due to low business value and the third product they worked on is called IoT platform for managing milk testing on trucks. This last one needs further development so it's not on the market yet.

UC 2.5 - Early Lameness Detection Through Machine Learning is an open call use case, so the total duration of this project was two years instead of four. They started from a proof-of-concept product with a machine learning model to detect lameness in cows, using leg-mounted sensors. In their first iteration cycle they moved from a third party cloud provider to their own private cloud infrastructure which gave them more control over their collected data. Their app was also made available on multiple platforms (no longer only Android). Authentication and data security were also important aspects of this first iteration cycle. In the following iteration, they implemented automated model retraining based on the farmers' feedback through the app (in which they added multilingual support). In the third and last cycle, they delivered the vendor dashboard and they added a feature to the app which makes it possible for the farmer to filter by group. After a duration of about two years, they developed their final product, called Early Lameness Detection as a Service. The product is not launched to the market yet, because they are still collecting data to also be able to provide detection of other health issues.

UC 2.6 - Precision Mineral Supplementation ran for two years. They developed a solution, called Pitstop+. This solution makes sure that cows that are in the transition period get a sufficient amount of minerals, without over-supplementing the cows that are not in this critical period. When their project within IoF2020 started, they had an MVP that was tested on one farm. After two years, they came to their final product which is almost market ready. They are still working on the CE-marking (Conformité Européene, European Conformity) before launching the product into the market. Unfortunately, it was not possible to divide the development into iteration cycles, because the optimization of their system was continuous. What we can say is that they improved the backend and frontend software with several functions over the years. They also improved the hardware (electronic parts, dosing aggregates, feed bodies, cabling and so on). One of the main things they stumbled upon was that ISO-based (International Standards Organization) transponders were used to equip the cows in a certain deployment site. That caused interference with the signals form the electronic ear tags. UC 2.6 was not able to solve this issue, but apart from that they were able to find a solution for all the other problems they faced. In summary, it can be said that their entire system has been upgraded and that they found a whole list of points for improvement by testing during the UC. On top of that, testing in several countries turned out to be an added value in the development process due to the different systems that each country uses.

UC 2.7 - Multi-Sensor Cow Monitoring developed a rumen bolus to monitor the health and fertility status of the cows. They started from a TRL6-technology, a prototype, which they installed and tested on several test farms. In their first iteration, they increased the lifespan of the device as well as the communication range. In the second iteration they redesigned the antenna so their device has a better coverage and they also fixed some firmware related errors. In general, they continuously developed their product according to the farmers' feedback. After two iterations and nearly two years, their final product, called Moonsyst Smart Rumen Monitoring System for Dairy and Beef Cattle, is almost market-ready. At the time they submitted their final progress report, they were still working on the CE-approval.

3.1.3. TRIAL 3: FRUIT

The Fruit Trial consists of six use cases (four initial UCs and two open call UCs).

UC 3.1 – Fresh Table Grapes Chain has the following final products: Low-cost sensors, BLOW device, Cellular data-logger and SynField ecosystem. Low-cost sensors were equipped with a unique QR code allowing registration and management of all the nodes via the mobile application. The QR code is used to easily access the entire dataset of the specific node. The two applications have been finalized and deployed to the final users. Implementation of BLOW device - prolongation of the shelf life of the fresh table grapes through the use of an IoT solution (BLOW label) was achieved. The shelf life of table grapes was achieved through 4 years of testing within the project and better use of the device year by year through the improvement of the labelling, use of adequate machines, etc. SynField ecosystem - At the beginning of the project the SynField solution was at a prototype state. The second version of the device was produced, the basic firmware was developed, and the portal was fully functional but with a lot of shortcomings. Some basic sensors were only supported. A mature, robust, cellular data-logger family with control support is a user-friendly portal with enhanced functionality. Mobile applications for simplified, user friendly operations and for in-site configuration and maintenance went through three iterations allowing support of more sensors and support for control (valves, relays). In addition more features and an Android application for devices configuration and diagnostics were developed.

UC 3.2 - Big Wine Optimization has three products: Remote Wine Analysis, Wine Shipping Monitoring (including wine shelf-life indicator) and Process2Wine - IoT Module. Process2Wine IoT Module became a platform with IoT capabilities, further leading to an independent platform to monitor the winery. A new module will be added to the final version of the "Platform for wineries management" to check if there are no missing data and send alerts if this is the case. Remote vine analysis - ISVEA laboratory and analytical services experience with the idea to develop and fill a market gap. This had three iterations – performing tests with VIS-NIR SPECTROMETER were low cost and were handy for users. Further, experiments with a Fourier-transform infrared spectroscopy (FTIR) spectrophotometer were preformed, the hardware was adapted in order to be able to interact with the cloud and the calibration curves. The final product FTIR spectrophotometer and a platform to simplify wine analysis and reduce its times and costs is a market ready model. Wine shipping monitoring – started with ISVEA laboratory and analytical services experience and Vinidea experience of the exporting wineries needs and ideas to develop and fill a market gap. End of application software development and Jodyn prototype tested in real shipments allowed prompt detection of accidents during shipments, identification of responsible causes of damages and information on logistic and behavior of the distributors. Jodyn prototype beta versions were tested in real shipments and finally lead to a final product Jodyn for wine shipping with prolonged battery lifetime.

UC 3.3 - Automated Olive Chain SynField ecosystem is composed of three products: Olive Production Manager, Olive Oil Quality Manager and traceability, all market ready as of January 2021. At the beginning of the project the SynField, production manager and Olive Oil quality manager solutions were at a prototype state. The second version of devices and software were produced afterwards, the basic firmware was developed, and the portal was fully functional but with a lot of shortcomings. Some basic sensors were only supported. New enclosure and connector systems were added, more sensors supported and also support for control (valves, relays), following more features, an Android application for devices configuration and diagnostics were developed. Firmware and portal debugging was done based on the feedback from farmers and olive mills masters. Finally, total revamp of the portal was conducted, and updated connector system and encryption support resulted in a final product - a mature, robust, cellular data-logger family with control support. A user-friendly portal with enhanced functionality was developed with mobile applications for simplified, user-friendly operations and for in-site configuration and maintenance.

UC 3.4 – Intelligent Fruit Logistics worked with location management, tracker geolocation and temperature measurement. A prototype IoT Tracker for Geolocation & Temperature was custom built and improved in the UC. From the third prototype version, all preliminary requirements of UC3.4 were fulfilled, the previous prototypes were not yet custom-built but were of the shelf ones used for testing. The fourth prototype version included additional functionalities (NFC, energy budgeting) compared to the previous version. Some change requests (motion-based geolocation info) from UC owners were also incorporated. The final prototype 5 IoT tracker was made in M40. Also a final Location Management application prototype was built, ready for daily operational use by EPS (EuroPool System) and ready for integration with other applications in EPS's IT landscape. Before the start of IoF2020, the tracking of RTI (Returnable Transport Item) movements was limited mainly to using scanning technology at defined places in the value chain that are getting in contact with the RTIs, e.g. EPS's depots. A location management application was not yet required, as the RTIs were only registered/scanned in known locations. The need for the location management application emerged due to the new IoT-enabled RTIs developed in the scope of IoF2020. The first MVP of the Location Management application (developed by ATB) was followed by extended and improved prototypes of the Location Management application, resulting in the stable final application in operational use by EPS. Similarly, the need for a Temperature Management application emerged due to the new IoT-enabled RTIs developed in the scope of IoF2020.

After focusing mainly on location data from IoT-enabled RTIs in the previous project phases, this application based on temperature data was developed in the final phase of the project. This software is a prototype for EPS-internal use and validation. Plans for future extension of this application after the end of IoF2020 have been discussed and refined, aiming to increase the usability of the application and to offer functionalities directly to EPS's customers. One main challenge discussed in this area was the need to separate the data per rotation, as on each rotation of a smart tray a different customer can use it, and each customer/stakeholder should only see the data gathered by the tray during the respective rotation.

UC 3.5 – Smart Orchard Spray Application is a UC that lasted for two years. Third Party API data interfaces and agronomic input savings have been validated in 3 countries under real world conditions. Cyber physical system with cloud connected sprayers and tractors with the capability to organize field jobs and monitor their outcome online with GUI access was the starting product. Mainly usability aspects of the system where improved, as the main concern that users could intuitively use the system without too long waiting times for data refresh. Partial treatments working in field zones were possible following API Interfaces with John Deere's Operation Center and Hispatec's FMIS following the final product development. Improved Specialty Crop Gateway, improved Sprayer Control System and improved Specialty Crop Platform are market ready. SCG is sold as a retrofit to be installed on any Specialty Crops Tractor. SCS is sold as part of FEDE's and John Deere's high end specialty crops sprayers, and subscriptions to the SCP are marketed under Software as a Service business model with first paid subscriptions coming in under a paid plan.

UC 3.6 – Beverage Integrity Tracking is an open call use case, so the total duration of this project was two years instead of four. The development of product Wenda started with the availability of a version of the Web platform, a mobile app and an IOT device, developed by Wenda since 2015 and made available for the Use Case 3.2 for what concerns the hardware device and the data collection platform. In particular, the APP has been developed to be used by users in cases where they need to interact with IOT devices that do not include Real Time communication. Solution for the traceability of shipments of wine bottle boxes monitored in temperature through the use of IOT devices started as a Proprietary hardware device with several integrated sensors, and modem based communication. Firmware on the device for direct connection to a server application through Socket protocol was developed, as well as a WEB application platform with MySQL database with functions representing the main processes of the Supply Chain of a potential customer. Display of RAW DATA in tabular and graphical form on dashboards for geo-localization and alarm thresholds were provided. Further developments lead to a Web Platform and section for wine shipment traceability and MVP 1 Availability of the integrated IOT system - Web platform, Mobile APP, IOT BT Verigo POD Device, MVP 2 Availability of the integrated IOT system after 1 TEST BED - Web platform, Mobile APP, IOT BT Verigo POD Device and resulting in the final solution for the traceability of shipments of wine bottle boxes monitored in temperature through the use of IOT devices.

3.1.4. TRIAL 4: VEGETABLES

The Vegetables Trial consists of five use cases (four initial UCs and one open call UC).

UC 4.1 – City Farming Leafy Vegetables developed a dynamic lighting control system (GrowWise Control System), a Sensor platform and a Growth monitoring and dashboard application (GrowView). A first implementation of a lighting control system - At first implementation of a sensor communicating with a gateway via the LoRa protocol was conducted, followed by implementation of a data backend to store the sensor data and a possibility to visualize the sensor readings. Improvements were made in the areas of functionality, reliability, and data security allowing testing of early prototypes in the city farm environment of prospective customers and enabling refining of the MVP. Finally resulting in products that perform well and are well received by customers: IoT sensor, data and control platform for city farms. The sensor platform is used to monitor the performance of the city farm. A dashboard and monitoring application provides insights to the operator of the city farm. The dynamic lighting control system provides optimal lighting conditions to the crop at all times, in an energy efficient manner. The dynamic lighting control system is on the market while the IoT sensor and data platform are not yet on the market (pending a decision).

UC 4.2 – Chain-Integrated Greenhouse Production worked with greenhouse data integration and modeling as a service system. The start product was a set of models designed by the University of Almería as a result of different R&D projects. Installation of FIWARE IoT service, including Context-Broker, Cygnus and IoTAgent on a server located at the University of Almeria in the Data Processing Centre to integrate all the data generated in a greenhouse. Design of a UI based on NodeJS for greenhouse monitoring followed by Inclusion of the models, the Greenhouse Model as a Service (GMaaS) component to help growers in the day-to-day decisions as a result of a co-design approach. All of this resulted in redesigned user interface including all new features and improvement of graphical analysis including all the user's requests. The product needs more testing at the deployment sites to be prepared for the market, as we want to avoid users losing trust as is happening with other technological solutions. This final testing would take one or two seasons, but it is practically ready for that.

UC 4.3 - Added Value Weeding Data worked with Smart Intra-row weeding device, lettuce growth model and farm maps crop map application. Steketee IC Weeder is a commercially available weeding device with camera technology enabling in-row weeding and reducing labor requirements compared to hand weeding. Setting up an IOT system to connect data sources enabled the possibility to remotely access the machine while developed algorithms will enable the farmer and manufacturer to optimize the machine settings. Further, logging functionality of images was added on an additional laptop including machine settings and GPS coordinates. Calculations of plant parameters were improved enhancing better information for the user while Visualization of field data allowed the possibility to connect, and upload logged data automatically with the FMIS. Data can be visualized and used for the growth model. Finally logging functionality of images on the machine itself was improved leading to a final product

Smart Steketee IC Weeder with added value data. The Crop map application is operational on Farmmaps. Expected launch is early 2021. The product will be hosted on Farmmaps and distributed by Steketee. First target market will be the Netherlands, other EU countries will be added during 2021. Lettuce Growth Model was adapted to be able to handle crop parameters from Steketee IC Weeder and to output expected harvest date and growth indication parameter. After fine-tuning the model on reference data for Butterhead Lettuce and on reference data for Iceberg Lettuce, the harvest prediction tool based on IOT data was finalized and expected launch to market is during 2021. Within Farmmaps application the data infrastructure was adapted to handle and process plant parameters from the Steketee IC Weeder. Crop parameters log files as heat map were visualized as heat maps on a satellite image and followed by improved functionality for handling large dataset files. The final product Farmmaps crop map application is operational on Farmmaps. The launch is expected in early 2021. The product will be hosted on Farmmaps and distributed by Steketee. First target market will be the Netherlands, other EU countries will be added during 2021.

UC 4.4 – Enhanced Quality Certification System developed a set of Cellar and Vineyard software allowing the client based personalization. The paper based audit was the starting point, while the first version of the Audit tool for cellar was performed allowing Integration of cellar sensors, use of augmented reality and easy handling limited to the cellar. The second version of the Audit tool for cellar was released followed by first version of the audit tool for vineyard allowing access of data online, access to GIS functions and therefore access to different sources of data. With the final product, there was no further need to use paper based auditing. eWineMaking is a spinoff of eAudit product. Investigation was performed on the possibility to develop a product for wine makers using real winemaking conditions. Cost of the solutions were too high compared to the given benefit and the product needs more tests to reach the market.

UC 4.5 - Digital Ecosystem Utilisation is the only open call UC within the vegetables trial. QUHOMA was FINT's solution for Quality Horticulture Marketplace and mainly targeted farmers through networked sensors and actuators that optimize remote monitoring of the farm. QUHOMA was a vertical application of the backbone IoT platform that FINT has been building since 2014, FINoT. Parts of QUHOMA like the User Interface, backend tools and hardware devices could be updated after customers' feedback and competition evolution. IoF2020 provided the area to perform these upgrades due to i) the good number of test sites and variations in field conditions (18 pilots in two different countries with diverse climatic conditions) and ii) available and interoperable tools. The platform-level was upgrades with the integration of QuantuLeap and other FIWARE tools, advanced Identity Manager and Complex Event Processor. Better mechanical design and assembly for FINoT node and a bigger PV panel allowed coverage of northern territories and a 6LoWPAN/LoRa Gateway (e.g. Slovenian pilots). Off-grid irrigation controller was further offered and a new sensors' suite (weather station). New user interface was created for mobile viewing and a native (android) app that providing more features presentable to the WebApp. All this lead to QUHOMA being a modern solution on the market, covering the basic needs of the farmer in terms of farm's remote monitoring and inputs' reduction and paves the way for extended collaboration with farmers' stakeholders.

3.1.5. TRIAL 5: MEAT

The Meat Trial consists of six use cases (three initial UCs and three open call UCs).

UC 5.1 - Pig Farm Management developed two dashboards for pig farmers, a group level / business intelligence dashboard and an individual level dashboard. For the development of the group level dashboard, they started from a demo dashboard based on a solution for poultry. The ability to be flexible with the implementation of the data visualization and the possibility to provide extra functionalities was a real advantage. However, several differences between the management of pigs and poultry exist and the data differs as well – and is much more numerous in size. In the first iteration cycle they focussed on the data, which required integrations with the systems present on farm: the UC contacted all these external parties, made specific pieces of software for the secure data exchanges, gained experience with it, identified missing info and did a base implementation of the early warning algorithms developed on the first data collected. MVP 1 included all visualisations and data exchange, while MVP2 included the live alerts of the warning systems and some additional features the farmers requested. The product is not on the market yet as extra development and testing needs to be done. UC 5.1 also worked on an individual level dashboard, on which they started roughly from scratch. In a first iteration (year 1), alerts for all pigs were made available for both drinking data and feeding data. Those alerts were based on fixed alert levels and not yet on individual alert levels. In the second iteration (year 2), the UC developed a manually initialized dashboard, MVP1, and they created warnings by e-mail for the caretakers of the pigs with individual alert levels. In the third iteration they reached MVP2, a redesigned automated dashboard. The developments they did in this iteration cycle are numerous, e.g. a general page with group level data was added, the possibility to have multiple accounts was created and a section that shows the technical status of sensors was included. In month 45 of the project, they developed an updated version of the MVP, a prototype, for the individual level dashboard. The possibility to include feedback on alerts in the dashboard was added, the alert algorithms were updated, bugs were fixed and the feature to automatically check the status of the sensors was added. This product is at prototype stage.

UC 5.2 - Poultry Chain Management has made a distinction between the products they provided iteration cycles for (separate products developed by different partners) and the products they discussed in the business tables of the final report (services for users based on combinations of those products). In this section, we will refer to the reported iteration cycles. The first product is the environmental wireless sensors. The starting version had many attention points yet to be tackled (e.g. optimization of the size and shape) to be valuable for this UC. By the end of the project, they developed IoT ready environmental wireless sensors both for farms and for transport. The sensor product was redesigned to be smaller and measurements of acceleration, CO_2 and ammonia were added, besides temperature, luminosity and humidity already present. A third party is needed to commercialize it and to launch this product to the market. The second product UC 5.2 worked on, are the Exafan Dynamic Scales. In the first iteration (two years), the UC made it possible to upload data to the cloud and to connect devices without a cable, so remote data transfer and use of a battery. The dynamic scales were developed during the second iteration and prototypes were installed in a farm (in year 3). UC 5.2 did a third iteration cycle in the last year of the project to improve the wireless communication and the mechanical design (making it easier for the poultry to get on the scale). Their final product 'Chicken Wireless Scales' is on the market. A third product the UC worked on is the Porphyrio® dashboard. When IoF2020 started, there already was a first commercial product active in the market. The functionalities were however improved. In the first iteration cycle, the UC focussed on the data collection and the creation of the dashboard structure for each farm, making it possible for the end-users to, for example, access their data and to compare the performance of the flocks. In the second iteration cycle, the UC optimized the dashboard and activated the long-term prediction and early warning systems. When the UC reached their final product they noticed that the end-users didn't open and close the flocks properly. The UC invested on training the end-users so they can use the dashboard and all its functionalities. A fourth product this UC worked on is called PUMA (a smart poultry chain management tool). There was no initial product at the beginning, so in the first 2.5 year of the project, the UC worked on the first iteration cycle in which they collected the data from multiple sources and developed this tool. The solution is linked to an IoT platform, which allows managing the information of each stage and support decision making through computational algorithms. Their second iteration cycle lasted for about 1.5 year, extra functionalities were added to visualize early warning and anomalous behaviours during farm- and transport phases to guarantee the comfort and health of the birds. The final version of PUMA is not market-ready yet, since it needs further improvement. The fifth product UC 5.2 worked on is called IOF Farm Predictor. It visualizes the measurements regarding the environment for the animals. At the start of the project, a preliminary version with basic functionalities was available. The UC did not report different iteration cycles for this product. In their final version of the product the early warnings were categorized according to their impact on the poultry welfare, making it easier for the end-user to identify an undesirable situation (and its level of severity) on the farm. The IOF farm predictor would still need further improvements regarding the stability and reliability.

UC 5.3 - Meat Transparency and Traceability worked on two products. The Oliot Gateway is one of them but will not be discussed in this section because the product was developed by KAIST, with the support of UC5.3 and 5.1. The Proactive Auditing Dashboard is the other product UC 5.3 developed themselves. They started without (interested) stakeholders and without an application scenario for transparency, which was a big challenge. After one year they found an application scenario, namely proactive auditing, and interested stakeholders. From there on, UC 5.3 had a business case and a scalable solution because of the use of a global standard (EPICS). This was great news, but attention had to be paid to explain the stakeholders how this new approach works and they need to keep an eye on stakeholders who wanted to regress to their old methods. Starting in year two, the second iteration cycle took place. In this stage, UC 5.3 convinced committed stakeholders to proactive auditing and they had access to data from limited actors. A mock-up for dashboard was created. In the last year of the project, the UC started iteration cycle three. A positive outcome of the UC is that they had successful collaborations with other UCs (e.g. 5.1) and WP3 of IoF2020 to build a FIWARE component (the Oliot gateway). At the end of the project, they succeeded in having a proactive auditing dashboard, the Oliot Gateway, Proactive auditing practices and a meat transparency data model. Only minor improvements were needed for this final iteration. The product is ready to go to the market. Stakeholders of this UC have chosen to build their own dashboard, which shows their commitment to the solution. UC 5.3 thus promoted transparency and traceability in the meat sector.

UC 5.4 - Decision-Making Optimization in Beef Supply Chain developed five different products. The first one is the 'Crop Monitoring Service', a meteorological station. They started with an already existing solution with several functionalities (e.g. farm monitoring and alert zones). The main attention point however was that this solution did not include a Decision Support System (DSS) yet. They worked more than three years on their first iteration to develop a DSS functionality to turn data into advice for the farmers. In the fourth year of the project, their product is market ready. A second product this UC worked on is the 'Animal Location and Monitoring Service' that is a neck-mounted collar for cattle. The challenges of UC 5.4 were to improve its functionalities, to reduce the cost per animal and to improve the coverage in rural areas. They introduced a new IoT device that allows monitoring of other livestock animals at a lower cost. They also improved algorithms and decisions-making tools for detecting reproductive events. This solution was included in a Plug & Play antenna, capable of generating coverage in a larger radius. The product is market-ready, although continuous improvement of the connectivity possibilities remains important. The third developed product is the 'Animal Weighing and Monitoring Service'. They started with the development in the second year of the projects' running time. Their start product was a device that was robust, user-friendly and that could monitor the animals' individual weight. Improvements regarding different aspects were made, e.g. reducing the cost of the solution, improving the hardware and improve the estimation of weight and growth of the cattle. This results in a final, market-ready product. A fourth developed product is the 'Data Exchange for Decision Making Service'. There is no iteration cycle for this product, since the start and end product are the same. It's a platform for the registration of events related to the beef production cycle "From Farm To Fork". This is ready to get early adopters. The fifth product is the 'Grazing and Welfare Certification Service'. There is also no iteration cycle as this development started in the last month of the project. Reports regarding well-being and certain certifications can be generated (e.g. origin and pasture) due to the large amount of acquired data. This tool does not require user intervention and thanks to the block-chain platform, the security of the data is secured. The 'Grazing and Welfare Certification Service' is not market-ready yet, because it's an MVP product and it requires further testing and the business value still needs to be confirmed.

UC 5.5 - Feed Supply Chain Management worked on their volumetric sensor, called the Insylo device, and the 'Smart Monitoring Platform'. UC 5.5 also reported the Smart Logistics Platform solution in their MVP-tables, but since the iteration cycle for this product is not available it will not be discussed here. They had a starting product for the Insylo device, but there were quite some things that needed further development like the solar efficiency that needed to be tested, the accuracy of the device and the camera sensitivity in large silos. Two iteration cycles were finished in two years' time. Energy efficiency, a new casing with better isolation and improved software were tackled amongst others. The second product UC 5.5 worked on during IoF2020 is the 'Smart Monitoring Platform'. User requirements were tackled to improve the use of data and improved algorithms. In their final product they developed new visuals with recipes assigned to the silo and also a configuration system for various parameters and a cloud data download. This product is ready to go to the market.

UC 5.6 - Interoperable Pig Health Tracking worked on three solutions within the IoF2020 project. The first one is the Smart Spot Gateway. They started from a device for use in smart cities, it could monitor the air quality and the environmental conditions. An update for on-farm gas measurements (NH_3, CO_3 and dust particles) was made, together with an update for ear tag collection via Bluetooth. This product is market-ready, but UC 5.6 is waiting on improvements in the ear-tags since it will be sold as a joint product. The second product UC 5.6 developed is the 'Ear Tag'. The starting product was a device for human use (wrist band or ear plug). One of their challenges was that the form of the devices was not designed for animals, as well in terms of fitting as in terms of solidity (pigs bite their devices). They also had to pay attention to the reduced autonomy (recharging the device). In the first iteration cycle, which took 6 months, they focussed on the autonomy of the battery and the housing of the device to resist pig bites. At the end of the running time of the UC, they made an IoT Heart Rate monitoring device embedded into an ear tag for pigs. This device needs further work for commercial practice but can be used for scientific research. UC 5.6 also worked on a functional app. They started with an app mock-up which had a quick design to validate functionalities and finished with a fully functional application in which the farmer can see the status of the animals and the information of the sensors (the other two products).

3.2. LESSONS LEARNED

Overview

Each UC provided a list of lessons learned on the technical level. To make it easier to analyse the text, they could select from predefined categories that relate to a certain technical challenge and then write an explanation together with it. These categories are the same as in D2.6. The number of times a certain category is chosen across all use cases and per trial has been analysed. For this deliverable, two tables were made. Table 2 shows the number of UCs that selected a certain category of the lessons learned in terms of technical issues. Per trial, the number of UCs (initial, open call and total) that encountered these categories are displayed. Table 3 on the other hand shows the total number of occurrences of a certain category of lessons learned (one use case could select the same category multiple times). In this table, the number of times a certain category was reported by the UCs is represented per trial (initial, open call and total).

In the previous technical improvements deliverable (D 2.6), a table displaying the different categories of the lessons learned in relation to the number of use cases that have encountered these specific categories was also added. Unfortunately, it's not possible to compare that table with the new gathered information in order to make this deliverable. Now all 33 UCs have to be included, both initial and open call UCs. In the previous report, only the results of the initial UCs were taken into account. Besides that, the way that the information was gathered differs as well. In D 2.6 the information was gathered through various channels (for example questions that were asked to the UCs and information gathered on the stakeholder event in Prague) and the information was put into categories by WP2. For this deliverable, WP2 created a template that was included in a specific section in the final progress report of each individual UC. Therefore, every UC had to complete it and select the applicable categories themselves. There are 19 initial UCs with a running time of four years and there are 14 open call UCs with a running time of two years. This makes the comparison even more difficult.

Therefore, the decision was made not to compare the table displayed in this report and the table in D 2.6, but to consider it as two different tables. In essence, the results and the lessons learned from D 2.6 are still valid however. Also, the categories seem very appropriate as only seven UCs (for 12 occurrences) used the category 'Other'. This category was also used to categorize a lessons learnt which was not categorized by the UC itself. One of the things that can be seen in Table 2 is that there are some categories where more than 25% of all UCs (meaning more than eight UCs per category) reported the same lessons learned. The categories that occur in that 25% and more of the UCs will be further discussed in this deliverable. The total amount of times the unique lessons learnt categories are chosen by the UCs is 142. The distribution of the amount of UCs that reported a lessons learnt category is relatively seen approximately equal between initial UCs and open call UCs.

Table 2: Overview of the different categories of lessons learned in relation to the number of UCs that encountered a specific category.

	Initial	Open Call	Trial 1 Total	Initial	Open Call	Trial 2 Total	Initial	Open Call	Trial 3 Total	Initial	Open Call	Trial 4 Total	Initial	Open Call	Trial 5 Total	Total (all trials)
Additional Alerts	0	0	0	1	0	1	1	0	1	0	0	0	1	0	1	3
Additional Features	2	1	3	2	2	4	1	0	1	1	0	1	3	1	4	13
Calamities	1	0	1	0	0	0	0	1	1	2	0	2	0	1	1	5
Dashboard user interface	2	2	4	2	1	3	3	1	4	3	1	4	0	1	1	16
Data file formatting	1	0	1	0	0	0	0	0	0	1	0	1	0	0	0	2
Data loss	0	3	3	0	1	1	1	0	1	1	0	1	1	1	2	8
Data processing	1	1	2	3	0	3	2	0	2	2	1	3	0	1	1	11
Efficient Power Management	0	0	0	1	1	2	2	0	2	1	0	1	0	1	1	6
Hardware design/placement	0	2	2	1	1	2	2	0	2	0	1	1	1	1	2	9
Interoperability	3	3	6	0	0	0	1	0	1	1	0	1	2	1	3	11
Network Communication	3	1	4	3	1	4	3	1	4	1	1	2	1	1	2	16
Prediction algorithms	0	0	0	0	2	2	0	0	0	0	1	1	0	1	1	4
Quality of data	0	1	1	2	1	3	0	0	0	1	0	1	1	2	3	8
Sensor accuracy/calibration	2	1	3	0	0	0	1	0	1	3	0	3	0	1	1	8
Sensor Placement	2	3	5	1	0	1	2	0	2	2	0	2	0	2	2	12
Standardization	1	0	1	1	0	1	0	0	0	1	0	1	0	0	0	3
Other	0	1	1	0	2	2	0	1	1	1	0	1	0	2	2	7
	18	19	37	17	12	29	19	4	23	21	5	26	10	17	27	142

Total Initial	85
Total Open Call	57

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Table 3: Overview of the different categories of lessons learned in relation to the number of times the UCs reported that specific category.

	Initial	Open Call	Trial 1 Total	Initial	Open Call	Trial 2 Total	Initial	Open Call	Trial 3 Total	Initial	Open Call	Trial 4 Total	Initial	Open Call	Trial 5 Total	Total (all trials)
Additional Alerts	0	0	**0**	1	0	**1**	1	0	**1**	0	0	**0**	1	0	**1**	**3**
Additional Features	2	1	**3**	2	2	**4**	1	0	**1**	1	0	**1**	3	1	**4**	**13**
Calamities	1	0	**1**	0	0	**0**	0	1	**1**	2	0	**2**	0	1	**1**	**5**
Dashboard user interface	2	2	**4**	2	1	**3**	3	1	**4**	5	1	**6**	0	1	**1**	**18**
Data file formatting	1	0	**1**	0	0	**0**	0	0	**0**	1	0	**1**	0	0	**0**	**2**
Data loss	0	3	**3**	0	1	**1**	1	0	**1**	1	0	**1**	1	1	**2**	**8**
Data processing	1	1	**2**	3	0	**3**	3	0	**3**	2	1	**3**	0	1	**1**	**12**
Efficient Power Management	0	0	**0**	1	1	**2**	2	0	**2**	1	0	**1**	0	1	**1**	**6**
Hardware design/placement	0	3	**3**	1	1	**2**	4	0	**4**	0	1	**1**	1	1	**2**	**12**
Interoperability	5	3	**8**	0	0	**0**	1	0	**1**	1	0	**1**	2	1	**3**	**13**
Network Communication	3	1	**4**	3	1	**4**	4	1	**5**	2	1	**3**	1	1	**2**	**18**
Prediction algorithms	0	0	**0**	0	2	**2**	0	0	**0**	0	1	**1**	0	1	**1**	**4**
Quality of data	0	2	**2**	3	1	**4**	0	0	**0**	1	0	**1**	1	2	**3**	**10**
Sensor accuracy/calibration	2	2	**4**	0	0	**0**	1	0	**1**	3	0	**3**	0	1	**1**	**9**
Sensor Placement	3	3	**6**	1	0	**1**	4	0	**4**	4	0	**4**	0	2	**2**	**17**
Standardization	1	0	**1**	1	0	**1**	0	0	**0**	1	0	**1**	0	0	**0**	**3**
Other	0	1	**1**	0	2	**2**	0	3	**3**	3	0	**3**	0	3	**3**	**12**
	21	22	**43**	18	12	**30**	25	6	**31**	28	5	**33**	10	18	**28**	**165**

Total Initial	102
Total Open Call	63

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As in table 2, table 3 also shows the numbers of the initial UCs and the open call UCs separately, followed by a column that sums up these numbers. Several UCs reported the same category multiple times (see Annex 1), but the content of that lessons learned category refers to another aspect. For example the category 'sensor placement' has been reported three times for a single vegetable trial use case. One of those lessons is about the problems of the presence of the wires, another is about the adaptation of vats to new sensors and the last one is about miniaturization. So it's possible that a category can occur more than once in a single UC. Based on the numbers reported in table 3, it can be said that there are 5 reported lessons learnt per UC on average. The average number of reported lessons learnt of the initial UCs is 5.37, while the average number of reported lessons learnt of the open call UCs is 4.5. A possible explanation for this is that the duration of the open call UCs was two years, whereas the duration of the initial UCs was four years. There is no difference in TRLs at the start of the project between the developed solutions by the open call UCs and initial UCs.

Table 2 and table 3 show no obvious differences between open call UCs and initial UCs. This can be explained because many of the issues occur in most product development cycles. The challenges that everyone has to go through are more or less alike, but at the same time very different due to the uniqueness of the product. It's possible that a UC is aware that a certain problem might come up, based on the experience of other UCs, but that doesn't mean that the UC already has a solution for this issue or that they can just copy it from the other UCs. Every UC is unique and so are the (sub-)products and solutions they develop. For example, another type of transfer, another dataset or even confidentiality can make sure that a lessons learnt category can return in a development cycle of various UCs.

When a comparison is made between table 2 and table 3, it's clear that the categories that include the highest total amount of UCs (> 25% of the UCs) are the same as the categories that include the most times it has been reported (> 12 times). This results in 7 remaining categories that will be further discussed in detail. The only category that has been left out of the detailed discussion that also occurred 12 times, is the category 'other'. 'Other' is a residual category, meaning that issues that couldn't be linked to a predetermined category are placed in the category 'other'. There are also different reasons why a lesson learned is placed under this category, like in UCs that have not selected a category. The information in the pie-charts below is based on table 3 and covers all 33 UCs.

Another striking conclusion that can be drawn from these tables is that there are three lessons learned categories that can be considered as the most important (Dashboard User Interface, Network Communication and Sensor Placement). They appear in the top five of the total number of UCs that encountered a particular category, as well as in the initial and open call UCs separately. On top of that, they are also in the top five of the total number of times a category occurred in total, as well as the initial and open call UCs separately. We can thus conclude that these issues are coming back in the majority of IoT developments, regardless of the specific UC.

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Dashboard user interface

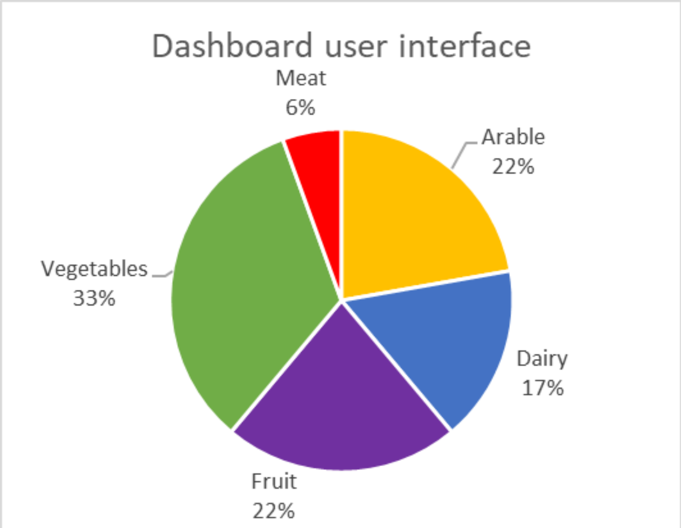

Figure 3: The number of times the lessons learned category 'Dashboard User Interface' across the trials has been reported (n = 18), displayed in a pie chart based on the percentage distribution.

This lesson learned occurred in 16 UCs and was reported 18 times. The distribution of the number of times (in percentage) this has been reported per trial is shown in figure 3. Although all UCs are in one way or another working with and/or developing dashboards (e.g. vender dashboards, user interfaces, web applications, mobile apps, DSS, etc.) , the vegetable trial reported most lessons learned regarding the dashboard user interface. This lesson learned can also be found in the fruit, arable and dairy trial and to lesser extent in the meat trial. The content of this category mostly refers to the importance of the user friendliness of the dashboard. In several cases, multiple iterations were needed to come to a final version of the dashboard that represents the data in a clear way and that makes it easy for the end-user to navigate through different features. Limiting the showed information according to the needs of the end-users seemed to be a stumbling block that popped up several times within the UCs. End-users' feedback is crucial in the development of a dashboard user interface, since they're the ones that will be using it on a daily basis.

Network Communication

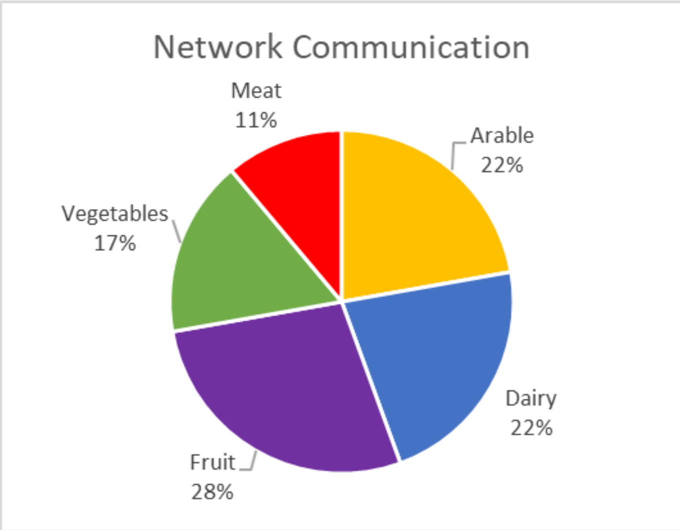

Figure 4: The number of times the lessons learned category 'Network Communication' across the trials has been reported (n = 18), displayed in a pie chart based on the percentage distribution.

The category of technical lessons learned regarding Network Communication occurred in 16 UCs and has been reported 18 times. The distribution of the number of times (in percentage) this lesson learned has been reported per trial is shown in figure 4. The fruit trial reported the most lessons learned regarding the network communication, but it's close to the dairy and arable trial as well. The vegetable trial also reported some lessons learned on this topic and the meat trial represents the smallest part of the lessons learned regarding the network communication. An aspect that comes up in several reports of the UCs is the problem with the data transfer efficiency (e.g. there is no real optimal solution for long range and high data rate communication or image transfer takes a lot of energy). Some UCs suggest that the use of 5G could possibly be a solution for their data transfer issues. A stable internet connection is also a huge problem in several UCs, especially within buildings due to the presence of metal and concrete and also when testbeds are located on a remote location. The coverage of certain antennas is also a challenge. Some UCs placed extra antennas or gateways to address this problem, while other UCs worked on improving their already existing antenna.

Additional Features

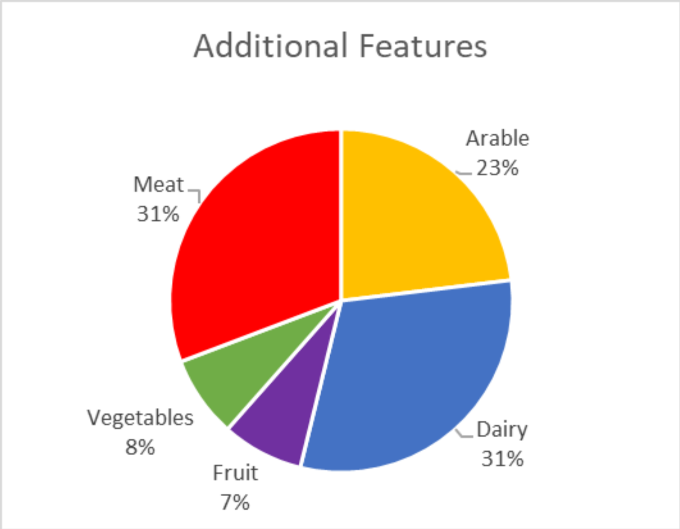

Figure 5: The number of times the lessons learned category 'Additional Features' across the trials has been reported (n = 13), displayed in a pie chart based on the percentage distribution.

Lessons learned regarding Additional Features occurred in 13 UCs and were also reported 13 times. The distribution of the number of times (in percentage) this has been reported per trial is shown in figure 5. Both the meat and dairy trial reported most lessons learned regarding the additional features, followed by the arable trial. Both the fruit and vegetables trial only reported one lesson learned regarding this topic. Because an important aspect of the IoF2020 project is developing solutions through different MVP cycles that are based on the needs, feedback and inputs from the end-users, the UCs got a lot of requests to add additional features to their devices. Several UCs report that they might develop additional features for their solution, even after the end of IoF2020. There are several reasons for these continuing developments. Some UCs reported that working with farmers revealed some needed additional functions or they reported that the information provided by IoT devices can be used in many ways, making it possible to develop additional features. Thanks to the information provided by IoT devices and related analysis for example with deep learning, there is a huge potential in continuing these developments. Some features add value, while others are absolutely necessary to improve the ROI of the solution. A couple of examples of additional features are a crop model for irrigation, using the solution for other plants/animals or type of product (e.g. milk powder in addition to raw milk) and a fermentation sensor.

Sensor Placement

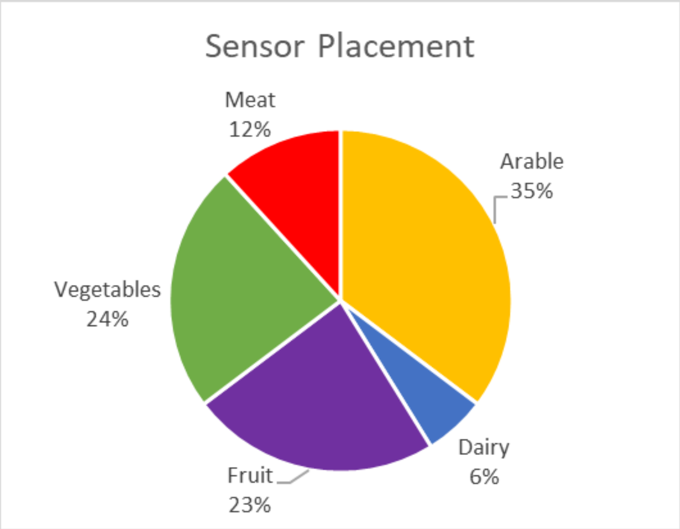

Figure 6: The number of times the lessons learned category 'Sensor Placement' across the trials has been reported (n = 17), displayed in a pie chart based on the percentage distribution.

The lesson learned regarding the sensor placement occurred in 12 UCs and was reported 17 times. The distribution of the number of times (in percentage) this has been reported per trial is shown in figure 6. The arable trial reported most lessons learned regarding the sensor placement, followed by the fruit and vegetables trial. The meat and dairy UCs only reported respectively two and one lesson learned regarding the sensor placement. It can be noticed that in several trials (e.g. dairy and arable) the importance of a user manual for end-users to avoid incorrect placement of the sensors is reported. Also the exact location where the sensors must be placed should be considered carefully. Sensor placement is very broad and can vary from the placement on the animal (through an ear-tag, a leg-mounted sensor, a collar or even inside the animal), to the location on a crop field (e.g. if the solution is solar-based, one must consider plant growth so that the solar panel won't be covered in shade) and even inside a silo (not all silos have the same size and are manufactured from the same material). In addition, the sensors need to be designed in such a way that they can function in harsh agricultural conditions because the difference between a controlled testing environment and the real-life farm environment is very different.

Data Processing

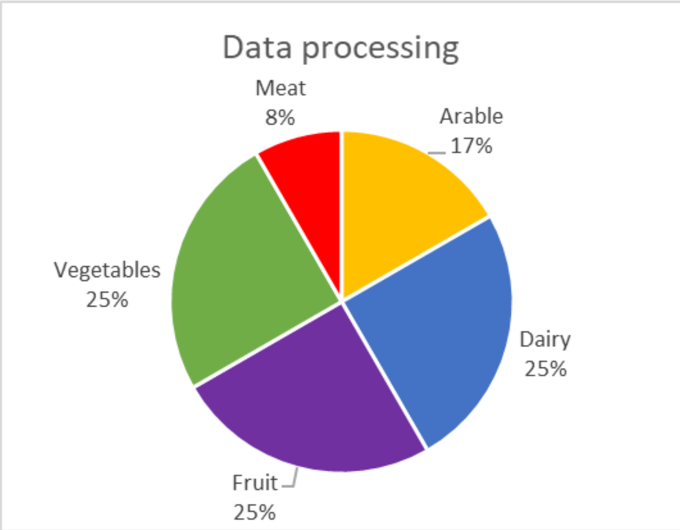

Figure 7: The number of times the lessons learned category 'Data Processing'' across the trials has been reported (n = 12), displayed in a pie chart based on the percentage distribution.

The 'Data Processing' lessons learned occurred in 11 UCs and were reported 12 times. The distribution of the number of times (in percentage) this has been reported per trial is shown in figure 7. All three trials, vegetables, fruit and dairy reported most lessons learned regarding data processing, followed by the arable trial and to lesser extent the meat trial. The amount of data some UCs collected often resulted in time-consuming data-processing. Filtering the input data and only processing the actual data was a possible solution. It also helped to move the processing to the cloud infrastructure. In this way, the processing could happen more rapidly. Also, the collected data must be easily readable for the farmer and it must generate several alerts to help the farmer to make quick decisions (e.g. health alerts for animals and drought warnings for crop fields). Thanks to the collection and processing of the data, algorithms could be developed and improved, resulting in a more stable and reliable solution.

Interoperability

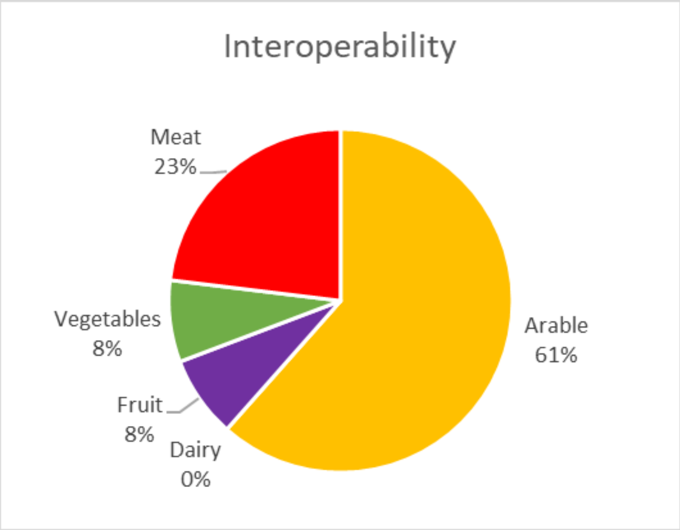

Figure 8: The number of times the lessons learned category 'Interoperability' across the trials has been reported (n = 13), displayed in a pie chart based on the percentage distribution.

The category 'Interoperability' came up in 11 UCs and has been reported 13 times. The distribution of the number of times (in percentage) this has been reported per trial is shown in figure 8. The arable trial clearly takes the lead in the lessons learned regarding interoperability. The meat trial comes in second place, followed by the vegetables and fruit trial. The dairy trial did not report any lesson learned regarding interoperability. Interoperability mostly means that the developed solution can easily be used together with already existing (or other) solutions. Best case scenario is that the different solutions can work together and add value to the whole system. However, today, most of the solutions for agriculture lack interoperability. Some companies are selling their own individual product, without taking in consideration the solutions that are already on-site, meaning that the end-users have to collect information from all different products instead of being able to see everything they want to know in one place. Another challenge is that UCs had to come up with some in-between solutions to make their product interoperable because some systems that are already available on the farm sites, are not IoT devices.
Interoperability is of high importance to the IoF2020 project so most UCs attached great importance to make this work.

Hardware design/placement

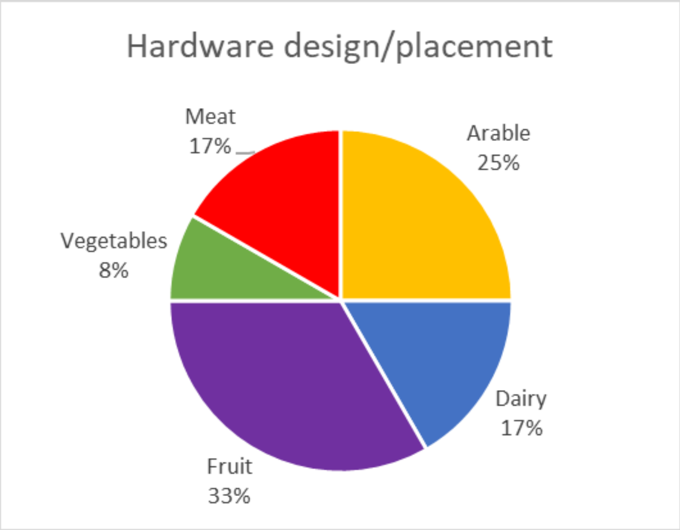

Figure 9: The number of times the lessons learned category 'Hardware design/placement' across the trials has been reported (n = 12), displayed in a pie chart based on the percentage distribution.

The lessons learned regarding the Hardware design/placement came up in 9 UCs and have been reported 12 times. The distribution of the number of times (in percentage) this has been reported per trial is shown in figure 9. The lessons learned regarding hardware design/placement are mostly represented in the fruit trial, followed by the arable trial. The meat and dairy trial each reported two lessons learned regarding this topic (good for 17%) and the vegetables trial only reported one lesson learned regarding the hardware design/placement. The major lesson learned that has been reported by several UCs, is the importance of developing hardware that can operate in harsh environments over prolonged periods. The use of chemicals, the various climates, dirt and so on sometimes makes it difficult to come up with a solution that can withstand these conditions. Another important element regarding the hardware is the power supply. Some UCs use a battery, they have to select the most suited type of battery and if possible, they also investigated possibilities regarding the recharging of that battery. Other UCs used solar energy. They had to be careful that the solar panel is kept out of the shade as much as possible, but also that birds can't sit on the device and litter on the solar panel.

4. CONCLUSIONS

This deliverable describes the Technical Improvements during the lifetime of the IoF2020 project. In total, the 33 UCs delivered 58 technical development tables of their (sub) products and services, with each 3.16 iteration cycles on average. No clear differences between initial UCs and open call UCs could be determined, apart from logical consequences of the shorter duration of the open call UCs. Across all UCs one iteration cycle takes about 10 months on average. For the initial UCs, the average iteration cycle lasted 11.73 months, while the average duration of one iteration cycle from the open call UCs is 5.56 months. These findings are in line with the theoretical approach to ask the initial UCs for four iterations in four years' time (12 months per iteration cycle) and to ask the open call UCs for four iterations in two years' time (6 months per iteration cycle). The UCs mostly held to an MVP cycle and have significantly improved their products, prototypes and services throughout the lifetime of the project with the help of real-life testing and end user feedback. These improvements were driven by attention points that were identified by the users or through the testing. UCs had different timelines for their improvement processes, depending on their own needs. Although a strict schedule of monitoring was used during the IoF2020 project and minimum requirements were set, this flexibility was offered to the UCs and allowed them to be adaptive and accelerate their own developments.

UCs also reported their lessons learned on the technical level, and the most frequently occurring categories were dashboard user interface, network communication, additional features, sensor placement, data processing, interoperability and hardware design/placement. Those seven categories show the types of technical challenges that occurred during the lifetimes of the UCs. Overall, a multitude of products and services for the agri-food sector were developed and improved during the project, for a diverse set of domains and applications. The UCs tackled this in a wide variety of ways, but they encountered common technical challenges and lessons learned. Real-life testing, end user feedback and also a flexible and adaptive approach were crucial to the success of the UCs in IoF2020.

5. ANNEXES

Only part of the confidential version.