# PROJECT DELIVERABLE REPORT

## Project Title:
**Zero-defect manufacturing strategies towards on-line production management for European FACTORies**

FOF-03-2016 - Zero-defect strategies at system level for multi-stage manufacturing in production lines

<table>
<thead>
<tr>
<th>Deliverable number</th>
<th>D5.4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deliverable title</td>
<td>Methodology for Z-Fact0r solution validation/evaluation</td>
</tr>
<tr>
<td>Submission month of deliverable</td>
<td>M33</td>
</tr>
<tr>
<td>Issuing partner</td>
<td>ATLANTIS ENGINEERING SA</td>
</tr>
<tr>
<td>Contributing partners</td>
<td>CERTH, CETRI, BRUNEL, EPFL, DATAPIXEL, MICROSEMI, SIR</td>
</tr>
<tr>
<td>Dissemination Level (PU/PP/RE/CO)</td>
<td>PUBLIC</td>
</tr>
<tr>
<td>Project coordinator</td>
<td>Dr. Dionysis Bochtis</td>
</tr>
<tr>
<td>Tel:</td>
<td>+30 24210 96740</td>
</tr>
<tr>
<td>Fax:</td>
<td></td>
</tr>
<tr>
<td>Email:</td>
<td><a href="mailto:d.bochtis@certh.gr">d.bochtis@certh.gr</a></td>
</tr>
<tr>
<td>Project web site address</td>
<td><a href="http://www.z-fact0r.eu/">http://www.z-fact0r.eu/</a></td>
</tr>
</tbody>
</table>
Document Information

<table>
<thead>
<tr>
<th>Filename(s)</th>
<th>D5.4 - Methodology for Z-Fact0r solution validation-evaluation_v1.0.docx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner</td>
<td>Z-Fact0r Consortium</td>
</tr>
<tr>
<td>Distribution/Access</td>
<td>Z-Fact0r Consortium, **</td>
</tr>
<tr>
<td>Quality check</td>
<td>NECO, CERTH/IBO</td>
</tr>
<tr>
<td>Report Status</td>
<td>Submitted</td>
</tr>
</tbody>
</table>

Revision History

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Responsible</th>
<th>Description/Remarks/Reason for changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>07/02/2019</td>
<td>ATLANTIS ENGINEERING SA</td>
<td>Initial Table of Contents</td>
</tr>
<tr>
<td>0.2</td>
<td>03/04/2019</td>
<td>CETRI</td>
<td>Contribution</td>
</tr>
<tr>
<td>0.3</td>
<td>03/04/2019</td>
<td>SIR</td>
<td>Contribution</td>
</tr>
<tr>
<td>1.0</td>
<td>31/05/2019</td>
<td>ATLANTIS ENGINEERING SA</td>
<td>Full document</td>
</tr>
</tbody>
</table>
Contents

Summary ....................................................................................................................................................... 5
1 Introduction .................................................................................................................................................. 6
2 Z-Factor® sub systems ............................................................................................................................... 7
3 Testing process overview ........................................................................................................................ 9
   3.1 Objectives ........................................................................................................................................... 9
   3.2 Requirements ....................................................................................................................................... 9
   3.3 General approach .............................................................................................................................. 9
   3.3.1 Questionnaires ........................................................................................................................... 9
   3.4 Examination techniques .................................................................................................................. 9
         3.4.1 Functional tests .................................................................................................................... 9
         3.4.2 Negative tests (e.g., testing with bad data to check error recovery) ................................... 10
         3.4.3 Usability testing .................................................................................................................... 10
         3.4.4 Maintainability evaluation ................................................................................................... 10
         3.4.5 Security testing ...................................................................................................................... 11
   3.5 Goals and results ............................................................................................................................. 11
4 End users’ activities ................................................................................................................................ 13
   4.1 DURIT ............................................................................................................................................... 13
   4.2 MICROSEMI ................................................................................................................................... 13
   4.3 NECO ................................................................................................................................................. 14
5 Questionnaire ........................................................................................................................................... 15
   5.1 Questions .......................................................................................................................................... 15
   5.2 Answers analysis and acceptance indicators ................................................................................ 15
         5.2.1 Effectiveness ........................................................................................................................... 15
         5.2.2 Efficiency .................................................................................................................................. 15
         5.2.3 Learnability .................................................................................................................................. 16
         5.2.4 Satisfaction .............................................................................................................................. 16
6 Key Performance Indicators (KPIs) ....................................................................................................... 17
   6.1 Correctly detected defects per time interval ................................................................................. 17
   6.2 Precision and recall - F-Measure .................................................................................................. 17
   6.3 False Alarm Rate ............................................................................................................................. 17
   6.4 Minimum or Mean Time Between Failures ............................................................................... 17
   6.5 System Uptime .................................................................................................................................. 17
   6.6 Number of production facilities breakdown and amount of idle time improvement ............... 18
   6.7 Machinery deterioration rate and achieved improvement ......................................................... 18
   6.8 Reduction of production costs, of waste and scrap ................................................................... 18
6.9 Production output quality (qualified output to total output produced ratio) ........................................ 19
6.10 Products to successfully repaired workpieces ratio ........................................................................... 19
6.11 Prediction and prevention efficiency, improvement in detection efficiency ......................................... 19
6.12 Production cost improvement ............................................................................................................. 19
6.13 Single-stage production defect rate, average multistage production defect rate improvements .................. 19
6.14 Defect propagation to downstream stages improvement ......................................................................... 20
7 Conclusions ........................................................................................................................................ 21
8 References ........................................................................................................................................ 21

Figures
Figure 1. Durit - Defects detection and repair sub system .............................................................................. 7
Figure 2. Durit - Defects prediction sub system .............................................................................................. 7
Figure 3. Microsemi - Defects detection and repair ...................................................................................... 8
Figure 4. Microsemi - Defects prediction sub system ...................................................................................... 8

Tables
Table 1. UAT questionnaire ......................................................................................................................... 15

Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>HIP</td>
<td>Hot Isostatic Pressure</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
</tr>
<tr>
<td>MTBF</td>
<td>Mean Time Between Failures</td>
</tr>
<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
</tr>
<tr>
<td>PVD</td>
<td>Physical vapor deposition</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>Research &amp; Development</td>
</tr>
<tr>
<td>SIP</td>
<td>System in package</td>
</tr>
<tr>
<td>TRL</td>
<td>Technology readiness levels</td>
</tr>
<tr>
<td>UAT</td>
<td>User Acceptance Testing</td>
</tr>
<tr>
<td>WC</td>
<td>Tungsten carbide (chemical formula: WC)</td>
</tr>
</tbody>
</table>
Summary

This deliverable D5.4 “Methodology for Z-Fact0r solution validation/evaluation” introduces a validation/evaluation approach that is one of the outcomes obtained within the task T5.3 and it will be followed and applied in Z-Fact0r project. The end users, will test and evaluate the software systems included into the Z-Fact0r solution by answering a set of questions while measuring a number of Key Performance Indicators (KPIs) to check the solution’s impact to the production line.

The main goal of this part regards the development of the methodological framework for the validation of the Z-Factor solution and overall architecture within industrial relevant environments, for incoming demonstration, including the metrics and KPIs to evaluate the level of fulfilment of the Z-Fact0r objectives; as well as their appreciation by factory stakeholders and decision makers.

In particular, the Z-Fact0r solutions will be developed at Technology Readiness Levels six TRL6 and the following will be defined:

- The methodology for the types of evaluation activities, timeframe and expected results per activity, instruments to be used (e.g. users’ acceptance questionnaires, impact checklists and data collection forms) to assist the different types of evaluation exercise.
- The technical indicators for performance assessment (KPIs). Indicative e.g. number of correctly detected defects per time interval, precision and recall (where precision will capture positive defect-detection values, and recall will capture sensitivity), F-Measure, False Alarm Rate, Min Time Between Failures, System Up Time, etc.

Such methodology has been applied during demonstration in relevant environments in order to collect evaluation data and feedback to ease and facilitate pilot demonstrations, including pilot area analysis and topology design, and the actual installations and pilot realization.

Therefore, the methodological framework encompasses the activities for the preparation of the pilot installations, with the analysis of each pilot and the design of the specific topologies to be applied (specific areas to be covered by the pilot, legal and operational, constraints, planning of physical deployment, etc.), while the physical installation of the platform in each pilot will be enabled by a Z-Fact0r architecture modularization (software, supporting hardware, communication networks, interface with existing sensors, new sensing and inspection h/w, etc.), as well as the basic Z-Fact0r configuration and on-field operational testing.

Specifically:

- **Chapter 2:** defines the Z-Fact0r solution sub systems.
- **Chapter 3:** describes the testing process.
- **Chapter 4:** includes the end users’ activities that will be tested with the Z-Fact0r solution.
- **Chapter 5:** provides the questionnaire details.
- **Chapter 6:** explains the KPIs that need to be measured.
1 Introduction

User acceptance testing (UAT) consists of a validation process that a solution works for the user [7]. This testing should be undertaken by a user whose is related to the final solution, preferably the owner or client of the solution under test, and provide a summary of the findings for confirmation to proceed after trial or review. In software development, UAT as one of the final stages of software development, often occurs before a client or customer accepts the new system. Users of the system perform tests in line with what would occur in real-life scenarios [8].

Defining the criteria is a useful step in really understanding what’s required. Importantly, it also helps the team to drive out a shared understanding of the requirements. Criteria should be implementation independent and written at a high level. We then implement the criteria in terms of one or more user acceptance tests. A single criterion (“the total basket value is displayed correctly”) may require multiple examples to be comprehensive (what exactly does it mean to “display correctly”?).

The end users can express their use cases details in the form of criteria; a specification against which the system can be verified. They may verify functional requirements or non-functional requirements such as performance or reliability. An important addendum should be that acceptance tests don’t have to be about just business behaviour; they can also be about broader system qualities such as non-functional requirements and usability. It’s still about the operators’ confidence.

It is important the delivered system given to the tester be similar to the system that the end user will have. Testing should be conducted on real-life scenarios. The UAT acts as a final validation of the required business functionality and proper functioning of the system, emulating real-world conditions. If the software works as required and without issues during normal use, one can reasonably extrapolate the same level of stability in production [9].
2 Z-Fact0r sub systems

In order to validate and evaluate the complex Z-Fact0r solution, we decided to break the system into two sub systems for end user:

1. The defects detection and repair sub system.
2. The defects prediction sub system.

The “defects detection and repair” sub systems focused on repairing detected defected parts and the “defects prediction” sub system, is focusing on the data analysis and classification in order to predict possible defects. Testing the two sub systems separately, will provide much clearer feedback regarding the user satisfaction. Figures 1-4, consist of details of these sub systems for our two end users, Microsemi and Durit.

![Figure 1. Durit - Defects detection and repair sub system](image1)

![Figure 2. Durit - Defects prediction sub system](image2)
Please note that the third end user NECO will also execute the same process as the other two partners. Their sub-subsystems are under assembly and their UAT results will be included and presented within in D5.3 (M36).
3 Testing process overview

3.1 Objectives

The testing process requires effective management skills as well as technical expertise. The objectives of any task and a plan for meeting them, must be defined. Defining the objectives and a plan to meet them, requires careful thought and covers all aspects of the testing process. The approach focus on the test environment details that should be clearly defined. The test approach may be determined by the installation technique for a software system. For example, a new software system may be installed and tested while the end users continue to use an older system; this is an approach referred to as parallel testing.

Alternatively, the new software system may be installed and tested in parts, while phasing out the old system. A software system may be installed with different hardware/software configurations at various sites. Real time software may require simulation testing or other techniques. In each of these situations, the selection of test techniques and organization of test cases may be different. Acceptance criteria are necessary to determine if the implementation of the acceptance test plan has achieved the test objectives.

Broadly, the test objectives are to demonstrate that the software system satisfies the end users requirements. The development of the acceptance criteria should occur when the requirements for the software system are initially defined. The requirements document should specify the functions of the software system, descriptions of the system features, and deliverable items, (e.g., user documentation). The acceptance criteria should specify baselines against which the performance of the functional requirements and other features and deliverables of the software system will be evaluated.

3.2 Requirements

This validation is carried out by the end users who are familiar with the business requirements. The solution is complete, according to the functional and nonfunctional specifications but there are some business requirements and processes that are known only to the end users are either missed to communicate or misinterpreted. Use of live data and real use cases make this testing an important part of the release cycle.

3.3 General approach

3.3.1 Questionnaires

Questionnaires in general, are typically developed from the characteristics, requirements, and classifiers based on the project’s Grant Agreement and the project’s progress itself. Developing the questionnaire exposes any uncertainties and lack of clarity in one’s own understanding of the solution itself. It forces the operators to express their interaction with the solution in measurable terms. We have developed discrete questions in order to screen various criteria in order to evaluate and validate, whether an operator is able quite easily to interact with the solution.

3.4 Examination techniques

3.4.1 Functional tests

Functional Testing is defined as a type of testing which verifies that each function of the software application operates in conformance with the requirement specification. This testing mainly involves black box testing and it is not concerned about the source code of the application. Each and every functionality of the system is tested by providing appropriate input, verifying the output and comparing the actual results with the expected results. The testing can be done either manually or using automation [1]. The prime objective of Functional testing is checking the functionalities of the software system. It mainly concentrates on [1]:

- Mainline functions: Testing the main functions of an application.
- Basic Usability: It involves basic usability testing of the system. It checks whether a user can freely navigate through the screens without any difficulties.
• Accessibility: Checks the accessibility of the system for the user.
• Error Conditions: Usage of testing techniques to check for error conditions. It checks whether suitable error messages are displayed.

3.4.2 Negative tests (e.g., testing with bad data to check error recovery)
Negative testing ensures that the solution can gracefully handle invalid input or unexpected user behavior. For example, if a user tries to type a letter in a numeric field, the correct behavior in this case would be to display the “Incorrect data type, please enter a number” message. The purpose of negative testing is to detect such situations and prevent applications from crashing. Also, negative testing helps to improve the quality of the solution and find its weak points. The core difference between positive testing and negative testing is that throwing an exception is not an unexpected event in the latter. When negative testing is performed, exceptions are expected – they indicate that the application handles improper user behavior correctly. It is generally considered a good practice to combine both the positive and the negative testing approaches [1].

3.4.3 Usability testing
In usability testing basically has the operators to check if they can use the user interfaces with ease. It tests that whether the solution built is user-friendly or not. The Usability Testing is a black box testing technique. It reveals whether the operators feel comfortable with the solution – the flow, navigation and layout, speed and content – especially in comparison to prior or similar applications [1].

Usability Testing tests the following features of the software [1]:
• How easy it is to use the software.
• How easy it is to learn the software.
• How convenient is the software to operators?

Usability testing includes the following five components [1]:
1. **Learnability:** How easy is it for users to accomplish basic tasks the first time they encounter the design?
2. **Efficiency:** How fast can experienced users accomplish tasks?
3. **Memorability:** When users return to the design after a period of not using it, does the user remember enough to use it effectively the next time, or does the user have to start over again learning everything?
4. **Errors:** How many errors do users make, how severe are these errors and how easily can they recover from the errors?
5. **Satisfaction:** How much does the user like using the system?

The benefits of usability testing to the end user or the customer [1]:
• Better quality software
• Software is easier to use
• Software is more readily accepted by users
• Shortens the learning curve for new users

3.4.4 Maintainability evaluation
Maintainability is the capability of the software/ system to readily go through any type of changes, to update it, in order to meet the requirements. It is the degree of measuring the software or system potential to undergo changes, to meet the requirements. These requirements may include [1]:
• Correction of errors or faults,
• Additional functionality,
• Adapting the changing environment,
- Prevention of unexpected failures,
- Future maintenance, etc.

3.4.5 Security testing

Security testing is a process intended to reveal flaws in the security mechanisms of an information system that protect data and maintain functionality as intended. Due to the logical limitations of security testing, passing security testing is not an indication that no flaws exist or that the system adequately satisfies the security requirements [5].

Typical security requirements may include specific elements of confidentiality, integrity, authentication, availability, authorization and non-repudiation. Actual security requirements tested depend on the security requirements implemented by the system. The parameters the need to evaluate are the following [5]:

- **Confidentiality**: A security measure which protects against the disclosure of information to parties other than the intended recipient is by no means the only way of ensuring the security.
- **Integrity**: Integrity of information refers to protecting information from being modified by unauthorized parties. A measure intended to allow the receiver to determine that the information provided by a system is correct. Integrity schemes often use some of the same underlying technologies as confidentiality schemes, but they usually involve adding information to a communication, to form the basis of an algorithmic check, rather than the encoding all of the communication. To check if the correct information is transferred from one application to other.
- **Authentication**: This might involve confirming the identity of a person, tracing the origins of an artifact, ensuring that a product is what its packaging and labeling claims to be, or assuring that a computer program is a trusted one.
- **Authorization**: The process of determining that a requester is allowed to receive a service or perform an operation. Access control is an example of authorization.
- **Availability**: Assuring information and communications services will be ready for use when expected. Information must be kept available to authorized persons when they need it.
- **Non-repudiation**: In reference to digital security, non-repudiation means to ensure that a transferred message has been sent and received by the parties claiming to have sent and received the message. Non-repudiation is a way to guarantee that the sender of a message cannot later deny having sent the message and that the recipient cannot deny having received the message.

3.5 Goals and results

The goals have to be pragmatically chosen. In the domain of software validation, the goals can be characterised by one of the two following questions [6]:

- **How good is it?** This goal aims at the determination of the degree of desired qualities of a finished system. The respect to “Usability-Goals” is one of the applications of this goal.

- **Why is it bad?** To determine the weaknesses of a software such that the result generates suggestions for further development.

In every development cycle, formative evaluation results in [6]:

- **Quantitative**: data for the description of the progress of the realisation of usability goals.

- **Qualitative**: data which can be used to detect the usability problems of the system.

The resulting data can be classified by the following criteria [6]:

---

11
• **Objective:** Directly observable data; typically, user behaviour during the use of the interface or the application system.

• **Subjective:** Opinions, normally expressed by the user with respect to the usability of the interface or the application system.

• **Quantitative:** Numerical data and results, e.g. user performance ratings.

• **Qualitative:** Non-numerical data, e.g. lists of problems, suggestions for modifications to improve the interaction design.
4 End users’ activities

4.1 DURIT

DURIT is a company that develops and produces special tools and wear parts carbides. It developed an international network of experienced production companies specialized sales experts and scientific institutions. The main qualities of DURIT are its high-quality standards, trend-setting innovative capacity and maximum product safety. DURIT is dedicated to the research, development and production of wear tooling in hard metals (WC-Co), special steels and technical ceramics (Si3N4; Zr2O) by the powder metallurgy process. The hard-metal grades production ranges from coarse grain size WC for impact wear processes to submicron and ultrafine WC grades with very low content for extremely aggressive wear conditions. DURIT main markets of operation are the oil and gas, with flux control parts, signal transmitter and protection sleeves for electronics systems and multiple other valve components.

Since its beginning, DURIT has built a philosophy of production per order, which means that its production is mainly orientated for medium/small orders and complex shaped tools although, a small number of cutting tools geometries are also produced. DURIT has a complete autonomy in the powder metallurgical route from powder preparation to surface finishing. Due to its specific production concept DURIT is equipped with powder preparation equipment, uniaxial and isostatic pressing, green machining, sinter HIP sintering and HIP, and state-of the art surface finishing engineering including EDM and fully equipped metrology control systems. Associated processes as brazing, steel thermal treatments, surface coatings as electrolytic, PVD and thermal spraying are also performed by the company.

DURIT has its own R&D and innovation department, dedicated to the study and development of new materials and process engineering updates, particularly related with powder metallurgy, surface treatments and specific wear applications.

DURIT will consult and guide the consortium members in order to maximize Z-Fact0r’s efficiency. The hard-metal processes during the respective use-case will be led by DURIT providing feedback, input and access to its current infrastructure.

4.2 MICROSEMI

Microsemi Semiconductor Ltd (formally Zarlink Semiconductor Ltd), is a multinational semiconductor company with a strong UK manufacturing base. At the UK facility in Caldicot, the team design, develop and manufacture advanced microelectronic technologies for low power wireless communication, energy harvesting and high ambient temperature electronics. The site has extensive micro-packaging capabilities for medical, wireless, telecommunications and security customers. Microsemi is a leading “system in package” supplier to the medical electronics industry and has a proven track record in implementing new concepts developed under the EU and InnovateUK funding.

Microsemi first joined collaborative projects in 2003. Since then Microsemi has been involved with 8 EU projects and 5 InnovateUK as well as managing projects using its integral industrial expertise and systems up to the value of €10M.

With over 20 years’ experience in microelectronics assembly, focusing on miniaturization through SIP packaging Microsemi is are well placed to understand the potential for new innovative product As a major “system in package” supplier to the medical and industrial electronics markets (particularly implant medical OEM), Microsemi (MSL) is keenly placed to verify the suitability of the new solders in a production environment. MSL’s main role will be in the specification and proving of the viability of the solders in the production volumes. Key to this will be in the careful design of test patterns that ensure the solder is FIT for purpose, reliable, repeatable. MSL is one of the few PCB manufacturers who still have their
manufacturing facilities in European ground. Therefore, they will not only provide technical guidance but also more info about the industry problems.

against the Asian manufacturing MSL will lead the respective use-case to their premises providing access to the production infrastructure. Moreover, during the validation of the system MSL will have an active role in the defect recognition and following actions for reworking and repairing.

4.3 NECO

Nueva Herramienta de Corte (NECO) is a tool manufacturer which possesses an experience of over 75 years in the design, manufacturing and marketing of precision cutting tools and thread rolling tools.

NECO is integrated into the structure of Tivoly Group, and currently, the plant of NECO in Elorrio has become the focal point of the group for the design and manufacturing of taps, providing solutions to all requirements of the group on such tools. Currently, NECO’s most important products are drills, taps, end mills, reamers, rollers and other special tools.

NECO uses the European Excellence Model of the EFQM management model as reference. Based on the exercise of leadership and guided by a multi-year Strategic Plan, NECO is driven by the satisfaction of its customers, counting with the participation of all the people.

50% of the NECO net sales (over 10 million €) take place in foreign markets, with a presence in over 40 countries worldwide. The orientation towards the customer is reflected in its organization into divisions aimed at different markets to which they target their products and services. To provide greater responsiveness to changing market needs, the divisions are organized into multidisciplinary teams.

NECO has significant resources, both human and material, oriented to the innovation of its products and services. NECO conducts joint development projects with technology centres, devoting to them a 2% of its sales budget.

The R&D Department, created in 1997, is primarily focused on the development of projects, plans and target search, definition, development and implementation of innovations and improvements on products, processes or services.

The main activities carried out in this area are: development and definition of new products, definition of technical criteria, design high speed tools, participation in the development of coatings with superfine hard layers, cutting tests, strengthening partnerships with technology centres and research institutions, training of staff, technical advice to customers, other departments, etc.

During the course of the project NECO will consult and guide the consortium members in order to maximize Z-Fact0r's efficiency. NECO will provide feedback, input and access to its current infrastructure during the manufacturing of the zero-defect taps. The NECO use case will be open to the integration of 3D scanning technologies and advanced machines that can help to perform online inspection on the taps generated.
5 Questionnaire

5.1 Questions

The questionnaire, is undoubtedly essential to collect answers from large scale end users. Especially when releasing a brand-new complex product, like Z-Fact0r, user experience survey plays a big role to understand the user satisfaction and what needs to be improved. The ten questions set is simple and straightforward. We decided to keep a short list of comprehensive questions, and give the chance to the operators to be as honest as possible. The questionnaire presented in Table 1, will be provided to the operators via the Google Forms platform, in order to automatically collect the results.

<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly disagree</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I intent to use the system frequently</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. The system is easy to use</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. The various functions are well integrated</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. Prior knowledge is needed before I could use the system</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. Z-Fact0r helps me to complete a task faster</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. The information flow is received on time through the Z-Fact0r platform</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7. Z-Fact0r provides unreadable and incomprehensible data/information</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8. Z-Fact0r system crashes frequently</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>9. Z-Fact0r UI is well designed and the UX is satisfying</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>10. The authentication and authorization process make me feel secure</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 1. UAT questionnaire

5.2 Answers analysis and acceptance indicators

The questions are designed in such a way that the expected answers to be specific, observable and measurable. The answers are going to be exploited in order to verify that the solution works for ‘the user’. Through the answers analysis we will try to measure the acceptance indicators, as defined in ISO 9241 - parts 10, 12-17 ISO/IEC 9126-2/3 [10], in the following sub-sections below.

5.2.1 Effectiveness

Effectiveness is an indicator of how well a system is working. It can help determine the direction to be taken on order to address any issue occurred. The effectiveness indicator is usually assigned a scale, with ratings on the scale from unacceptable to outstanding. Effectiveness indicators differ from process to process, however, there are certain characteristics that effective indicators have in common:

- Effective indicators are relevant; they show you something about the system that you need to know.
- Effective indicators are easy to understand, even by people who are not experts.
- Effective indicators are reliable; you can trust the information that the indicator is providing.
- Lastly, effective indicators are based on accessible data; the information is available or can be gathered while there is still time to act.

5.2.2 Efficiency

Efficiency is an indicator of how effectively a user can perform in a system with increasing the productivity and learning capacity of a user. In the context of Z-Fact0r, efficiency may be defined as how much time and how many resources are required to achieve the project’s objectives. In simple terms, the solution has to be fast enough and does not require too many steps.
5.2.3 Learnability
Learnability as an indicator can be defined as the ease to learn the functionality of a new system, i.e., how easy to start to use the solution and learn functionalities.

5.2.4 Satisfaction
Satisfaction is one of the key attributes that measures the comfort level through the system and its acceptance for further use. Z-Fac0r platform user’s satisfaction is a vital attribute since it is highly anticipated that the overall performance of the system will suffice the increased needs of the customers.
6 Key Performance Indicators (KPIs)

Key performance indicators are values that show the success factors of the production system. A KPI is a measurement of the critical success factors that can both help define and aid to reach the pre-set goals. Using KPIs means having a way of measuring progress, as well as comparing the progress to the goals. By comparing with the goals the KPIs give an indication if the goals have been realized or not. The KPI indicators that will be exploited in the context of the Z-Fact0r, are discussed below.

Some KPIs that do not have a mathematical equation, because each end user has its own standards and specifications on how to measure those KPIs.

6.1 Correctly detected defects per time interval

A KPI for evaluating the platform detection process is the number of the defected parts that are detected correctly by the platform, during a specific time interval. Apart from the performance, correctly detected defects can also be considered as a measure of platform’s accuracy.

6.2 Precision and recall - F-Measure

Precision, Recall and F-Measure are known metrics used extensively in the fields of information retrieval, pattern recognition and etc. and they can be used as performance indicators for understanding and measure relevance. In particular, in the context of Z-Fact0r, we can define Precision as the fraction of correctly detected defects among the total number of defects detected among the examined parts, while Recall can be defined as the fraction of detected defects among the total number of defects. We can say that precision represents "how effective is the detection process ", and recall is "how complete is the detection process" [2].

F-measure combines precision and recall and corresponds to their harmonic mean, defined as:

\[
F = 2 \times \frac{\text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}}
\]

6.3 False Alarm Rate

If we define an event as the detection of a defected part and an alarm as a warning of such detection, then a false alarm rate is defined as the number of false alarms (in which an alarm, or warning, is given in spite of a non-event) per the total number of “non-events” (times the event didn’t happen). A false alarm rate is also known as the probability of false detection [3] [4].

6.4 Minimum or Mean Time Between Failures

By definition, a system failure is declared when the system does not meet its desired objectives. Similarly, a return to normal operations signals the end of downtime or system failure. To measure these cases, MTBF (mean time between failures) is a measure of how reliable a hardware product or component is. For most components, the measure is typically in thousands or even tens of thousands of hours between failures. A desired MTBF can be used as a quantifiable objective when designing a new product. The MTBF figure can be developed as the result of intensive testing, based on actual product experience, or predicted by analysing known factors. The manufacturer may provide it as an index of a product's or component’s reliability and, in some cases, to give customers an idea of how much service to plan for.

6.5 System Uptime

System Uptime is defined as the length of time that a system is online between outages or failures and can be thought as an indicator for the “time to failure” for that system.
6.6 Number of production facilities breakdown and amount of idle time improvement

A major problem of industrial systems is unexpected downtime of production facilities as well as the amount of time that systems are in idle status. Idle time in particular, while traditionally viewed as an inherent part of warehouse operation, represents a significant obstacle to improved productivity. An unexpected breakdown of production facilities as well as idle time increase, lead to delayed production and negatively influences the reputation of a company and thus leads to financial costs. Therefore, a maximum effort is required to reduce downtimes and minimize idle time. This would increase reliability and minimize operating and maintenance costs.

6.7 Machinery deterioration rate and achieved improvement

Machinery deterioration rate is the pace at which the machinery degrades over time under normal operating conditions. This indicator is an expression of the durability and robustness of the machinery. The rate of deterioration is presented graphically on a performance curve (survivor curve) where the slope of the curve indicates the rate. Quantification and objective measurement of the deterioration rate can be analyzed through a variety of means, including the percentage of current replacement value per year or the Deterioration model that describes the process and mechanisms by which assets deteriorate and pass through different stages of failure, including: Early-Life Metrics, Late-Life Metrics and Mid-Life Metrics.

6.8 Reduction of production costs, of waste and scrap

Reduction of production costs, together with reduction in the production of waste and scrap are indicators that could be used to increase profit margins. Various cost-saving methods are available to reduce the cost of the manufacturing process, for e.g. reduce the cost of materials, or use lean manufacturing techniques.

Materials are a significant part of the production costs involved in manufacturing. When much of manufacturing expense is due to raw material costs, it makes sense to look for ways to reduce this expense. The materials should be bought in large amounts to take advantage of discounts on bulk purchases from your supplier, or negotiate with multiple suppliers and compare them with one another, such as in a procurement process, to ensure the most competitive price.

Lean manufacturing allows the reduction of waste to an absolute minimum. According to lean manufacturing principles, seven types of waste should be addressed and corrected, if necessary, for a manufacturing process to be efficient:

- Overproduction: Overproduction occurs when you produce a product that cannot be sold or must be sold at a lower price than anticipated, which affects the company's bottom line.
- Inventory: Occurs when more product is produced than the market demands, requiring resources to store it until it is sold. Holding inventory that is slow to sell involves the expenditure of money because storage costs money.
- Conveyance: Conveyance itself is not a form of waste. However, incorrect transport can lead to waste. When a part is moved unnecessarily during the manufacturing process, it may be damaged or lead to a delay in the manufacturing process.
- Correction: Three types of correction lead to waste. The first occurs when you must correct work that has been completed. The second happens when you repeat a manufacturing process, and the third occurs when you inspect parts to make sure they have been properly manufactured. By perfecting the process itself in the first place, the need for correction is minimized.
- Motion: When the workers, processes, and techniques involve unnecessary or awkward motions, the potential for injury increases and the time taken for the processes also increases, which is wasteful.
- Processing: When there is no clear picture of the needs of the customer or what the manufacturing process should look like, the whole process becomes wasteful.
• Waiting: Whenever there are delays in the process, idle time is incurred both by the workers and your capital, which is a waste all on its own.

6.9 Production output quality (qualified output to total output produced ratio)
To have long-term business success and profit, maintaining the quality of production is crucial and leads to optimum quality of the final product. We define as actual production count the final product which is ready for distribution, i.e., the amount of total product manufactured minus the scrapped product. Production output quality indicator can help to compare and monitor the quality of processes and represents the percentage of goods count out of the actual production count for the products. This KPI helps supervisors to take care of the product from the very beginning that is from the raw material stage. This, as a result, also helps to lower its production costs.

6.10 Products to successfully repaired workpieces ratio
An indicator for the performance of the repairing process is the number of the defected parts that are successfully repaired. This can be defined as the ratio of the products with successfully repaired parts to the total number of the products with defected parts.

6.11 Prediction and prevention efficiency, improvement in detection efficiency
Prediction and prevention efficiency are indicators of the system’s ability to predict and subsequently prevent the errors in the manufacturing process. These indicators would result in the improvement of system’s detection efficiency and are strongly depended on the performance of the prediction/detection algorithm exploited during the data analysis tasks.

6.12 Production cost improvement
Production cost improvement can be understood as the decrease in the unit cost of goods produced and services provided by the company, without compromising with its quality and suitability for the use intended, with the help of new and improved methods. Production cost improvement is a systematic and corrective technique used by most of the firms to cut the inessential expenses of the goods manufactured and increase the overall profits. In this process, the essential features and quality of the product are kept intact and is limited to the constant savings in the cost of production, administration, selling and distribution. The basic purpose is to lower down the cost occurring at the time of production, storing, selling etc.

Production cost improvement is not related to fixing targets and standards, but it is about improving the standards. It is an ongoing process, which can be applied to all the activities of the concern. It focuses on the two primary areas and can be attained by the integration of these factors:

• Reduction in Expenses: Decrease in the expenditure in the given volume of output, leads to the decrease in unit cost
• Increase in Productivity: The overall decrease in unit cost, by increase in the output, for the given expenditure.

6.13 Single-stage production defect rate, average multistage production defect rate improvements
A defect rate is the percentage of output that fails to meet a quality target and it can be used to evaluate and control programs, projects, production, services and processes.

A defect rate is calculated by testing output for non-compliances to a quality target. Quality is typically specified by functional and non-functional requirements. The following formula can be used to calculate defect rate.
\[
\text{defect rate} = \frac{\text{defects}}{\text{output tested}} \times 100
\]

Defect rate is given by the number of items that failed quality tests, whereas output tested is the total number of tests conducted.

6.14 Defect propagation to downstream stages improvement

Improvement of defect propagation to downstream stages is another impact indicator and characterizes the quality of the system. Minimum propagation of defected parts to downstream manufacturing stages would affect two other main impact indicators and in particular production cost improvement and production output quality. A simple metric to estimate this indicator could be the ratio of defected parts propagated without repair to the total number of defected parts. A weight could also be assigned to the stage in which the defected part has finally been identified.
7 Conclusions

In D5.4 “Methodology for Z-Fact0r solution validation/evaluation” we presented the questions that need to be answered and the KPIs that need to be measured by the end users, as results of the UAT process. We will collect that data through two iteration, one in June, and one in September. The goal is to ensure, on one hand, that the system is accepted from the end users, and on the other that there is a positive impact of the Z-Fact0r solution over the production process.

8 References


